



TÜRKİYE BİLİMLER AKADEMİSİ
TURKISH ACADEMY OF SCIENCES



COP31
TÜRKİYE
ANTALYA

THE SYNTHESIS REPORT OF COP31 ACTION AGENDA TARGETS

Ankara 2026





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TÜBA Report No: 71

ISBN: 978-625-6110-84-7

DOI: 10.53478/TUBA.978-625-6110-84-7



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Print Place and Date

Tek Ses Matbaacılık - ANKARA • 2026

The scientific responsibility for the language, scientific, ethical and legal aspects of all the articles included in the work belongs to the authors. Turkish Academy of Sciences has no responsibility.

The Synthesis Report on COP31 Action Agenda Targets. -- Ankara : Turkish Academy of Sciences, 2026.
162 s. : fig. ; 19 x 27 cm. – (TÜBA Reports No: 71)
Includes bibliographical references.
ISBN 978-625-6110-84-7
1. Climatic changes—Government policy. 2. İklim değişikliği—Hükümet politikası. 3. Sustainable development. 4. Sürdürülebilir kalkınma. 5. Environmental policy. 6. Çevre politikası.
QC903 .S98 2026
363.73874



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Attribution: Şeker, M., Hasar, H., Koyuncu, İ., Dinçer, İ., Aydın, M. E., Şahin, K., Gültekin, F., Evci Kiraz, E. D., Kam, E., Arıkan, O. A., Korkut, C., Doğrul, M., Taşdelen, A., Maçın, K. E., Erdemir, D., Gören, A. Y., & Şahintaş, Z. A. (2026). *The Synthesis Report on COP31 Action Agenda Targets*. Turkish Academy of Sciences. <https://10.53478/TUBA.978-625-6110-84-7>



FOREWORD

The Turkish Academy of Sciences (TÜBA) is the modern-day representative of a distinguished scientific tradition dating back to the scholarly institutions of the late Ottoman period, such as the Encümen-i Dâniş and other learned societies. Since its establishment, TÜBA has been committed to advancing all branches of science, from the natural and engineering sciences and health sciences to the social sciences and humanities, by supporting exceptional researchers, recognising scientific excellence and promoting the application of scientific knowledge for the benefit of society. Today, TÜBA serves as both Türkiye's national academy of sciences and a leading institution in science diplomacy, interdisciplinary collaboration, and sustainable development.

Hosting the 31st Conference of the Parties (COP31) to the United Nations Framework Convention on Climate Change is a historic responsibility and significant opportunity for both our country and the international community. In this context, TÜBA has mobilised its working groups, members and the wider scientific community to provide scientific knowledge and evidence-based recommendations for the COP31 process. Our sustained work over the past fifteen years through the Environment, Biodiversity and Climate Change, Energy, Food and Nutrition, Sustainable Development and Finance, International Relations, and Information Technologies, Communication and Artificial Intelligence Working Groups has established a robust scientific basis for tackling climate-related issues. This interdisciplinary collaboration has produced the present report, which reflects the collective expertise of TÜBA's scientific community.

Today, climate action requires more than just environmental policy; it also requires science, technology and international cooperation. As a national academy of sciences, TÜBA actively promotes the scientific basis of climate action and sustainable development by engaging with international scientific organisations and networks. These include the G20 Chief Science Advisers' Roundtable (G20 CSAR), Science20 (S20), the International Science Council (ISC), the InterAcademy Partnership (IAP), All European Academies (ALLEA), and the Union of Academies of the Turkic World. TÜBA also actively contributes to regional scientific cooperation through the Association of Academies and Societies of Sciences in Asia (AASSA), meetings of the Asian Academy of Sciences, and the Euro-Mediterranean Academic Network (EMAN). Key areas of collaboration here include climate change, biodiversity, environmental sustainability and science diplomacy. Through these platforms, TÜBA participates in preparing



joint policy briefs, supports organising international scientific events and collaborates with partner academies to strengthen evidence-based policymaking and foster responses to shared environmental challenges. Reflecting this commitment, TÜBA is set to host the World Science Forum 2027 in Istanbul, centring on the theme of ‘Science in Times of Global Crises: Transcending Boundaries in a Fragmented World’, which will bring together scientists, policymakers, and international organisations to promote science-based responses to global issues such as climate change, sustainability, and resilience. These initiatives demonstrate our belief that science diplomacy is essential for improving international cooperation and developing collective solutions to the global climate crisis.

Recognising that addressing climate change depends on empowering future generations of scientists, TÜBA places particular emphasis on nurturing scientific excellence through its flagship programmes. These include the TÜBA Outstanding Young Scientist Award Programme (GEBİP) and the TÜBA-TEKNOFEST Doctoral Science Awards. Across these programmes, TÜBA prioritises research in advanced technologies, artificial intelligence, climate science, climate security, and other fields that promote environmental sustainability and resilience. By supporting exceptional young researchers and promoting interdisciplinary scientific excellence, TÜBA aims to accelerate technological innovation, bolster national scientific capabilities, and contribute to global initiatives aimed at mitigating the effects of climate change and promoting sustainable development.

Artificial intelligence is set to become one of the defining technologies in humanity’s response to climate change. AI offers unprecedented opportunities to enhance environmental resilience, from early warning systems and disaster prediction to energy optimisation, water resource management, biodiversity monitoring, carbon accounting and climate modelling. However, we believe that these technologies should not become instruments of competition that exacerbate inequalities between nations, but rather tools that unite humanity in safeguarding our shared future. TÜBA therefore emphasises the ethical, responsible and human-centred development of artificial intelligence, recognising its transformative role in supporting environmental sustainability and accelerating the achievement of global climate goals.

At the same time, many of today’s environmental crises are not just a consequence of climate change, but also the result of human activities, the unsustainable use of resources, and armed conflicts. Conflicts in regions such as Gaza and Ukraine inflict devastating humanitarian losses and long-lasting damage to ecosystems, biodiversity, water resources, agricultural lands and environmental health. Recent United Nations assessments have increasingly highlighted the close relationship between armed conflict and environmental degradation. TÜBA’s International Relations Working Group continues to emphasise the interconnected nature of peace, security, environmental protection, and sustainable development. Lasting environmental sustainability cannot be achieved without lasting peace.



This report provides a thorough scientific evaluation of the priorities, implementation strategies, and policy suggestions that could help to achieve the goals of COP31. We hope that scientists, policymakers, diplomats and all other COP31 stakeholders will collaborate to establish a broad international consensus based on scientific evidence, international cooperation and shared responsibility. We firmly believe that science will continue to be humanity's most reliable guide in addressing the climate crisis, mitigating its adverse effects and building a more resilient and sustainable future for generations to come.

I would like to express my deepest gratitude to H.E. Murat Kurum, the Turkish Minister for the Environment, Urbanisation and Climate Change, for his distinguished leadership, strong commitment and invaluable efforts in preparing for Türkiye to host COP31. His vision and dedication have significantly strengthened national and international cooperation in addressing climate change and mitigating its adverse effects. I would also like to express my sincere appreciation to Prof. Dr. Halil Hasar, Director General of the Presidency of Climate Change, for his hard work, expertise, and valuable contributions to the COP31 preparation process and to Türkiye's climate action.

Finally, I would like to thank the authors of this report, all TÜBA Working Group members, the contributing scientists, and everyone whose dedication, expertise and hard work made this report possible.

Prof. Dr. Muzaffer Şeker
Turkish Academy of Sciences (TÜBA), President



NOMENCLATURE

1. Acronyms

AD	Anaerobic digestion
AI	Artificial intelligence
BAU	Business as usual
CBAM	Carbon border adjustment mechanism
CIB	Climate implementation bridge
CH₄	Methane
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
CMUR	Circular material use rate
COP	Conference of the Parties (UNFCCC)
COP28	28 th Conference of the Parties (Dubai, United Arab Emirates, 2023)
COP29	29 th Conference of the Parties (Baku, Azerbaijan, 2024)
COP30	30 th Conference of the Parties (Belém, Brazil, 2025)
COP31	31 st Conference of the Parties (Antalya, Türkiye, 2026)
DMC	Domestic material consumption
DMI	Direct material input
EMDE	Emerging market and developing economies
EPA	Environmental Protection Agency
EPR	Extended producer responsibility
ESCO	Energy Service Company
ETS	Emissions Trading System
EU	European Union
EUI	Energy use intensity
EV	Electric vehicle
EXP	Exports
GDP	Gross domestic product
GHG	Greenhouse gas
GlobalABC	Global Alliance for Buildings and Construction
GWP	Global warming potential
IEA	International Energy Agency

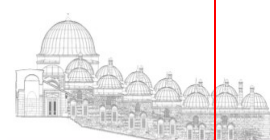


IIoT	Internet of Things
IMP	Imports
IRENA	International Renewable Energy Agency
IRP	International Resource Panel
LCA	Life cycle assessment
LCOE	Levelized cost of electricity
MBT	Mechanical-biological treatment
MEPS	Minimum energy performance standards
MRF	Material recovery facility
MSW	Municipal solid waste
NDC	Nationally Determined Contribution
NZE	Net Zero Emissions by 2050 Scenario (IEA)
nZEB	Nearly zero-energy building
OFMSW	Organic fraction of municipal solid waste
OIZs	Organized Industrial Zones
PTB	Physical Trade Balance
PV	Photovoltaic
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
SMEs	Small and medium-sized enterprises
STEPS	Stated Policies Scenario (IEA)
TCIB	Türkiye Climate Implementation Bridge
TFC	Total final (energy) consumption
TÜBA	Turkish Academy of Sciences (Türkiye Bilimler Akademisi)
TÜİK	Turkish Statistical Institute (Türkiye İstatistik Kurumu)
UN DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UNSD	United Nations Statistics Division
WHO	World Health Organization
YEKDEM	Renewable energy resources support mechanism (Türkiye)



2. Symbols and Units

CH₄	Methane
CO₂	Carbon dioxide
FU	Functional unit
GW	Gigawatt (10 ⁹ watts)
kg CO₂-eq/tonne	Kilograms of CO ₂ -equivalent per tonne of waste
kWh	Kilowatt-hour
kWh/m²	Kilowatt-hours per square metre per year (energy use intensity)
kWh/m²	Kilowatt-hours per square metre
mb/d	Million barrels (of oil) per day
Mt	Million tonnes
Mt CO₂-eq	Million tonnes of CO ₂ -equivalent
m²	Square metre
N₂O	Nitrous oxide
TWh	Terawatt-hour (10 ¹² watt-hours)
USD	United States dollar
°C	Degree Celsius



CHAPTER 1

ELECTRIFICATION

Abstract

The world has been in the Age of Electricity since 1882 when Thomas Edison first opened the Pearl Street power station in New York City (USA). Electricity currently accounts for about 21% of global final energy consumption, yet it is considered the key source of energy for sectors representing over 40% of the global economy, and its use is growing roughly four times faster than overall energy demand. This report begins examining some key drivers, namely economy, energy, environment, population, sectoral growth, technology and social and policy dimensions, accelerating this transition and the conditions required to make the electrification sector resilient and sustainable for future. It first characterizes electricity's position in today's energy system and the economic, technological, energy-system and policy drivers behind surging demand, which is projected to grow by nearly 1,000 TWh annually to 2035 under stated policies. It then assesses the role of electrification in energy transitions across industry, transport and buildings, alongside the parallel decarbonization of electricity supply, in which the renewables share rises from one third today to over half by 2035. Finally, it analyses the implications of this transformation for energy security, including grid flexibility, storage and critical mineral supply chains; for affordability and investment, in a context where spending on electricity already represents half of the USD 3.3 trillion invested in energy in 2025; and for inclusive electrification, given that around 730 million people still lack electricity access. The report concludes that accelerating electrification to reach a 35% share of final consumption by 2035 is technically feasible and economically advantageous, but requires anticipatory investment in grids, storage and access, and deliberate policies for resilient supply chains and just outcomes.

Keywords: COP31, Net-zero targets, Energy transition, Electricity demand, Resilience, Renewable energy, Sustainability



1.1. Introduction

The global energy debate of the past decade has been dominated by fuels: the volatility of oil and natural gas markets, the security of supply chains disrupted by geopolitics, and the imperative of phasing down unabated coal. However, underlying these headline concerns, a more subtle structural shift has been gaining momentum. Since 2010, electricity demand has grown at almost twice the rate of total energy demand, and in 2024 it will accelerate to 4.3%, adding 1,080 TWh in a single year, nearly doubling the preceding decade's annual average (IEA, 2025c). The International Energy Agency's flagship World Energy Outlook 2025 concludes that the world has now moved firmly into the Age of Electricity, with electricity use projected to rise four times faster than overall energy demand to 2035 (IEA, 2025a).

This report targets raising the global electrification rate, the share of electricity in total final energy consumption, to 35% by 2035. The report situates that target within the global evidence base. Section 2 characterises electricity's position in today's energy system and the drivers of the Age of Electricity. Section 3 examines the role of electrification in energy transitions across the four principal end-use sectors, industry, grid, transport and buildings, together with the decarbonisation of electricity supply itself. Section 4 assesses the wider implications of the transition: the co-benefits it can deliver and the key enablers it requires, spanning energy security, affordability and investment, and inclusive electrification, with a special focus on small island systems. Throughout, figures are prepared by the Working Group on the basis of data published by the IEA, IRENA and the peer-reviewed literature, with sources cited directly beneath each figure; projection values are approximate and rounded.

The objective of this chapter is to provide the scientific and analytical foundation for Goal 1 of the COP31 Presidency's 2035 Global Implementation Goals: raising the share of electricity in global final energy consumption to 35% by 2035. Specifically, the chapter pursues four aims: to establish, on the basis of the most recent global data, that the transition to an electricity-centred energy system is already under way and to identify the dimensions accelerating it; to quantify the realisable electrification potentials in industry, transport and buildings, together with the supply-side decarbonisation required for electrification to deliver its full climate value; to assess the enabling conditions without which the target cannot be reached; and to translate this evidence into a sequenced set of action plans, aligned with the United Nations Sustainable Development Goals and the Paris Agreement, through which the 35% goal can be delivered and verified by 2035. In doing so, the chapter is intended to serve both as a reference document for Parties preparing their national electrification roadmaps and as the analytical basis for the electrification pillar of the Climate Implementation Bridge (CIB) mechanism.



1.2. Critical Era of Electricity

The transformation examined in this report rests on a factual premise: electricity has moved from being one energy carrier among several to the strategic centre of the global energy system. This section establishes that premise in two steps. It first characterises electricity's position in today's energy system, its share of final consumption, its disproportionate economic weight, the acceleration of demand growth and the widening differences in electrification levels across major economies (Section 2.1). Section 2.2 then examines why this critical era has arrived now, tracing five mutually reinforcing dimensions: the economic forces of rising incomes, cooling demand and shifting centres of consumption; the inherent efficiency advantage of electric end-uses within the energy system; the technology cost revolution in renewables, batteries and digital tools; the policy architecture built around the Paris Agreement and national industrial strategies; and the environmental dividends, cleaner air, reduced water stress and lower upstream emissions that electrification delivers directly.

1.2.1. Electricity's Role in Today's Energy System

Electricity accounts for approximately 21% of global total final energy consumption today, up from around 15% at the turn of the century (IEA, 2025a). This aggregate share understates electricity's economic significance: it is the principal source of energy for sectors representing more than 40% of the global economy and the main source of energy for most households, which is why electricity prices are increasingly the key reference point for consumers and policy makers alike (IEA, 2025a). Electrification levels vary considerably across major economies: the share of electricity in final consumption has reached about 28% in China, which has electrified faster than any other major economy over the past fifteen years, compared with roughly 22% in the United States and 21% in the European Union (IEA, 2025b).

The comparison in Figure 1.1 shows the scale and the character of the transformation required in global power generation over the coming decade. In 2024, unabated fossil fuels still supplied roughly 59% of the world's electricity, which is approximately 18,300 TWh out of a total of some 30,900 TWh, with coal alone accounting for 34% (10,600 TWh) and natural gas for 22% (6,800 TWh) (Ember, 2025). On a net-zero-aligned pathway, this share must fall to around 13% by 2035, even as total generation expands by more than 40% to approximately 44,000 TWh to serve the electrification of transport, buildings and industry (IEA, 2025a). The transition is therefore not a substitution at constant volume: the system must decarbonise and grow simultaneously.

Three quantitative shifts define the pathway. First, coal-fired generation must decline from roughly 10,600 TWh to about 2,200 TWh that is a reduction of nearly 80% in absolute terms, equivalent to a sustained decrease of around 13% per year. This implies halting new unabated



coal construction, accelerating the retirement or repurposing of the existing fleet, and prioritising the phase-down in systems where coal plants are young and would otherwise operate for decades. Unabated gas generation must roughly halve, transitioning from a baseload resource to a flexibility provider with progressively lower capacity factors.

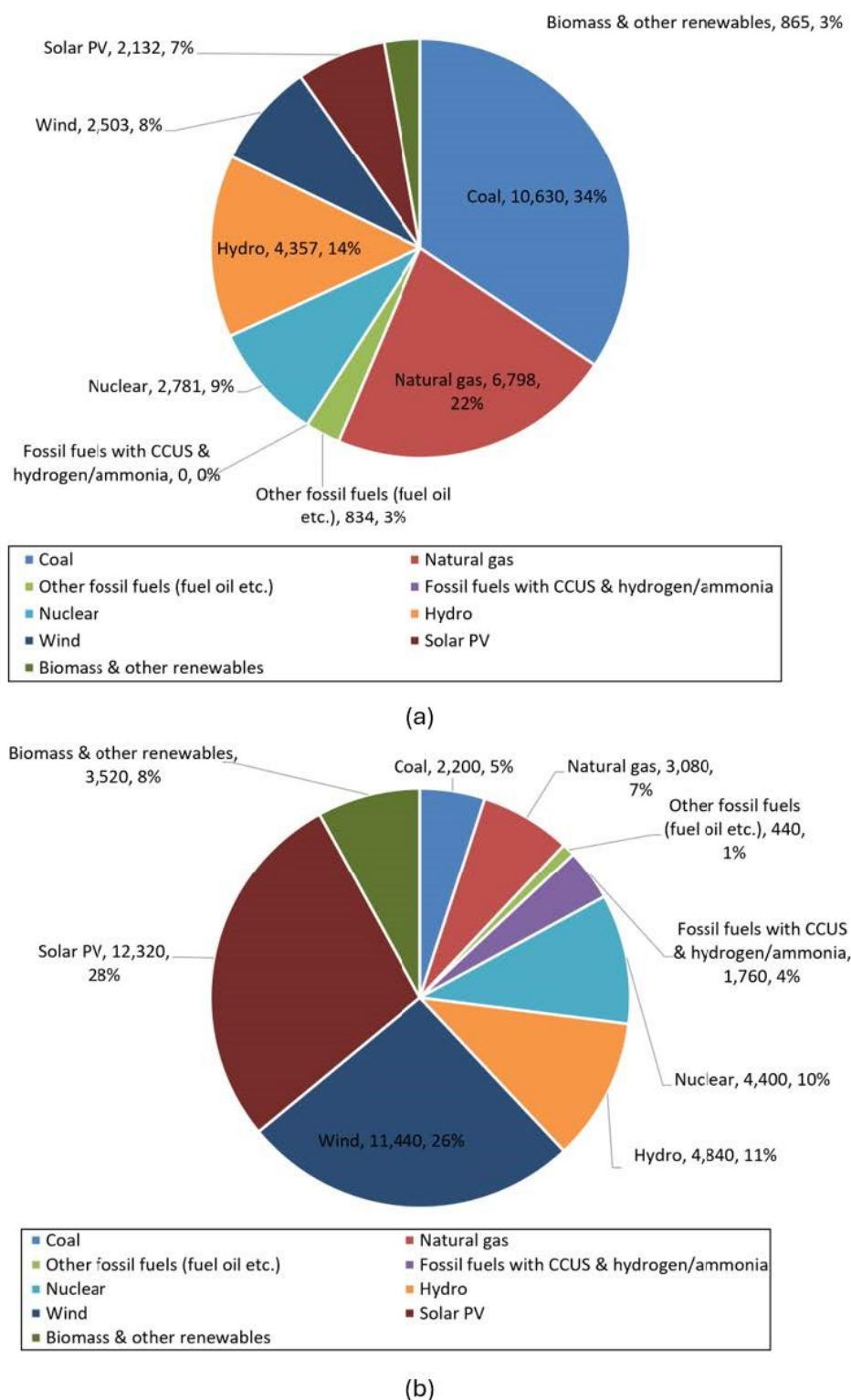


Figure 1.1 Global electricity generation mix (a) 2024 vs (b) 2035 (NZE-aligned) (Data from: IEA, 2025a, 2025b; Ember, 2025)



Second, solar PV and wind must become the backbone of the system: their combined share rises from 15% in 2024 to approximately 54% by 2035, requiring solar output to grow nearly six-fold (2,100 to 12,300 TWh) and wind more than four-fold (2,500 to 11,400 TWh) consistent with sustained annual capacity additions in the range of 600 GW or more (IEA, 2025a). Third, firm low-emissions sources expand in absolute terms even where their shares appear stable: nuclear generation grows by roughly 40% while holding a nearly 10% share, hydro output increases by around 10% despite a declining share, and fossil generation equipped with CCUS together with hydrogen- and ammonia-fired capacity emerges from a negligible base to about 4% of supply, providing dispatchable balancing in deeply decarbonised systems.

The structural implication of these shifts is as important as their magnitude. A system in which variable renewables supply over half of all electricity cannot be operated with the tools of the fossil era: grid investment must rise to broadly match generation investment, storage capacity must scale in line with the COP29 pledge of 1,500 GW by 2030, and demand-side flexibility, smart charging, thermal storage, industrial load shifting, which must be mobilised at scale (IEA, 2025a). Figure 1.2 thus carries two messages for policymakers. First, the destination is a solar- and wind-led power system nearly half again as large as today's. Second, the decade to 2035 is the interval in which the enabling infrastructure for that system must be built.

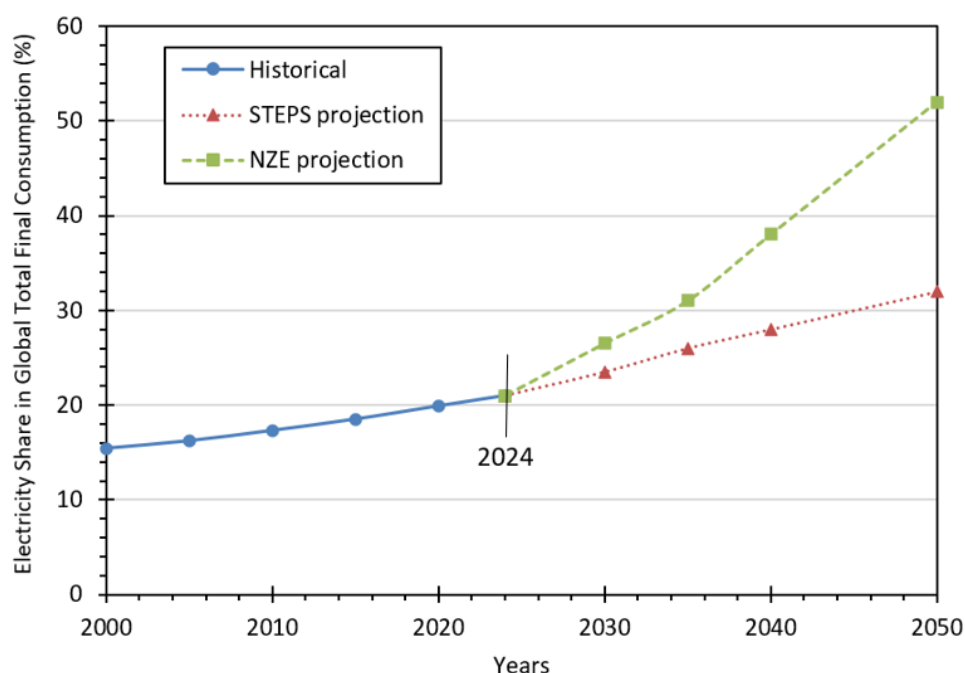


Figure 1.2 Electricity shares in global total final energy consumption between 2000-2050, including past actual data and future projections (Data from: IEA, 2025a)

It is important to note that the demand dynamics confirm the structural nature of the shift. As shown Figure 1.3, Global electricity consumption is set to exceed 29,000 TWh in 2026 and, under the IEA's Stated Policies Scenario (STEPS), expands by nearly 1,000 TWh every year through 2035, the equivalent of adding more than the annual consumption of Japan each year (IEA, 2025a, 2025d). Growth is broad-based: China remains the single largest source of



additional demand, expected to add the equivalent of the European Union's entire current consumption by 2030, while India (6.3–6.4% annual growth) and Southeast Asia (whose consumption is projected to rise from 1,300 TWh in 2024 to 2,100 TWh by 2035) are emerging as major new growth poles; advanced economies, after fifteen years of stagnation, have also returned to growth on the back of data centres, electric vehicles and heat pumps (IEA, 2025b, 2026).

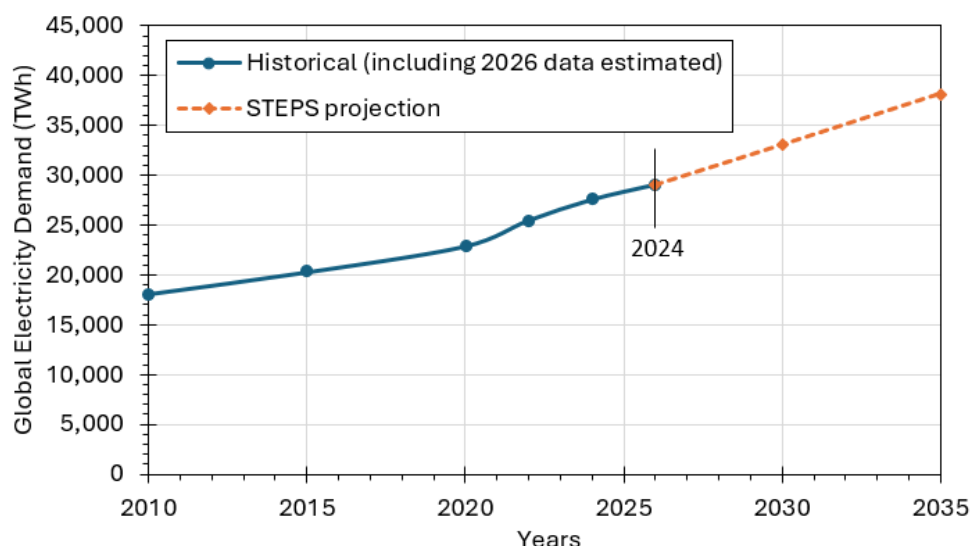


Figure 1.3 Variations of the global electricity demand, historical growth and STEPS projection to 2035 (Data from: IEA, 2025a; 2025; 2025c; 2025d)

1.2.2. Dimensions of Electricity Era

In the age of electricity, there are five key dimensions: economic, energy-system, technology, policy, and environmental dimensions. Five interrelated sets of factors facilitate the acceleration. Figure 1.4 shows five pillars which are considered the key drivers of the Age of Electricity, and their relationships determines the quality of electrification.



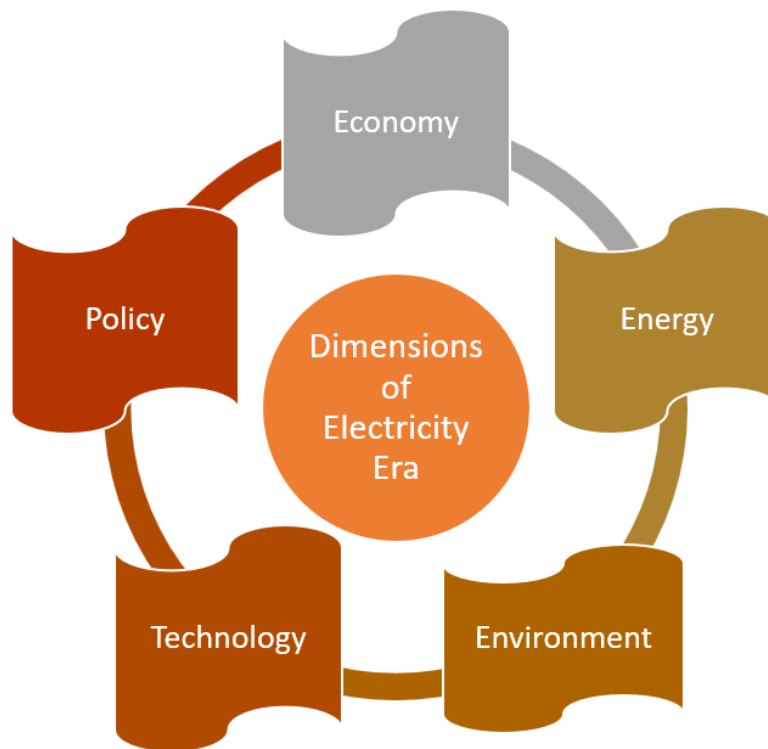


Figure 1.4 Five pillars of some key dimensions of the Age of Electricity

Economic dimensions:

Rising incomes in emerging market and developing economies are translating directly into electricity demand through appliance ownership and, above all, space cooling: peak electricity demand rises by around 40% to 2035 in the STEPS largely due to cooling, and electricity demand for space cooling alone climbs by almost 1,500 TWh by 2035 in the absence of strengthened efficiency standards (IEA, 2025a). The centre of gravity of demand is shifting between today and 2035, half of the growth in the global car fleet comes from emerging and developing economies outside China, and 80% of energy consumption growth occurs in regions endowed with high-quality renewable resources (IEA, 2025a).

Energy system dimensions:

Electric end-use technologies are inherently more efficient than their fuel-burning counterparts: heat pumps deliver three to four units of heat per unit of electricity, and electric motors convert far more input energy into useful work than internal combustion engines. More electrified pathways therefore use less final energy overall by avoiding waste heat from fuel combustion (IEA, 2025a). This efficiency dividend means electrification simultaneously advances decarbonisation, energy productivity where electricity is generated domestically and energy security.



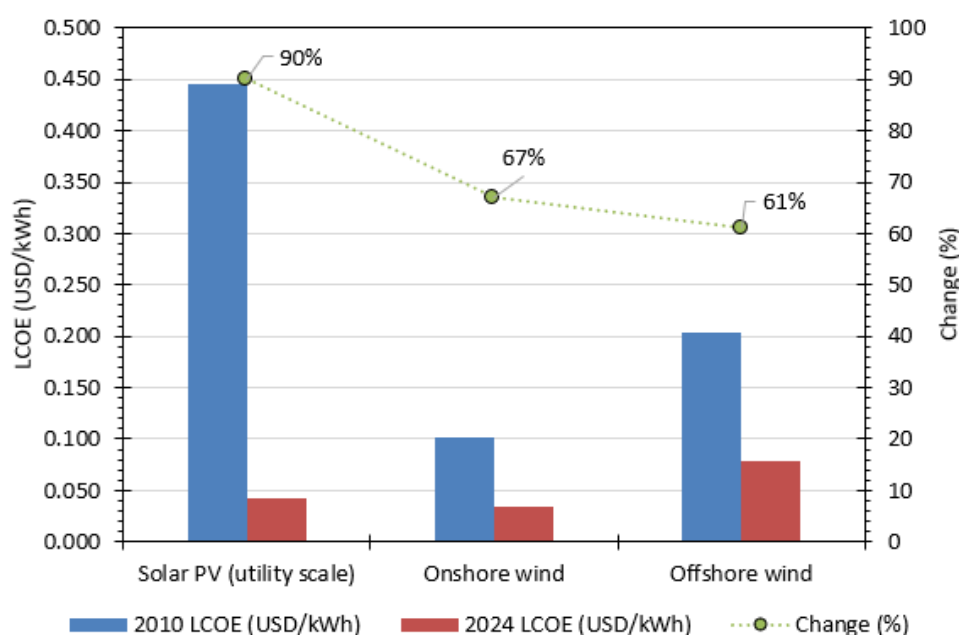


Figure 1.5 Levelized cost of electricity from renewables: 2010 vs 2024 (Data from: IRENA, 2025), Renewable Power Generation Costs in 2024, including global weighted-average LCOE, 2024 USD)

Technology dimensions:

Technology has played a critical role in shaping the electricity generation and its marked, and dramatic cost reductions have been achieved by providing more affordable electricity for various sectors and users. In this regard, some historical cost variations of electrification are illustrated in Figure 1.5. Between 2010 and 2024, the global weighted-average levelized cost of electricity fell by roughly 90% for utility-scale solar PV, 67% for onshore wind and 61% for offshore wind, making new renewables the cheapest source of bulk electricity in most of the world (IRENA, 2025). Battery costs have fallen dramatically as well, underpinning both electric mobility and grid-scale storage (IEA, 2025a). Digitalisation and hence artificial intelligence in this regard act as a dual force: data centres add new demand, though they account for less than 10% of global demand growth to 2035, concentrated in the United States, China and Europe, while AI-enabled forecasting, grid management and demand response improve the efficiency and reliability of increasingly complex power systems (IEA, 2025a; TÜBA, 2022).

Policy dimensions:

The policy architecture of the Paris Agreement reinforces these trends, as shown Figure 1.6. The first Global Stocktake at COP28 called for tripling global renewable capacity and doubling the rate of energy efficiency improvement by 2030 (UNFCCC, 2023), and the 2035 horizon of the third round of nationally determined contributions (NDC 3.0) places electrification at the centre of most national mitigation strategies. Industrial policy from clean technology manufacturing incentives to critical mineral strategies and heightened energy security concerns following the 2022 energy crisis have further accelerated the electricity pivot. Investors have responded: spending on electricity supply and end-use electrification already accounts for half of today's global energy investment (IEA, 2025a).



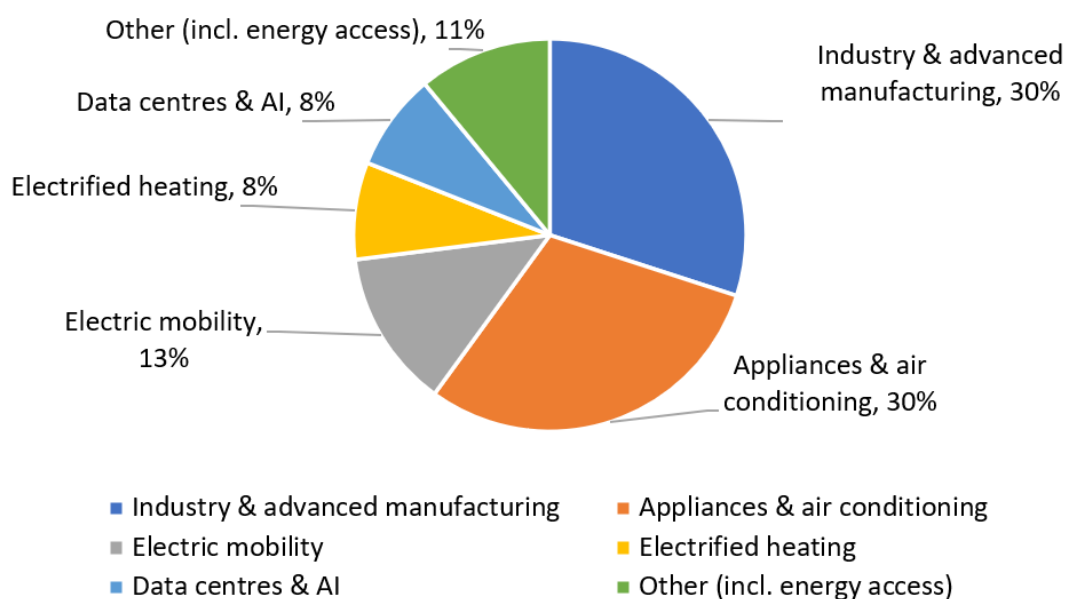
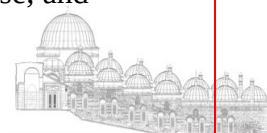


Figure 1.6 Drivers of global electricity demand growth up to the year 2035 (STEPS) (Data from IEA, 2025a; World Energy Outlook, 2025)

Environmental dimensions:

Beyond economics and technology, electrification is propelled by its direct environmental dividends. Because electric end-uses eliminate combustion at the point of use, they deliver benefits that arrive immediately and locally, independent of the pace of grid decarbonisation. Air quality is the most significant: ambient and household air pollution together cause around seven million premature deaths each year, concentrated in the same dense urban areas and low-income households where electrification of transport, heating and cooking has the greatest reach (WHO, 2024). Electric vehicles remove tailpipe emissions of nitrogen oxides and particulate matter from city streets; heat pumps and electric cooking displace the fuel combustion that dominates indoor air pollution, a burden borne disproportionately by women and children among the roughly two billion people still lacking clean cooking access as elaborated elsewhere (IEA, 2025a). Electrification also reduces the upstream footprint of fuel supply, such as methane leakage, flaring, spills and mining impacts and, where wind and solar PV replace thermal generation, cuts freshwater withdrawals for power plant cooling, an increasing material co-benefit in water-stressed regions. These local, visible and near-term gains give electrification a political constituency that global climate targets alone rarely command.

Clean cooking deserves particular emphasis within this agenda. Around two billion people still rely on traditional biomass, coal or kerosene for cooking, and the resulting household air pollution is linked to millions of premature deaths each year, with the burden of both exposure and fuel collection falling disproportionately on women and children (IEA, 2025a; WHO, 2024). Electric cooking solutions, which are induction cooktops, electric pressure cookers and other efficient appliances, are increasingly recognised as central clean cooking applications: they eliminate emissions at the point of use entirely, become cleaner as grids decarbonise, and



have reached cost-competitiveness with charcoal and LPG in a growing number of markets as appliance efficiency improves and electricity access expands. Realising this potential requires clean cooking to be planned jointly with electrification rather than as a separate programme: sizing access investments that will cover grid connections, mini-grids and solar home systems to support cooking loads, deploying appliance financing and bulk-procurement schemes that bring efficient e-cooking devices within reach of low-income households, and integrating cooking into national energy access strategies. Reflecting this priority, the COP31 Action Agenda explicitly includes clean cooking, positioning universal access to clean cooking as an inseparable component of the electrification and energy access goals pursued in this chapter.

1.3. Role of Electricity in Energy Transitions

Electrification is the central demand-side mechanism of the energy transition: it links the decarbonisation of electricity supply to emission reductions across the whole economy, and its pace largely determines whether the climate, security and affordability benefits described in this report materialise. This section examines that mechanism in three steps. Section 3.1 sets out why electrification occupies this position, explaining the efficiency, emissions and system-level logic that make a rising electricity share the signature of successful energy transitions. Section 3.2 then assesses the technologies, strategies and realisable potentials in the three principal end-use sectors: industry, where roughly half of energy demand is already electrifiable with mature technologies; transport, the fastest-electrifying end-use; and buildings, which anchor the largest block of future demand growth. Finally, Section 3.3 turns to the supply side, evaluating the pace at which the generation mix must decarbonise for electrification to deliver its full climate value.

1.3.1. Electrification in Energy Transitions

Electrification is the principal demand-side lever of decarbonisation: it substitutes fuels that emit at the point of use with a carrier whose emissions intensity falls continuously as the generation mix decarbonises. Every heat pump, electric vehicle and electric furnace installed today therefore becomes cleaner over its lifetime. Electrification also compounds the efficiency dividend described in Section 2.2, which is why scenarios with faster electrification exhibit lower total final energy consumption despite delivering more energy services (IEA, 2025a). Under stated policies, the share of electricity in final consumption rises from 21% today to around 26% by 2035; the COP31 target of 35% is aligned with the more ambitious end of the scenario range and is consistent with the Net Zero Emissions by 2050 trajectory, in which electricity exceeds half of final consumption by mid-century (IEA, 2025a). Achieving it requires action on both sides of the meter: accelerated adoption of electric end-use technologies, and a clean, secure and affordable supply to power them.



1.3.2. Technologies, Strategies and Potentials in End-Uses

The intensity target can be met only by acting on every part of the building stock simultaneously, and the four strategies presented below do exactly that. Section 3.2.1 begins with new construction, where building codes lock in performance for decades; Section 3.2.2 addresses the deep renovation of the buildings that already exist; Section 3.2.3 targets heating and cooling, the thermal services that dominate buildings' energy balance; and Section 3.2.4 adds the digital layer of smart operation and demand flexibility that binds the other three together. Individually, each strategy is proven; it is their combined deployment at scale that more than doubles the pace of intensity improvement.

1.3.2.1. Industry

Industry is both the largest electricity-consuming sector and the fastest-moving frontier of electrification: it accounted for nearly 40% of total growth in global electricity demand in 2024, driven by electro-intensive advanced manufacturing, in China alone, the production of solar modules, batteries and electric vehicles consumed more than 300 TWh in 2024, as much as Italy's total annual consumption (IEA, 2025b, 2025c). The technical potential for further electrification is substantial. Detailed bottom-up analysis of European industry indicates that roughly half of industrial final energy demand could be electrified with technologies that are already mature, industrial heat pumps and electric boilers for low- and medium-temperature process heat, and electric arc furnaces in steelmaking, and that the share rises to about 78% when emerging technologies such as electric crackers and high-temperature resistance and induction heating are included, as demonstrated in Figure 1.7. The residual hard-to-electrify segment, concentrated in very high-temperature processes and feedstock uses, is the natural domain of indirect electrification through green hydrogen and its derivatives (TÜBA, 2024).

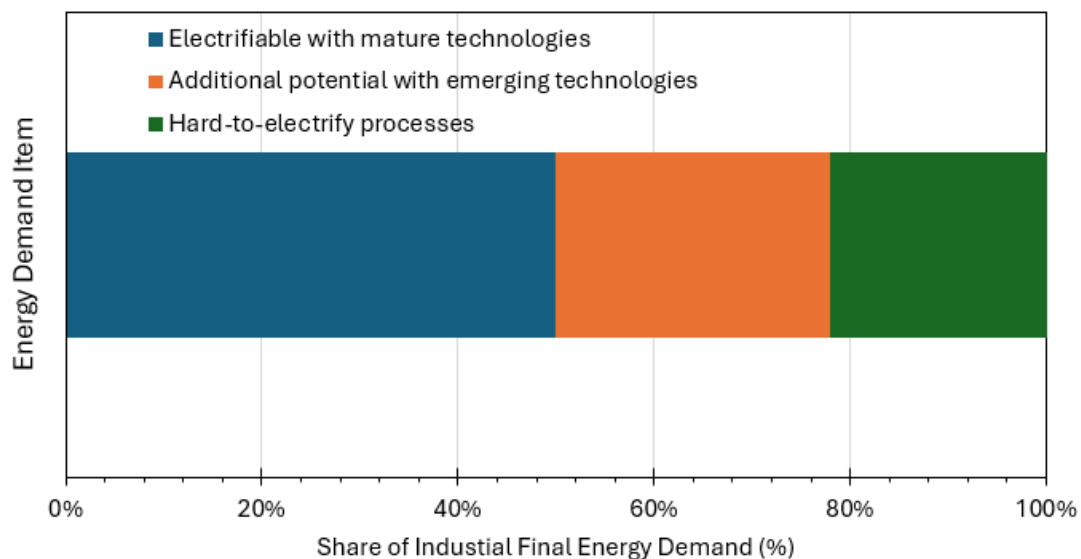


Figure 1.7 Direct electrification potential of industrial energy demand (Data from Madeddu et al., 2020)



1.3.2.2. Transport

Transport is electrifying faster than any other end-use. As shown in Figure 1.8, electric cars exceeded 20% of global new car sales in 2024, with more than 17 million units sold that is a rise of over 25% year on year and are set to surpass 25% of sales in 2025; China accounted for almost two thirds of global sales, while emerging markets outside China grew by 80% from a lower base, with Brazil and Indonesia expanding by 140% and 190% respectively (IEA, 2025c). Under the STEPS, the EV share of new car sales doubles to 2030 and rises above 50% by 2035, putting more than 840 million electric vehicles on the road and displacing around 10 million barrels of oil per day, which is the single largest factor behind the projected plateau of global oil demand around 2030 (IEA, 2025a). Electricity use in transport rose by over 8% in 2024 alone (IEA, 2025c). Beyond passenger cars, the electrification of two- and three-wheelers offers the fastest returns in emerging economies, while electric buses, urban delivery fleets and railways represent mature, scalable segments; heavy trucking, shipping and aviation will combine direct electrification with hydrogen-based and synthetic e-fuels. The critical enablers are charging infrastructure deployment, grid connection procedures and smart-charging frameworks that turn the 13EV fleets from a load into a flexible resource.

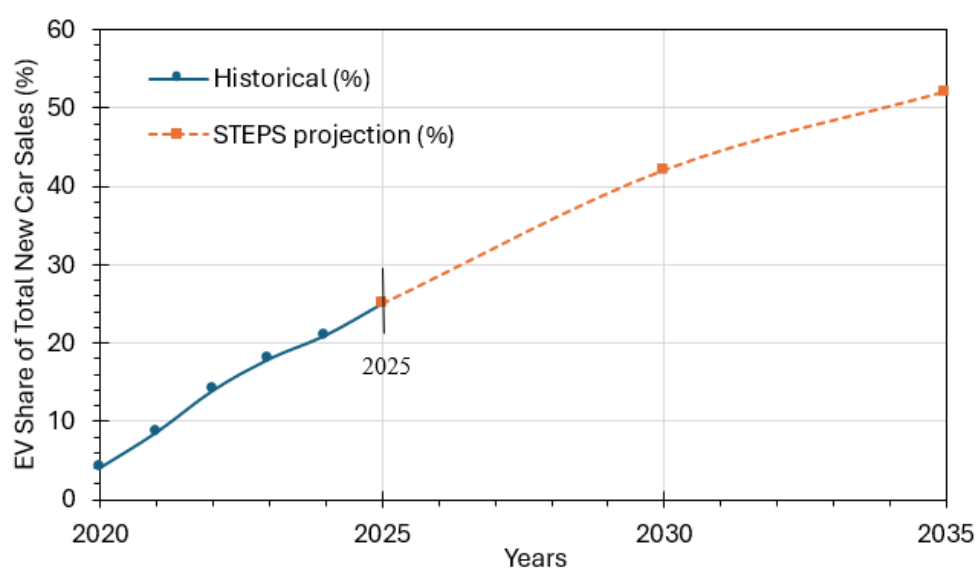


Figure 1.8 Electric vehicle share of global new car sales between 2020 and 2035 (Data from: IEA, 2025a; 2025b; 2025c)

1.3.2.3. Buildings

Buildings anchor the largest single block of future demand growth: appliances and air conditioning together contribute roughly 30% of the increase in global electricity demand to 2035, and cooling is the dominant driver of the projected 40% rise in peak demand (IEA, 2025a). The policy challenge in buildings is therefore twofold: to electrify heat while containing the system costs of cooling-driven peaks. Heat pumps are the central technology for the first task, delivering three to four times the efficiency of fossil boilers; although global heat pump



sales dipped by 1% in 2024 on weakness in Europe, the structural trajectory remains upward as carbon pricing, building codes and phase-out schedules for fossil boilers take effect (IEA, 2025c). For the second task, minimum energy performance standards for air conditioners, nearly zero-energy building codes, district cooling, thermal energy storage and demand response are the principal instruments; strengthened cooling standards alone can avoid a large share of the 1,500 TWh of additional cooling demand projected to 2035 (IEA, 2025a; TÜBA, 2020). Smart meters, building automation and AI-supported energy management systems knit these measures together and enable buildings to provide flexibility back to the grid (TÜBA, 2022).

1.3.3. Decarbonising Electricity Supply

The climate value of electrification depends on the parallel decarbonisation of supply and here the momentum is unprecedented, as indicated in Figure 1.9. It should be emphasised, however, that the climate case for electrification does not wait for a fully decarbonised grid. Because electric end-use technologies are inherently more efficient than the fuel-burning equipment they replace. For example, heat pumps deliver three to four units of heat per unit of electricity, and electric motors far exceed the conversion efficiency of internal combustion engines. Therefore, switching to electricity reduces emissions through the efficiency channel even where the power mix is unchanged. Peer-reviewed analysis across 59 world regions finds that electric cars and heat pumps already generate lower life-cycle emissions than their fossil-fueled counterparts in around 95% of global transport and heating demand, under current electricity mixes (Knobloch et al., 2020). Electrification of final consumption is therefore valuable in its own right, whatever the generation portfolio a country starts from an inclusiveness that the COP31 Presidency's 2035 Global Implementation Goals deliberately embody while the decarbonisation of supply progressively multiplies this benefit, ensuring that every electrified end-use becomes cleaner over its lifetime.

Renewables provide about one third of global generation today; under stated policies their share rises to around 55% by 2035 and two thirds by 2050, led by solar PV with support from wind and batteries, with renewable capacity additions averaging 620 GW per year to 2035 (IEA, 2025a). Solar generation overtook coal in the European Union in 2024, and China, the United States and India are all set to see solar reach a 10% generation share within this decade (IEA, 2025b). Nuclear output grows by 40% to 2035, maintaining a 9% share and providing a firm low-emissions backbone, supported by lifetime extensions, restarts in Japan and new construction across Asia (IEA, 2025a; 2025b). The fossil share of generation correspondingly falls from about 60% in 2024 to below 40% by 2035 and around 20% by mid-century in the STEPS, with global coal demand peaking before 2030 (IEA, 2025a). Yet the STEPS trajectory remains consistent with warming of around 2.5 °C by 2100; closing the gap to well below 2 °C requires the faster renewables deployment, grid expansion and end-use electrification embodied



in the NZE Scenario that is precisely the acceleration that the COP31 2035 Global Implementation Goals are designed to catalyze accordingly for achieving the specific targets (IEA, 2025a).

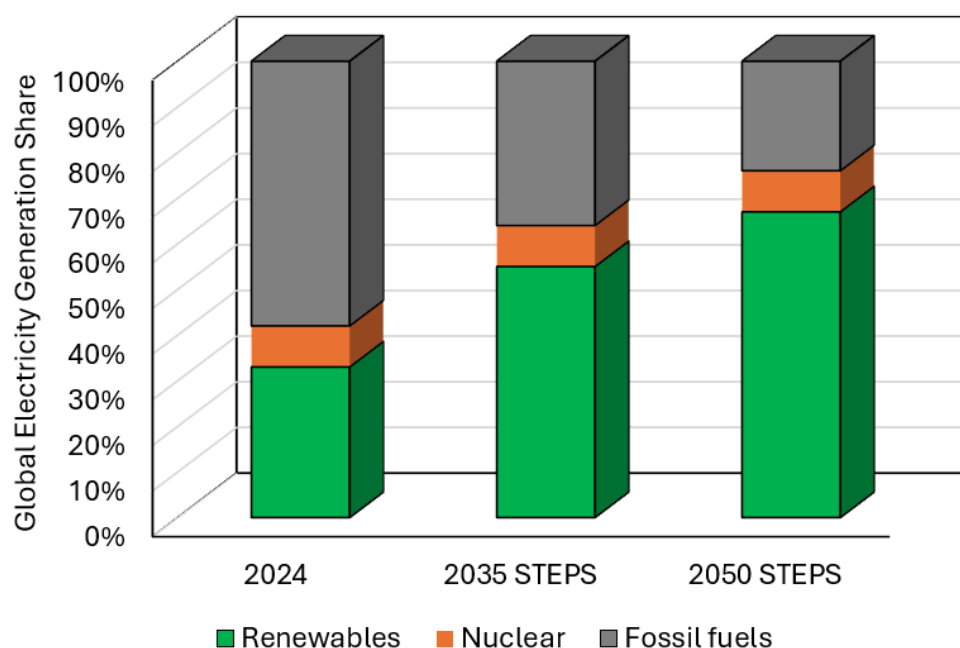


Figure 1.9 Global electricity generation mix by considering renewables, nuclear and fossil fuels together for 2024 and STEPS projections (Data from: IEA, 2025a; 2025b)

1.4. Implications: Co-Benefits and Key Enablers

The rise in electricity examined in the preceding sections is not an end in itself: its value lies in the benefits it can bring up and the conditions under which it delivers them. This section assesses those implications across three domains. Section 4.1 addresses energy security, showing how electrification reshapes the geography of dependence while raising new priorities in electricity system security, where flexibility, grids and storage become the binding constraints, and in the supply chains for critical minerals and clean technologies on which the hardware of electrification depends. Section 4.2 turns to affordability and investment, examining how a capital-intensive, low-fuel-cost power system stabilizes prices and reduces import bills, and why redirecting capital towards emerging and developing economies is the decisive financial challenge of the decade. Section 4.3 completes the picture with inclusive electrification, covering the roughly 730 million people still without electricity access, the reform agenda for fragile electricity markets, and the distinctive opportunities of small island systems. Together, these three domains define the co-benefits that make the transition worth accelerating and the enablers without which it will stall.



1.4.1. Energy Security

Resilience begins with an honest account of exposure. Climate hazards do not threaten the built environment uniformly: they differ in mechanism, geography and the design responses they demand, and the subsections that follow therefore treat them in turn. Section 4.1.1 characterizes the principal physical hazards bearing down on buildings and urban infrastructure and the scale of assets and populations exposed to each. Section 4.1.2 then sets out how this exposure is translated into resilient practice: climate-informed risk mapping that steers development away from the highest-risk locations, structural and drainage standards calibrated to the future climate rather than the historical record, nature-based solutions, and the integration of adaptation requirements into building codes, where policy still lags well behind mitigation provisions.

1.4.1.1. Diversification and Import Dependence

Electrification fundamentally reshapes the geography of energy security. For fuel-importing economies, every barrel of oil displaced by an electric vehicle and every cubic meter of gas displaced by a heat pump converts an exposure to volatile international commodity markets into demand for electricity that can, to a large extent, be generated domestically. The 840 million EVs on the road by 2035 in the STEPS displace some 10 mb/d of oil, import savings concentrated in Asia and Europe (IEA, 2025a). The mapping of future demand onto resources is favorable: by 2035, 80% of energy consumption growth occurs in regions with high-quality solar and wind resources (IEA, 2025a). Security concerns do not disappear, however; they migrate from fuels to electricity systems, technologies and minerals, as examined below. The IEA (2025a) further emphasizes that the nature of energy security is expected to change drastically in a digitalized era: traditional risks remain, but electricity security and critical mineral security are rising as key priorities.



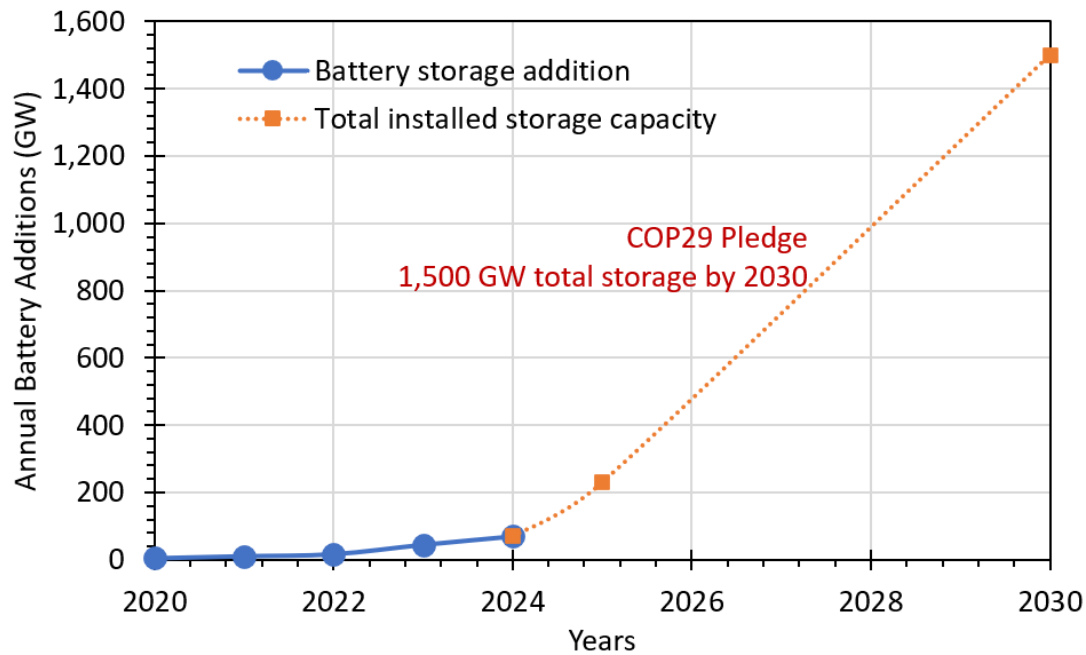


Figure 1.10 Grid-scale battery storage: annual additions and the 2030 global pledge (Data from: IEA, 2025a; 2025b; UNFCCC, 2024)

1.4.1.2. Electricity Security: Flexibility, Grids and Storage

As electricity becomes the backbone of economies, the cost of failure rises, a lesson underscored by the major blackouts experienced in Chile and the Iberian Peninsula in 2025 (IEA, 2025a). Three challenges dominate. First, adequacy under rapidly rising peaks: peak demand grows around 40% by 2035, faster than average demand, driven by cooling (IEA, 2025a). Second, flexibility to integrate variable renewables: the diurnal ‘duck curve’ pattern of net demand requires storage, dispatchable capacity, demand response and interconnection (TÜBA, 2020). Third, grids themselves: the IEA identifies a widening gap between generation deployment and grid readiness, making transmission and distribution investment, which must roughly match generation investment, the binding constraint in many markets (IEA, 2025a). As shown in Figure 1.10, storage is scaling rapidly in response: annual grid-scale battery additions rose from about 5 GW in 2020 to roughly 70 GW in 2024, and the Global Energy Storage and Grids Pledge adopted at COP29 targets 1,500 GW of installed storage capacity by 2030 alongside the addition or refurbishment of 25 million kilometres of grids (IEA, 2025b; UNFCCC, 2024). AI-supported forecasting and autonomous grid management will be indispensable for operating systems of this complexity (TÜBA, 2022).

1.4.1.3. Supply Chains

Supply chain for critical minerals is one of the critical subjects for the hardware of electrification like batteries, motors, wind turbines, solar cells, cables, since they are mineral-intensive. Figure 1.11 compares 2023 and 2040 levels for lithium, graphite, nickel, cobalt, rate



earth and copper. Demand for lithium from clean energy applications grows up to nine-fold by 2040 in the NZE Scenario, with graphite, nickel and cobalt demand multiplying two- to four-fold and copper (the workhorse of grids) rising by roughly half (IEA, 2024). The security concern apparently lies less in geological scarcity than in the geographic concentration of mining and, especially, refining and processing, where single countries dominate several value chains. Diversification of sources, recycling at scale, material efficiency and innovation in chemistries (for example sodium-ion batteries) are the principal mitigation strategies.

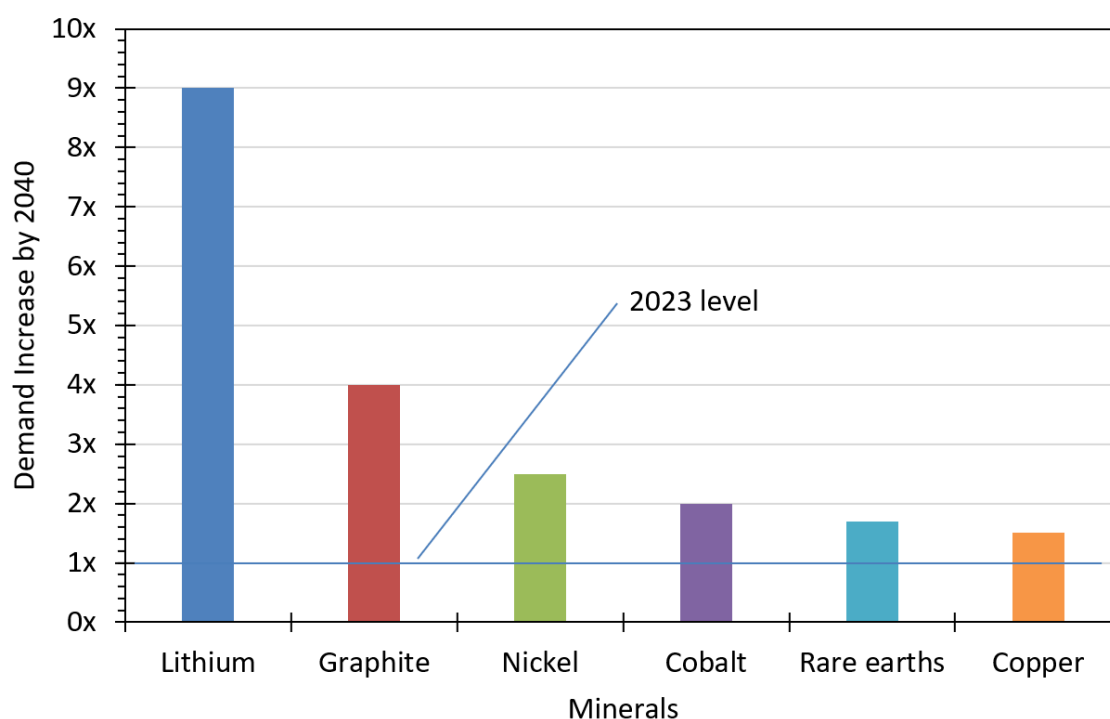


Figure 1.11 Growth in electricity demand for some specifically selected critical minerals to 2040 (Data from: IEA, 2024)

It is important to highlight that the manufacturing capacity for many clean energy technologies is now ample, record solar module manufacturing capacity substantially exceeds current deployment, but it is highly concentrated geographically (IEA, 2025a). For importing regions, this creates a different form of dependence; for the system as a whole, it has driven costs down dramatically. Balanced policy seeks resilient, reasonably diversified supply chains without sacrificing the affordability gains of scale, combining trade, domestic manufacturing incentives and technology partnerships.

1.4.2. Affordability and Investment

Global energy investment reached USD 3.3 trillion in 2025, more than 20% above 2015 levels, with roughly two thirds directed to low-emissions technologies; spending on electricity supply and end-use electrification already accounts for half of total energy investment (IEA, 2025a). The affordability case for electrification rests on three pillars. First, operating-cost advantage: renewables are the cheapest new generation in most markets (Figure 1.5), and efficient electric



end-uses reduce the energy bill per unit of service. Second, price stability: electricity systems dominated by capital-intensive, zero-fuel-cost assets are structurally less exposed to the fuel price shocks that drove the 2022 crisis, during which European industrial electricity prices reached multiples of those in the United States and China (IEA, 2025b). Third, macroeconomic resilience through reduced import bills. The investment challenge is distributional: capital remains concentrated in China, the United States and Europe, while Africa and Latin America lag despite accelerating demand, largely because high costs of capital in emerging and developing economies inflate the financing cost of capital-intensive clean technologies (IEA, 2025a). De-risking instruments, concessional finance and the aggregation of projects into investable portfolios, which is the core logic of the CIB under Goal 6 of the COP31 Presidency, are therefore central enablers of an affordable Age of Electricity.

1.4.3. Inclusive Electrification

As societies electrify, the resilience of buildings becomes inseparable from the resilience of their power supply and nowhere are the stakes higher than in the facilities on which lives depend. The subsections that follow address this dependence in two steps. Section 4.3.1 establishes what is at risk: the growing exposure of hospitals, water and sanitation systems, communications, schools serving as shelters and disaster coordination centres to grid outages, illustrated by the systemic costs of recent large-scale blackouts in highly electrified systems. Section 4.3.2 then sets out the solution architecture: distributed solar generation paired with battery and thermal storage, configured as islandable microgrids that sustain critical loads through outages while delivering daily economic value, supported by resilience standards with defined backup-duration requirements and the hardening of network assets against flood and heat.

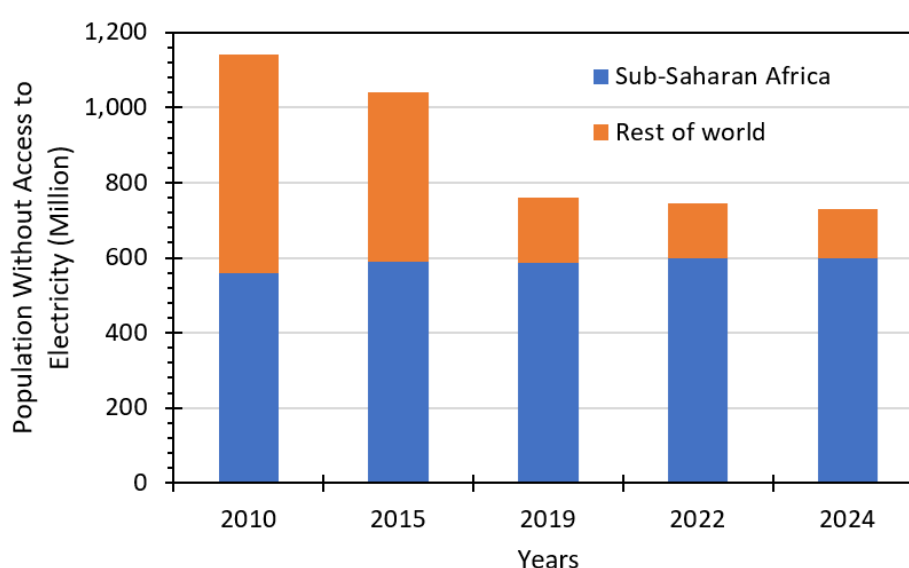


Figure 1.12 Variation of the population without access to electricity, particularly ranging from 2010 to 2024
(Data from: IEA, 2025a; 2025b)



1.4.3.1. Electricity Access

It is quite unfortunate that the subject matter electricity age is not yet for everyone in the world. Around 730 million people still live without access to electricity, a figure that has recently worsened rather than improved, with some 600 million of them in sub-Saharan Africa and the world is not on track to close the gap, as shown in Figure 1.12 (IEA, 2025a, 2025b). Yet the same technology revolution driving electrification elsewhere has transformed the economics of access: solar home systems, mini-grids and grid densification, deployed in an integrated least-cost planning framework, can deliver universal electricity access by 2035, as set out in the IEA's new universal access pathway drawing on the experience of countries that have achieved rapid progress (IEA, 2025a). Achieving this requires roughly a tripling of annual access investment, concentrated concessional finance for last-mile connections, and business models that pair connections with productive uses (irrigation, agro-processing, cold chains) so that access translates into income and demand growth that sustains the systems built. Between full access and none lies a broad category of fragile electricity markets: systems characterized by financially distressed utilities, high technical and commercial losses, unreliable supply, subsidy burdens and constrained public finances. In such contexts, electrification of end-uses can stall not for lack of demand but for lack of dependable supply, pushing consumers and firms towards diesel self-generation at very high economic and environmental cost. Priority enablers include utility governance and cost-recovery reform with protection for vulnerable consumers; loss reduction and revenue collection programmes supported by digital metering; distributed solar and storage to improve reliability while grid investments catch up; and regional power pools and interconnection to share reserves and smooth hydrological and demand shocks. International climate finance can be catalytic where it is structured to strengthen, rather than bypass, the domestic institutions that must ultimately sustain the system.

1.5. Action Plan

The previous sections declared that raising the share of electricity in global final consumption from 21% today to 35% by 2035 is technically feasible and economically advantageous, but will not occur under stated policies alone, which deliver only around 26% (IEA, 2025a). Closing this gap requires coordinated action across seven fronts, sequenced over three phases: a launch phase (2026-2028) in which governance, national roadmaps and pilot programmes are established; a scale-up phase (2028-2032) in which deployment reaches the required annual run-rates, with an interim milestone of a 28–30% electrification rate by 2030; and a consolidation phase (2032-2035) in which the target is attained and verified through the Global Stocktake. Figure 1.13 demonstrates the action plans for electrification globally.





Figure 1.13 An illustration of the action plan

Action 1

Transform into green electricity generation

The change required in the composition of electricity supply is quantitatively defined: the fossil share of generation must fall from about 58% in 2024 to below 40% by 2035 and coal from 34% to a residual share while renewables rise from one third to around 55%, led by solar PV and wind, with nuclear holding a firm 9-10%, as stated in IEA's World Energy Outlook 2025. Governments should embed these mix milestones in national power-sector plans and NDC 3.0 targets, and monitor them annually alongside the electrification rate itself, since the two indicators jointly determine the emissions outcome. The environmental case for managing this shift deliberately extends well beyond CO₂. Replacing coal and oil-fired generation removes the sulphur dioxide, nitrogen oxides and fine particulate emissions that contribute to the roughly seven million premature deaths caused by air pollution each year, with benefits concentrated in the dense urban regions of emerging economies where coal fleets and demand growth coincide.



Substituting wind and solar PV for thermal plants cuts freshwater withdrawals for power-plant cooling, an increasingly material constraint in water-stressed regions and displacing gas reduces upstream methane leakage and flaring, addressing a potent near-term warming agent. These dividends are not automatic by-products: they should be actively captured by prioritising the retirement of the most polluting units near population centres, applying air-quality and water-use criteria alongside cost in capacity planning, and pairing renewables siting frameworks with land-use and biodiversity safeguards so that the expanded footprint of solar, wind and transmission infrastructure does not create new environmental conflicts. Managed this way, the transformation of the generation mix becomes the single largest public-health investment of the energy transition, and builds the local political constituency (cleaner air, healthier cities, secure water) that sustains climate ambition through 2035 and beyond.

Action 2

Electrify end-uses at large scale

In transport, governments should adopt binding zero-emission vehicle sales trajectories consistent with electric cars exceeding 50% of global sales by 2035, backed by charging-infrastructure rollout obligations, smart-charging standards and purchase support that is progressively shifted from early adopters to mass-market and fleet segments; the electrification of two- and three-wheelers and urban bus fleets should be prioritised as the fastest wins in emerging economies. In buildings, fossil-fuel boiler installations in new construction should be phased out this decade, heat pump deployment supported through tariff structures that correct electricity-to-gas price ratios, and appliance and cooling efficiency standards strengthened to contain peak demand. In industry, low- and medium-temperature process heat should be systematically converted through industrial heat pumps and electric boilers, roughly half of industrial energy demand is electrifiable with mature technologies alone, while R&D and demonstration programmes mature electric options for high-temperature processes.

Action 3

Decarbonise supply in step with demand

The COP28 commitment to triple renewable capacity should be operationalised through streamlined permitting, expanded auction volumes and de-risked revenue frameworks that sustain renewable additions of at least 620 GW per year to 2035, complemented by lifetime extensions and new construction that grow nuclear output by around 40%, in IEA's World Energy Outlook 2025. Unabated coal generation should be placed on a managed phase-down pathway, with gas repositioned from baseload to flexibility service. Without parallel supply decarbonisation, electrification shifts rather than eliminates emissions; with it, every electrified end-use becomes cleaner over its lifetime.



Action 4

Build smart grids with storage options

The binding constraint identified in Section 4.1.2 must be addressed pre-emptively: transmission and distribution investment should be raised to broadly match generation investment, anticipatory-investment frameworks adopted so that grid capacity precedes rather than follows demand, and connection queues reformed. Storage deployment should be aligned with the COP29 pledge of 1,500 GW by 2030, and demand-side flexibility (smart EV charging, thermal storage, industrial load shifting, AI-supported demand response) mobilised as a system resource to contain the roughly 40% rise in peak demand.

Action 5

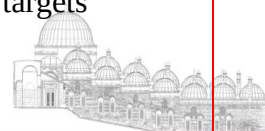
Develop resilient supply chains

Critical mineral strategies should combine diversification of mining and refining, recycling at scale, material-efficiency standards and support for alternative chemistries such as sodium-ion, reflecting demand growth of up to nine-fold for lithium by 2040, as stated in IEA's Global Critical Minerals Outlook 2024. Among these levers, recycling and circularity deserve particular weight: they are the only supply sources that simultaneously reduces import dependence, price exposure and the environmental footprint of extraction. The coming decade is the window in which to build this capacity. The first mass wave of electric vehicle batteries reaches end of life in the early 2030s, and recycled materials could meet a meaningful and steadily rising share of demand for lithium, nickel, cobalt and copper by 2040 if collection systems, recycling capacity and product standards are put in place now. Priority measures include extended producer responsibility and mandatory collection schemes for batteries and clean energy equipment; minimum recycled-content requirements that create stable demand for secondary materials; battery passports and design-for-disassembly standards that make recovery economical; and support for second-life applications, in which retired vehicle batteries serve stationary storage before material recovery. Framed this way, circularity turns today's deployment wave into tomorrow's domestic mineral resource, which makes it an urban mine that grows with the transition itself. Clean-technology manufacturing should be broadened geographically through trade frameworks, technology partnerships and targeted industrial policy that build resilience without sacrificing the affordability gains of scale.

Action 6

Provide finance and protect affordability

Investment in electricity supply and electrification, already half of the USD 3.3 trillion invested in energy in 2025, must continue to grow and critically be redistributed towards emerging and developing economies, where high costs of capital are the principal barrier, as mentioned in IEA's World Energy Outlook 2025. Within this total, grid investment warrants explicit targets



of its own, because networks are where the widening gap between generation deployment and system readiness is concentrated. Global grid investment, currently on the order of USD 400 billion per year, needs to roughly double towards USD 800 billion annually by the early 2030s and broadly match generation investment on a sustained basis; the COP29 Global Energy Storage and Grids Pledge translates this need into a collective commitment to add or refurbish 25 million kilometers of grids by 2030, alongside 1,500 GW of storage capacity (IEA, 2025a; UNFCCC, 2024). Meeting these targets requires regulatory frameworks that permit anticipatory investment together with streamlined permitting for transmission corridors and reformed connection queues, since grids are the longest-lead-time assets in the electrification chain. Concessional finance guarantees and currency-risk instruments should be scaled through development banks and climate funds, and national electrification projects aggregated into standardised, investable portfolios under the Climate Implementation Bridge. Tariff and taxation reform should ensure that efficient electric end-uses are also the economical choice for consumers.

Action 7

Make electrification inclusive

The universal access pathway should be resourced to deliver electricity for all by 2035, roughly tripling annual access investment with a focus on sub-Saharan Africa, integrated least-cost planning across grid extension, mini-grids and solar home systems, and business models that pair connections with productive uses. In fragile electricity markets, utility governance and cost-recovery reform, loss reduction and distributed solar-plus-storage should precede or accompany end-use electrification; for small island systems, dedicated concessional windows and aggregated project platforms should convert the least-cost economics of solar-battery hybrids into deployed systems.

Action 8

Develop hydrogen economy

Direct electrification has technical or economic limits in a residual set of applications, such as very high-temperature industrial heat, steelmaking, chemical feedstocks, shipping and aviation, and in these segments, hydrogen produced from low-emissions electricity is the natural extension of the electrification agenda: indirect electrification through a storable, transportable carrier. Governments should scale electrolysis capacity through auctions, contracts-for-difference and offtake guarantees that close the cost gap with fossil-based hydrogen; prioritise deployment where hydrogen is hardest to substitute, beginning with the conversion of existing fossil-based hydrogen demand in refining and ammonia production before expanding into steel, e-fuels and seasonal power storage; build the enabling infrastructure of pipelines, storage and ports, with harmonised international standards and certification schemes for the emissions



intensity of traded hydrogen; and embed safety codes and public-acceptance programmes from the outset, since hydrogen's physical properties demand rigorous leak detection, ventilation and material-compatibility requirements across the value chain. Designed well, the hydrogen economy also strengthens the power system itself: electrolyzers operating flexibly absorb surplus renewable generation that would otherwise be curtailed, provide demand response, and convert variable electricity into seasonal storage, deepening rather than competing with the electrification of end-uses. This action line advances SDG 9 on industrial innovation, SDG target 7 on international cooperation in clean energy technology, and SDG 13, as hydrogen unlocks emission reductions in precisely the sectors that electrification alone cannot reach.

Action 9

Use artificial intelligence for management and assessment

As electricity systems grow larger, more decentralised and more dependent on variable renewables, their complexity is outpacing the capabilities of conventional operational tools; artificial intelligence should therefore be deployed as core system infrastructure rather than an optional add-on. Governments and system operators should scale AI-supported applications across four layers of the power system: forecasting, where machine-learning models sharpen predictions of renewable output, demand and prices; grid operation, where AI enables real-time congestion management, autonomous fault detection, predictive maintenance of network assets and self-healing grid functions; demand-side management, where intelligent control of EV charging, heat pumps, building systems and industrial loads converts millions of distributed devices into a coordinated flexibility resource that reduces peak demand and system investment costs; and market and asset management, where AI-driven aggregation allows virtual power plants to bid distributed resources into electricity markets. Enabling policies include open, standardised access to system and smart-meter data with strong privacy safeguards, regulatory sandboxes for AI applications in network operation, cybersecurity standards commensurate with the criticality of AI-controlled infrastructure, and workforce programmes that build AI competence within utilities and regulators. Deployed this way, artificial intelligence lowers the cost of the entire electrification agenda, from grid expansion to inclusive access, is delivered more efficiently with intelligent management and control. This action line advances SDG 9 on innovation and resilient infrastructure and supports SDG target 7.3, since optimisation-driven efficiency gains are among the cheapest available forms of energy saving.

In closing, it is important to highlight that delivering these eight action lines requires a standing governance architecture: annual reporting of electrification rates by the IEA and UNFCCC against the 2030 and 2035 milestones, peer-review at each COP through 2035. The measure of success is unambiguous, a 35% electrification rate, achieved with clean supply, secure systems and universal access.



1.6. Conclusions

The evidence assembled in this report supports three conclusions. First, the Age of Electricity is a present reality, not a forecast: electricity demand is growing four times faster than total energy demand, electricity already powers the sectors that generate most of the world's economic value, and half of global energy investment is flowing to electricity supply and electrification. Second, the direction of travel under stated policies (a 26% electrification rate and a 55% renewables share by 2035) is encouraging but insufficient for climate goals; the COP31 target of a 35% electrification rate by 2035, pursued together with the tripling of renewables agreed at COP28, defines the ambition level consistent with keeping well-below-2 °C outcomes within reach. Third, the benefits of the transition do not materialise automatically. They must be secured through anticipatory investment in grids and storage, resilient and diversified supply chains, financing frameworks that lower the cost of capital in emerging and developing economies, and deliberate inclusion of those still without power. Since resilient electrification sector requirement has been a major task to achieve in many countries, there are critical actions required in this regard. Making smoother transition to a more electrified world requires artificial intelligence tools deployed to ensure that people get affordable electricity and live in a more sustainable world. Some key points extracted from the study are listed as follows:

- The Age of Electricity has even become a more critical reality, not a forecast. Electricity demand is growing roughly four times faster than total energy demand, electricity already powers the sectors that generate more than 40% of global economic value, and half of the USD 3.3 trillion invested in energy in 2025 is flowing to electricity supply and electrification.
- The direction in the electrification is encouraging but insufficient. Under stated policies, the electrification rate reaches only about 26% and the renewables share about 55% by 2035; the COP31 targets of a 35% electrification rate, pursued together with the COP28 commitment to triple renewables, defines the ambition level consistent with keeping well-below 2 °C outcomes within reach.
- Electrification and supply decarbonisation must advance together. Reducing the fossil share of generation from 58% today to below 40% by 2035 is what converts every electric vehicle, heat pump and electric furnace into a durable emissions reduction.
- Infrastructure must be built ahead of need, not behind it. Grids, storage aligned with the COP29 pledge of 1,500 GW by 2030, and demand-side flexibility are the binding constraints of a system whose peak demand rises by around 40% to 2035; anticipatory investment is the difference between a secure transition and a stalled one.
- Resilient supply chains and affordable capital are strategic prerequisites. Demand for critical minerals such as lithium grows up to nine-fold by 2040, and the geographic



concentration of refining and clean-technology manufacturing requires deliberate diversification; meanwhile, redirecting capital towards emerging and developing economies where financing costs, not resources, are the barrier, is the central financial task of the decade.

- The transition must reach everyone to succeed. Around 730 million people remain without electricity access; the universal access pathway to 2035, fragile-market reform and dedicated solutions for small island systems are integral to 35% electrification rate target, not appendices to it.
- The task of this decade is defined and measurable. The eight action lines set out in Section 5, tracked annually against the 2030 interim milestone (28–30%) and verified through the Global Stocktake, provide the delivery framework; the measure of success is unambiguous, a 35% electrification rate by 2035, achieved with clean supply, secure systems and universal access.

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CHAPTER 2

ZERO WASTE AND METHANE REDUCTION

Abstract

Global municipal solid waste (MSW) generation is projected to increase from 2.56 billion tonnes in 2022 to 3.86 billion tonnes by 2050. The waste sector is responsible for around 20% of global anthropogenic methane emissions, most of which are generated by the anaerobic decomposition of biodegradable organic waste in landfills. One of the global implementation goals proposed under the COP31 Action Agenda is to halve the growth in waste generation by 2035. This study presents a comparative assessment of Türkiye's MSW management system within the context of global MSW management practices and a scenario-based life cycle assessment (LCA) spanning a 2014 historical baseline, the 2021 status quo, and a 2035 target scenario aligned with Türkiye's national 60% recovery target. The results show the sector's carbon intensity declining from 351 kg CO₂-eq per tonne of waste in 2014 to 61 kg CO₂-eq per tonne in 2021, reaching a net-negative offset of -175 kg CO₂-eq per tonne by 2035. Despite this substantial decarbonisation, the analysis suggests that achieving the COP31 objective of halving the growth in waste generation will require not only continued investment in waste recovery but also a fundamental transition from waste management to resource management, underpinned by circular economy principles, waste prevention, source separation and effective waste sorting. Finally, a set of action plan recommendations are proposed for Türkiye to achieve the COP31 waste target.

Keywords: Circular Economy, Life Cycle Assessment, Municipal Solid Waste, Methane Emission Reduction, Waste-to-Resource Transition



2.1. Introduction

For the past decade, sector-specific decarbonisation roadmaps across energy, industry and the built environment have converged on a common recognition: material reduction, reuse and recycling belong at the centre of climate strategy, not at its periphery. Municipal solid waste (MSW) management remains a critical challenge: less than half of the world's population currently has access to adequate waste management. Global MSW generation is projected to increase from 2.56 billion tonnes in 2022 to 3.86 billion tonnes by 2050 (Figure 2.1), while per capita MSW generation is projected to increase from 0.88 to 1.10 kg per capita per day over the same period (Figure 2.2), under a business-as-usual (BAU) scenario (World Bank, 2026). These trends pose a growing threat to both the environment and socio-economic development (UNEP, 2024a). Food loss and waste constitute a major global challenge with far-reaching environmental, social, and economic consequences. Approximately 1.3 billion tonnes of food is lost or wasted each year (Erol & Sırken, 2024).

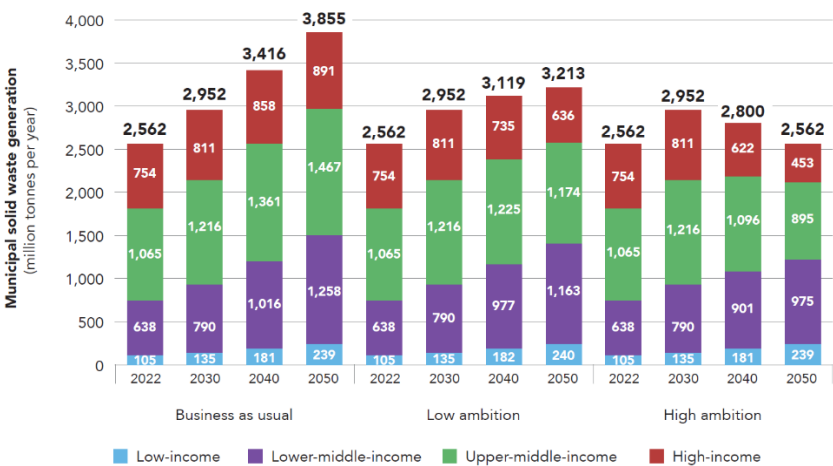


Figure 2.1 Total MSW Generation Projection Scenarios (World Bank, 2026)

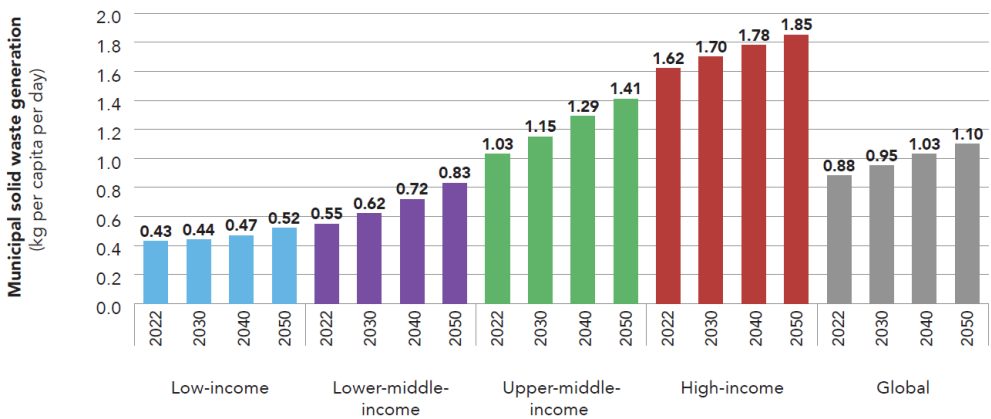


Figure 2.2 Per Capita MSW generation by income group for BAU scenario (World Bank, 2026)



Climate mitigation policy has historically concentrated on energy generation, industrial processes and transport, reflecting the fact that roughly three-quarters of global greenhouse gas emissions stem directly from fossil fuel combustion. Waste management has, by comparison, long been treated as a secondary concern. MSW management was estimated to generate around 1.28 GtCO₂-eq in 2022, with 85% of these emissions are originating from waste disposal and a further 11% from other solid waste management activities (World Bank, 2026). The International Solid Waste Association had earlier calculated that MSW management alone could deliver up to 18% of the original Kyoto Protocol reduction commitment of the EU-15 (ISWA, 2009) evidence that the sector's climate relevance is not a recent discovery but one that policy has been slow to act on. Recent intergovernmental scientific assessments have gone further, establishing that limiting warming to 1.5 °C also requires urgent emission reductions in agriculture, land use and, specifically, the waste sector (IPCC, 2021).

The technical mechanism behind the waste sector's outsized role in global climate diplomacy is the control of methane emissions. Although methane's atmospheric lifetime is far shorter than that of carbon dioxide, it carries a global warming potential 84 times that of CO₂ over a 20-year horizon and 28–32 times over a 100-year horizon (IPCC, 2021), and is estimated to be responsible for roughly a third of greenhouse gas (GHG)-induced warming (Wang et al., 2024). In Türkiye, the waste sector, including wastewater treatment emissions, is a significant and closely tracked component of the national greenhouse gas inventory (TÜİK, 2026).

The waste sector as a whole, including wastewater treatment, is directly responsible for approximately 20% of global anthropogenic methane emissions (UNEP, 2024b; World Bank, 2026); landfills and dumpsites specifically account for roughly 10% of that total on their own, some 50 Tg of methane per year, generated by landfill gas from the anaerobic decomposition of the biodegradable organic fraction of solid waste (Wang et al., 2024). This dynamic underlies the Global Methane Pledge launched at COP26, under which signatory countries committed to reducing global methane emissions by at least 30% below 2020 levels by 2030 (Global Methane Pledge, 2021). Methane management has consequently become the most critical and verifiable component of Nationally Determined Contributions (NDC) (IEA, 2024) although the accuracy of the inventory methods used to track it remains an open scientific question.

This study consists of six sections. Section 2.1 introduces the study. Section 2.2 situates Türkiye's MSW system within the global landscape of MSW management systems. Section 2.3 presents the COP31 zero waste and methane target and the systemic transformations it requires. Section 2.4 presents the scientific and policy basis for the assessment, comprising a scenario-based life cycle assessment (LCA) of Türkiye's MSW system spanning a 2014 historical baseline, the 2021 status quo, and a 2035 target scenario. The latter is constructed around the recovery and diversion targets set out in Türkiye's National Waste Management Action Plan and draws on the LCA methodology and results reported by Maçın (2026). Section 2.5 presents



a set of action plan recommendations and proposed measures derived from the study's own analysis, rather than an official government action plan to align the national target trajectory with the COP31 objective. The conclusions are presented in Section 2.6.

2.2. The Global Waste Management and Türkiye's MSW Trajectory

2.2.1. From Linear to Circular: The Global Waste Transition

Waste management policy over the past three decades has largely followed an “end-of-pipe” logic. However, escalating global raw material pressures, and the fact that material consumption growth now exceeds planetary boundaries, have exposed this linear model as unsustainable. The global economy consumes more than 100 billion tonnes of primary material annually, of which only 6.9% is returned to economic circulation as secondary raw material (Circular Economy Foundation, 2025). The extraction and processing of materials, fuels and food account for around half of global greenhouse gas emissions and over 90% of biodiversity loss and water stress (UNEP 2024a). This evidence has reinforced a broader shift in climate policy, from how waste is disposed of to why it is generated in the first place, placing the circular economy model at the centre of the agenda. The European Commission's second Circular Economy Action Plan (European Commission, 2020), building on the first plan adopted in 2015 and serving as a central pillar of the European Green Deal (European Commission, 2019), linked this approach to carbon border measures and industrial competitiveness. This policy direction is now being reinforced through binding legislation, with the forthcoming Circular Economy Act, set to reframe circularity explicitly as an instrument for industrial competitiveness and strategic autonomy, rather than solely as an environmental policy (EPRS, 2026).

Globally, landfilling remains the predominant municipal waste treatment method, accounting for 29% of total MSW. Around 21% is recovered through recycling, composting, and anaerobic digestion (AD) (biomethanization), while a further 20% is treated by incineration. However, nearly one-third of MSW receives no treatment, as it is either dumped or remains uncollected (Figure 2.3) (World Bank, 2026). Figure 2.4 presents waste management practices in selected countries, while Figure 2.5 provides an overview of global MSW management pathways by income group.



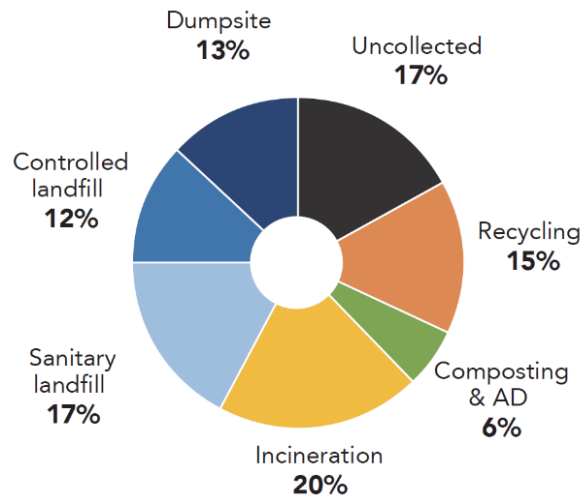


Figure 2.3 Global MSW Treatment and Disposal (World Bank, 2026)

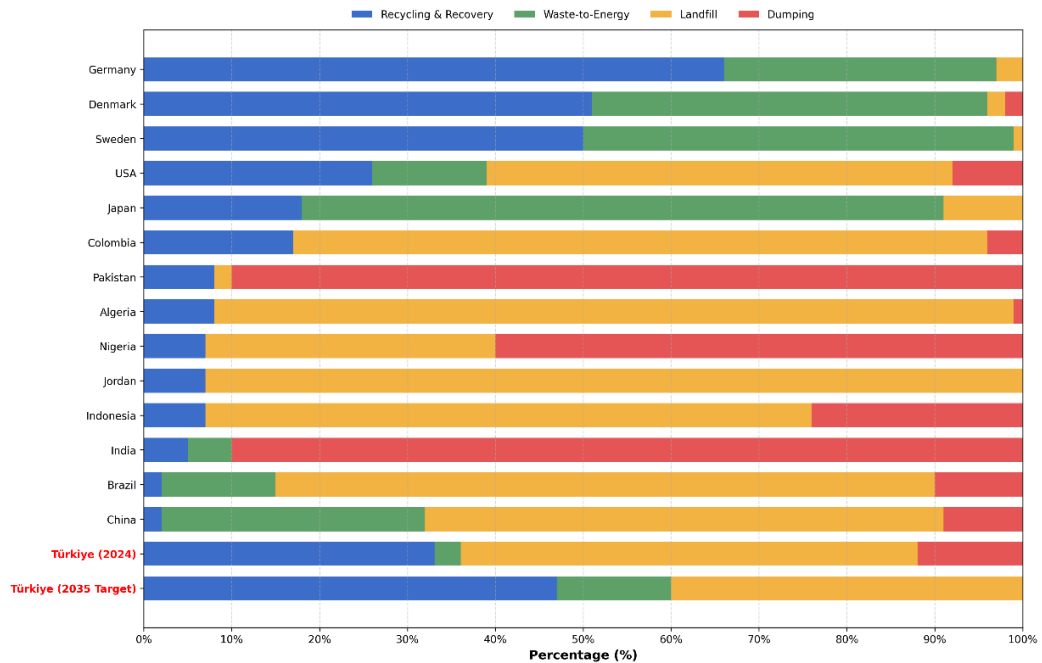


Figure 2.4 Comparison of Waste Management Practices in Selected Countries (%) (Adapted from: Maçın, 2026))

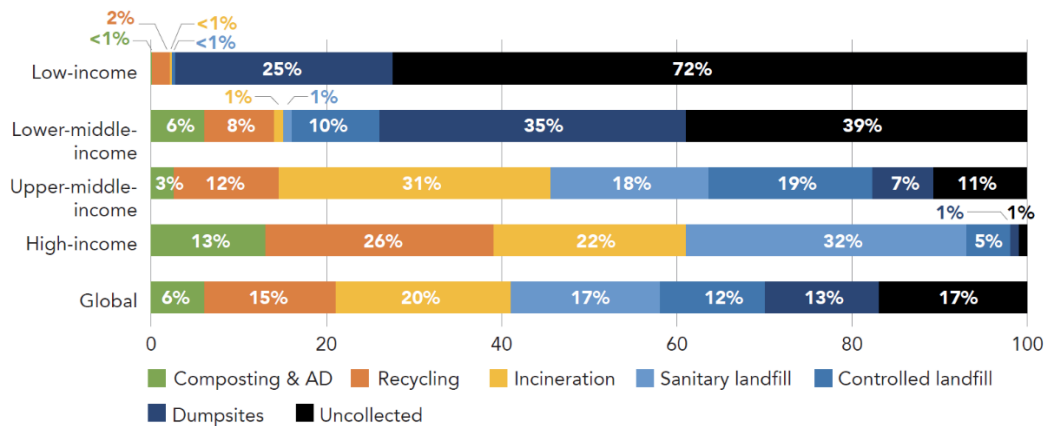


Figure 2.5 Global MSW Management by Income Group (World Bank, 2026)



2.2.1.1. High-Income Economies and EU Standards

Comparative international data show that the countries applying the waste hierarchy most rigorously have largely phased out landfilling in favour of source separation and circular economy models. Among material-recovery-oriented countries, Germany (69%), Austria (62.8%) and Belgium (55.8%) rank among the EU's highest municipal waste recycling rates, while energy-recovery-oriented Nordic countries such as Sweden and Denmark have virtually eliminated landfilling (1–2% and below 10%, respectively) by relying heavily on waste-to-energy capacity. Sweden converts about 59% of its municipal waste to energy, alongside a 39% recycling rate (Eurostat, 2024; EEA, 2024). Across the EU-27, MSW management is distributed as 48.0% recycling, 25.2% incineration and 22.5% landfilling; the EU's 2035 target is to reduce the share of waste sent to landfill below 10% (Eurostat, 2025; European Commission, 2018a). By contrast, the United States, owing to extensive land availability, still sends 50% of MSW to landfill, with its combined recycling and composting rate remaining at 32.1% (U.S. EPA, 2025).

2.2.1.2. Emerging and Middle-Income Economies

Countries in this group, which share similar socio-economic dynamics and a high organic-waste fraction (around 50%), are generally closing dumpsites and directing investment towards mechanical-biological treatment (MBT) and sanitary landfills. China landfills 60% of its waste while incinerating 29.8%, and is the world's fastest-growing waste-to-energy market; a national, province-level quantification covering 2004–2021 attributes approximately 1,271 Mt CO₂-eq of cumulative emissions to landfilling and a further 198 Mt CO₂-eq to incineration over the period, with landfill emissions rising until around 2020 before beginning to decline as the country's 2020 “zero waste city” policy shifted disposal towards incineration, while incineration-related emissions have risen continuously through three distinct growth phases (Luo et al., 2024). In Brazil, 75.2% of waste goes to landfill and formal recycling stands at 1.4%, although the informal sector accounts for 89% of total material recovered (Fidelis et al., 2023). Jordan sends 93% of its waste to landfill and recovers 7%; the country's high organic-waste content, make composting and AD investment environmentally efficient.

2.2.1.3. Low-Income Economies

In this group, institutional and economic constraints mean that formal waste infrastructure is nearly absent, and uncontrolled management practices are triggering climate and public health issues. In Pakistan, 90% of waste is disposed of in uncontrolled dumpsites, while the corresponding figure is 60% in Nigeria the regional average for sub-Saharan Africa is 69% (Maalouf & Mavropoulos, 2023).



2.2.2. Türkiye's MSW Trajectory

Türkiye's waste management system has undergone a significant transformation over the past two decades. In the early 2000s, the principal policy priority was eliminating dumpsites; today, the policy agenda is increasingly oriented towards resource efficiency, the circular economy and climate mitigation. Milestones in this transformation span several decades: the phased expansion of landfill infrastructure and municipal-scale recovery systems from the early 2000s, the subsequent introduction of extended producer responsibility (EPR) schemes, and, more recently, the Zero Waste Project launched in 2017 (T.C. Ministry of Environment and Urbanisation, 2021; Mısıır & Arıkan, 2022). This transformation is not uniform nationwide, however; significant differences in technical capacity, financing and institutional infrastructure persist between metropolitan municipalities and small and medium-sized municipalities.

According to the Turkish Statistical Institute (TÜİK) data and national projections, MSW generation rose from approximately 28.0 million tonnes in 2014 to 31.2 million tonnes in 2021, reaching 43.1 million tonnes in 2035 (TÜİK, 2025). If the population reaches 94.5 million by 2035 and current trends continue, generation is projected to exceed 43.1 million tonnes (Figure 2.6, Figure 2.7). This increase is not solely a function of population growth: rising per capita income, shifting consumption patterns and urbanisation are also driving per capita waste generation upward. This trend is critical for achieving the COP31 goal of halving the growth in waste generation by 2035, since Türkiye's current national targets focus predominantly on improving source separation and raising recovery rates, whereas the COP31 approach centres on reducing the growth rate of waste generation itself (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a).

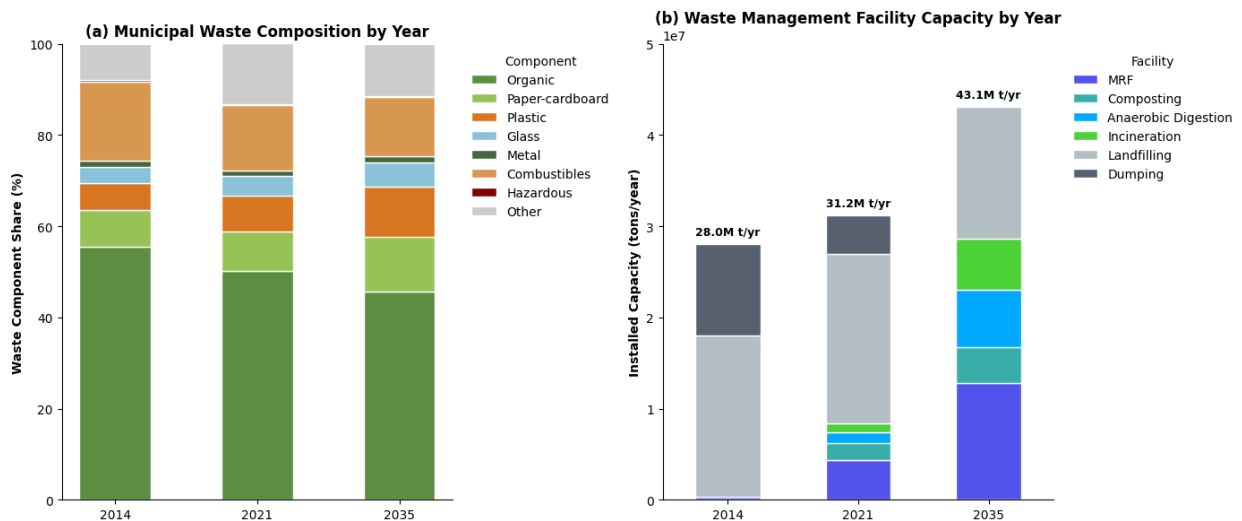


Figure 2.6 Changes in Waste Composition and Facility Capacity Projections in Türkiye (Adapted from: Maçın, 2026)



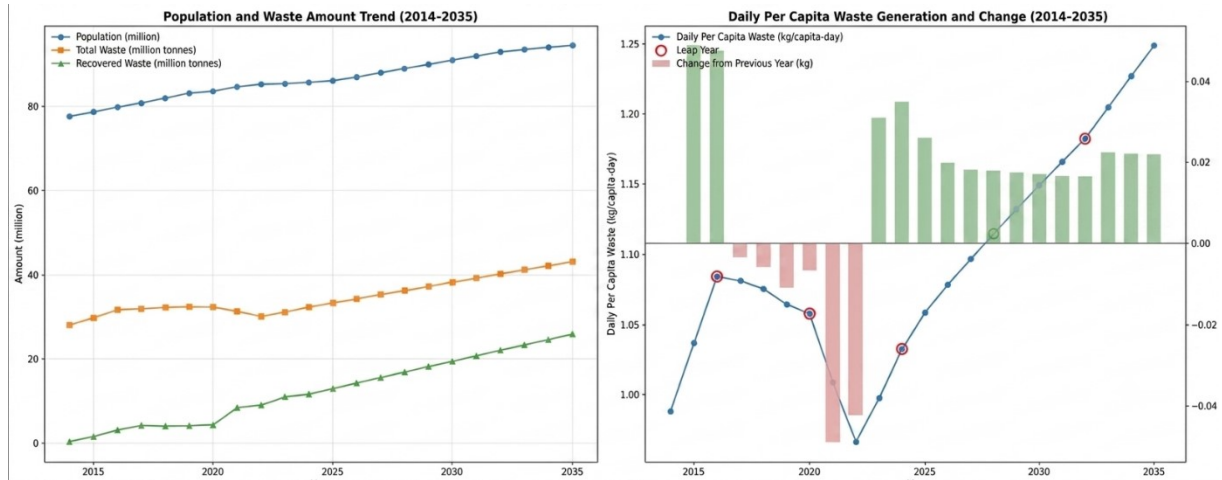


Figure 2.7 Historical and Projected Waste Generation in Türkiye (Data from: TÜİK, 2025)

Türkiye's national recycling & recovery rate rose from 27% in 2021 to 36,1 % in 2024 and 37,5 % in 2025, is projected to reach 60% by 2035 (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026b). As of 2022, 52% of MSW was disposed of in sanitary landfills, 11.7% in uncontrolled sites, and 36.1% was processed through recycling/recovery facilities (TÜİK, 2023). The expansion of Material Recovery Facilities (MRFs) has delivered important progress in returning recyclable materials to the economic system. In addition, continued investment in biological treatment and recovery facilities for the biodegradable waste fraction, which accounts for approximately half of MSW, is contributing to reduce methane emissions by diverting biodegradable waste from landfills. AD is the most widely adopted technology for treating the mechanically sorted organic fraction of MSW (OFMSW) and has the capacity to process up to 28% of the OFMSW generated in Türkiye with the support of the Renewable Energy Resources Support Mechanism (YEKDEM) (Musluoglu et al., 2026).

Türkiye's greatest advantage in achieving the 2035 targets lies in the institutional and technical infrastructure it has developed in recent years, together with the policy framework established through strategic waste management documents. National Circular Economy Strategy and Action Plan sets out 53 actions across seven priority sectors, targeting reduced raw material use and increased circular material uptake (2025–2028) (T.C. Ministry of Environment, Urbanisation and Climate Change, 2025a). National Waste Management Strategy and Plan (2025–2035) presents the waste management investments required to achieve the 60% recovery target by 2035 (T.C. Ministry of Environment, Urbanisation and Climate Change, 2025b). Roadmap on Single-Use Plastics, Marine Litter and Microplastics (2025) addresses recycled-content requirements specifically within the plastics value chain (T.C. Ministry of Environment, Urbanisation and Climate Change, 2025c). The Zero Waste policy has raised public awareness of resource recovery, strengthened municipal data collection and reporting, and accelerated private-sector investment recycling and recovery (T.C. Ministry of Environment and Urbanisation, 2021).



Assessed against COP31 goals, several gaps remain. First, most policy instruments still target post-generation management, while reuse, the repair economy and sustainable consumption models remain limited in scale. Second, the limited uptake of source separation for organic waste at the national level constrains the potential for both composting and biomethane production. Third, technical-capacity gaps persist between municipalities. Finally, national performance indicators still rely predominantly on recovery rates; indicators such as per capita waste generation, the share of biodegradable waste diverted from landfill, methane emission intensity, and the CMUR need to be integrated into the national monitoring system in line with COP31 (Eurostat, 2024).

2.3. The COP31 Zero Waste and Methane Target

2.3.1. Announcement and Systemic Reorientation

During the first week of the Bonn intersessional climate talks in June 2026, the COP31 Action Agenda was presented, outlining ten priority themes and six global implementation goals ahead of the summit itself (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a; Carbon Brief, 2026). The ten priority themes span the circular economy and methane reduction; clean energy and electrification; food security and sustainable agriculture; green industrialisation; oceans and seas; climate-resilient cities; youth participation; dynamic and resilient health systems; cross-sectoral synergy between climate, biodiversity and land degradation; and strengthened support for implementing NDC (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a).

Of the six global implementation goals, the second is the zero waste and methane target that is the subject of this study (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a). The waste sector generates roughly a fifth of anthropogenic methane emissions, proven and scalable solutions already exist, and all Parties are invited to adopt the goal of halving the growth in waste generation by 2035 (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a).

This target departs methodologically from historical emission-reduction goals: it recasts the waste sector from a passive unit that cleans up after the linear economy into an active climate actor that regulates macroeconomic material flows. However, the Action Agenda and its six goals are a presidency-led initiative, run in parallel to, and explicitly separate from, the formal UNFCCC negotiating track, and as of the Bonn talks had not yet been formally endorsed by national governments (Carbon Brief, 2026). The goals therefore function as a political reference point and coordination device for voluntary national action, rather than as a binding obligation under the Paris Agreement; their durability will depend on the coalition of countries, cities, businesses and financiers that choose to adopt them at and after COP31.



The COP31 vision requires three systemic transformations: (i) preventing waste generation at source through measures such as reducing food loss, restricting single-use plastics, and enforcing EPR and eco-design criteria; (ii) achieving systematic methane abatement through source-separated collection of the organic fraction for AD and composting, as well as landfill gas capture at existing sites (IEA, 2024); and (iii) closing material loops by deploying MRFs and validating investment decisions using LCA-based net carbon metrics (ISO 14040, 2006a; ISO 14044, 2006b).

2.3.2. Second-Generation Indicators and Policy Directions

International financing mechanisms and performance indices are increasingly structured around second-generation indicators: absolute per capita waste generation, the diversion rate of biodegradable waste from landfill, specific greenhouse gas intensity per tonne of waste, and the Circular Material Use Rate (CMUR) (Eurostat, 2024; European Commission, 2018b). Türkiye has made significant progress towards first-generation (disposal and recovery oriented) waste management objectives over the past decade by closing dumpsites and developing Zero Waste infrastructure. However, achieving alignment with the COP31's 2035 targets will require a transition to second-generation policy instruments focused on resource management and methane mitigation.

2.4. Scientific and Policy Basis

2.4.1. Türkiye's Long-Term Climate Strategy and National Emissions Profile

Türkiye's Long-Term Climate Strategy, submitted to the UNFCCC Secretariat, positions waste management not merely as a disposal service but as a leverage sector delivering macro-level emission reductions through circular economy instruments (UNFCCC, Türkiye Long-Term Climate Strategy; T.C. Ministry of Environment, Urbanisation and Climate Change, 2022).

According to Türkiye's 2024 national greenhouse gas inventory, emissions from the waste sector totalled 15.4 Mt CO₂-eq, accounting for 2.6% of national total greenhouse gas emissions (TÜİK, 2026). Of these emissions, 61.4% originated from solid waste landfills, while the second-largest source (38.5%) was wastewater treatment and discharge. Methane accounted for 85.0% of total waste sector emissions, with nitrous oxide contributing for 15.0% (TÜİK, 2026).

Municipalities collected 32.3 million tonnes of solid waste in 2024 in Türkiye (TÜİK, 2025), equivalent to 1.09 kg per capita per day, above the global average of 0.88 kg/capita/day (World Bank, 2026) but below the EU-27 average of approximately 1.42 kg/capita/day (Eurostat, 2026). By the end of 2025, the municipal waste recovery rate reached 37.5% (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026b).



Under Türkiye's updated first NDC, Türkiye has committed to increasing the municipal waste recovery rate to 60% by 2035, and to 70% under the 2053 net-zero vision, while reducing the share of waste sent to landfills to below 30% and eliminating uncontrolled disposal entirely (Republic of Türkiye, 2023).

Türkiye's Long-Term Climate Strategy identifies eight sectoral strategies for the waste sector (T.C. Ministry of Environment, Urbanisation and Climate Change, 2022):

- Strategy 1: Preventing and reducing waste and wastewater generation combating food loss and waste; dematerialisation through repair, refurbishment and remanufacturing.
- Strategy 2: Increasing high-quality recycling and recovery rates, dual source separation, a national deposit-return system, critical mineral recovery.
- Strategy 3: Reducing the acceptance of untreated waste at landfills, fiscal instruments such as a landfill tax.
- Strategy 4: Upgrading wastewater management infrastructure with innovative technology extending treatment access to 100% by 2028.
- Strategy 5: Developing human capital for the circular economy and ensuring a just transition formalising the informal workforce.
- Strategy 6: Developing incentives and financing mechanisms for the transition to a circular economy, Green Public Procurement.
- Strategy 7: Increasing the use of waste as raw material in production processes mandatory minimum secondary-material quotas, Digital Product Passport.
- Strategy 8: Reducing emissions from vehicles used in waste management through route optimization and the deployment of electric collection fleets.

2.4.2. Assessment Approach: Scenario-Based LCA

The COP31 target cannot be assessed solely by tracking the change in waste tonnage; it requires the joint evaluation of waste generation, composition, collection systems, recovery technologies and disposal methods. The assessment presented in this section is based on a scenario-based, national-scale LCA conducted under ISO 14040 and ISO 14044 using the ReCiPe 2016 midpoint characterisation method (Maçın, 2026; ISO 14040–ISO 14044, 2006). Three scenarios are evaluated:

- 2014 reference scenario: 63.5% landfill, 35.5% dumping, 1.0% MBT;
- 2021 status quo scenario: 59.5% landfill, 13.5% dumping, 13.8% MBT, 6.0% composting, 4.0% AD, 3.2% incineration (Istanbul).
- 2035 target scenario: 33.5% landfill (0% dumping), 29.7% MBT, 9.0% composting, 14.8% AD, 13.0% incineration (consistent with the national 60% recovery target).



The underlying waste data in Maçin (2026) were obtained from the TÜİK database. Between 2014 and 2021, Türkiye's population increased from 77.6 to 84.6 million, accompanied by a rise in MSW generation from 28.0 to 31.2 million tonnes. The 2035 target scenario extends this trajectory using UNDP population projections (population reaching 94.5 million by 2035) and the national 60% recovery target set by Türkiye's Ministry of Environment, Urbanisation and Climate Change, modelled through linear extrapolation combined with strategic policy assumptions consistent with planned investment in MRFs, composting, AD and incineration capacity.

2.4.3. Comparison of Scenarios

The national-scale scenario analysis shows that Türkiye's waste management system has developed substantially over the past decade. In 2014 the system relied largely on sanitary landfilling; by 2021 recovery infrastructure had strengthened markedly; and in the 2035 scenario, mechanical sorting, composting, AD and waste-to-energy facilities substantially increase their share within the system (Maçin, 2026). The expansion of MRFs, particularly through metal and plastic recovery, reduces primary raw material production and delivers environmental benefits across multiple impact categories, a finding consistent with Sund et al. (2025), who reported that metal recycling accounts for approximately 83% of total climate savings across the EU-27 waste management system.

2.4.4. Climate Change Performance

According to the LCA results, the climate change impact of the municipal waste management system decreased from 351 kg CO₂-eq per tonne of waste (approximately 1.0×10^{10} kg CO₂-eq for the total functional unit) in 2014 to 61 kg CO₂-eq per tonne (approximately 1.9×10^9 kg CO₂-eq for the total functional unit) in 2021 (Table 2.1, Figure 2.8), following the introduction of MRFs and partial AD-based energy recovery. This represents an approximately 83% a reduction between 2014 and 2021 (Maçin, 2026).

Table 2.1 *Climate Change Impact of the Türkiye Municipal Waste Management System*

Scenario	Climate Change Impact (kg CO ₂ -eq/tonne waste)
2014	351
2021	61
2035 (target)	-175



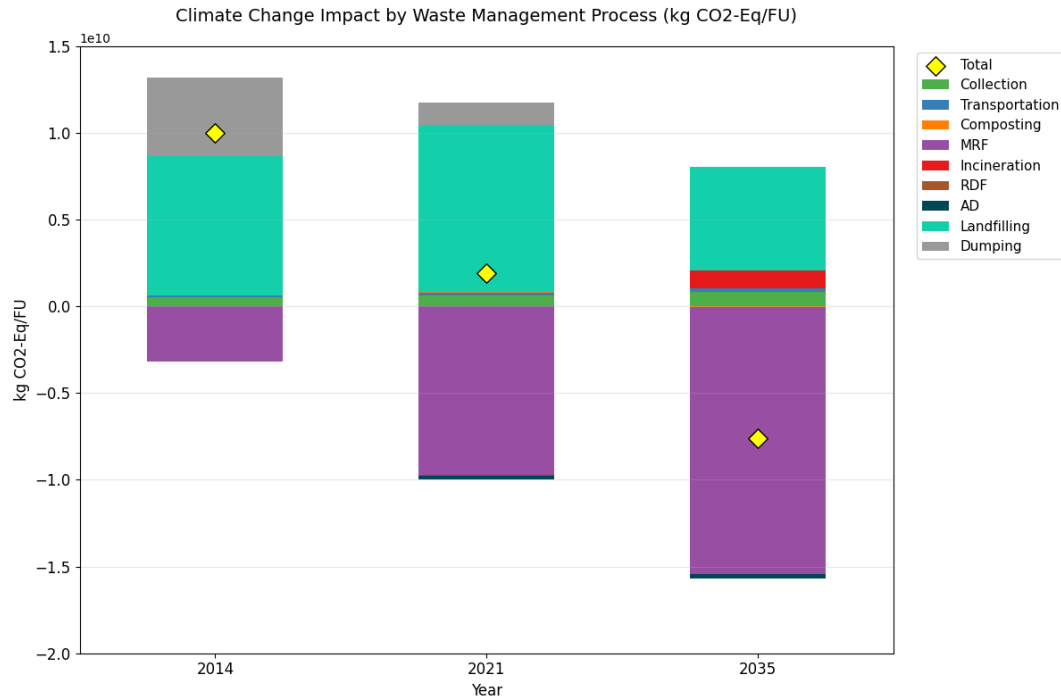


Figure 2.8 Climate Change Impact of Waste Management in Türkiye (kg CO₂-eq per functional unit) (Adapted from: Maçin, 2026)

In the 2035 scenario, the system reaches a net-negative greenhouse gas offset ($-175 \text{ kg CO}_2\text{-eq}$ per tonne, $-7.6 \times 10^9 \text{ kg CO}_2\text{-eq}$ for the total functional unit), driven principally by improved recycling performance (approximately $-1.54 \times 10^{10} \text{ kg CO}_2\text{-eq}$ for the total functional unit of avoided impact) and the complete elimination of dumping. Landfilling nonetheless remains the system's largest persistent emission source even in 2035, at $6 \times 10^9 \text{ kg CO}_2\text{-eq}$ for the total functional unit, confirming that methane emissions cannot be eliminated unless biodegradable waste is fully diverted from landfill. These results place Türkiye in an intermediate position internationally, between the $-644 \text{ kg CO}_2\text{-eq}$ per tonne reported for Zagreb's integrated system (Hadzic et al., 2018) and the $-124 \text{ kg CO}_2\text{-eq}$ per tonne reported for China's incineration-weighted scenarios (Liu et al., 2017) indicating that Türkiye's 2035 target is technically plausible on an international scale, though still conservative relative to best practice (Maçin, 2026).

This finding carries three policy implications: (i) Türkiye has, over the past decade, not only raised recycling rates but substantially reduced the carbon intensity of the waste sector; (ii) once the 2035 scenario is realised, the system becomes, for the first time, a net contributor to greenhouse gas reduction; and (iii) this transformation stems not only from new facility investment, but from recycled materials displacing primary raw material production, compost and biogas production reducing chemical fertiliser use, and energy recovery displacing fossil fuels (Maçin, 2026).



2.4.5. Findings Relative to COP31 Targets

While the LCA results are encouraging, one finding requires careful interpretation in light of COP31's goals. Although the 2035 scenario's carbon footprint reaches net-negative values, MSW generation continues to rise in absolute terms, from 31.2 million tonnes to 43.1 million tonnes (Figure 2.9).

The waste management system becomes more environmentally sound even as total resource consumption continues to increase. This highlights the distinction between improving the sustainability of waste management and preventing waste generation: if Türkiye achieves its current national targets, it can substantially decarbonise its waste management system; however, the COP31 goal of 'halving the growth in waste generation' cannot be achieved through recovery investment alone. Achieving this goal requires shifting policy priority towards reducing per capita waste generation, preventing food loss, expanding reuse systems, extending product lifetimes, reducing single-use products and increasing resource efficiency. In this sense, the COP31 target is not, technically, a waste management target; rather, it is a sustainable production and consumption target.

2.4.6. Türkiye's Waste Reduction Target: A Complementary Estimate

The scenario analysis shows that Türkiye's greatest advantage is having completed the initial phase of its transformation: landfill infrastructure is largely established, recycling and recovery facilities are expanding rapidly, biogas investment is growing, and the Zero Waste system is institutionalised. The core requirement for the coming decade is to transform the existing waste management system into a resource management system within the circular economy policy framework that Türkiye has already begun to formalize. The National Circular Economy Strategy and Action Plan (2025–2028), establishes a policy framework for delivering this transition, comprising 53 actions across seven priority sectors (T.C. Ministry of Environment, Urbanisation and Climate Change, 2025a). The most critical shift will be transition from a 'waste management' approach to a “resource management” approach; success will no longer be measured by the amount of waste disposed of, but by the extent to which materials are kept in circulation within the economic system.



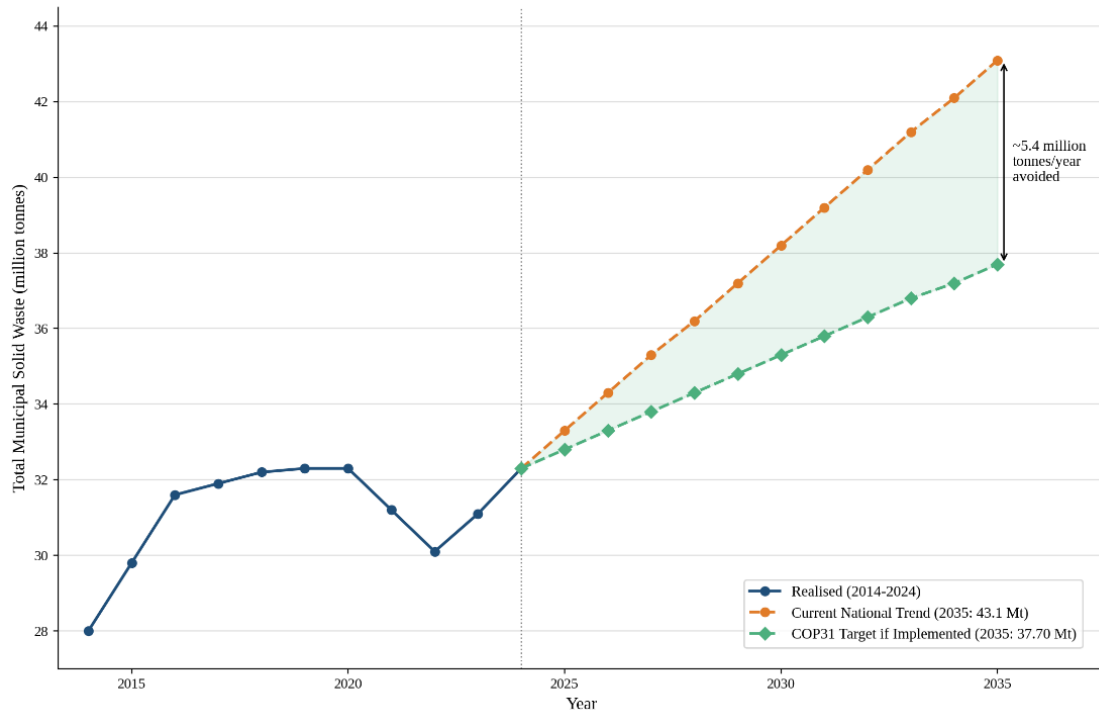


Figure 2.9 Historical and Projected Waste Generation in Türkiye Under the COP31 Scenario (Data from: TÜİK, 2025; Maçin, 2026)

The LCA model was designed to compare three policy scenarios (2014, 2021 and the 2035 national 60% recovery target) based on total waste tonnage; its research question is 'which technology mix delivers the lowest carbon impact for the given/projected waste amount, not "what happens if total waste amount itself is reduced". No such counterfactual was therefore calculated within the scope of the original study; this is not a shortcoming but a deliberate boundary of the study's scope. Because the COP31 target of "halving the increase in waste generation" directly raises this second question, a simple, linear complementary estimate is derived here, based on the intensity values (kg CO₂-eq/tonne) reported by the published model.

Cross-checking was carried out using three scaling approaches applying the official per-tonne intensity (−175 kg CO₂-eq/tonne) to the new tonnage; scaling the official total impact (−7.60 Mt) by the tonnage ratio; and scaling the process-based total by the same ratio and all three produced consistent results within a narrow range (Table 2.2).



Table 2.2 2035 COP31 Scenario: Türkiye's Waste Reduction Target and Total Climate Impact

Scenario	Total Waste (Mt)	Total Climate Impact (Mt CO ₂ -eq)*
2035 Current National Trend (BAU)	43.10	−7.60
2035 COP31 Scenario — Method 1: per-tonne intensity	37.15	−6.50
2035 COP31 Scenario — Method 2: scaling the total	37.15	−6.55
2035 COP31 Scenario — Method 3: process-based scaling	37.15	−6.58

**This estimate assumes that the technology-mix shares of the 2035 target scenario (MBT 29.7%, composting 9%, AD 14.8%, incineration 13%, landfill 33.5%) remain constant under the COP31 scenario, and that per-tonne intensity scales linearly and independently of total waste volume; it is not derived from re-modelling the LCA inventory and should be read only as an order-of-magnitude indicator, not as a formal projection.*

The result may appear counter-intuitive at first glance: although total waste is 14% lower in the COP31 scenario, the system's net carbon sink is smaller than under BAU (−6.50 Mt versus −7.60 Mt). This is not a calculation error but stems directly from a methodological boundary in Maçin (2026): the study applies a zero-burden assumption that excludes the upstream production burden of the products that become waste. Within this framework, the model's negative (carbon sink) values arise solely from recovered material displacing primary raw material; when the total waste entering the system falls, so does the quantity of material reaching MRFs and generating substitution credits. The primary climate benefit of waste prevention the raw material and manufacturing emissions of the product that is never produced falls entirely outside this model's system boundary and is therefore not reflected at all in this estimate.

This finding strengthens, rather than weakens, the thesis argued throughout this study. An LCA conducted at the scale of the waste management system structurally underestimates the true carbon value of prevention policies; accurately capturing the carbon benefit of the COP31 goal of “halving the growth in waste generation” therefore requires a consumption-based LCA or hybrid input–output analysis that extends beyond the waste management system boundary to include the product/material manufacturing stage. This is precisely why the calculation above was deliberately kept simple: the aim is not to produce a precise carbon budget, but to demonstrate numerically why the existing LCA scope is insufficient for evaluating prevention policies.

To partially relax the zero-burden assumption common to Methods 1–3, and to illustrate the order of magnitude of the excluded upstream production burden, a complementary fourth estimate was developed. This approach is methodologically consistent with the method the authors applied to waste-prevention scenarios in a previous campus-scale study (Maçin et al., 2025). The same logic is applied here to the 5.95 Mt total tonnage difference between BAU and the COP31 scenario (43.10 Mt – 37.15 Mt).



The calculation proceeds in two steps: (i) the composition of the 5.95 Mt difference was allocated to packaging material categories (paper, cardboard, other plastic, plastic bags, PET bottles) based on literature data on Türkiye's MSW composition; and (ii) for each category, the cradle-to-gate global warming potential (GWP) factors reported in the literature, corresponding to the Ecoinvent processes.

Table 2.3 Allocation of the BAU–COP31 Tonnage Difference and Estimated Burden of Emissions from Türkiye's Waste Management

Component	Assumed Share (%)	Tonnage (Mt)	GWP (kg CO ₂ -eq/kg)*	Avoided Burden (Mt CO ₂ -eq)
Paper	5	0.30	~0.8	0.24
Cardboard	9	0.54	~0.9	0.48
HDPE	7	0.42	~1.9	0.79
Plastic bag	2	0.12	~8.0	0.95
PET bottle	3	0.18	~2.3	0.41
Packaging subtotal	26	1.55	—	~2.9

*GWP factors are approximate, order-of-magnitude figures derived from cradle-to-gate values reported in the literature corresponding to the Ecoinvent processes. This is a coarse assumption derived from the Türkiye MSW characterisation literature, not measured data on the actual material composition of the BAU–COP31 difference.

Adding the estimated ~2.9 Mt CO₂-eq of additional avoided burden associated with packaging components (Table 2.3) to the Method 1 result reported in Table 2.2 (–6.50 Mt CO₂-eq) yields a total impact of approximately –9.4 Mt CO₂-eq, which is greater than the BAU impact of –7.60 Mt CO₂-eq. In other words, once the production stage is included, the counter-intuitive result described above reverses, and the COP31 scenario delivers a larger net carbon sink than BAU. This finding does not invalidate Methods 1–3; rather, it quantifies the direction and rough magnitude of the system-boundary issue discussed above: as long as the zero-burden assumption is retained, the climate benefit of waste prevention is structurally underestimated, and the true benefit likely exceeds the official –6.50/–6.55/–6.58 Mt range. Including the remaining ~74% organic/food and other material components would predictably widen this gap further, since the per-unit-mass GWP burden of food production is generally higher than that of packaging materials.

2.5. Action Plan Suggestions

Türkiye's existing national strategies are built predominantly around raising recovery rates, expanding sanitary landfill infrastructure, whereas the COP31 approach is oriented around a fundamentally different question: how can less waste be generated in the first place? (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a). Closing this gap requires coordinated action across eight fronts (Figure 2.10), each aligned with the United Nations 2030



Agenda for Sustainable Development and the Paris Agreement, sequenced over three phases: launch (2026–2028), in which legislation, monitoring systems and pilot programmes are established; scale-up (2028–2032), with an interim milestone of independently verified organic-waste diversion; and consolidation (2032–2035), in which the target is attained and verified through the Global Stocktake.



Figure 2.10 Action plan suggestions

Action 1

Preventing Waste Generation at Source

The core innovation of the COP31 target is that it measures success not by recycling rates but by the reduction in the growth of waste generation itself. Prevention occupies the top tier of the waste hierarchy in the international literature, and the EU Waste Framework Directive makes this priority a legal obligation (European Parliament and Council, 2008/2018). In Türkiye, current practice still concentrates on recovery and disposal; reuse infrastructure, the repair economy, refill systems and sustainable product design remain limited in scale. Priority in



2026–2028 should go to completing legislation that incentivises prevention at source: performance-based EPR schemes and eco-design criteria. This action operationalises SDG target 12.5 on substantially reducing waste generation and SDG target 12.3 on halving per capita food waste.

Action 2

Organic Waste Management and Methane Abatement

Roughly half of Türkiye's municipal waste is organic; scenario analysis shows that reducing the volume of organic waste sent to landfill is the single most important driver of improved climate performance. Yet even in the 2035 scenario, not all organic waste is separately collected, and sanitary landfilling retains a 33.5% share of the system, meaning methane emissions cannot be fully eliminated (Maçın, 2026). Successful international examples share common features: mandatory source separation of organic waste, progressive restriction of biodegradable waste acceptance at landfill, and the parallel development of composting and AD technology (Zhang et al., 2014). Priority actions include making source separation of organic waste a legal requirement in metropolitan municipalities in 2026–2028, extending source-separation obligations to restaurants, hotels and mass caterers, and progressively restricting the acceptance of biodegradable waste at sanitary landfill in 2029–2031. This action supports SDG 13 on climate action.

Action 3

Transition to a Circular Economy and Circular Material Use

The future of waste management lies not only in recycling more, but in keeping materials in economic circulation for as long as possible. The EU directly tracks the share of secondary raw materials used in the economy through the CMUR (Eurostat, 2024). The COP31 Action Agenda has separately set a global target of raising the CMUR in manufacturing to at least 15% by 2035 (T.C. Ministry of Environment, Urbanisation and Climate Change, 2026a). Priorities in 2029–2031 should include the development of secondary raw material quality standards, incentives for the use of recycled material in public procurement, and the establishment of minimum recycled-content targets for the cement, iron and steel, plastics, and packaging sectors. This action supports SDG 12 on sustainable consumption and production and reinforces coordination with the Green Industrialization goals on circular material utilisation.



Action 4

Digitalisation and Data-Driven Waste Management

Success against the COP31 goals depends not only on physical infrastructure but on data quality. Türkiye's National Waste Transport Form system has delivered significant progress, but real-time decision-support systems for municipal waste remain limited. AI-supported forecasting models, dynamic collection planning and LCA-based decision-support tools would raise operational efficiency while also reducing emissions. Priority should go to establishing a national methane monitoring system and standardising municipal data infrastructure in 2026–2028, and scaling up digital waste management systems in 2029–2031. This action supports SDG 9 on industry, innovation and infrastructure.

Action 5

Integrating LCA into Decision-Making

Waste investment in Türkiye is predominantly planned on technical and economic feasibility grounds. Future investment decisions should also be assessed against environmental indicators such as climate change, resource use, water consumption and human health. This study is itself a demonstration of how LCA can be used as a standard public decision-support tool, beyond its role as an academic method (Maçın, 2026). LCA-based decision mechanisms are recommended for municipal waste management plans, national strategies, environmental impact assessment processes for large-scale facilities, and public support programmes—an approach consistent with the EU's Product Environmental Footprint methodology (JRC, 2019). This action reinforces SDG 12 on sustainable consumption and production and strengthens the evidentiary basis for Actions 1–4.

Action 6

Financing, Institutional Capacity and Behavioural Change

Institutional capacity and financing mechanisms are as important as technical solutions. Investment costs, operating expenditure and a shortage of specialist personnel particularly constrain the uptake of advanced waste management technology in small and medium-sized municipalities. Green bonds and sustainability-linked financing mechanisms, results-based municipal support programmes, carbon markets and voluntary carbon credits should be deployed to support methane abatement projects, and public–private partnerships should be encouraged, particularly for organic waste and biomethane investment. International evidence also shows that per capita waste generation is strongly influenced by behavioural factors, including food waste, single-use product consumption, and purchasing habits, rather than economic growth alone. School curricula, public procurement policies, and municipal awareness programmes should therefore be considered integral components of achieving the COP31 targets. This action contributes to SDG 17 on partnership for the goals and SDG 4 on quality education.



Action 7

Reforming Tariffs and Cost Recovery

A progressive landfill tax, Pay-As-You-Throw systems, and the linkage of municipal financing to verified prevention and methane abatement outcomes rather than tonnage collected should be prioritised as key instruments. This action supports the achievement of SDG 11 on sustainable cities and communities and reinforces the financing base for Actions 1–3.

Action 8

Governance and Monitoring

Delivering the actions above requires a robust and permanent governance framework. This should include establishment the 2025 national baseline and annual reporting of key performance indicators, including per capita waste generation, the biodegradable-waste landfill diversion rate, methane emission intensity per tonne of waste, and the CMUR, assessed against the 2030 and 2035 milestones. It should also incorporate independent verification of national data, peer review of national waste roadmaps within the NDC 3.0 cycle; and coordination with the Global Waste Methane Financing Mechanism and the UNFCCC Secretariat. Success should be measured against two complementary outcomes: halving the growth in waste generation by 2035 and achieving a verified net-negative greenhouse gas offset for the waste management system.

2.6. Conclusions

Türkiye's progress over the past decade in developing solid waste infrastructure and institutionalising the Zero Waste vision has positioned the country favourably on its pathway towards waste-sector decarbonisation. Macro-scale LCA scenario modelling conducted in accordance with ISO 14040/14044 demonstrates that, once the 2035 national actions are implemented, the municipal waste management sector can transition from a net source of greenhouse gas emissions to a net-negative contributor to the national carbon balance.

Türkiye has reached a considerable level of technological maturity in managing and recovering waste after generation. The most fundamental shift on Türkiye's strategic horizon is the legal and institutional transition from traditional 'waste management' mechanisms towards a holistic and interdisciplinary 'resource management' paradigm, a direction already reflected in Türkiye's recent policy architecture. Under this approach, success should be measured by reductions in absolute per capita waste generation, diversion of biodegradable waste from landfills, the CMUR, and LCA-verified embodied-carbon savings.



This study is aligned with EU Product Environmental Footprint methodology, IPCC guidance (2019) and UNEP's circular economy measurement framework and policy guidance (UNEP, 2024c). By providing an evidence-based policy assessment, it aims to support national decision-making and represents a scientific contribution towards Türkiye's COP31 global climate leadership objectives.

The key conclusions of this study are as follows:

- The waste sector represents a decisive and currently underutilised opportunity for near-term methane abatement: it accounts for approximately 20% of global anthropogenic methane emissions, while Türkiye's inventory attributes 15.4 Mt CO₂-eq, (2.6% of national emissions) to the waste sector, with methane accounting for, 85% of these emissions.
- Türkiye's waste management system is already undergoing rapid decarbonising: LCA modelling indicates that the sector's carbon intensity decreases from 351 kg CO₂-eq/tonne in 2014 to 61 kg CO₂-eq/tonne in 2021 and reaches a net-negative value of -175 kg CO₂-eq/tonne by 2035 if national actions are fully implemented.
- A critical policy gap exists between decarbonisation and dematerialisation: even under the net-negative 2035 scenario, absolute MSW generation increases from 31.2 to 43.1 million tonnes; therefore, the COP31 goal of halving waste growth cannot be achieved through recovery investment alone.
- Organic waste management and landfill diversion remain the largest opportunities for further emission reduction: approximately half of MSW is organic, and landfill remains the dominant emission source unless biodegradable waste is effectively diverted.
- Circular material utilisation represents the next frontier: the CMUR and a 15% circular material use target in manufacturing by 2035 provide the complementary indicators alongside waste-generation targets.
- Financing mechanisms must reward prevention and verified emission reductions: this requires dedicated, polluter-pays mechanisms and results-based municipal financing schemes.
- The pathway for the coming decade is defined and measurable: the eight actions presented in Section 2.5, monitored through interim milestones and independent verification, provide a delivery framework for halving the growth in waste generation by 2035 while maintaining a net-negative greenhouse gas balance.

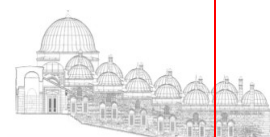


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CHAPTER 3

CLIMATE RESILIENT CITIES

Abstract

The built environment is where the global energy transition will be won or lost. The buildings and construction sector accounts for around 37% of global CO₂ emissions, 28% of final energy consumption and nearly half of global material extraction, while representing 11–13% of global GDP and employing about 9% of the world's workforce. Global floor area reached 273 billion m² in 2024 and continues to expand rapidly, with about half of the buildings that will exist in 2050 yet to be built or renovated. The international organizations, such as the United Nations, show a widening gap between current trends and the targets of the Paris Agreement, and the sectoral decarbonisation has even slowed down as the floor areas have accelerated drastically. This report presents the status, technologies and enabling conditions of the built environment transition. Building energy use intensity has fallen by only 8.5% since 2015, roughly 1% per year, whereas the Paris-aligned scenarios require intensity improvements of 2.5–3% annually; the COP31 target of at least a 25% reduction by 2035 is therefore not an arbitrary ambition but the scientifically grounded correction that closes this gap, returning the sector to a trajectory consistent with net-zero buildings by mid-century. Delivering it requires more than doubling the current pace, through nearly zero-energy building codes for new construction, deep renovation of the existing stock at 2–3% annually, heat pumps and thermal energy storage, and smart, AI-supported building operation. The report further examines the resilience imperative, escalating climate risks to buildings and infrastructure, urban heat and the cooling paradox, the energy security of critical facilities, seismic resilience and the water–energy nexus, and analyses the enablers: investment and affordability, embodied carbon and circular materials, skills, and inclusive urban transitions, with a special focus on informal settlements and hot-climate cities. It concludes that efficiency and resilience are two faces of the same transformation, and that the choices made this decade will lock in outcomes for generations.

Keywords: Buildings, Energy use intensity, Energy efficiency, Renovation, Resilient cities

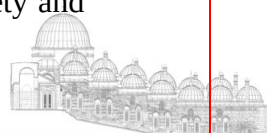


3.1. Introduction

Buildings are humanity's largest artefact and their most intimate infrastructure: the places where people live, work, learn and heal. They are also central to the climate challenge. The buildings and construction sector appears to be responsible for around 37% of global energy- and process-related CO₂ emissions and 28% of global final energy consumption, and it consumes nearly half of all materials extracted worldwide (UNEP, 2026). At the same time, the sector is expanding at extraordinary speed: more than 5 billion m² of floorspace was added in 2023 alone, and global floor area reached 273 billion m² in 2024, growing by 1.7% in a single year, driven largely by construction in emerging economies including India and Southeast Asia (UNEP, 2025, 2026). The tenth Global Status Report for Buildings and Construction, pointedly subtitled 'Building fast. Falling short' finds that decarbonisation of the sector has slowed, leaving it both a major emissions source and increasingly vulnerable to climate impacts and energy price shocks (UNEP, 2026).

This report is prepared by the TÜBA Energy Working Group in support of the COP31 Presidency's 2035 Global Implementation Goals, and specifically Goal 3 on Climate Resilient Cities, which targets a reduction in the energy use intensity of the buildings sector of at least 25%, and preferably 35%, by 2035, consistent with a pathway aligned with the goals of the Paris Agreement. The report proceeds as follows. Section 2 is given to characterize the position of buildings and cities in today's energy system and the structural drivers of demand. Section 3 assesses the technologies, strategies and potentials for cutting energy use intensity across new construction, the existing stock, heating and cooling, and smart operation. Section 4 addresses the resilience dimension of the goal: climate risks to the built environment, urban heat, and the energy security of critical facilities. Section 5 examines the implications with co-benefits and key enablers, spanning investment and affordability, embodied carbon, skills, and inclusive urban transitions, with a special focus on informal settlements and hot-climate cities. There are numerous figures drawn in this chapter based on the published data by various international organizations, including UNEP (2025, 2026) and IEA (2025a). Some of these data are actual and some forecasted by these organizations, which are also modified in various cases based on modeling priorities and projected timelines.

The objective of this chapter is to provide the scientific and analytical foundation for Goal 3 of the COP31 Presidency's 2035 Global Implementation Goals: reducing the energy use intensity of the buildings sector by at least 25% by 2035, delivered together with a climate-resilient transformation of cities. Specifically, the chapter pursues four aims: to establish, on the basis of the most recent global data, the weight of the built environment in the world's energy, emissions and material balances and the structural forces, which are urbanisation, floor area growth, cooling demand and digitalisation, shaping its trajectory; to quantify the strategies through which the intensity target can be met, spanning building energy codes for new construction, deep renovation of the existing stock, efficient heating, cooling and thermal storage, and smart building operation; to assess the resilience imperative in its full breadth, from climate hazards, urban heat and the energy security of critical facilities to seismic safety and



the water–energy nexus; and to translate this evidence into a sequenced set of action plans, aligned with the United Nations Sustainable Development Goals and the Paris Agreement, through which the target can be delivered and verified by 2035. In doing so, the chapter is intended to serve both as a reference document for Parties and local governments preparing national and municipal building roadmaps and as the analytical basis for the buildings and resilient-cities pillar of the CIB mechanism.

3.2. Buildings and Cities in Today’s Energy System

The built environment’s claim on the world’s energy and resources is best understood from two complementary perspectives, presented together in Figure 3.1a shows the share of buildings within the global energy system: the operation of residential and non-residential buildings accounts for approximately 30% of global final energy consumption where 21% in homes and 9% in offices, schools, hospitals and other service buildings, making buildings comparable in scale to the entire industrial sector and larger than transport; when the energy used to manufacture construction materials such as cement and steel is included, the buildings and construction perimeter approaches 34%. Figure 3.1b looks inside that block, showing how the energy is used: thermal services dominate, with space heating (about 32%), water heating (16%) and space cooling (8%) together representing roughly 56% of buildings’ final energy demand, followed by cooking (21%, reflecting substantial traditional biomass use in developing regions), appliances and equipment (16%) and lighting (4%). This dual picture frames the analysis that follows. Section 2.1 examines the energy use, emissions and material footprint of the built environment in detail, and Section 2.2 traces the four structural drivers such as urbanisation, floor area growth, cooling and digitalisation, that will shape its trajectory to 2035.

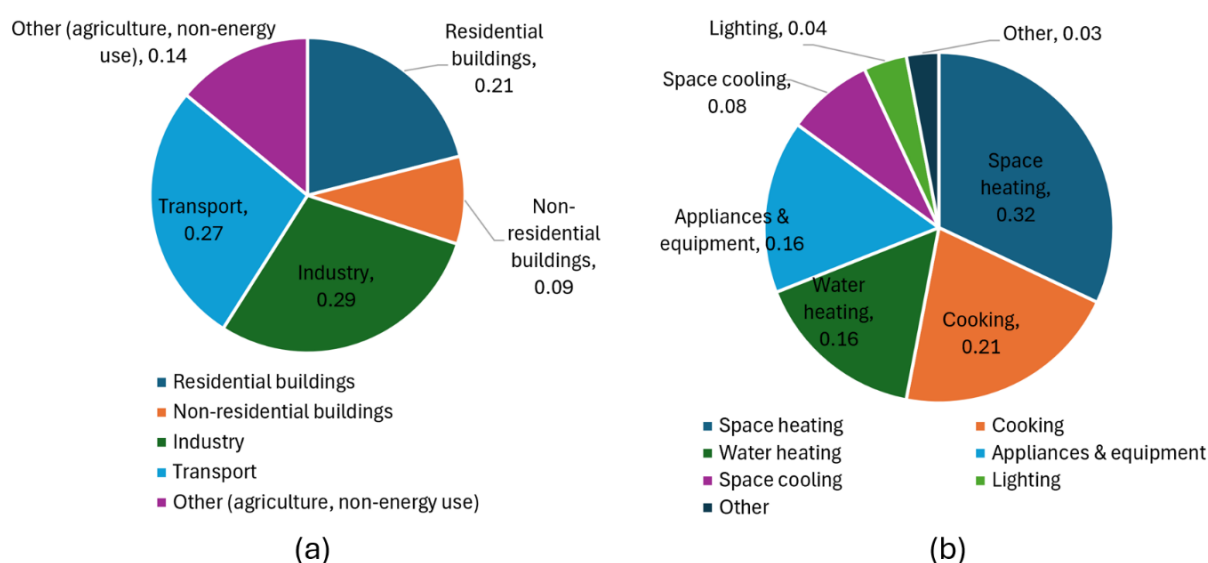


Figure 3.1 Buildings in the global energy system: (a) sectoral shares of global final energy consumption; (b) buildings final energy consumption by end use (Data from: IEA, 2025a; UNEP, 2026)



3.2.1. Energy and Material Use and CO₂ Emissions of the Built Environment

The significance of the built environment extends across every dimension of the global economy and environment. As shown in Figure 3.2, beyond its 37% share of CO₂ emissions and 28% share of final energy consumption, the sector represents 11–13% of global GDP and about 9% of global employment across construction, renovation, demolition and engineering (UNEP, 2026). Emissions arise through two channels: operational emissions from heating, cooling, lighting, appliances and hot water, which increased between 2015 and 2024; and embodied emissions from the production of cement, steel and aluminum, which remain stubbornly high. The materials underpinning construction are alone responsible for close to a fifth of global emissions (UNEP, 2025; 2026). Progress indicators are mixed: green building certifications have nearly tripled and more than 14 countries or sub-national governments have updated building codes since 2023, yet few of these codes align with net-zero goals, renewables supplied only 17.3% of buildings' energy demand in 2024, and the Global Buildings Climate Tracker shows a widening gap between current trends and the pathway required for full decarbonisation by 2050 (UNEP, 2026).

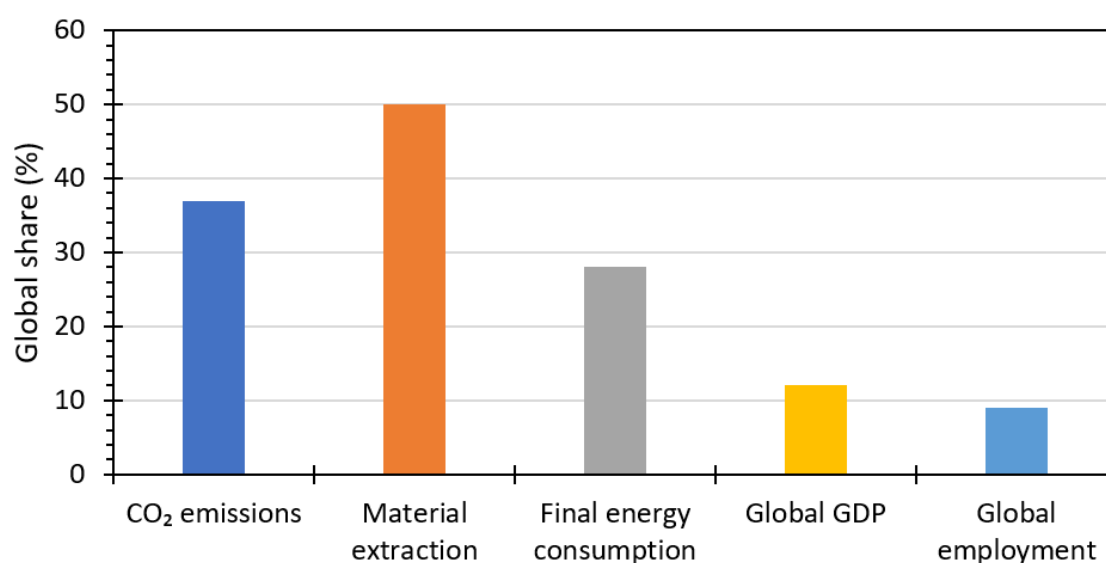


Figure 3.2 The global shares of buildings and construction sector in terms of economic and environmental dimensions (Data from UNEP, 2026)

3.2.2. Drivers of Demand: Urbanisation, Floor Area, Cooling and Digitalisation

Four structural forces shape the sector's trajectory. The first is urbanisation as shown in Figure 3.3, a total of 57.5% of humanity lives in cities today, a share projected to reach 68% by 2050, adding roughly 2.2 billion urban residents, close to 90% of them in Asia and Africa (UN DESA, 2019). Figure 3.3 presents a dynamic trajectory through complementary paths crossed in 2007 which was a turning point historically, when humanity first became mostly urban-based as a critical step for urbanization. Alongside the United Nation's projection, a target trajectory is



included in which the urban and rural shares will reach 60% and 40% worldwide. It is important to have a specific target to keep urbanization increase constant along with ruralization being increased by providing specific sustainability targets available to people leaving in rural areas and making them part of societal development as well as flourishing their rural existence a priority while developing a healthy relationship between urban and rural communities. In this regard, this illustrates a balanced territorial development scenario: rather than concentrating a further two billion people in cities, which require the attendant surge in urban construction, cooling loads, infrastructure investment and heat exposure, policies that keep rural livelihoods viable, including distributed renewable energy, rural electrification and decentralised services, would moderate the pace of urban demand growth and spread it across a wider territorial base, easing the energy management challenge that the remainder of this section describes. The gap between the projected and target pathways after 2024 thus represents the demand pressure that balanced development could avert.

The second is floor area growth (see Figure 3.4): with about half of the buildings that will exist in 2050 yet to be built or renovated, the standards applied to new construction this decade will lock in energy and emissions outcomes for the better part of a century (UNEP, 2026). The third is cooling, the fastest-growing end use in buildings: the global air conditioner stock, around 2.4 billion units today, is on course to more than double by 2050, and space-cooling electricity demand grows by almost 1,500 TWh to 2035 in the absence of strengthened efficiency standards, cooling is the main reason global peak electricity demand rises by about 40% to 2035 (IEA, 2018, 2025a). The fourth is digitalisation, which cuts both ways: connected devices and data infrastructure add load, while smart meters, building automation and AI-supported management systems unlock efficiency and flexibility (IEA, 2025a; TÜBA, 2022). Buildings sit at the heart of the Age of Electricity: appliances and air conditioning alone contribute roughly 30% of global electricity demand growth to 2035 (IEA, 2025a).



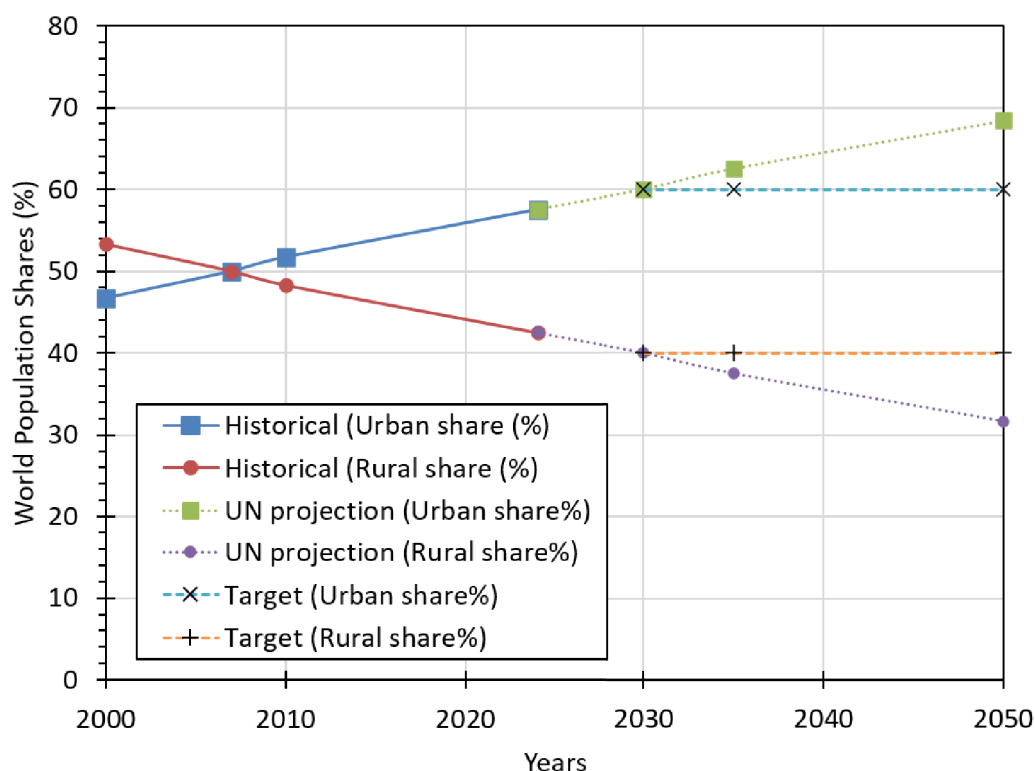


Figure 3.3 Actual and projected urban and rural population shares (Data from UN DESA, 2019)

3.3. Reducing Energy Use Intensity: Technologies, Strategies and Potentials

Cutting the energy use intensity of the buildings sector by at least 25% by 2035 is the quantitative core of Goal 3, and this section sets out how it can be achieved. Section 3.1 defines the intensity metric itself and establishes the scale of the challenge: with global building energy intensity having declined by only about 1% per year since 2015, the target requires the pace of improvement to more than double. The four sections that follow present the strategy pillars that together deliver this acceleration. Section 3.2 addresses new construction, where mandatory building energy codes and nearly zero-energy building standards offer the highest leverage, since much of the 2050 building stock is yet to be built. Section 3.3 turns to the existing stock, where deep renovation must scale from around 1% to 2–3% of buildings per year. Section 3.4 covers the thermal services that dominate buildings’ energy balance, heat pumps for heating, efficient equipment and standards for the rapidly growing cooling load, and thermal energy storage that helps turn buildings into flexible assets. Finally, Section 3.5 examines the digital layer of smart meters, automation and AI-supported energy management that binds the other pillars together and connects buildings to the wider power system.



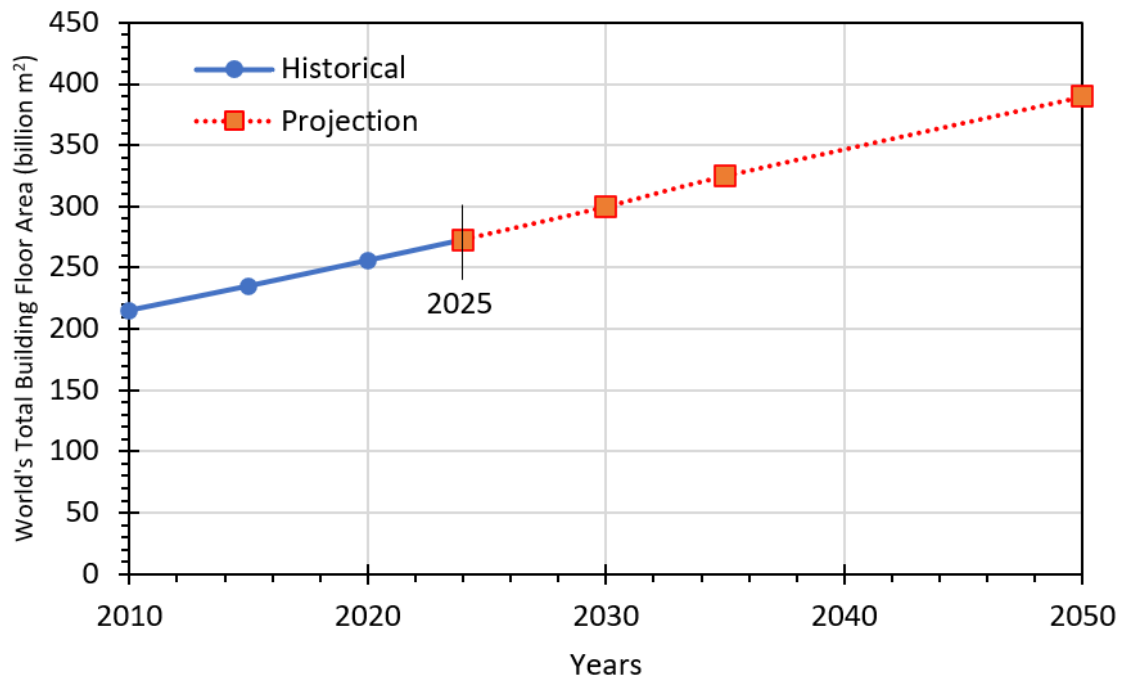


Figure 3.4 Global buildings floor area variation between 2010 and 2050 (Data from: UNEP, 2025; 2026)

3.3.1. The Intensity Metric and the 2035 Target

Energy use intensity (EUI), annual final energy consumption per unit of floor area, expressed in kWh/m² is the sector's core performance metric because it separates efficiency progress from floor area growth. Global building energy intensity has declined by 8.5% since 2015, an average of roughly 1% per year, while floor area has grown faster, so that absolute energy use and operational emissions have continued to rise (UNEP, 2026). The COP31 Goal 3 target at least a 25% reduction in EUI by 2035. Therefore, it requires the annual pace of intensity improvement to more than double, from about 1% to approximately 2.6% per year. Figure 3.5 shows both trends, current and COP31 target. This is demanding but consistent with the IEA's net-zero pathway, in which the rate of global energy efficiency improvement doubles this decade (IEA, 2025a). Four strategy pillars, detailed below, together deliver the target.

3.3.2. New Construction: Building Codes and Nearly Zero-Energy Buildings

Because so much of the 2050 building stock is yet to be built, mandatory performance-based building energy codes are the single highest-leverage instrument available. Figure 3.5 shows the task they must deliver: after a decade in which global building energy use intensity declined by only about 1% per year. A continuation of current trends (BAU) leaves the sector far above a Paris-aligned trajectory, whereas the IEA Net Zero Emissions pathway requires intensity to fall to roughly 80% of its 2015 level by 2030 and less than half by 2050. The COP31 targets of a 25% and preferably 35% reduction by 2035 sit on, and slightly ahead of, this NZE trajectory; the shaded gap between the BAU and target pathways in the figure is, in effect, the space that



building codes for new construction must close first, since every square meter built to nZEB standards enters the stock at the bottom of the intensity range rather than adding to the problem. Nearly zero-energy building (nZEB) standards combine a high-performance envelope (insulation, airtightness, high-performance glazing) with passive design adapted to climate zone (orientation, shading, natural ventilation, thermal mass) and efficient, preferably electric, technical systems, so that the small residual demand can be met by on-site or nearby renewables. The policy gap is stark: although over 14 countries or sub-national governments have updated their codes since 2023, few align with net-zero goals, and a large share of new floorspace in fast-growing emerging economies is still built without any mandatory energy code at all (UNEP, 2026). Extending code coverage to all new construction by 2030, with clear nZEB trajectories, is therefore a defining condition for keeping the sector on the target pathways shown in Figure 3.5. Initiatives such as the Buildings Breakthrough, endorsed at COP28 to make near-zero emission and resilient buildings the new normal by 2030, together with the Déclaration de Chaillot and the Intergovernmental Council for Buildings and Climate, provide international scaffolding (UNEP, 2025; UNFCCC, 2023).

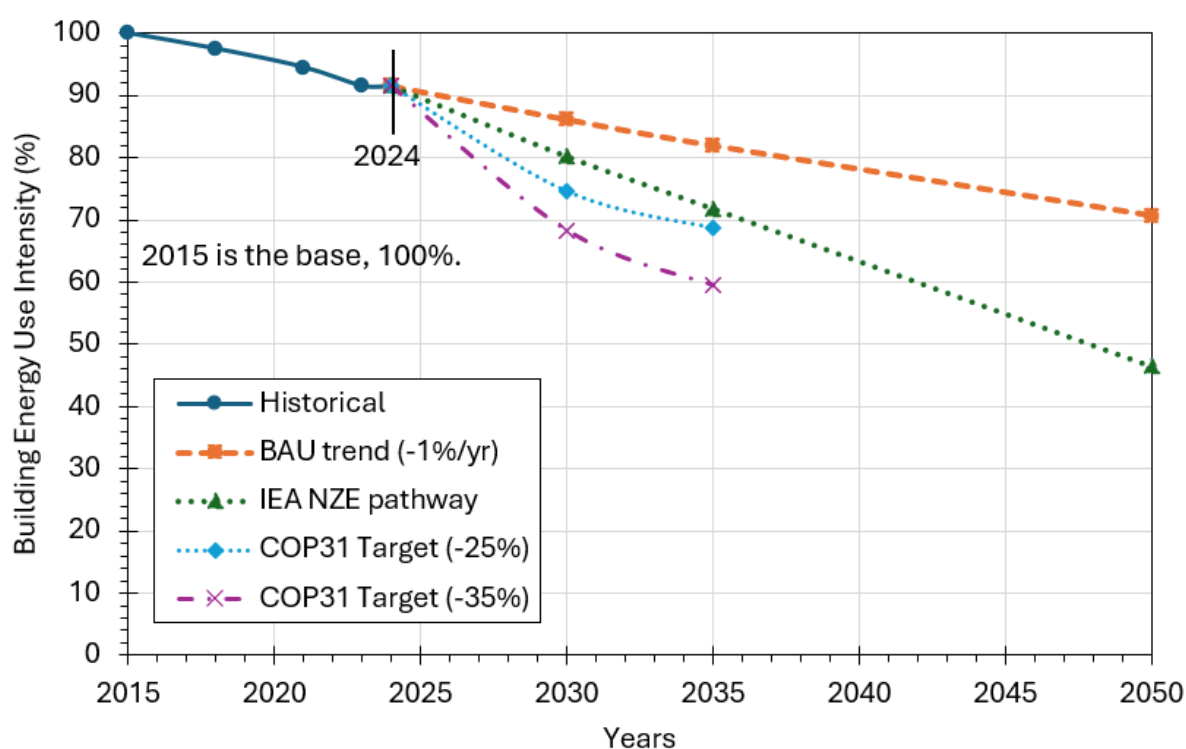


Figure 3.5 Building energy use intensity: historical trend versus potentially COP31 2035 pathway (Data from: UNEP, 2026)

3.3.3. Existing Stock: Deep Renovation

In advanced economies and increasingly in middle-income countries, most of the buildings of 2035 already exist; their transformation is a renovation problem. Current global renovation rates hover around 1% of the stock per year, and much of what is renovated undergoes only shallow



measures; net-zero-aligned pathways require deep renovation, packages combining envelope upgrades, efficient windows, lighting and appliance replacement, and heating system conversion that typically cut a building's energy use by half or more, at a rate of 2–3% annually by 2030, as demonstrated in Figure 3.6.

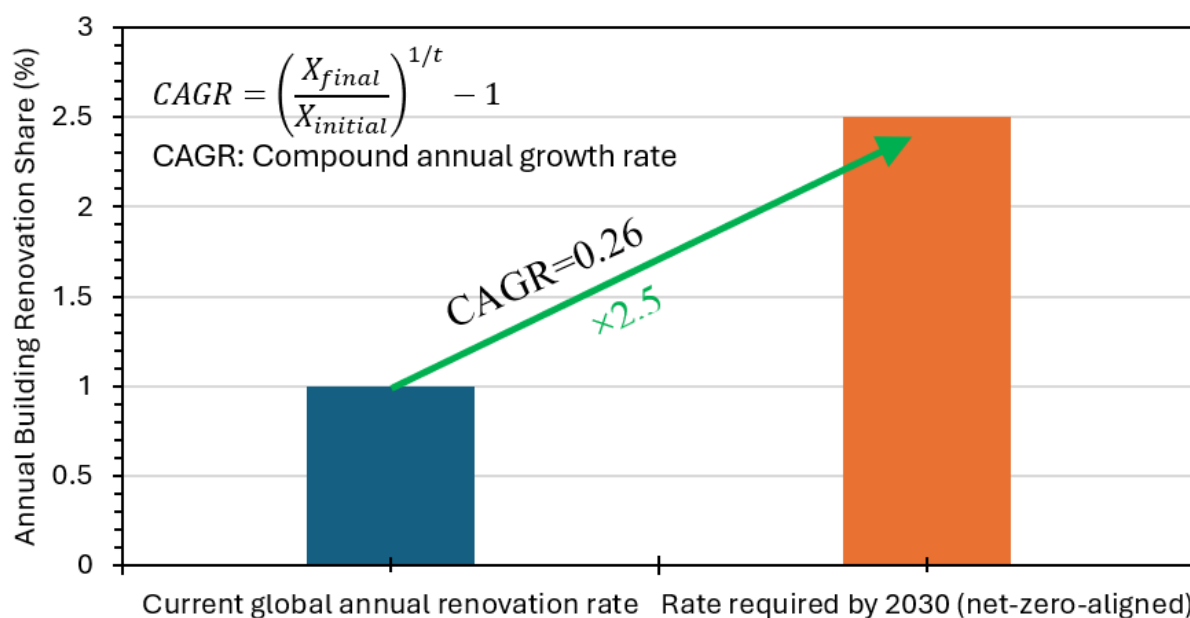


Figure 3.6 Renovation and improvement of the existing building stock: current global rates versus the net-zero-aligned requirement (Data from: IEA, 2025; UNEP, 2026)

Public buildings should lead as visible demonstrations; minimum energy performance standards for existing buildings, renovation obligations at trigger points (sale, rental, major refurbishment), one-stop-shop delivery models, and industrialized prefabricated retrofit solutions are really becoming the key instruments with the strongest track record. Deep renovation is also social policy: it is among the most effective durable remedies for energy poverty, lowering bills while improving health and comfort (UNEP, 2026).

3.3.4. Heating, Cooling and Thermal Energy Storage

Heating and cooling dominate buildings' energy balance. On the heating side, heat pumps are the central technology, delivering three to four units of heat per unit of electricity and becoming cleaner as grids decarbonise; they currently meet on the order of 10% of global space-heating needs, a share that roughly triples by 2035 on net-zero-aligned pathways, as shown in Figure 3.7 (IEA, 2025a, 2025c). Global heat pump sales dipped by 1% in 2024 on European weakness, underlining the sensitivity of the market to policy signals and electricity-to-gas price ratios, a key design variable for tariff and taxation policy (IEA, 2025c). District heating and cooling networks, fed increasingly by large-scale heat pumps, waste heat and geothermal sources, offer system-level efficiency in dense urban areas. As seen in Figure 3.8, on the cooling side, the priority is to serve rapidly growing demand efficiently: the average air conditioner sold today



is far less efficient than the best available models, so strengthened minimum energy performance standards (MEPS) and labelling can roughly halve the growth of cooling electricity demand to 2035, avoiding on the order of 800 TWh, comparable to Japan's total annual consumption, while passive measures and the Global Cooling Pledge's commitment to reduce cooling-related emissions by 68% by 2050 frame the wider effort (IEA, 2018, 2025a; UNFCCC, 2023).

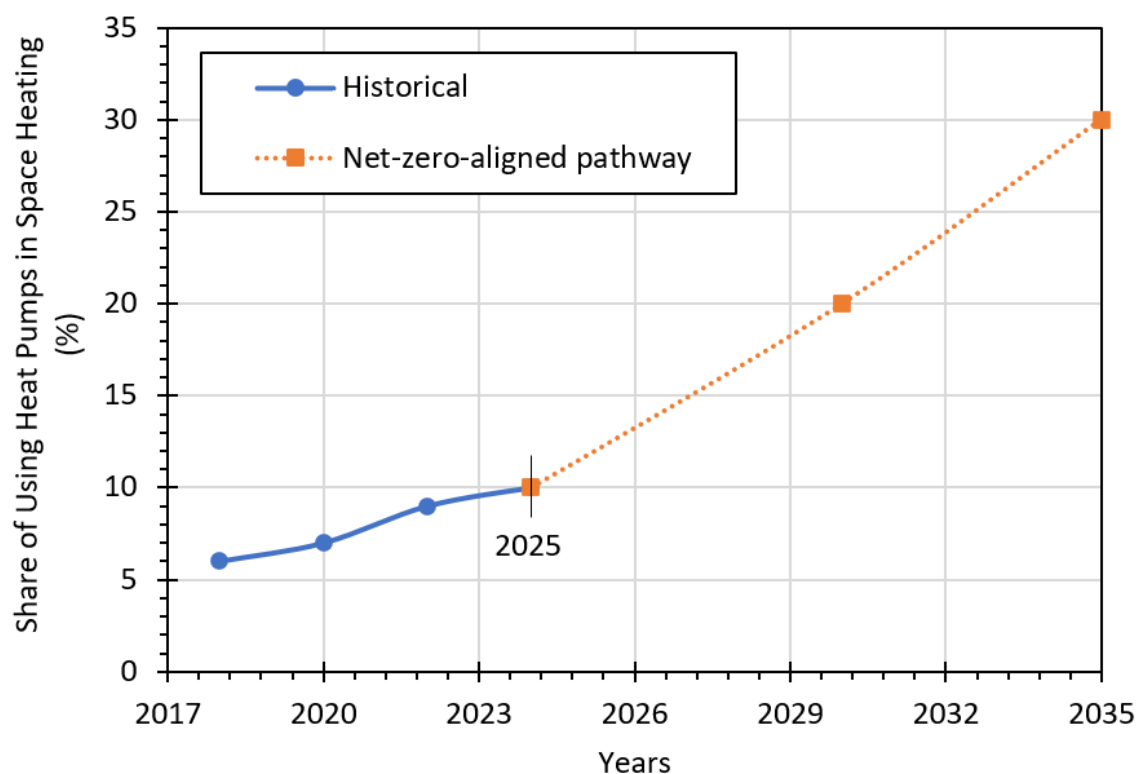


Figure 3.7 Share of global space-heating needs met by heat pumps: historical status and net-zero-aligned pathway to 2035 (Data from: IEA, 2025a; 2025c)

Sustainable cooling must, however, be understood as more than a mitigation measure. As UNEP's Global Cooling Watch documents, cooling is increasingly a matter of adaptation and survival: access to cooling protects human health during heatwaves, safeguards labor productivity, preserves food and vaccine cold chains, and underpins socioeconomic welfare more broadly, while more than a billion people at high risk from extreme heat still lack adequate access to it (UNEP, 2023). With extreme heat among the priority workstreams of the COP31 Presidency, the cooling agenda of this chapter is therefore positioned as an integrated instrument: efficient, low-emission cooling simultaneously curbs the sector's contribution to climate change and strengthens the resilience of societies to the heat that is already locked in as advancing mitigation and adaptation through the same set of measures. Thermal energy storage systems, from hot-water tanks and ice storage to phase-change materials at building and district scale, decouple the timing of heating and cooling from electricity system peaks, turning buildings into flexibility assets (TÜBA, 2020).



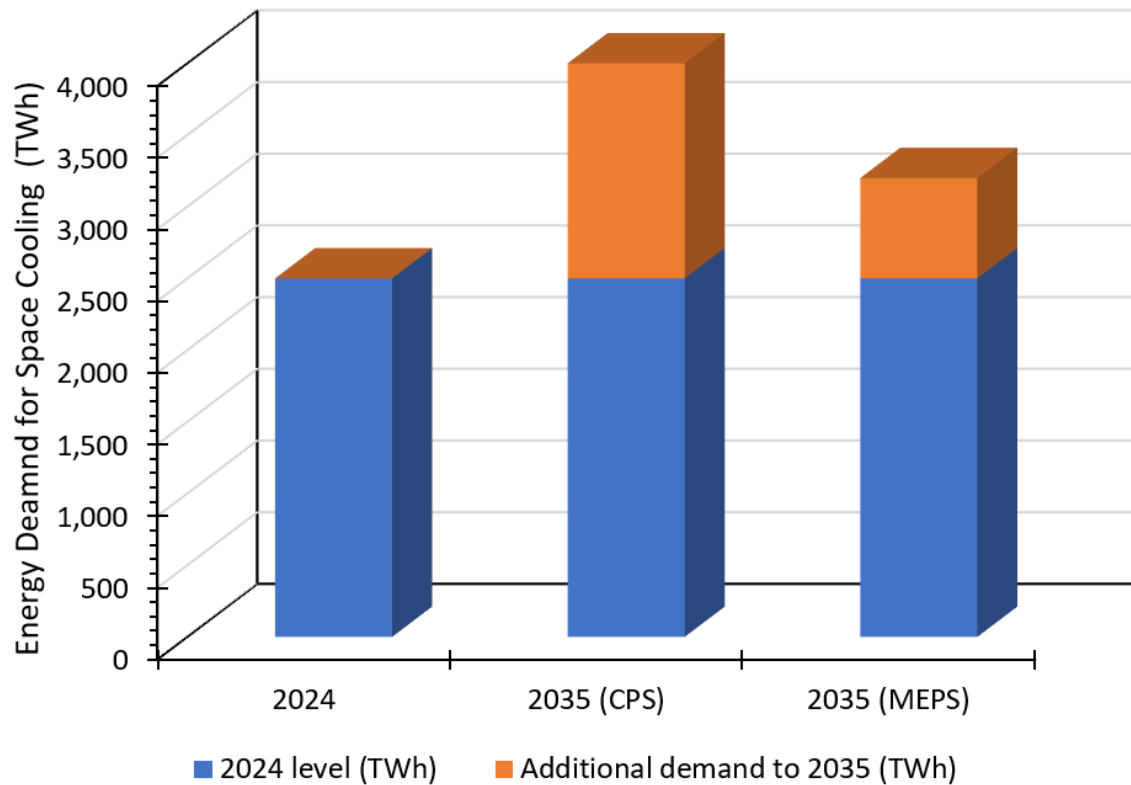


Figure 3.8 Space-cooling electricity demand to 2035 under weak and strengthened efficiency standards (Data from: IEA, 2025a)

3.3.5. Smart Buildings, Digitalisation and Demand Flexibility

Digital technologies are the connective tissue of an efficient, resilient building stock. Smart meters and sub-metering create the data foundation; building automation and AI-supported energy management systems optimize heating, cooling, ventilation and lighting in real time against occupancy, weather and price signals, typically yielding double-digit percentage savings at low capital cost; and benchmarking systems that compare buildings of the same type make performance visible and actionable (TÜBA, 2022). Beyond efficiency, digitalisation unlocks demand flexibility: pre-cooling and pre-heating, thermal storage dispatch, smart EV charging at buildings and demand response aggregation allow the building stock to shave the cooling-driven peaks that would otherwise force costly grid and generation investment, effective demand-side participation materially reduces system investment needs (IEA, 2025a; TÜBA, 2022).

Turkish research on smart and sustainable city standards situates building-level digitalisation within a broader municipal performance framework: ISO 37120:2018 defines city performance indicators in which energy figures as a core criterion, complemented by the newer ISO 37125:2024 standard, while integrated ISO 50001 energy management combined with a Sustainable Energy and Climate Action Plan (SECAP) provides the operational backbone for tracking building and city-level energy performance over time (Hepbaşlı, 2025a, 2025b). At



city scale, smart-city technologies that collect and analyse data in real time to optimise urban services deliver three principal benefits, cost, time and sustainability, provided that the underlying hardware and software capacity is developed with strong local and national industrial participation to safeguard data sovereignty and security (Dener, 2025).

3.4. Building Climate Resilience

Reducing energy use intensity addresses only half of Goal 3; the other half is ensuring that buildings and cities can withstand the hazards that are already growing. This section examines that resilience imperative in five steps. Section 3.4.1 surveys the climate risks bearing down on the built environment and sets out how resilience can be designed through risk-informed planning, forward-looking design standards, nature-based solutions and the integration of adaptation requirements into building codes, an area where policy still lags well behind mitigation. Section 3.4.2 gives the defining challenge of urban climate risk: the urban heat island effect and cooling paradox. Section 3.4.3 addresses the energy resilience of critical facilities, showing how distributed solar, storage and islandable microgrids can keep hospitals, water systems and disaster coordination centres running when the grid fails. Section 3.4.4 discusses the agenda beyond climate to seismic resilience, drawing on the lessons of recent major earthquakes for building codes and urban transformation. Finally, Section 3.4.5 completes the picture with water resilience and the water–energy nexus, treating water security as an integral dimension of building and city resilience. Across all these dimensions, one core insight remains: energy efficiency and resilience strengthen each other, because the measures that reduce energy use also enhance the ability of buildings and cities to protect people when hazards occur.

3.4.1. Climate Risks to the Built Environment

The resilience half of Goal 3 is not an add-on: buildings and urban infrastructure are among the assets most exposed to intensifying climate hazards, like extreme heat, floods, storms, wildfire and sea-level rise, and the sector is increasingly vulnerable to climate impacts alongside energy price shocks (UNEP, 2026). Resilience must therefore be designed in, through climate-informed risk mapping that steers development away from the highest-risk locations; updated structural and drainage standards reflecting future rather than historical climate; nature-based solutions such as urban green space and permeable surfaces; and the systematic integration of adaptation requirements into building codes, an area the Global Status Report identifies as lagging well behind mitigation provisions (UNEP, 2026). Efficiency and resilience are mutually reinforcing: a well-insulated, airtight building with external shading maintains safe indoor temperatures for far longer during heatwaves and power outages, a property known as passive survivability.

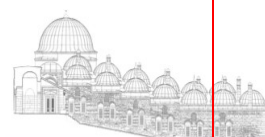


Effective adaptation planning also depends on the disaster-management ecosystem within which building-level resilience measures are embedded. Evidence from Türkiye shows that despite documented increases in the frequency, intensity and duration of hydrometeorological hazards under climate change, integrated risk management that combines meteorological engineering with climate adaptation planning remains underdeveloped, with significant gaps persisting in the forecasting and early-warning systems on which building and infrastructure resilience ultimately depend (Kadioğlu, 2023).

3.4.2. Urban Heat and the Cooling Paradox

Cities locally and globally face climate challenges. The urban heat island effect can raise city temperatures by several degrees above surrounding areas, compounding heatwaves whose frequency and intensity are rising; heat is already the deadliest weather-related hazard in many regions, and exposure is growing fastest in the rapidly urbanising hot climates of Asia and Africa. The result is a cooling paradox: mechanical cooling protects health but adds heat to the street, load to the grid and where power is carbon-intensive, emissions to the atmosphere, further warming the climate. Breaking the loop requires a hierarchy: first reduce heat at source through reflective and green roofs, shading, urban trees and ventilation corridors; then serve the residual need efficiently through MEPS, district cooling and thermal storage; and finally protect the most vulnerable through cooling centres and heat-health action plans. The Global Cooling Pledge and the passive-design provisions of modern codes provide the policy framing (UNFCCC, 2023; UNEP, 2026).

Figure 3.9 illustrates the scale of the cooling wave now building in the global building stock. The number of air conditioners in operation worldwide has more than doubled since 2010, rising from roughly 1.1 billion units to about 2.4 billion in 2024, and is projected to reach approximately 3.7 billion units by 2035 and 5.6 billion by 2050. In other words, more air conditioners will be added in the coming quarter-century than exist today. Growth is concentrated in the hot-climate emerging economies of Asia, Africa and Latin America, where rising incomes are converting latent cooling need into purchased equipment, often at efficiency levels far below the best available technology. The trajectory shown in the figure is therefore not a forecast to be accepted passively but a policy variable: whether this expanding stock becomes a manageable load or an overwhelming one depends on the minimum energy performance standards, labelling schemes and passive design measures examined in Sections 3.4 and 4.2, which together determine how much electricity each of those billions of units will draw.



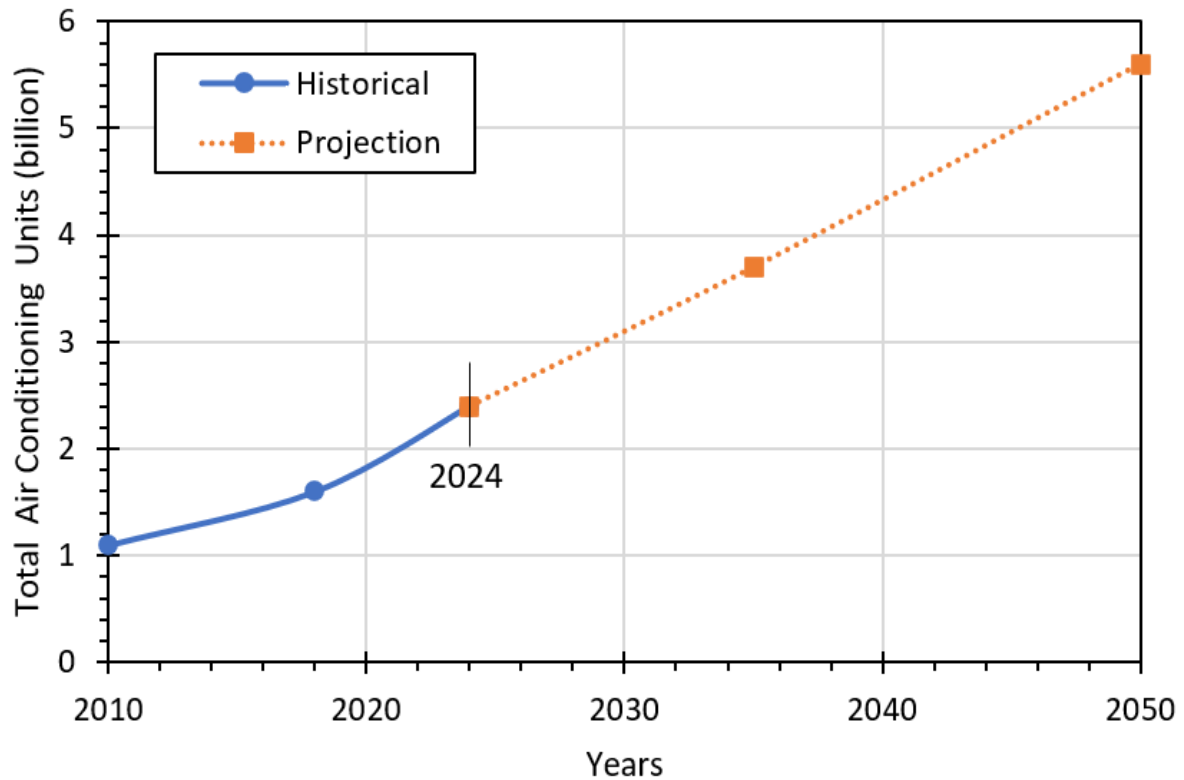
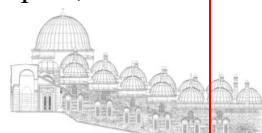


Figure 3.9 Variation of stocks of global air conditioner units between 2010 and 2050 (Data from: IEA, 2018; 2025a)

3.4.3. Energy Resilience of Critical Facilities

As societies electrify, the continuity of power supply to critical facilities, such as hospitals, water and sanitation systems, communications, schools serving as shelters, and disaster coordination centres, becomes a core dimension of urban resilience. The blackouts experienced in Chile and the Iberian Peninsula in 2025 illustrated the systemic cost of failure in highly electrified societies (IEA, 2025a). Distributed energy resources reconfigure the solution space: rooftop solar combined with battery and thermal storage, designed as islandable microgrids, can sustain critical loads through grid outages while providing daily economic value in normal operation. Resilience standards for critical facilities, backup-duration requirements, and the hardening of substations and network assets against flood and heat should be embedded in national adaptation plans and urban master plans, with AI-supported monitoring enabling early detection of stress across building portfolios (TÜBA, 2020; 2022).

Water security is an equally critical, and frequently underappreciated, dimension of critical-facility resilience. Hydrological and climate modelling for Türkiye's river basins to 2100 project significant shifts in net water surplus and deficit, with implications for the water supply on which hospitals, cooling systems and sanitation infrastructure depend; city-scale experience, illustrated by Istanbul's integration of water resources planning into its climate action plan,



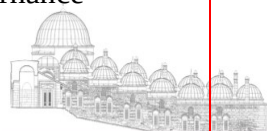
shows that embedding water security explicitly within urban resilience strategies that is alongside energy and structural measures, is essential for maintaining the continuity of critical services under a changing climate (Öztürk et al., 2023).

3.4.4. Seismic Resilience and Earthquake-Resistant Buildings

The resilience agenda addressed above is framed largely in climate terms, yet for many COP31 Parties, including the host country, seismic hazard is an equally decisive dimension of building and urban resilience. Türkiye lies on the Alpine-Himalayan seismic belt and has experienced major destructive earthquakes throughout its history; the 6 February 2023 Kahramanmaraş earthquakes once again demonstrated that poorly designed, inadequately supervised buildings on inadequate ground conditions pose severe risk even within well-mapped seismic zones (Elmas, 2025). Structures built before the major revisions to Türkiye's building codes in 1998, 2007 and 2018 remain especially vulnerable: buildings constructed under regulations in force between 1937 and 1999 account for around 43.5% of the national building stock, and 42% of that share lies within Seismic Zone 1, the highest-hazard category on Türkiye's earthquake hazard map (Akgün & Mostura, 2025).

Post-earthquake structural assessments of reinforced-concrete buildings damaged in the Kahramanmaraş earthquakes attribute much of the observed damage to substandard concrete quality, inadequate lateral load-resisting systems and weak construction supervision, while documenting that targeted ground-improvement techniques (such as jet-grouting) can substantially protect buildings even on poor soil conditions, underscoring the importance of soil-structure interaction in seismic risk reduction (Pürsünlü & Çevik, 2025). Türkiye's post-2018 Turkish Building Earthquake Code, together with Law No. 6306 on the Transformation of Areas Under Disaster Risk and the 2019 Principles for the Identification of Risky Buildings, provide the regulatory basis for retrofitting and reconstructing the vulnerable pre-1999 stock through urban transformation, but enforcement gaps in field supervision continue to undermine the effectiveness of these regulations in practice (Akgün & Mostura, 2025).

Building seismic resilience into cities requires a systematic approach: geological, geophysical and geotechnical microzonation to identify fault lines and site-specific hazard; land-use and construction planning that keeps buildings and green space away from the highest-risk areas; strengthened critical infrastructure, such as electricity, communications and other lifeline services, designed to remain functional after an earthquake; a comprehensive building inventory to prioritise retrofitting and reconstruction; safe evacuation routes, open spaces and resilient emergency shelters; and public education and regular drills that build community earthquake preparedness (Altunışık, 2025). Risk-informed urban planning of this kind, integrating ecological, infrastructural and socio-economic dimensions within a participatory governance



framework, is central to reducing disaster losses from a sustainability perspective (Türkoğlu, 2025). As with climate resilience, seismic resilience and energy efficiency are complementary rather than competing agendas: the urban transformation process that retrofits a building's structural system is also the point at which envelope insulation, airtightness and efficient systems can be added at marginal extra cost, and both COP31 Goal 3 and Türkiye's own urban transformation programme should treat seismic and energy retrofit as a single, coordinated intervention (Yüksel & Çalım, 2025).

3.4.5. Water Resilience and the Water-Energy Nexus in Buildings and Cities

Water receives little attention in most building resilience and efficiency agendas, yet it is both a resource under increasing stress and a hidden dependency of the energy-efficiency measures addressed elsewhere in this report. Of all water on Earth, only about 2.5% is fresh, two-thirds of which is locked in glaciers, leaving barely 0.3% of the planet's water in an accessible, potable form; as population growth and rising industrial and agricultural demand intensify pressure on this limited resource, water scarcity (spanning water stress, water shortage and water crisis) has become a defining global sustainability challenge alongside energy and climate (Koyuncu et al., 2023). Membrane-based treatment and reuse technologies are increasingly the most viable route to expanding usable water supply, particularly through the recovery and reuse of wastewater, and offer a direct parallel to the deep-renovation and circular-material strategies addressed for energy and materials elsewhere in this report (Koyuncu et al., 2023).

The building sector's exposure to this stress operates in both directions. On the demand side, evaporative and water-cooled systems used to meet the rising cooling loads addressed in Sections 3.4 and 4.2 draw directly on municipal water supply, meaning that strengthened cooling efficiency standards deliver a water security co-benefit that is rarely quantified alongside their electricity savings. On the supply side, reclaimed municipal wastewater reused for irrigation of urban green infrastructure, the same cool roofs, urban trees and vegetated surfaces identified in Section 4.2 as central to mitigating the urban heat island that offers a proven, lower-cost route to sustaining that vegetation without adding to potable water demand, with projections warning that under pessimistic global consumption scenarios, as many as 7 billion people across 60 countries could face water scarcity by mid-century absent such measures (Aydın & Aydın, 2023).

Embedding water security into building and city resilience strategies therefore requires the same systemic, cross-sectoral approach applied to energy and seismic resilience elsewhere in this report: water-efficient fixtures, greywater and rainwater harvesting systems, and treated-wastewater reuse should be integrated into building energy codes and nearly zero-energy



building standards (Section 3.2); city-scale climate action plans should embed integrated water management alongside energy and emissions targets, following the basin-scale hydrological modelling and municipal planning approach demonstrated for Istanbul (Öztürk et al., 2023); and critical facilities should be assessed for water as well as energy continuity risk, consistent with the treatment of water and sanitation systems as core critical infrastructure in Section 4.3.

3.5. Implications: Co-Benefits and Key Enablers

The technical agenda set out in Sections 3 and 4 will succeed or fail in its enabling conditions, and this section examines them alongside the co-benefits that make the effort worthwhile. Section 5.1 addresses investment, affordability and energy poverty, showing why the front-loaded financing of efficiency measures requires dedicated instruments, essentially from green mortgages to energy performance contracting, and how, with the right distributional design, deep renovation becomes one of the most powerful anti-poverty and public-health investments available. Section 5.2 turns to embodied carbon and circular materials: as operational emissions fall, the cement, steel and other materials behind nearly half of global material extraction claim a rising share of the sector's footprint, making material efficiency, low-carbon substitution and design for reuse a first-order priority. Section 5.3 examines skills, supply chains and industry capacity, the delivery constraint behind every renovation target and heat pump projection, in a sector that already employs about 9% of the world's workforce. Section 5.4 completes the analysis with inclusive urban transitions, reaching hundreds of millions without electricity access and more than a billion people in informal settlements, and closes with a special focus on hot-climate cities, where the resilience and equity dimensions of Goal 3 converge most sharply.

3.5.1. Investment, Affordability and Energy Poverty

The specific transition of buildings is inseparable from the global housing and energy affordability crisis amid which the latest Global Status Report was published (UNEP, 2026). Energy efficiency investment in buildings has recently declined even as needs grow, and the sector's capital stock turns over slowly, so the financing challenge is front-loaded: efficiency measures carry upfront costs whose returns accrue over decades in lower bills. The instruments are well understood, such as green mortgages and renovation loans with preferential terms, on-bill and property-tax-linked repayment, energy performance contracting through ESCOs, minimum performance standards that shift market expectations, and the aggregation of small renovation projects into investable portfolios, the core logic of the CIB under Goal 6 of the COP31 Presidency. Distributional design is essential: without targeted grants and social-



housing programmes, efficiency requirements can burden low-income households that occupy the least efficient dwellings; with them, deep renovation becomes one of the most powerful anti-poverty and public-health investments available, cutting bills, cold- and heat-related illness, and exposure to energy price shocks simultaneously.

Public policy design is a further enabler of front-loaded efficiency and resilience investment. Evidence from Türkiye shows that as urbanisation concentrates an increasing share of GDP, integrated disaster-risk-reduction strategies engage a wide range of actors (central and local government administrators, construction-sector technical staff and contractors) across urban planning, construction, building inspection and building-use stages, and that gaps in enforcement and professional culture, rather than an absence of legislation, are often the binding constraint on effective risk and cost mitigation; strengthening these public-policy and enforcement instruments alongside financing mechanisms is therefore a precondition for scaling efficiency and resilience investment (Esen, 2025).

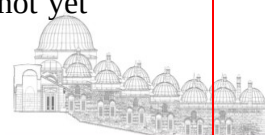
3.5.2. Embodied Carbon and Circular Materials

As operational emissions fall, embodied emissions, from cement, steel, aluminum and other materials, claim a rising share of the sector's footprint, and the sector's nearly 50% share of global material extraction makes circularity a first-order issue (UNEP, 2026). Priorities include material-efficient design and the sufficiency question of how much floor area is actually needed; substitution with low-carbon and bio-based materials such as engineered timber where appropriate; clinker reduction and green hydrogen-based steel in coordination with Goal 4 on Green Industrialisation; whole-life carbon assessment and disclosure requirements in codes and procurement; and design for disassembly, reuse and high-value recycling of construction materials. Circular construction is gaining ground in policy discourse but remains limited in practice, which closes that gap is a defining task of the coming decade (UNEP, 2025).

Circular-construction priorities in the buildings sector sit within the wider transition to sustainable production and consumption patterns, which requires resource-efficient production processes, extended product life cycles and closed-loop material flows across manufacturing sectors, including construction materials; embedding these principles at the design and procurement stage complements the sector-specific measures above and strengthens the coordination with Goal 4 on Green Industrialization.

3.5.3. Skills, Supply Chains and Industry Capacity

Doubling the pace of intensity improvement is ultimately a delivery challenge. Deep renovation at 2–3% per year, universal code enforcement and heat pump roll-out at scale require millions of trained installers, energy auditors, inspectors and engineers, a workforce that does not yet



exist at the required scale in most markets, in a sector already employing about 9% of the global workforce (UNEP, 2026). Vocational training and certification programmes, digital tools that raise installer productivity, industrialised prefabrication that moves renovation from craft to manufacturing, and stable policy pipelines that give firms the confidence to invest in capacity are the enablers. Supply chains for heat pumps, insulation materials, efficient glazing and smart equipment must scale in parallel; unlike some clean technologies, their manufacture is comparatively distributable, offering local industrial and employment opportunities in nearly every economy.

3.5.4. Inclusive Urban Transitions

The buildings' transition must reach everyone to succeed. Around 730 million people still lack electricity access entirely, and over a billion urban residents live in informal settlements where formal codes, land tenure and utility service are weak or absent (IEA, 2025a; UN DESA, 2019). Inclusive strategies pair incremental upgrading, safe wiring, cool roofs, ventilation, basic insulation, with community-scale solutions such as mini-grids and shared cooling facilities, and with tenure and finance arrangements adapted to informality. Gender-responsive design matters: energy poverty and heat exposure fall disproportionately on women, who also represent an underused talent pool for the sector's workforce needs.

Inclusive delivery also depends on addressing the social and legal dimensions of urban transformation directly. Evidence from Turkish urban transformation practice shows that renewal projects concentrated in areas with a high density of at-risk buildings have frequently deepened socio-economic inequality, driven displacement of long-term residents and damaged the existing social and cultural fabric where transformation is treated purely as physical reconstruction rather than as a socially just process (Kutlu, 2025). Legal analysis of urban transformation implementation further identifies unresolved problems around property rights, compensation and tenant relocation as a recurring source of conflict and delay, underscoring that secure tenure arrangements and accessible legal remedies are as important to inclusive delivery as physical upgrading and finance (Yasin, 2025).

3.5.5. Special focus: Hot-climate cities and informal settlements

The defining building-sector challenge of the coming decades is concentrated in the fast-growing cities of hot climates. Nearly all urban population growth to 2050 occurs in Asia and Africa, much of it in regions where extreme heat is intensifying, air conditioning ownership is rising steeply from a low base, and a substantial share of residents live in informal settlements built without codes, insulation or reliable power. These neighbourhoods experience the urban heat island at its most severe - dense, low-albedo roofing materials, little vegetation and scarce



cooling can make indoor conditions lethal during heatwaves. Yet the solution set is proven and inexpensive: cool (reflective) roofs can cut indoor temperatures by several degrees for a few dollars per square metre; shading, cross-ventilation and light-coloured surfaces are matters of design, not cost; community cooling centres anchored on solar-plus-storage microgrids provide refuge and grid-independent resilience; and hyper-efficient fans and air conditioners, procured in bulk, serve more people per unit of scarce grid capacity. Embedding these measures in slum-upgrading programmes, in the building codes now being written in fast-urbanising countries, and in heat-health action plans is among the highest-benefit climate investments available, simultaneously advancing adaptation, mitigation, health and equity. For hot-climate cities, efficient and resilient buildings are not a climate abstraction: they are the difference between habitable and uninhabitable urban futures.

3.6. Action Plan

The preceding sections establish that reducing the energy use intensity of the buildings sector by at least 25% by 2035 is demanding, but deliverable: it requires the historical pace of improvement, roughly 1% per year since 2015, to more than double, while resilience is built into a stock expanding by billions of square metres annually (UNEP, 2026). Closing this gap requires coordinated action across eight fronts, each aligned with the United Nations 2030 Agenda for Sustainable Development, above all SDG 11 on sustainable cities and communities and the Paris Agreement, sequenced over three phases: launch (2026–2028), in which codes, benchmarking systems and pilot programmes are established; scale-up (2028–2032), with an interim milestone of a 12–15% intensity reduction by 2030; and consolidation (2032–2035), in which the target is attained and verified through the Global Stocktake. Figure 3.10 demonstrates eleven potential actions for reaching the targets in the cities and buildings.





Figure 3.10 A layout of the action plan

Action 1

Extend Building Energy Codes and Nearly Zero-Energy Standards to All New Construction

Because about half of the 2050 building stock is yet to be built or renovated, mandatory performance-based energy codes are the single highest-leverage instrument available. All Parties should adopt code coverage for new construction by 2030, with clear trajectories towards nearly zero-energy building performance, climate-zone-adapted passive design requirements and universal energy performance certification; the Buildings Breakthrough, endorsed at COP28 to make near-zero emission and resilient buildings the new normal by 2030, and the Déclaration de Chaillot provide the international scaffolding. This action line operationalises SDG target 7.3 on doubling the rate of energy efficiency improvement and SDG target 11.c on supporting sustainable, resilient building in developing countries, and locks in decades of avoided emissions in line with SDG 13.



Action 2

Increase Deep Renovation of the Existing Building Stock

Annual renovation rates should be raised from around 1% to 2-3% of the stock by 2030, with depth prioritised over breadth: standardised deep retrofit packages, minimum energy performance standards for existing buildings, renovation obligations at trigger points such as sale or major refurbishment, one-stop-shop delivery models and industrialised prefabricated solutions, with public buildings renovated first as visible demonstrations. Deep renovation is simultaneously social policy: as the most durable remedy for energy poverty, it advances SDG 1 on poverty, SDG 3 on health through warmer, drier and cooler homes, and SDG target 7.1 on affordable and reliable energy services.

Action 3:

Electrify Heat and Cooling Efficiently with Storage Options

Fossil-fuel boiler installations in new buildings should be phased out this decade, heat pump deployment scaled towards meeting roughly triple today's 10% share of global space heating by 2035, supported by tariff structures that correct electricity-to-gas price ratios and district heating and cooling networks expanded around large-scale heat pumps, waste heat and geothermal sources. On the cooling side, strengthened minimum energy performance standards and labelling can roughly halve demand growth to 2035, avoiding on the order of 800 TWh, while implementation of the Global Cooling Pledge's commitment to cut cooling-related emissions by 68% by 2050 frames the long-term effort; thermal energy storage at building and district scale decouples thermal loads from grid peaks. This action line delivers SDG 7.2 and 7.3 jointly, and its cooling dimension is a direct SDG 3 health intervention in a warming climate.

Action 4:

Deploy Green Solutions with Demand Flexibility at a Large Scale

Smart meters, building automation and AI-supported energy management systems should be rolled out across the non-residential stock and progressively into homes, building energy performance benchmarking made mandatory for large buildings, and demand flexibility, pre-cooling, thermal storage dispatch, smart EV charging at buildings, mobilised as a system resource that contains cooling-driven peaks and reduces grid investment needs. This is the buildings application of SDG 9 on resilient infrastructure and innovation, and it operationalises SDG target 7.b on upgrading energy infrastructure and technology. Adaptation requirements (heat-resilient design, flood-resistant construction and drainage, wind loading updated to future climate) should be integrated into building codes on the same footing as energy provisions, closing the gap identified by the Global Status Report; urban heat island mitigation through



cool roofs, shading, urban trees and ventilation corridors should be embedded in city master plans and slum-upgrading programmes; and critical facilities such as hospitals, water systems, schools serving as shelters, should be equipped with islandable solar-plus-storage microgrids and covered by resilience standards with defined backup-duration requirements. This action line gives effect to SDG target 11.b on integrated disaster risk reduction aligned with the Sendai Framework, SDG 13 on adaptation, and SDG 3 aiming to prevent the heat-related mortality and its consequences.

Action 6

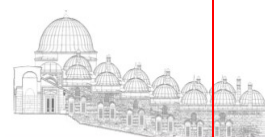
Incorporate Climate Resilience into Codes, Cities and Critical Facilities

Whole-life carbon assessment and disclosure should be phased into building codes and public procurement, material-efficiency and sufficiency principles applied in design, low-carbon and bio-based materials scaled where appropriate, and design for disassembly and high-value reuse made standard practice that is coordinated with Goal 4 on Green Industrialisation for the decarbonisation of cement and steel supply. Given the sector's nearly 50% share of global material extraction, this is the built environment's core contribution to SDG 12 on sustainable consumption and production, with circular-economy employment supporting SDG 8.

Action 7

Financing the Transition and Making It Inclusive

Building efficiency and resilience investment should be scaled through green mortgages and renovation loans, on-bill and property-linked repayment, energy performance contracting, and the aggregation of small projects into standardised, investable portfolios under the CIB mechanism established as Goal 6 of the COP31 Presidency, with concessional finance and guarantees directed to emerging and developing economies where financing costs are highest. Delivery must be inclusive by design: targeted grants and social-housing programmes to protect low-income households, incremental upgrading and community-scale solutions for the more than one billion residents of informal settlements, and gender-responsive programme design reflecting the disproportionate burden of energy poverty and heat exposure on women. This action line embodies SDG 17 on partnership and finance, SDG 10 on reduced inequalities, SDG target 11.1 on adequate, safe and affordable housing and upgrading slums, and SDG 5 on gender equality.



Action 8

Integrate Seismic Resilience into Building Codes and Urban Transformation

For Parties located in active seismic zones, building resilience must extend beyond climate hazards to earthquake risk. Seismic microzonation and hazard mapping should inform land-use and construction planning; building codes such as Türkiye's post-2018 Turkish Building Earthquake Code should be enforced through strengthened field supervision and independent building inspection, closing the gap between regulatory design and construction quality that repeated earthquake damage assessments have identified; urban transformation programmes addressing pre-1999, non-compliant building stock, such as those enabled by Türkiye's Law No. 6306, should be coordinated with the energy retrofit measures of Action 2 so that structural strengthening and deep energy renovation are delivered as a single intervention; and critical-infrastructure hardening, evacuation planning and public earthquake-preparedness education should be embedded in national disaster-risk-reduction strategies alongside the climate-resilience measures of Action 5. This action line extends SDG target 11.b on integrated disaster risk reduction to seismic as well as climate hazards and reinforces SDG 9 on resilient infrastructure.

Action 9

Provide Governance and Monitoring

Delivering these eight action lines requires a standing governance architecture: annual reporting of building energy use intensity (kWh/m²) against the 2030 and 2035 milestones through a common methodology, tracking via the Global Buildings Climate Tracker of the GlobalABC, peer review of national building renovation roadmaps within the NDC 3.0 cycle, verification through the Global Stocktake, coordination through the Intergovernmental Council for Buildings and Climate, and alignment with the SDG 11 and SDG 7 review processes of the UN High-Level Political Forum. The measure of success is unambiguous which is at least a 25% reduction in energy use intensity by 2035, achieved in buildings and cities that are demonstrably more resilient than today's.

Action 10

Develop Hydrogen Ecosystem

In the built environment, hydrogen's role is selective but strategic: for ordinary space heating, heat pumps are three to four times more efficient and should remain the default, but a well-designed urban hydrogen ecosystem unlocks applications that electrification and batteries cannot serve alone. Cities and governments should deploy hydrogen where its properties are decisive, as seasonal storage that carries surplus summer renewable generation into winter heating demand through district energy systems; as fuel-cell backup power and combined heat



and power for hospitals, data centres and other critical facilities, complementing the islandable microgrids of Action 5; as fuel for hard-to-electrify municipal fleets such as long-range buses, waste trucks and construction machinery; and as an industrial input in the urban-adjacent production of low-carbon cement and steel, linking directly to the embodied-carbon agenda of Action. Delivery requires city-scale "hydrogen valley" pilots that integrate production, storage and diverse end-uses in one district; the incorporation of hydrogen-specific provisions into building and infrastructure codes (ventilation, leak detection, material compatibility and setback distances) before deployment scales; planning frameworks that reserve corridors and sites for electrolyzers, storage and refuelling in urban master plans; and skills programmes for installers, inspectors and emergency services operating in hydrogen-equipped districts. Positioned this way, hydrogen deepens rather than dilutes the efficiency-first logic of this chapter: it serves the residual loads that remain after buildings have been made efficient, electric and smart. This action line advances SDG 9 on innovation and infrastructure, SDG 11 through resilient urban energy systems, and SDG 13 by extending decarbonisation to the segments of urban energy demand that other measures cannot reach.

Action 11

Use Artificial Intelligence for Management and Control

The building stock is the largest and most distributed energy asset in the world, and its transformation cannot be managed with manual tools; artificial intelligence should therefore be deployed as core infrastructure across the building–city–grid chain. At building scale, AI-supported energy management systems should be rolled out to optimise heating, cooling, ventilation and lighting in real time against occupancy, weather and price signals that typically deliver double-digit percentage savings at low capital cost, while predictive maintenance extends equipment life and machine-learning-based benchmarking makes the performance of millions of buildings visible and comparable. At district and city scale, AI-driven digital twins should be adopted for integrated planning of energy, climate risk and infrastructure decisions, from prioritising renovation across a municipal stock to modelling urban heat island mitigation and locating district energy assets. At the interface with the power system, intelligent control of heat pumps, air conditioners, thermal storage and EV charging should aggregate buildings into a coordinated flexibility resource that shaves cooling-driven peaks and reduces grid investment needs. AI also strengthens the resilience agenda of this chapter: continuous monitoring of structural health and water networks enables early detection of seismic damage and leakage, and AI-supported early-warning and emergency-management systems keep critical facilities operational when disasters strike. Enabling policies include open access to smart-meter and building performance data with strong privacy safeguards, interoperability standards for building automation, cybersecurity requirements for AI-controlled systems, and digital-skills programmes for facility managers and municipal staff. This action line advances



SDG 9 on innovation and resilient infrastructure, SDG 11 through smarter and safer cities, and SDG target 7.3, since optimisation-driven savings are among the cheapest efficiency gains available.

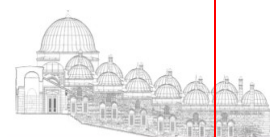
3.7. Conclusions

Three conclusions follow from the evidence assembled in this report. First, the built environment is decisive for the global transition: a sector responsible for 37% of emissions and half of material extraction, expanding by billions of square metres a year, with half of its 2050 stock yet to be built or renovated, will determine whether climate goals remain achievable (UNEP, 2026). Second, the COP31 Goal 3 target, cutting building energy use intensity by at least 25% by 2035, is demanding but deliverable: it requires roughly doubling the historical pace of intensity improvement through universal net-zero-aligned building codes, deep renovation at 2–3% per year, the scaling of heat pumps, efficient cooling and thermal storage, and smart, flexible building operation; every element rests on mature technology (IEA, 2025a; TÜBA, 2020, 2022). Third, efficiency and resilience must be pursued as one agenda: the same envelope that saves energy provides passive survivability in heatwaves; the same distributed solar and storage that cut bills keep hospitals running through outages; the same renovation wave that reduces emissions is the most durable remedy for energy poverty. Building fast is not enough; the task of this decade is to build and also rebuild well. The evidence assembled in this report supports the following concluding observations:

- The built environment is decisive for the outcome of the global energy transition. The buildings and construction sector is responsible for around 37% of global CO₂ emissions, 28% of final energy consumption and nearly half of all material extraction, and about half of the buildings that will exist in 2050 are yet to be built or renovated; the standards applied to this expansion will therefore determine whether climate goals remain achievable.
- The COP31 target of reducing building energy use intensity by at least 25% by 2035 is demanding but deliverable with technologies that already exist. Achieving it requires the pace of improvement to rise from roughly 1% per year, the average since 2015, to about 2.6% per year, through universal net-zero-aligned building codes, deep renovation of 2–3% of the stock annually, heat pumps, efficient cooling, thermal energy storage and smart building operation.
- Cooling is the defining pressure point of the coming decade. The global air conditioner stock is set to more than double by 2050, and cooling is the main driver of the roughly 40% rise in peak electricity demand to 2035; strengthened minimum energy performance standards can avoid on the order of 800 TWh of cooling demand by 2035, and they must be pursued together with urban heat mitigation and the Global Cooling Pledge as a single agenda.



- Efficiency and resilience must be pursued as one agenda rather than two. The same well-insulated envelope that saves energy keeps indoor temperatures survivable during heatwaves and power outages, the same distributed solar and storage that cut bills keep hospitals and water systems running when the grid fails, and the same renovation wave that reduces emissions is the most durable remedy for energy poverty; adaptation provisions should therefore enter building codes on the same footing as energy requirements.
- Embodied carbon and construction materials are the next frontier of the sector's decarbonisation. As operational emissions decline, the cement, steel and other materials behind nearly half of global material extraction claim a rising share of the sector's footprint, which makes whole-life carbon assessment, material efficiency and circular construction first-order priorities, coordinated with Goal 4 on Green Industrialisation.
- Delivery capacity and finance, more than technology, will set the pace of the transition. Meeting the 2035 target depends on training millions of installers, auditors and engineers, industrialising retrofit supply chains, and deploying financing instruments that overcome the front-loaded cost of efficiency, including the aggregation of small projects into investable portfolios under the CIB mechanism.
- The transition will succeed only if it reaches informal settlements and the fast-growing cities of hot climates. Nearly all urban population growth to 2050 occurs in Asia and Africa, much of it in informal neighbourhoods that experience urban heat at its most severe; cool roofs, passive design, community cooling anchored on solar-plus-storage microgrids and inclusive upgrading programmes are among the highest-benefit climate investments available.
- The task of this decade is defined and measurable. The eight action lines set out in Section 6, tracked annually against the interim milestone of a 12–15% intensity reduction by 2030 and verified through the Global Stocktake, provide the delivery framework, and the measure of success is unambiguous: a building stock at least 25% less energy-intensive by 2035, in cities demonstrably more resilient than today's.



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CHAPTER 4

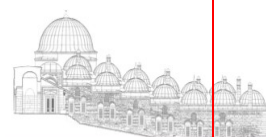
GREEN INDUSTRIALIZATION:

CIRCULAR MATERIAL UTILIZATION

Abstract

There is an urgent need for greening industry through circular economy where circular material utilization becomes an essential pillar. This particular report aims to discuss how the dark sides of increasing material consumption, continued dependence on raw materials and sources and rising industrial waste generation are creating a non-sustainable future and causing unrecoverable damages to today's society. It also brings up specific solutions about how to achieve a circular economic dimension where circular material utilization is managed in environmentally sound manner to accomplish transformation of industry to a greenized one through circular material utilization, cleaner production technologies, renewable energy integration, digital manufacturing, industrial symbiosis and sustainable product design. Furthermore, achieving the COP31-2035 Global Implementation Target of increasing circular material utilization to at least 15% by 2035 will require coordinated investments in advanced recycling infrastructure, digital monitoring systems, industrial innovation, and supportive regulatory frameworks. However, the report emphasizes that circular material utilization represents only one component of green industrialization and should be evaluated together with industrial decarbonization, cleaner production, renewable energy integration, resource efficiency, digital transformation, and other complementary sustainability indicators to provide a comprehensive assessment of green industrial transformation. To accelerate implementation, several strategic priorities should guide future industrial policy.

Keywords: Green industrialization, COP31, Circular economy, Material recycling, Decarbonization



4.1. Introduction

Industrial development has long been recognized as one of the fundamental drivers of economic growth, technological advancement, employment generation, and societal prosperity. However, due to increases in greenhouse gas (GHG) emissions, high energy consumption, resource depletion, loss of biodiversity, and dramatically increasing waste output, the unparalleled growth of manufacturing in recent decades has also increased environmental stresses. Industrial transformation is essential for reaching international climate targets because, based to the United States Environmental Protection Agency (EPA), industry is responsible for almost 37% of worldwide ultimate energy consumption and around 24% of global energy-related CO₂ emissions (EPA, 2025a). The shortcomings of traditional industrial processes have also been demonstrated by expanding geopolitical unpredictability, supply network problems, and increasing demand for essential raw supplies.

Natural resources are collected, converted into goods, utilized, and finally disposed of as waste material in the linear economy that drives the predominant industrial production paradigm. Due to limited resource availability and growing environmental effects, this “extract-manufacture-purchase-dispose” approach has grown more unsustainable, even though it has greatly supported industrial expansion since the Industrial Revolution. Therefore, one of the most important aspects of sustainable growth is the shift from linear production processes to circular and sustainable industrial frameworks as illustrated in Figure 4.1.

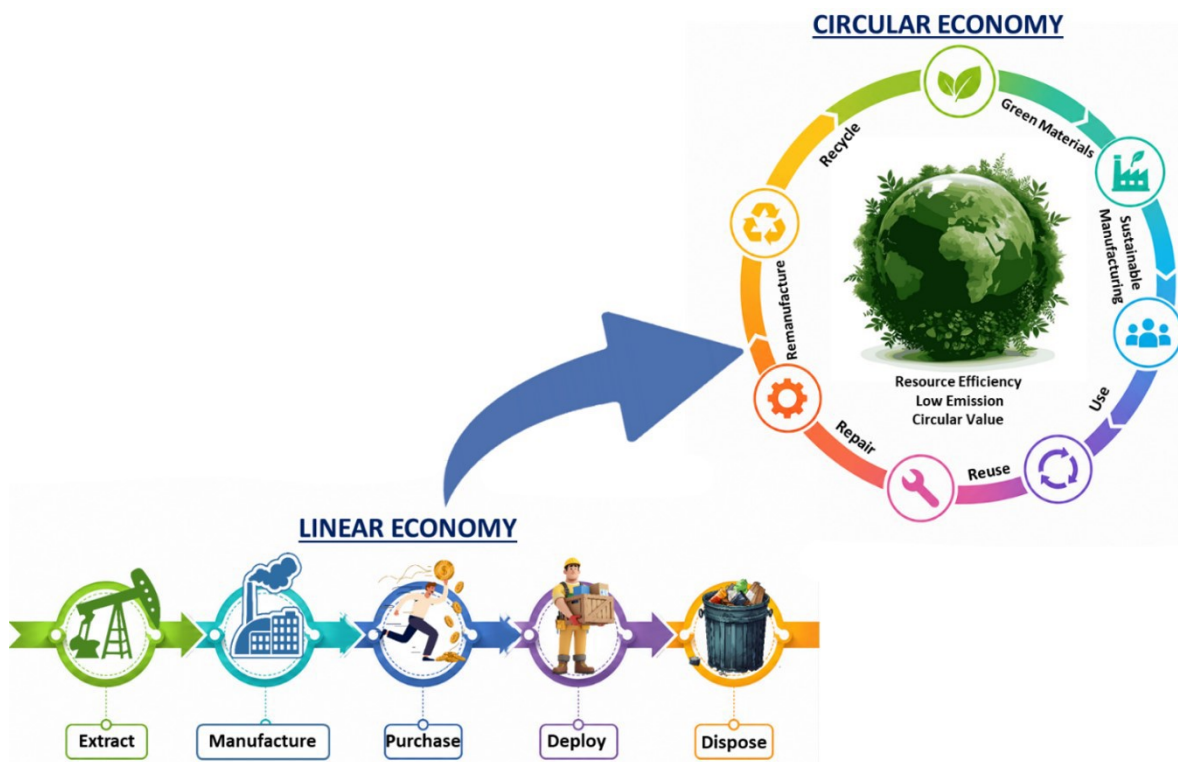


Figure 4.1 A green transition illustration from linear economy to a green circular economy in the industrial spectrum



Growing material demand has become one of the defining sustainability challenges of the twenty-first century. According to the Global Resources Outlook 2024 published by the United Nations Environment Programme (UNEP) and the International Resource Panel (IRP), annual global material extraction has increased from approximately 30 billion tonnes in 1970 to more than 106 billion tonnes in 2024, representing more than a threefold increase over five decades (UNEP-IRP, 2024). Without significant policy intervention, global material demand is expected to continue increasing, resulting in higher GHG emissions, accelerated ecosystem degradation, and greater pressure on critical raw material supplies.

Moreover, the rapid increase in global material demand is not uniformly distributed across the world. Still, it is concentrated in countries with intensive industrial activities and abundant natural resources, as illustrated in Figure 4.2 (UNEP, 2026a). The findings show the distribution of domestic material extraction worldwide in 2022, which represents the total quantity of primary materials extracted within each border of the nations, including biomass, fossil fuels, metal-based ores, and non-metallic mineral extraction. Higher extraction volumes are indicated by darker colors, which represent areas that are major suppliers of raw materials to the production and consumption systems of the world. China has the largest extraction volume, followed by Australia, Brazil, US, India, Russia, and other resource-dependent economies.



Figure 4.2 Global distribution of domestic raw material extraction by country in 2022 (taken from UNEP, 2026a)

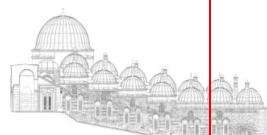
These nations suffer from severe environmental challenges driven on extensive extraction of resources while also being important suppliers of the raw materials needed for manufacturing, infrastructure development, building, and energy production. Construction, manufacturing, urbanization, and development of infrastructure are the main drivers of domestic material



extraction in Türkiye, which holds an intermediate position in the global distribution. Specifically, a significant portion of the material use of nations is derived from the mining of non-metallic minerals, such as clay, sand, gravel, and limestone. In general, the spatial distribution of material extraction emphasizes how modern economies are becoming more and more dependent on virgin natural resources. It also highlights how urgent it is to move toward resource-efficient production processes, circular material flows, and sustainable industrialization approaches that reduce environmental effects while sustaining economic development.

The Circular Material Use Rate (CMUR), which estimates the percentage of secondary materials that are recycled back into economic production, is one of the most useful metrics for assessing industrial sustainability. The Circularity Gap Report 2025 revealed that only 6.9% of the materials entering the global economy are secondary materials, representing a further decline from 7.2% reported in the previous assessment and 9.1% in 2018, despite increasing global efforts to promote circular economy principles (CEF, 2025). The current trend shows that increasing recycling rates is not enough to achieve circularity and highlights the continuing dependence of modern industrial systems on the extraction of raw resources. However, to lessen reliance on primary raw materials and reduce environmental effects, a systematic shift toward resource-effective production, circular product layout, material circularity, and green consumption is needed. As a consequence, using green materials has become a key component of sustainable transformation in industry. In addition to improving resource protection and industrial strength, the growing use of recycled, renewable, bio-based, recovered, and low-carbon materials greatly decreases environmental effects. Moreover, companies can maximize environmental performance throughout the whole product life cycle by incorporating sustainable material selections through Life Cycle Assessment (LCA), electronic product documents, and green design approaches. By incorporating renewable energy infrastructure, industrial energy efficiency, green hydrogen-based technologies, industrial symbiotic relationships, carbon capture, utilization, and storage, electronic manufacturing, artificial intelligence, Industry 4.0 and Industry 5.0 technologies, supply chains that are sustainable, and green procurement into industrial strategy, green industrialization extends beyond sustainable material management. While promoting long-term climate resilience, these interrelated approaches enhance productivity in operations, minimize GHG emissions, increase resource efficiency, and enhance competitiveness in industries.

In line with the Paris Agreement, the European Green Deal, and the Carbon Border Adjustment Mechanism, Türkiye has committed to achieve net-zero greenhouse gas emissions by 2053 (ETKB, 2026). Within the COP31-2035 Global Implementation Targets, increasing circular material utilization has been proposed as one of several global implementation priorities supporting green industrialization. Nevertheless, green industrialization extends far beyond circular material use and requires the integrated implementation of industrial decarbonization,



cleaner production, renewable energy deployment, digital transformation, industrial symbiosis, sustainable product design, and resource-efficient manufacturing. Therefore, circular material utilization should be considered as one of the enabling indicators rather than the sole measure of green industrial transformation. Integrated policy interventions covering sustainable manufacturing, the use of green materials, the integration of renewable energy, industrial innovation, circular resource management, digital transformation, financing mechanisms, and multi-stakeholder engagement are necessary to achieve this goal. As a result, this Action Plan provides a scientifically grounded framework for supporting the transition toward sustainable, resource-efficient, and circular industrial systems. While its recommendations are broadly aligned with the global implementation priorities of the COP31-2035 framework, they also offer practical guidance that can be adapted to national and regional contexts, including Türkiye. Green material use, circular manufacturing, advanced recycling and waste valorization, deployment of renewable energy, green hydrogen integration, sustainable supply chains, digital manufacturing, and performance monitoring are the main topics of the suggested implementation packages. In general, it is anticipated that these measures will lower industrial emissions, increase material productivity, strengthen resource security, encourage green investment, and establish Türkiye as a regional pioneer in green industrial growth where the locational strategic advantages and trade relationships with the European Community are considered.

4.2. Green Industrialization

Green industrialization, which aims to balance industrial growth with resource efficiency, environment neutrality, and environmental conservation, has become one of the most significant cornerstones of sustainable economic development. Future industrial systems must shift toward circular, low-carbon, and resource-efficient production routes, as conventional industrialization has mostly relied on intense raw material consumption, fossil energy, and linear manufacturing models. With energy decarbonization, this shift needs a thorough rethinking of industrial value networks which incorporate digital transformation, waste valorization, industrial symbiosis, sustainable material management, greener manufacturing technologies, and circular economy concepts. Specifically, increasing the use of secondary raw materials, increasing material productivity, and reducing waste production have emerged as key strategies for lowering GHG emissions, enhancing resource security, and increasing industrial strength. The rapid deployment of renewable energy systems, electric vehicles, advanced production, and electronic infrastructure has increased demand for critical raw materials, making the shift to green industrialization not only an economic and strategic priority but also an environmental necessity. Thus, a comprehensive strategy that incorporates technical innovation, efficient legislative systems, circular supply chains, and robust industrial ecosystems is absolutely needed to achieve a sustainable industrial development where green industrialization becomes a reality.



This transformation is anchored in a concrete regulatory framework at both the European and national levels. The European Green Deal sets binding targets of reducing GHG emissions by 55% by 2030 and by 90% by 2040 relative to 1990 levels, built on three policy pillars, renewable energy deployment, energy efficiency, and carbon pricing through the EU Emissions Trading System (ETS), whose free allocations to industry are scheduled to be phased out by 2034, with ETS revenues redirected to the Innovation Fund and the Modernization Fund (Aydın & Aydın, 2025). For Türkiye, which channels close to half of its exports to the EU, alignment with this framework is not optional: a Climate Law establishing a national ETS, a carbon market board, voluntary carbon markets and emission allowance trading has been drafted but not yet adopted, and its enactment is a precondition for Türkiye to operate its own emissions trading system in coordination with the EU Carbon Border Adjustment Mechanism (Karacan, 2025). In parallel, 2021 Green Deal Action Plan of Türkiye identifies 81 actions spanning industry, energy, agriculture, transport, and finance, providing the institutional backbone within which the circular material use rate target addressed in this report is expected to be delivered (Karacan, 2025).

4.3. Industrial Material Circularity

Industrial materials constitute the backbone of modern manufacturing systems and play a decisive role in determining the environmental performance, resource efficiency, and long-term sustainability of industrial production. Although considerable progress has been achieved through renewable energy deployment, process electrification, and energy efficiency improvements, the environmental problems associated with material production remain one of the most significant challenges facing industrial decarbonization. Every industrial product, from buildings and transportation infrastructure to electronic devices and renewable energy technologies, depends on the extraction, processing, transformation, and utilization of large quantities of materials. Consequently, the transition toward sustainable industry cannot be achieved solely by replacing fossil fuels with renewable energy; it also requires a fundamental transformation in the way industrial materials are sourced, manufactured, utilized, recovered, and reintegrated into production systems.

Material production represents one of the most resource-intensive activities within the global economy. Primary production of steel, cement, aluminum, plastics, and chemicals requires enormous quantities of energy, water, and mineral resources while generating substantial GHG emissions and industrial waste. According to the IEA, heavy industries are responsible for almost one-third of global final industrial energy consumption, with material-intensive sectors accounting for the majority of industrial carbon emissions (IEA, 2020). Among these sectors, iron and steel production contributes approximately 7-9% of global CO₂ emissions, cement manufacturing accounts for 7-8%, chemical production contributes 5-6%, while primary aluminum production represents nearly 2% of global emissions despite its comparatively lower



production volume. Collectively, these material sectors illustrate that future climate mitigation strategies must increasingly focus on reducing the environmental impacts embedded within industrial materials rather than addressing operational energy consumption alone.

In response to these challenges, the concept of green industrial materials has emerged as a comprehensive framework encompassing materials that reduce environmental impacts throughout their entire life cycle while maintaining or improving industrial performance. Rather than referring to a single material category, green industrial materials include recycled metals, circular materials recovered from secondary resources, sustainable polymers, bio-based composites, engineered biomaterials, low-carbon cementitious binders, recycled construction materials, and critical raw materials recovered through advanced recycling technologies. According to the IEA Critical Minerals Market Review 2024, global demand for minerals required in clean energy technologies is expected to more than double by 2040 under announced policy scenarios, creating growing concerns regarding supply concentration, geopolitical risks, price volatility, and long-term resource availability. Consequently, expanding secondary raw material markets, improving urban mining, recovering valuable materials from industrial waste streams, and increasing recycling efficiency have become essential strategies for reducing import dependency while strengthening industrial competitiveness.

Figure 4.3 illustrates the Economy-Wide Material Flow Analysis of the European Union for 2010 and 2024, illustrating the physical flows of biomass, metal ores, non-metallic minerals, and fossil energy materials throughout the economy. The Sankey diagrams quantify the movement of materials from domestic extraction and imports through industrial processing, material use, stock accumulation, recycling, waste treatment, and environmental emissions, providing a comprehensive overview of the progress of the EU toward resource efficiency and circularity. For instance, between 2010 and 2024, domestic extraction increased from 5,147 Mt to 5,427 Mt, while imports rose from 1,504 Mt to 1,589 Mt, resulting in an increase in direct material inputs from 6,650 Mt to 7,016 Mt (Figure 4.3a). Similarly, processed materials increased from 7,700 Mt to 7,925 Mt, indicating that industrial production continues to depend largely on primary raw materials despite the implementation of circular economy policies. Although material use slightly decreased from 4,615 Mt to 4,507 Mt, reflecting improvements in resource efficiency, the European economy still requires a substantial volume of virgin materials to sustain industrial activities.

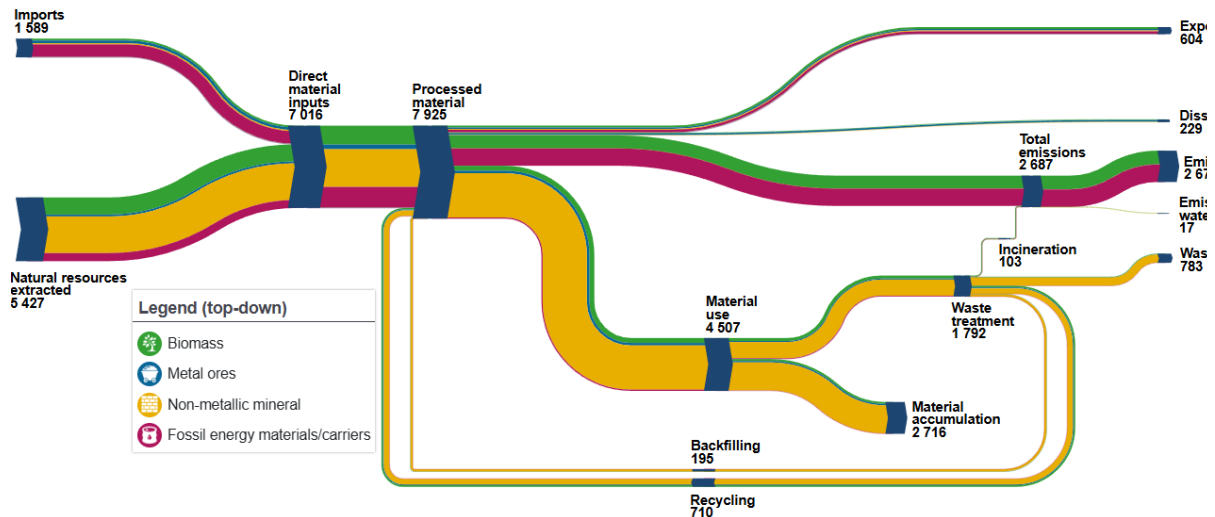
One of the most significant indicators shown in Figure 4.3b is the recycling flow, which decreased from 753 Mt in 2010 to 710 Mt in 2024. Although the European Union has considerably strengthened its recycling infrastructure and waste management policies over the last decade, these results suggest that the amount of secondary materials re-entering production has not kept pace with increasing material demand. Consequently, recycled materials continue to represent only a small fraction of total material inputs, indicating that industrial production



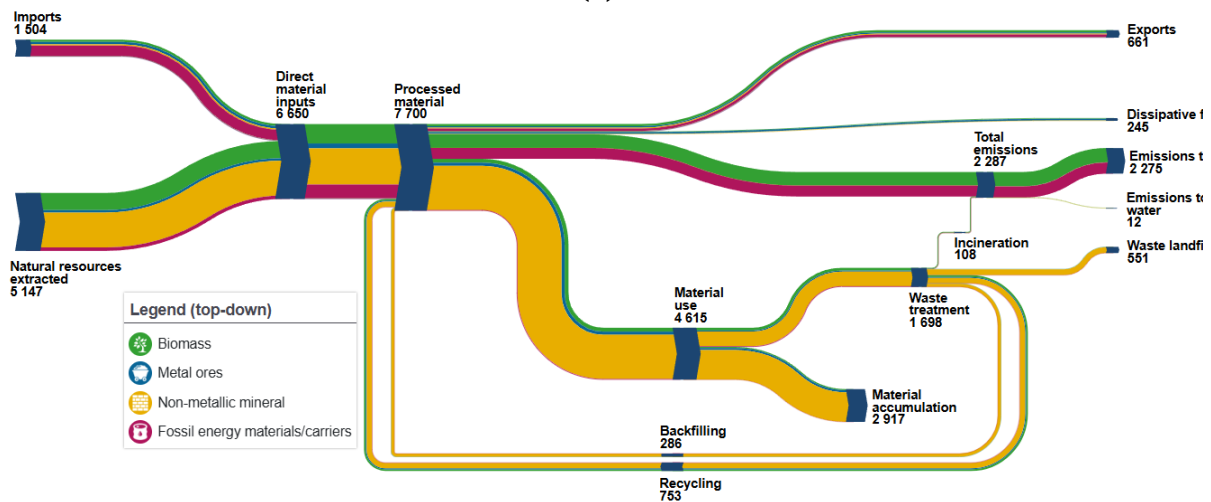
remains predominantly dependent on virgin resources. These findings demonstrate that expanding recycling capacity alone is insufficient to achieve material circularity. Greater emphasis should therefore be placed on eco-design, product durability, remanufacturing, industrial symbiosis, and the increased utilization of high-quality secondary raw materials.

While the material flow analysis presented in Figure 4.3 provides a comprehensive overview of the progress of materials throughout the European economy, it does not directly quantify the extent to which secondary materials replace virgin raw materials within industrial production. One of the most widely used indicators for evaluating this aspect of circularity is the Circular Material Use Rate (CMUR), which measures the proportion of material demand that is satisfied by recycled materials re-entering the economy. As a core indicator within the Circular Economy Monitoring Framework of European Union, the CMUR reflects the effectiveness of recycling systems, secondary raw material markets, and resource efficiency policies, thereby providing an important measure of progress toward a circular economy. Figure 4.4 illustrates the evolution of the CMUR in the European Union between 2014 and 2024. Overall, the indicator shows a gradual upward trend, increasing from 11.1% in 2014 to 12.2% in 2024, corresponding to an overall improvement of approximately 10% during the study period. This increase suggests that the European Union has gradually enhanced the integration of secondary raw materials into industrial production through improvements in waste collection, recycling infrastructure, and circular economy policies. Between 2014 and 2018, the circular material use rate increased steadily from 11.1 to 11.6%, indicating continuous progress in resource recovery and recycling performance. However, this positive trend was interrupted between 2019 and 2021, when the indicator declined to 11.1-11.2%. This temporary stagnation is likely associated with disruptions in industrial production, international supply chains, and waste management systems during the COVID-19 pandemic, which affected both the availability and utilization of secondary raw materials across Europe. Following this period, the CMUR recovered significantly, reaching 12.1% in 2023 and 12.2% in 2024, the highest value recorded during the observed period. The recent increase reflects the growing implementation of the European Green Deal, the Circular Economy Action Plan, and greater investment in secondary raw material markets. These policy initiatives have encouraged industries to increase the use of recycled materials while reducing dependence on virgin resource extraction.





(a)



(b)

Figure 4.3 Material flows (in million tonnes) diagram of the European Union for (a) 2010 and (a) 2024 (generated through Eurostat, 2024)

Despite this positive progress, the European economy remains predominantly dependent on primary raw materials. Even in 2024, only 12.2% of total material demand was met through secondary materials, meaning that nearly 88% of material inputs still originated from raw resources. This finding is consistent with the material flow analysis, which showed that primary resource extraction continues to dominate overall material inputs despite improvements in recycling. Therefore, increasing the CMUR remains one of the most important priorities for achieving resource-efficient and low-carbon industrial systems.



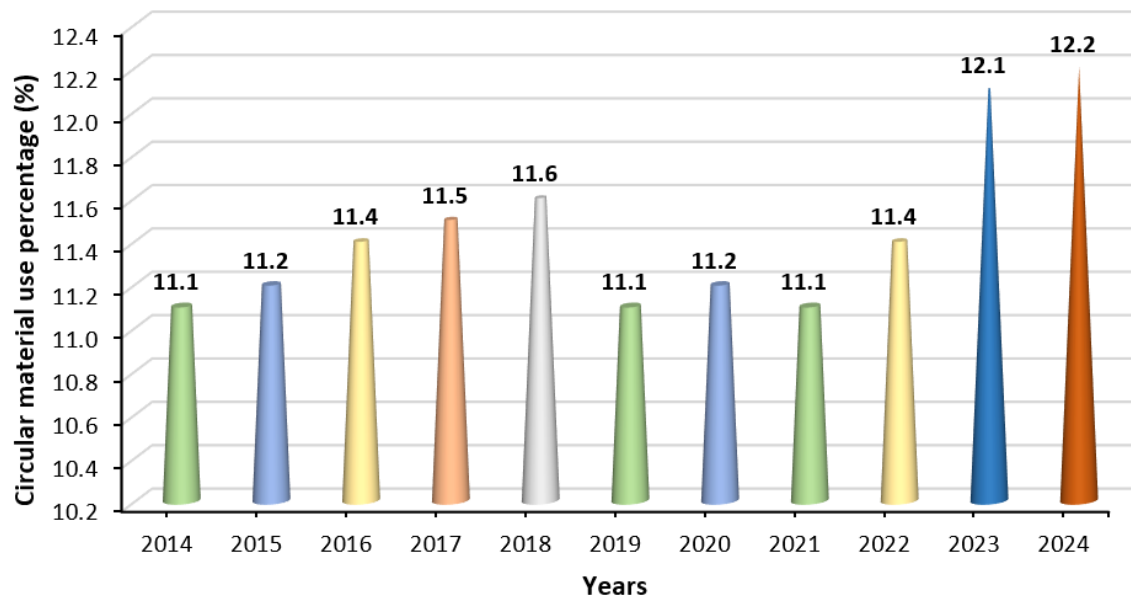


Figure 4.4 Circular material use rate for European Union Countries (data from Eurostat, 2026)

Rather than relying on a single indicator, assessing progress toward green industrialization requires a portfolio of complementary metrics that capture different dimensions of industrial sustainability. While CMUR reflects the recirculation of secondary materials, other indicators, such as material flow analysis, material footprint, resource productivity, waste recovery, and industrial emissions, provide additional insights into resource efficiency and the broader transformation of industrial systems. This multidimensional perspective is particularly important for countries where official CMUR statistics are not yet available, including Türkiye. Moreover, following the evaluation of the material circularity of the European Union, Figure 4.5 presents the evolution of major material flow indicators of Türkiye between 2015 and 2024, including Domestic Material Consumption (DMC), Direct Material Input (DMI), Imports (IMP), Exports (EXP), and Physical Trade Balance (PTB). These indicators provide a comprehensive overview of the relationship between industrial growth, resource consumption, and material use efficiency. Results show a clear upward trend in all major material flow indicators over the study period. DMC increased from almost 190 Mt in 2015 to 290 Mt in 2024, while DMI almost doubled, increasing from 220 Mt to 440 Mt. Imports and exports also increased steadily, indicating the growing integration of Türkiye into global supply chains and the increasing demand for raw materials driven by industrial production, urbanization, and infrastructure development. Similarly, the increase in PTB suggests that a larger quantity of materials remains within the domestic economy, supporting economic growth but also increasing pressure on natural resources. Overall, Figure 4.5 demonstrates that industrial development of Türkiye continues to be closely associated with increasing material consumption. While this trend reflects strong economic and industrial growth, it also highlights the need to improve resource productivity, increase the use of secondary raw materials, and strengthen recycling and circular material management. Since Türkiye does not yet report an official CMUR, the country's progress toward circularity is evaluated through complementary



indicators including Domestic Material Consumption, Direct Material Input, Material Footprint, manufacturing waste generation, waste recovery, recycling performance, and resource productivity. These indicators collectively provide a broader assessment of industrial resource efficiency while supporting future monitoring of circular economy performance.

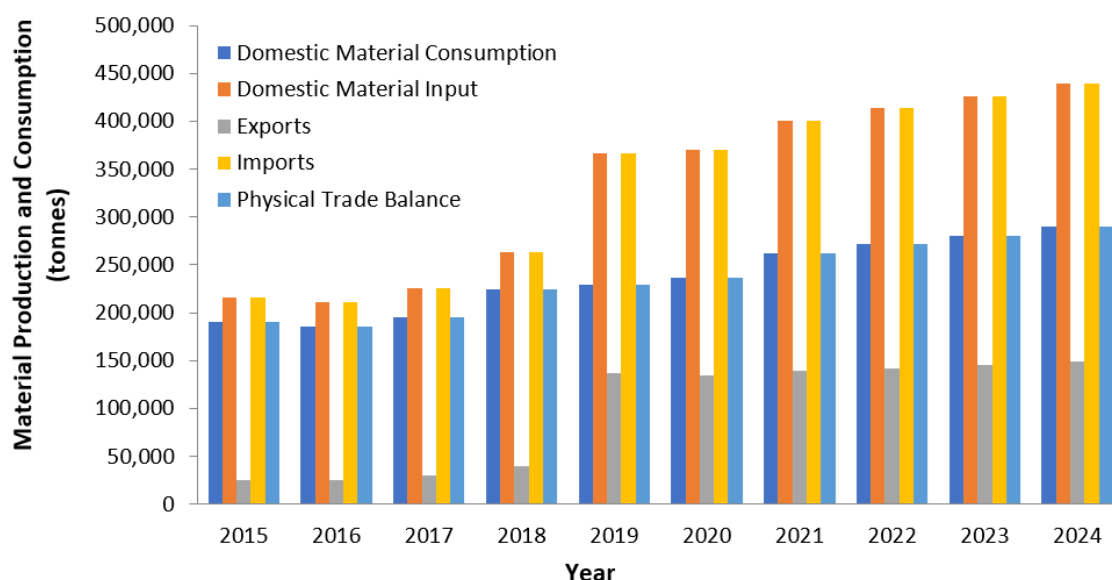


Figure 4.5 Material flow indicators of Türkiye from 2015 to 2024 (data from UNEP, 2026b)

Figure 4.6 presents the evolution of the material footprint of Türkiye by major material categories between 2015 and 2024, highlighting recent trends in resource demand. Results show an overall increase in the material footprint from 1.4 Bt in 2015 to 1.85 Bt in 2024, indicating that economic growth and industrial development continue to drive higher material consumption. Throughout the study period, biomass represents the largest share of the material footprint, followed by non-metallic minerals, metal ores, and fossil fuels. While all material categories exhibit an increasing trend, the most pronounced growth is observed after 2020, reflecting the recovery of industrial production, infrastructure investments, and increased demand for raw materials. The continued increase in non-metallic minerals and metal ores highlights the growing material requirements of the construction and manufacturing sectors. While material flow and material footprint indicators describe the magnitude of resource consumption, recycling rates provide a direct measure of how effectively materials are recovered and returned to the economy after use. As one of the key indicators of circular material use, recycling performance reflects the efficiency of waste collection systems, material recovery technologies, and secondary raw material utilization



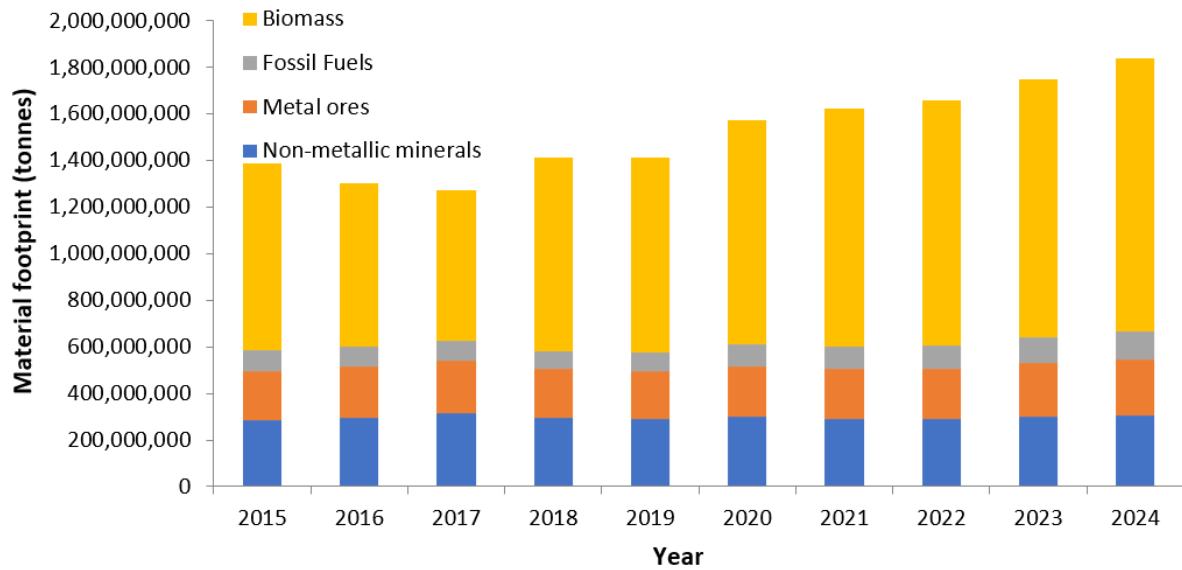


Figure 4.6 Türkiye material footprint data by material category between 2015 and 2024 (data from UNEP, 2026b)

As shown in Figure 4.7, packaging waste consistently achieved the highest recycling rate, increasing from 64% in 2010 to 66% in 2022. This strong performance reflects the success of well-established collection systems and extended producer responsibility policies implemented across the European Union. Municipal waste recycling also showed continuous improvement, rising from 38 to 49%, indicating considerable progress in waste separation and recycling infrastructure. In contrast, electrical waste recycling remained significantly lower, increasing to about 39% in 2020 before declining to nearly 32% in 2022. The relatively low recovery of electrical waste reflects the increasing complexity of electronic products and the technical challenges associated with recovering valuable metals and critical raw materials.

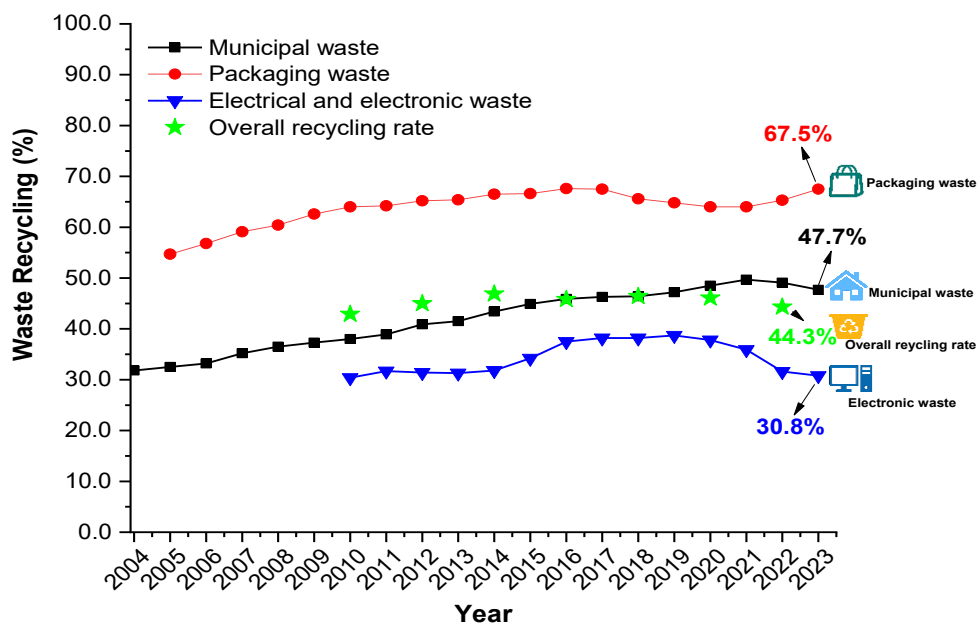


Figure 4.7 Recycling rates in Europe by waste stream between 2004 and 2023 (data from EEA, 2025)



Furthermore, end-of-life treatment pathways, including recycling, landfilling, and incineration, determine whether valuable materials are retained within the economy or permanently lost from productive use. Figure 4.8 presents the end-of-life management pathways for major material categories in the United States (DOE, 2024). The data compares the quantities of materials that are recycled, landfilled, and incinerated for aluminum, steel, glass, paper and cardboard, and plastics. Paper and cardboard exhibit the highest recycling volume with 46 Mt, substantially exceeding landfill (17 Mt) and incineration (4 Mt), reflecting the effectiveness of established collection and recovery systems. In contrast, plastics show the lowest circularity, with only about 3 Mt recycled compared with 27 Mt landfilled and 6 Mt incinerated, indicating that landfill remains the dominant end-of-life pathway. Steel and glass also exhibit higher landfill volumes (10 Mt and 7 Mt, respectively) than recycling, whereas aluminum generates comparatively small waste quantities across all treatment pathways. Although these data represent the US, they provide valuable insights into the relative recovery potential of different material streams and emphasize the need for material-specific circular economy strategies to improve resource efficiency and reduce landfill dependency.

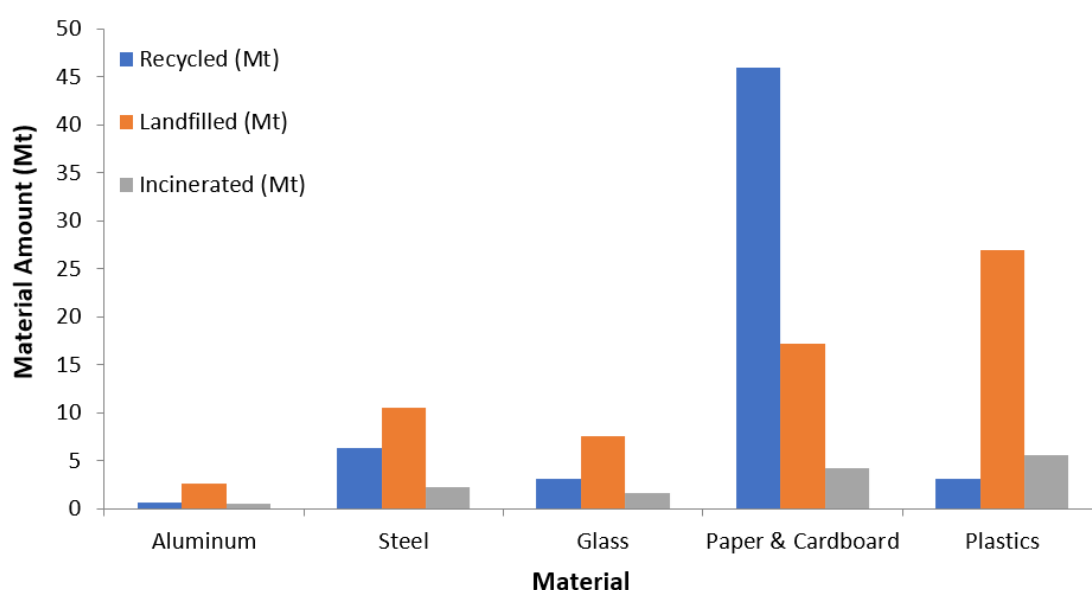
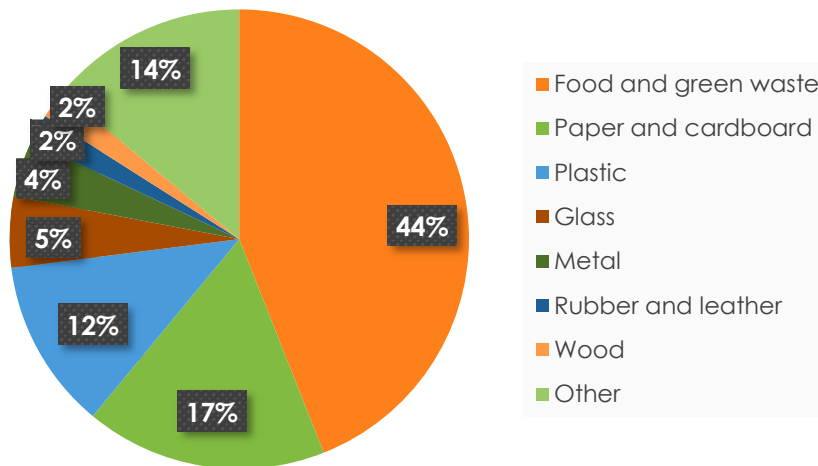


Figure 4.8 End-of-life management pathways (recycled, landfilled, and incinerated) for selected material categories in the United States (DOE, 2024)

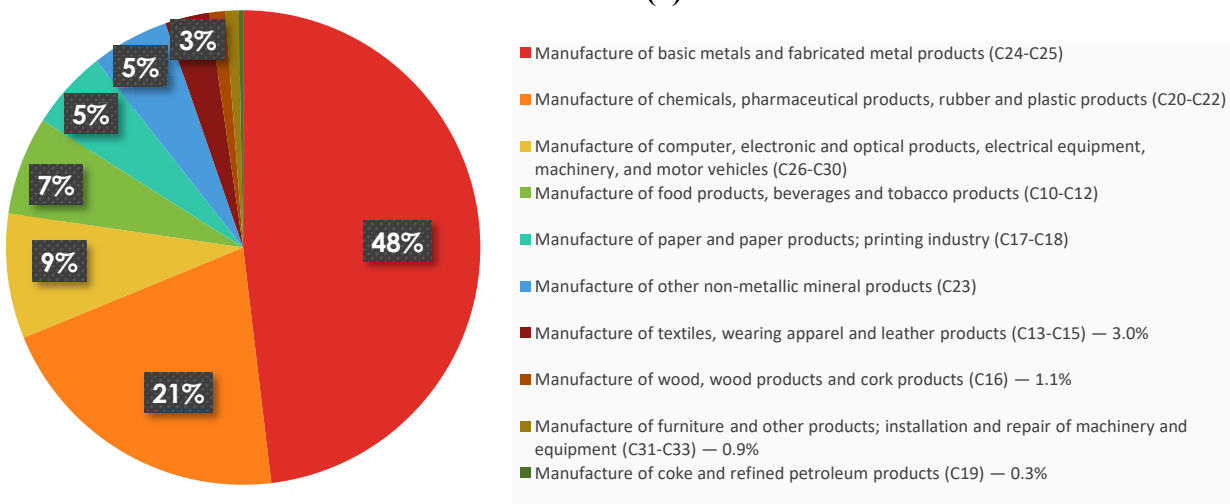
As shown in Figure 4.9, paper and cardboard exhibit the highest recycling volume, reaching 46 Mt, considerably exceeding the amounts landfilled (17 Mt) and incinerated (4 Mt). This reflects their well-established collection systems and high recyclability. In contrast, plastics remain the least circular material, with only about 3 Mt recycled compared with 27 Mt landfilled and 6 Mt incinerated, indicating that landfill remains the dominant disposal route for plastic waste. Steel and glass also show lower recycling volumes than landfill disposal, whereas aluminum, despite its relatively small waste volume, demonstrates a comparatively balanced end-of-life distribution due to its high economic value and recyclability. The material distribution of solid



waste from municipalities worldwide is shown in Figure 4.9a, where food and green garbage represent 44% of the total generation and organic waste is the most common component. More than 25% of the waste stream of the world is composed of materials with substantial recycling potential, with paper and cardboard accounting for 17%, other waste at 14%, and plastics at 12%. Although they constitute relatively smaller proportions, glass (5%), metals (4%), rubber and leather (2%), and wood (2%) are nevertheless significant secondary resources in circular manufacturing processes.



(a)



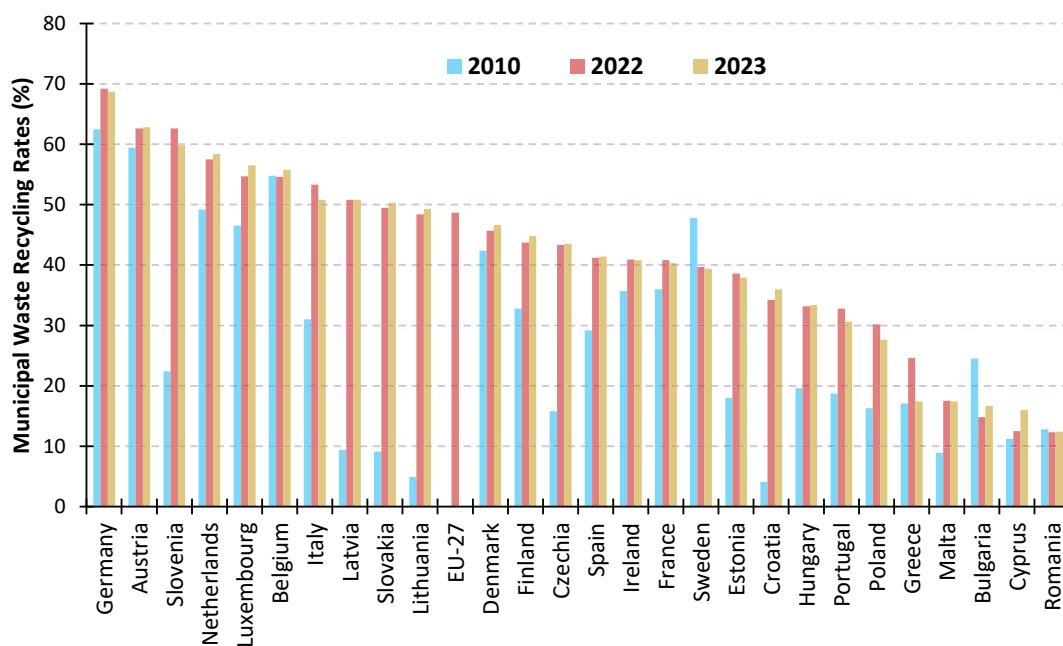
(b)

Figure 4.9 Waste generation distribution by manufacturing industry subsectors in (a) worldwide (data from WBG, 2026) and (b) Türkiye (data from TÜİK, 2024)

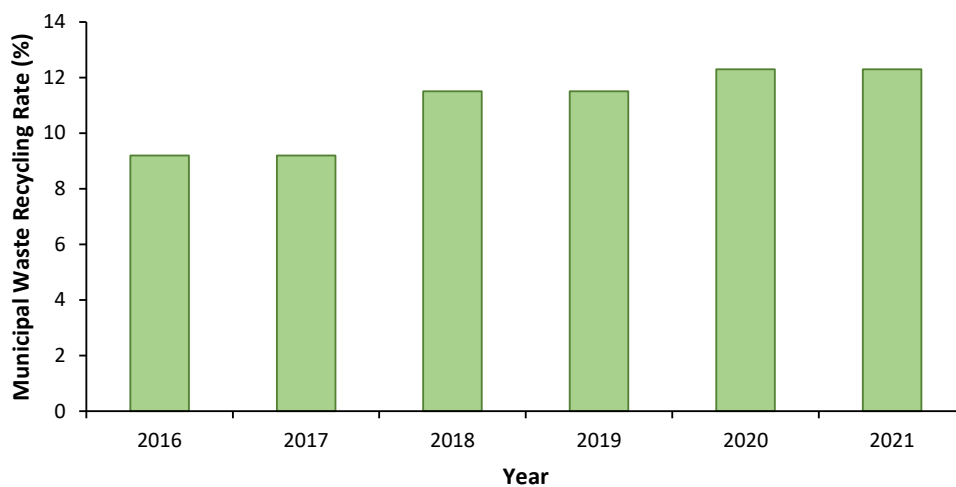
Moreover, Figure 4.9b presents the distribution of manufacturing waste generated by industrial subsectors in Türkiye in 2024, highlighting the sectors with the greatest potential for waste reduction, resource recovery, and circular material utilization. As illustrated in Figure 4.9b, the manufacture of basic metals and fabricated metal products is the largest contributor to industrial waste generation, accounting for 48% of the total manufacturing waste. This is followed by the chemical, pharmaceutical, rubber, and plastic industries (21%), while the manufacture of computers, electronic and optical products, electrical equipment, machinery, motor vehicles,



and transport equipment contributes approximately 9%. Other sectors, including paper and paper products (7%), other non-metallic mineral products (5%), and textiles (5%), represent comparatively smaller shares, whereas wood products, furniture, and coke and refined petroleum products each account for only about 1% of total manufacturing waste. These results clearly indicate that industrial waste generation in Türkiye is concentrated in a limited number of material-intensive sectors. Therefore, implementing sector-specific circular economy strategies, particularly in the metal, chemical, and mineral industries, offers significant opportunities to increase resource recovery, improve industrial symbiosis, and reduce waste generation. Prioritizing these sectors is likely to deliver the greatest environmental and economic benefits while supporting the transition of Türkiye toward a more resource-efficient and circular industrial system.



(a)



(b)

Figure 4.10 Recycling rate of municipal waste in (a) worldwide (data from EEA, 2025) and (b) Türkiye (data from Eurostat, 2026)



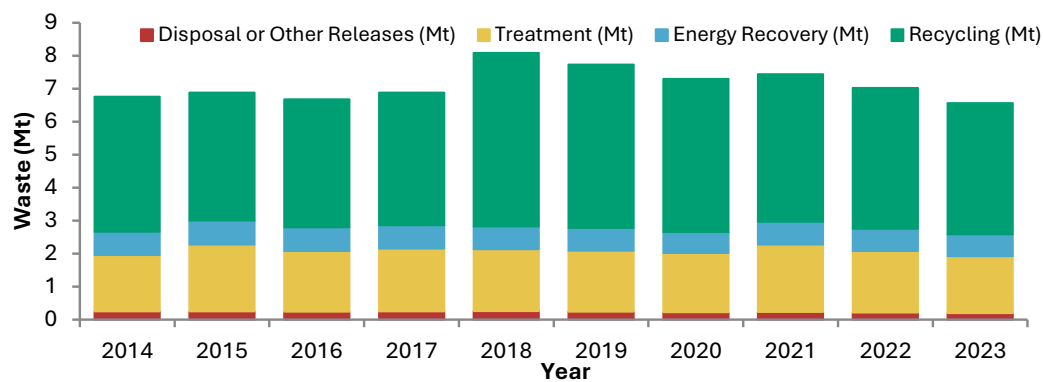
The majority of municipal waste recycling performance in European nations clearly improved between 2010 and 2023, as shown in Figure 4.10a, which reflects the growing success of standardized waste management techniques and circular economy policies. While most Eastern and Southern European nations-maintained recycling rates around 30%, Germany, Austria, and Slovenia continuously had the highest rates, over 60%. This suggests significant differences in recycling infrastructure and resource recovery capacity. In order to achieve more balanced development toward circular economy objectives, improved policy execution, investments in recycling systems, and unified waste management practices are necessary, despite the general favorable trend.

In addition, Figure 4.10b presents the evolution of the municipal waste recycling rate of Türkiye between 2016 and 2021. In Figure 4.10b, the municipal waste recycling rate increased from 9.2% in 2016-2017 to 11.5% in 2018-2019, before reaching 12.3% in 2020-2021. This gradual improvement reflects the expansion of separate waste collection systems, growing recycling infrastructure, and increasing awareness of circular economy practices. However, the overall recycling rate remains relatively low, indicating that a considerable proportion of municipal waste is still disposed of through landfill or other recovery pathways rather than being recycled. More recent national statistics also indicate continued progress in municipal waste recovery. According to the European Environment Agency (EEA, 2026), municipal waste recycling rate of Türkiye increased from 34.9 % in 2023 to 36.1% in 2024 under the Zero Waste Programme, with a national target of reaching 60% by 2035.

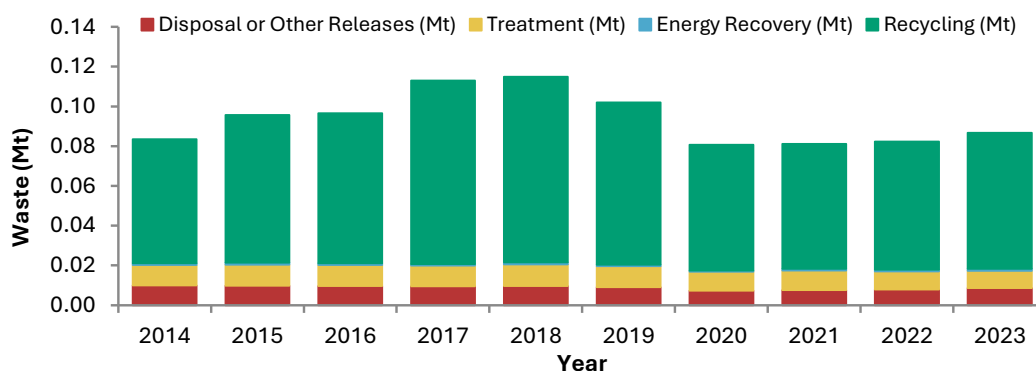
Overall, although Türkiye has achieved measurable progress in municipal waste recycling, the pace of improvement remains modest compared with the increasing volume of waste generated. The findings suggest that further investment in source separation, recycling facilities, public awareness, and local waste management systems will be necessary to increase recycling performance and support the transition of Türkiye toward a more circular and resource-efficient economy.

Figure 4.11 presents sector-specific waste management trends for the chemical, automotive, wood products, and electric utilities industries over the 2014-2023 period. In the chemical manufacturing sector (Figure 4.11a), recycling consistently remained the predominant waste management strategy, accounting for 4.5-6.0 Mt annually, while total waste generation fluctuated between 6.8 and 8.3 Mt. Treatment (1.8-2.2 Mt) and energy recovery (0.3-0.5 Mt) exhibited relatively stable contributions, whereas disposal accounted for only a minor fraction (<0.2 Mt), reflecting an established resource recovery framework. Similarly, the automotive industry (Figure 4.11b) achieved the highest recycling share among the sectors, with recycling increasing from 0.07 Mt in 2014 to a peak of 0.10 Mt in 2018 before stabilizing at around 0.07-0.08 Mt after 2020.

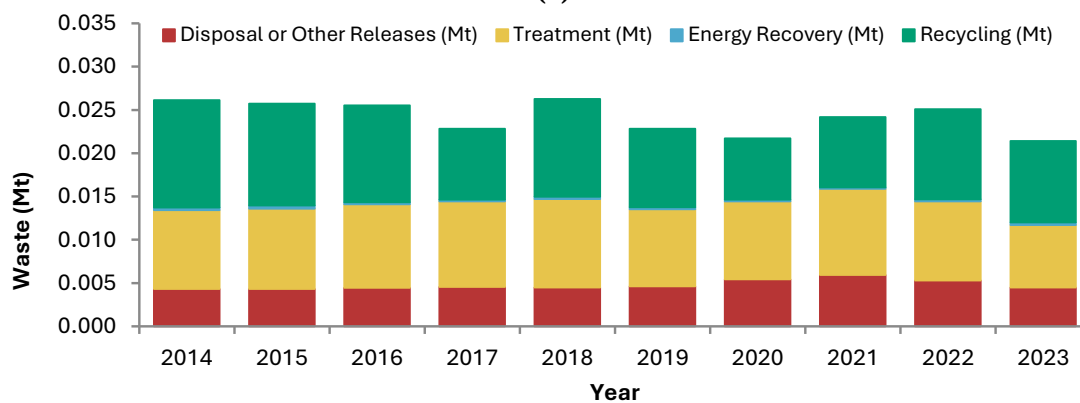




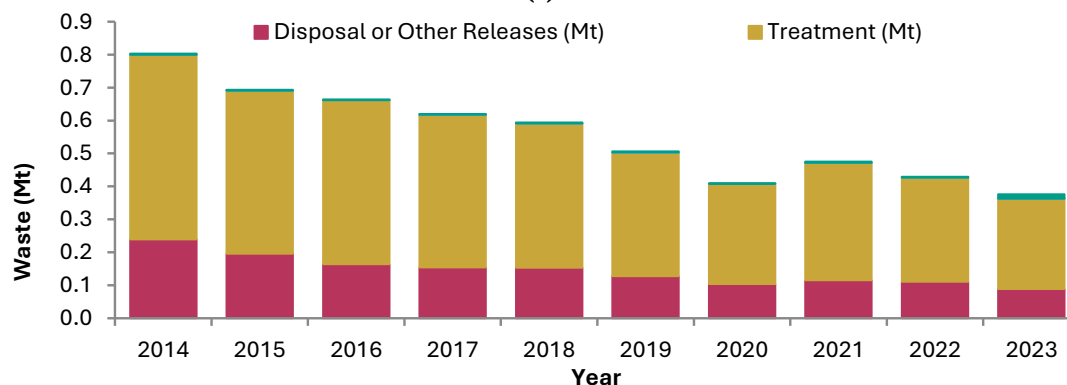
(a)



(b)



(c)



(d)

Figure 4.11 Manufacturing waste management trends of various industries: (a) chemical manufacturing, (b) automotive manufacturing, (c) wood products manufacturing, and (d) electric utilities. (data from EPA, 2026b)



In the wood products manufacturing sector (Figure 4.11c), recycling also represented the largest waste management pathway (0.01-0.012 Mt); however, treatment (0.008-0.010 Mt) and disposal (0.003-0.006 Mt) contributed a comparatively greater share than in the chemical and automotive industries, indicating additional opportunities for improving material circularity. On the other hand, the electric utilities sector (Figure 4.11d) revealed a substantial decline in total waste generation, decreasing from approximately 0.80 Mt in 2014 to 0.36 Mt in 2023, largely driven by significant reductions in waste requiring treatment and disposal, while recycling and energy recovery remained relatively limited. Overall, these trends indicate that although recycling has become the dominant waste management approach across manufacturing industries, the magnitude and effectiveness of circular resource utilization differ considerably among industrial sectors, highlighting the need for sector-specific strategies to further enhance resource efficiency and minimize waste generation.

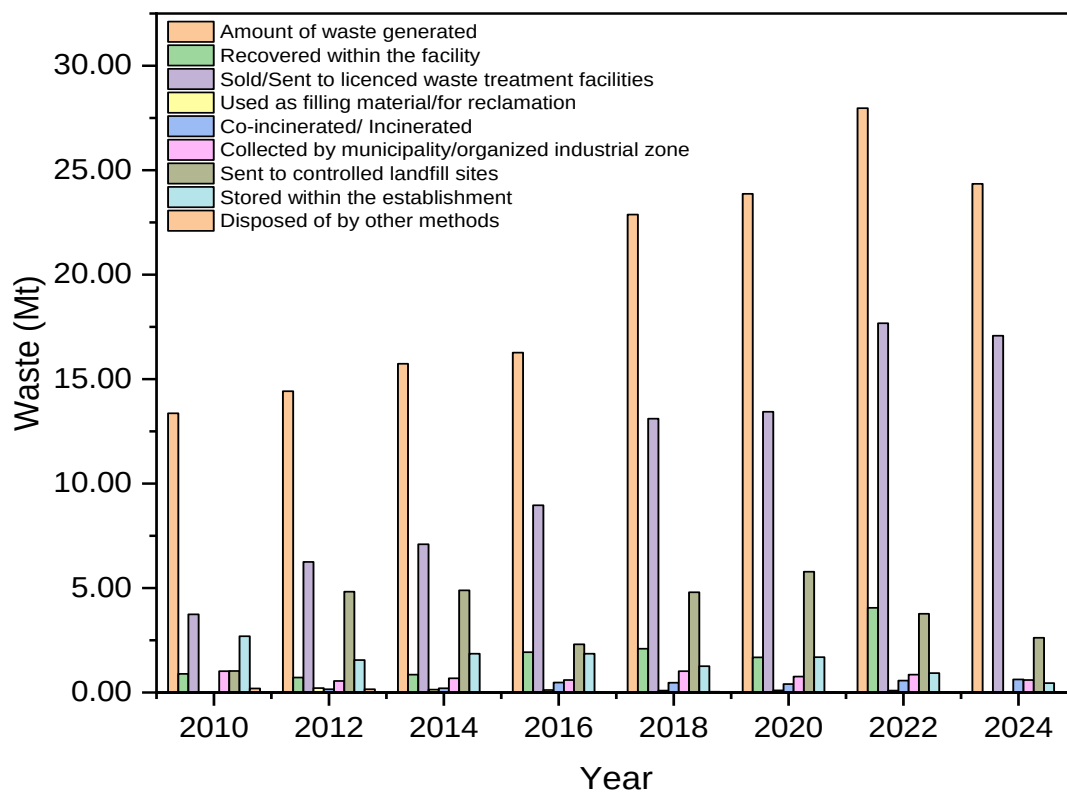


Figure 4.12 Historical variations of manufacturing waste generation and waste management pathways in Türkiye (2010-2024) (data from TÜİK, 2024)

Figure 4.12 illustrates the evolution of manufacturing waste generation and waste treatment pathways in Türkiye between 2010 and 2024. Manufacturing waste generation increased considerably during the study period, rising from 13,366 thousand tonnes in 2010 to 24,350 thousand tonnes in 2024. Despite this increase, a clear transition toward recovery-oriented waste management can be observed. In 2024, 17,079 thousand tonnes (70.1%) of manufacturing waste were transferred to licensed recovery and waste treatment facilities, representing the dominant waste management pathway. In addition, 2,946 thousand tonnes (12.1%) were



recovered within industrial facilities, indicating that a significant proportion of waste was reused directly in production processes without leaving the manufacturing site. Although representing a smaller share, the amount of waste used as filling material or for land reclamation also demonstrates an important resource recovery pathway by diverting waste from final disposal and returning it to productive use. On the other hand, only 10.8% were sent to controlled landfill sites, while 2.6% were treated through incineration. These results indicate that more than four-fifths of manufacturing waste was managed through recovery-based practices, with both off-site recovery and on-site material utilization playing a key role in improving industrial circularity.

Despite this increase, a clear transition toward recovery-oriented waste management can be observed. In 2024, 17,079 thousand tonnes (70.1%) of manufacturing waste were transferred to licensed recovery and waste treatment facilities, representing the dominant waste management pathway. In addition, 2,946 thousand tonnes (12.1%) were recovered within industrial facilities, indicating that a significant proportion of waste was reused directly in production processes without leaving the manufacturing site. Although representing a smaller share, the amount of waste used as filling material or for land reclamation also demonstrates an important resource recovery pathway by diverting waste from final disposal and returning it to productive use. On the other hand, only 10.8% were sent to controlled landfill sites, while 2.6% were treated through incineration. These results indicate that more than four-fifths of manufacturing waste was managed through recovery-based practices, with both off-site recovery and on-site material utilization playing a key role in improving industrial circularity.

Moreover, the projection indicates a steady improvement in industrial material recovery and reuse practices toward 2035 (Figure 4.13). Figure 4.13 presents the historical recovery trend (2010-2022) together with the projected business-as-Usual (BAU) and COP31 scenarios for 2026-2035. The BAU pathway was estimated to use an ordinary least-squares linear regression model fitted to the available historical recovery data (2010-2022), assuming that the long-term historical trend continues without additional policy interventions. The COP31 scenario was subsequently developed by applying a progressive policy-driven improvement to the BAU trajectory, with the additional recovery increasing gradually from 2026 onwards and reaching 15% above the BAU level by 2035. Under the BAU scenario, recovered materials are projected to reach 6,046.53 by 2035, while the COP31 scenario increases this value to 6,953.51, corresponding to an additional recovery of approximately 906.98 t.



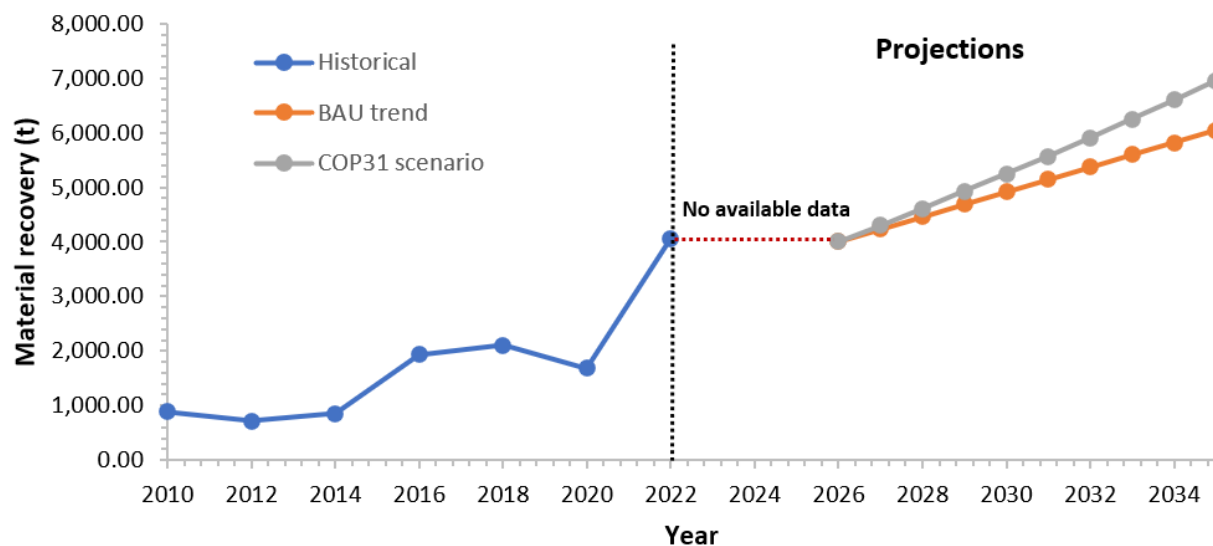
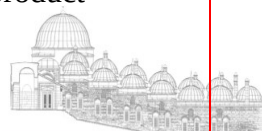


Figure 4.13 Historical trends and 2035 projection of material recovery and reuse under a 15% circular material recovery scenario in Türkiye (data from TÜİK, 2024)

4.4. Industrial Symbiosis and Organized Industrial Zones

Industrial symbiosis, which involves the exchange of by-products, waste streams, energy, water, and infrastructure between otherwise unrelated facilities, provides an additional way to reduce the demand for virgin materials and energy while lowering waste generation and processing costs, in addition to recycling and material recovery. In the classic Kalundborg Symbiosis, the nutrient-rich sludge from a paper mill is recovered for composting and biogas production, and food-sector residues provide feedstock for the production of biofuel and bioplastics, diverting material from landfills in accordance with a cradle-to-cradle design approach. These synergies directly support SDGs 8, 9, 10, 12, and 17 and indirectly support SDGs 6, 7, and 13 (Saraç et al., 2025). Industrial symbiosis is encouraged by both advanced and developing economies for diverse but complementary reasons, the earlier mainly to obtain feedstock and cut costs, the latter to meet sustainability targets, and both achieve simultaneous economic and environmental benefits (Saraç et al., 2025).

Organized Industrial Zones (OIZs) are the main institutional means of delivering this kind of symbiosis on a large scale in Türkiye (Aydın et al., 2025; Saraç et al., 2025). Operating since the 1960s as the equivalent of industrial parks of the country, OSBs have been crucial to planned industrialization and the creation of jobs. Their green transformation is specifically framed around the United Nations Industrial Development Organization (UNIDO) definition of green industry, which is defined as minimizing waste, using renewable resources as fuel and feedstock, and protecting workers, communities, and the environment while decoupling economic growth from resource use and pollution (Aydın et al., 2025). One of the most manageable short-term levers for increasing circular material use rate of the Türkiye toward the 2035 target is shared infrastructure for waste heat recovery, water reuse, and by-product



exchange within OIZs (Aydın et al., 2025). Environmental sustainability was already positioned as a priority objective for the sector in the 2015-2018 Industry Strategy Document, which pursued international integration through a green industry approach.

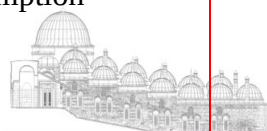
4.5. Circular Economy

Green transition is a development strategy that aims to develop a sustainable and green economy, in addition to addressing global issues like climate change and resource depletion. Energy-efficient solutions, sustainable technologies, low-carbon resources, and green investments are all used to accomplish this transition. Since the energy industry is involved in the majority of emission reduction activities, moving to renewable energy sources often becomes an issue. Nevertheless, globally, the current economic paradigm is primarily linear. Fundamentally, resources are extracted, goods are produced, utilized, and finally disposed. Namely, the “extract-manufacture-purchase-dispose” linear economy model, which is material and energy-demanding. Depends on global supply networks that find it difficult to adjust after interruption, and prioritizes limited-use goods that result in significant waste and negative impacts on the environment.

On the other hand, a circular economy places greater priority on recycling resources, reusing materials, and minimizing waste to develop a closed-loop system. This strategy reduces greenhouse gas emissions, prolongs product lifespans, and protects natural resources. To move toward a circular economy, environmentally friendly waste management techniques like prevention of waste, green design, and cutting-edge technologies for recycling are required. Namely, the circular economy is widely accepted to be based on three key concepts: conceptualization of waste and pollution, preserving products and resources in utilization, and renewing natural processes, regardless of different definitions and standards of practice. In order to transition from the linear model to a more sustainable system that places an emphasis on long-term resource efficiency, these concepts are crucial.

The key to understanding why circular economy policy cannot be limited to waste management is the systemic nature of this shift. The circular economy, which is framed as a coordinated change in production, consumption, and governance systems rather than a collection of individual technical solutions, directly links resource-efficiency policy to climate mitigation. By extending manufacturer responsibility, strengthening secondary material markets, and restructuring value chains around sustainability and reuse, it reduces tangible emissions in ways that operational decarbonization by itself cannot, establishing a circular economy policy as a fundamental alternative to climate policy rather than a parallel goal (Uyduranoğlu, 2025; Güloğlu et al., 2025).

Moreover, circular economy initiatives have gained significant momentum in Türkiye. In line with the 2053 Net Zero Emissions target, the National Circular Economy Strategy and Action Plan (2025-2028) was introduced to improve resource efficiency, reduce waste generation, support circular business models, and strengthen sustainable production and consumption



practices. Furthermore, within the Technical Assistance Project for Assessing Türkiye's Potential for Transition to a Circular Economy (DEEP/UDESEP), the Roadmap for Single-Use Plastics, Marine Litter and Microplastics was developed to support the implementation of circular economy principles. The roadmap establishes 44 strategic actions organized into three implementation periods, namely 2025-2027 (short-term), 2028-2032 (medium-term), and 2033 and beyond (long-term). The actions focus on reducing single-use plastic consumption, increasing the quantity and quality of separately collected and recycled plastic waste, preventing marine waste and microplastic leakage into ecosystems, promoting eco-design and reusable products, strengthening extended producer responsibility (EPR), and increasing public awareness through education and behavioural change. Collectively, these policy instruments provide a comprehensive framework for improving plastic circularity and accelerating transition of Türkiye toward a resource-efficient and circular economy (MoEUCC, 2025).

4.6. Decarbonization of Industrial Processes

Industrial decarbonization has become one of the defining priorities for achieving climate neutrality while maintaining industrial competitiveness and long-term economic resilience. Although significant progress has been achieved through improvements in energy efficiency, industrial emissions remain largely driven by fossil fuel dependence, energy-intensive manufacturing processes, and the continued use of raw materials. Consequently, reducing industrial carbon emissions requires a comprehensive transformation that extends beyond energy substitution and incorporates cleaner production technologies, circular material utilization, process optimization, and digital innovation across industrial value chains. Heavy industries, including iron and steel, cement, chemicals, aluminum, mining, and mineral processing, account for the majority of industrial GHG emissions because of their high-temperature process requirements and substantial material demand. These sectors therefore represent the greatest opportunities for emission reduction through technological modernization. Electrification of industrial heat using renewable electricity, deployment of green hydrogen as a reducing agent and fuel, waste heat recovery systems, and advanced energy management technologies can significantly decrease fossil fuel consumption while improving overall process efficiency. In parallel, increasing the share of recycled feedstocks and secondary raw materials lowers the carbon intensity associated with primary resource extraction and material processing.

Material efficiency is increasingly recognized as an essential component of industrial decarbonization. Every tonne of recycled steel, aluminum, paper, glass, or plastic introduced into production avoids substantial upstream emissions associated with mining, transportation, and primary manufacturing. Likewise, extending product lifetimes through repair, refurbishment, remanufacturing, and component recovery reduces the demand for new materials while conserving embedded energy throughout product life cycles. These circular strategies simultaneously decrease emissions, improve resource productivity, and strengthen supply chain resilience. Digital transformation further accelerates industrial decarbonization by enabling real-time monitoring of energy consumption, material flows, process emissions, and



equipment performance. Technologies such as artificial intelligence, industrial Internet of Things (IIoT), digital twins, blockchain-based material traceability, and predictive maintenance support data-driven decision making, optimize resource utilization, minimize production losses, and enhance operational efficiency. Achieving deep industrial decarbonization also depends on supportive policy instruments and financial mechanisms. Carbon pricing, green public procurement, eco-design regulations, minimum recycled-content standards, sustainable finance, research and innovation incentives, and public-private partnerships play a critical role in accelerating low-carbon investments and reducing technological risks (Engin, 2025). Coordinated action among governments, industry, academia, and financial institutions is therefore essential to create an enabling environment for large-scale industrial transformation. For Türkiye, industrial decarbonization represents not only an environmental obligation but also a strategic economic opportunity. Strengthening domestic circular material markets, expanding renewable energy integration, increasing industrial electrification, and adopting low-carbon manufacturing technologies will improve export competitiveness under mechanisms such as the Carbon Border Adjustment Mechanism (CBAM) while supporting the national 2053 Net Zero Emission target. Integrating these measures into long-term industrial policy will accelerate the transition toward a resilient, resource-efficient, and globally competitive green industrial economy.

Moreover, access to blended and concessional finance is a decisive enabler of this transition for the industrial base of Türkiye (Azbar, 2025; Özcan, 2025). EU instruments available to Turkish industry, including the Instrument for Pre-Accession Assistance, the Türkiye Investment Platform, Cross-Border Cooperation Programmes, and Union Programmes, support renewable energy and energy-efficiency infrastructure, smart transport systems, transition of the Small and Medium-sized Enterprises (SMEs) to green production technologies and digital capacity, climate-smart agriculture, and green urban infrastructure; each euro of EU guarantee under these instruments is estimated to mobilise approximately six euros of investment, illustrating the leverage achievable through coordinated public-private financing. Realizing this leverage requires a holistic, proactive approach in which the private sector engages directly with these mechanisms in coordination with public institutions, rather than treating EU alignment as a compliance exercise alone (Özcan, 2025). Small and medium-sized enterprises warrant particular attention: energy-efficiency investments such as LED lighting, waste-heat recovery and efficient motor systems can deliver energy savings of up to 20%, while avoiding CBAM-related carbon costs offers a direct competitiveness incentive for SMEs to adopt low-carbon and circular production practices early (Azbar, 2025).

4.7. Action Plan for Sustainable Material Circularity

Achieving green industrialization requires a comprehensive transformation of industrial production systems in which improving circular material utilization constitutes one of several complementary strategic priorities. Progress should therefore be supported through integrated actions encompassing industrial decarbonization, cleaner production, renewable energy deployment, digital transformation, industrial symbiosis, resource efficiency, and sustainable



material management. The strategic priorities proposed to accelerate transition toward green industrialization and a circular economy are summarized in Figure 4.14. The following strategic actions represent the most critical priorities for accelerating the transition toward a circular industrial economy:



Figure 4.14 Strategic pillars and possible action plans for green industrialization

Action 1

Strengthening Circular Material Recovery and Secondary Raw Material Markets

The transition toward a circular industrial economy should begin with strengthening secondary raw material markets and improving the quality, accessibility, and utilization of recovered materials. Türkiye should prioritize investments in advanced collection, sorting, and recycling infrastructure while establishing national quality standards and certification systems that increase industrial confidence in secondary materials. Expanding regional material exchange platforms, particularly within OIZs, would facilitate the efficient circulation of industrial by-products and recovered resources among manufacturers. At the same time, green public procurement policies and financial incentives should encourage industries to substitute raw materials with certified recycled alternatives, thereby reducing import dependency, improving resource security, and increasing the CMUR.



Action 2

Advancing Industrial Waste Valorization and Circular Bioeconomy

Industrial waste should increasingly be regarded as a valuable secondary resource rather than a disposal problem by promoting innovative waste valorization pathways across all industrial sectors. Organic residues, agricultural by-products, food processing wastes, sludge, industrial biomass, and other carbon-rich waste streams should be converted into high-value products such as biochar, activated carbon, biofuels, green hydrogen, bioplastics, construction materials, and advanced functional materials through thermochemical, biological, and electrochemical conversion technologies. Integrating waste valorization into industrial production systems would simultaneously reduce landfill disposal, decrease GHG emissions, recover critical resources, and generate new revenue streams. Strengthening investments in pilot-scale demonstration facilities, industrial biotechnology, and commercialization of waste-derived products will accelerate the transition toward a resource-efficient circular bioeconomy while improving industrial competitiveness and supporting national decarbonization objectives.

Action 3

Accelerating Circular Manufacturing Through Eco-Design and Sustainable Production

Industrial production should progressively shift from conventional linear manufacturing toward circular production systems that integrate sustainability throughout the entire product life cycle. Products should be designed to maximize durability, reparability, modularity, remanufacturability, and recyclability while minimizing material losses during manufacturing. The widespread adoption of LCA, electronic product passports, and sustainable material selection methodologies would improve environmental performance while increasing resource efficiency. Encouraging manufacturers to redesign products according to circular economy principles will significantly reduce waste generation, extend product lifetimes, and increase the value retained within industrial systems.

Action 4

Expanding Industrial Symbiosis and Resource Sharing Networks

Industrial symbiosis should become one of the core pillars of green industrialization strategy of the Türkiye by transforming industrial waste streams into valuable production resources. The OIZ should evolve into integrated circular industrial ecosystems where waste heat, wastewater, industrial by-products, recovered materials, and shared infrastructure are exchanged among neighboring industries. Such collaborative resource-sharing networks would simultaneously reduce disposal costs, improve material efficiency, lower GHG emissions, and create new economic opportunities through high-value resource recovery. Strengthening cooperation between public institutions, industries, and local authorities will further accelerate the large-scale implementation of industrial symbiosis projects nationwide.



Action 5

Accelerating Digital Transformation for Resource-Efficient Manufacturing

Digital technologies should be fully integrated into industrial material management to optimize resource utilization and improve operational efficiency. Artificial intelligence, blockchain-based material traceability, and real-time monitoring systems should be deployed to track material flows, identify inefficiencies, predict maintenance requirements, and minimize production losses. Data-driven manufacturing systems will enable industries to continuously improve resource productivity while supporting transparent monitoring of circular economy performance. Establishing a national digital material information platform would also facilitate evidence-based policymaking and enhance industrial decision-making.

Action 6

Advancing High-Value Recycling and Resource Recovery Technologies

Future industrial affordability will increasingly depend on the ability to recover valuable materials from complex waste streams through advanced recycling technologies. Investments should therefore prioritize high-efficiency recovery systems for metals, plastics, batteries, electronic waste, construction materials, and critical raw materials. In parallel, urban mining, chemical recycling, industrial biotechnology, and waste valorization technologies should be expanded to maximize the recovery of strategic resources while minimizing landfill disposal. Transitioning from conventional waste management toward resource recovery will significantly strengthen material security and support the development of domestic secondary resource industries.

Action 7

Integrating Renewable Energy and Nuclear Energy

Industrial decarbonization and material circularity should be implemented simultaneously to maximize environmental benefits. Manufacturing industries should accelerate the adoption of renewable electricity, industrial electrification, nuclear energy, waste heat recovery, and other low-carbon production processes to reduce dependence on fossil fuels. Nuclear energy, particularly through advanced reactor technologies and small modular reactors, can provide reliable, low-carbon baseload electricity and process heat for energy-intensive industries, thereby enhancing industrial resilience while supporting deep decarbonization. Particular attention should be given to sectors such as steel, cement, chemicals, mining, and aluminum production, where integrating renewable and nuclear energy with circular material utilization can substantially reduce lifecycle GHG emissions.



Action 8

Developing the Green Hydrogen Sector

The development of the green hydrogen sector should be accelerated to support industrial decarbonization, energy system flexibility, and long-term energy security. Increasing the hydrogen value chain requires coordinated investments in renewable-powered water electrolysis, hydrogen storage, transportation, distribution infrastructure, and end-use applications. Priority should be given to improving electrolyzer efficiency, reducing production costs, and establishing integrated hydrogen hubs that connect production facilities with industrial and transportation sectors. Green hydrogen should primarily be utilized in specific industries, including steel, cement, chemicals, refining, mining, heavy-duty transportation, shipping, aviation fuels, and long-duration energy storage, where direct electrification remains technically or economically challenging. The establishment of harmonized certification systems, carbon intensity standards, supportive regulatory frameworks, financial incentives, and international collaboration will facilitate market development and accelerate commercialization. Advancing research, innovation, and large-scale demonstration projects will further enhance technology maturity, strengthen supply chains, and position green hydrogen as a key pillar of the global transition toward a low-carbon and circular industrial economy.

Action 9

Strengthening Circular Economy Governance and Green Investment Mechanisms

A comprehensive regulatory and financial framework is essential to accelerate industrial transition toward circularity. National policies should establish minimum recycled-content requirements, progressively restrict landfill disposal, and expand green public procurement practices across strategic industrial sectors. Simultaneously, dedicated green investment funds, tax incentives, and public-private partnerships should be developed to reduce investment risks and encourage industries to adopt circular manufacturing technologies. Stable governance and predictable financial support will be critical for scaling up long-term industrial transformation.

Action 10

Enhancing Innovation Capacity and Research Collaboration

Achieving long-term industrial transformation requires continuous technological innovation and a highly skilled workforce capable of supporting emerging circular economy technologies. Greater investment should therefore be directed toward research and development in sustainable materials, industrial biotechnology, advanced manufacturing, green chemistry, carbon utilization, and resource-efficient production systems. Collaboration between universities, research institutions, government, technology centers, and industry should be strengthened to accelerate technology transfer and commercialization.



Action 11

Using AI tools for management and assessment

Artificial intelligence (AI) should be integrated into industrial management systems to improve operational efficiency, resource optimization, and environmental performance assessment. AI-driven analytics, machine learning algorithms, and predictive models can support real-time monitoring of material flows, energy consumption, waste generation, equipment performance, and GHG emissions. These technologies provide industries to optimize production processes, enhance predictive maintenance, improve recycling efficiency, and facilitate data-driven decision-making across the entire product life cycle. Furthermore, AI-based assessment tools should be adopted to evaluate circular economy performance, resource productivity, carbon footprints, and sustainability indicators, thus enabling continuous improvement, transparent reporting, and evidence-based policymaking for green industrial transformation.

4.7. Conclusions

The transition toward green industrialization is no longer an environmental aspiration but a strategic necessity for ensuring long-term industrial competitiveness, resource security, and sustainable economic growth. The analyses presented throughout this report demonstrate that increasing material consumption, continued dependence on raw resources, and increasing industrial waste generation remain significant barriers to achieving climate neutrality. Although improvements have been observed in recycling performance, material recovery, and circular economy implementation, current progress remains insufficient to meet future resource efficiency and decarbonization objectives. The findings indicate that industrial sustainability cannot be achieved through waste management improvements alone. Instead, a systemic transformation is required in which circular material utilization, cleaner production technologies, renewable energy integration, digital manufacturing, industrial symbiosis, and sustainable product design operate as complementary components of a unified industrial strategy. Expanding the use of secondary raw materials, improving recovery efficiency, extending material lifecycles, and minimizing process-related emissions will simultaneously reduce environmental impacts while strengthening industrial resilience against resource scarcity and global supply chain disruptions.

Consequently, improving circular material utilization should be regarded as one of the enabling components of green industrialization rather than a standalone objective. Sustainable industrial transformation requires the simultaneous implementation of industrial decarbonization, cleaner production, renewable energy integration, industrial symbiosis, digital manufacturing, sustainable material management, and circular economy practices. Accordingly, circularity indicators should always be interpreted together with complementary environmental and



industrial performance indicators. In this regard, achieving sustainable green industrialization requires a number of strategic priorities considered and implemented accordingly, as listed below:

- Well-developed green industrialization is no longer an option but a strategic necessity. Global material extraction has increased from 30 billion tonnes in 1970 to more than 106 billion tonnes in 2024, while only 6.9% of materials entering the global economy originate from secondary resources, demonstrating the urgent need to accelerate circular material utilization.
- The eco-design principles should be promoted to prioritize durability, repairability, modularity, and recyclability throughout product lifecycles.
- The direction of industrial circularity is encouraging but remains insufficient. Although the EU Circular Material Use Rate increased from 11.1% in 2014 to 12.2% in 2024, nearly 88% of material demand still relies on raw materials; the COP31-2035 target of at least 15% circular material utilization sets a practical benchmark for accelerating industrial transformation.
- Circular material utilization and industrial decarbonization must advance together. Namely, the utilization of renewable electricity, industrial electrification, green hydrogen, and secondary raw materials is essential for reducing GHG emissions while strengthening industrial effectiveness and resource security.
- Recovery-adapted manufacturing is becoming the dominant industrial pathway. In Türkiye, 70.1% of manufacturing waste was transferred to recovery and treatment facilities in 2024, whereas only 10.8% was landfilled, highlighting the growing role of resource recovery in industrial sustainability.
- Digitalization, industrial symbiosis, and innovation are strategic drivers of the transition. Artificial intelligence, digital manufacturing, industrial symbiosis, and advanced recycling technologies provide the basis for improving material productivity and accelerating circular manufacturing.
- There is a critical need for integration of LCA, Material Flow Analysis, and circularity indicators as decision-support tools in industrial planning and performance monitoring.
- Investments in sustainable material production from renewable resources to support green industrialization are extremely limited. Thus, investments in bio-based materials, advanced manufacturing, sustainable chemicals, industrial biotechnology, and low-carbon production technologies are necessary.
- The government agencies, industries, academia, financial institutions, and technology providers should be collaborating to accelerate innovation and technology transfer.



- The mission toward 2035 is clearly defined and measurable. The 11 strategic actions proposed in this chapter provide a practical implementation framework for achieving at least 15% circular material utilization by 2035, while supporting 2053 Net Zero Emissions target of Türkiye through resource-efficient, low-carbon industrial development.

Overall, green industrialization should be viewed as a comprehensive transformation of industrial systems rather than a collection of isolated environmental measures. By integrating circular material utilization, low-carbon technologies, resource efficiency, digital innovation, and sustainable industrial policies, Türkiye has the opportunity to build a resilient manufacturing sector capable of generating higher economic value with lower environmental impact. Successfully implementing these strategies will strengthen industrial competitiveness, reduce GHG emissions, improve resource security, and position the country in the transition toward a climate-neutral and circular economy.

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CHAPTER 5

RAISING AWARENESS

AND

EDUCATION ON CLIMATE CHANGE

Abstract

Climate mitigation and adaptation success depend on what people know, believe, and are equipped to do. This chapter sets out the case for treating climate education and climate-resilient agricultural training as a single, integrated implementation target. By 2035, climate change and climate-resilient farming training should reach 100% of society, delivered through a coordinated architecture spanning formal education, professional extension services, and lifelong learning. The chapter gives particular attention to children, young people, teachers, and vocational and technical education, arguing that green skills, meaningful youth participation, and climate-resilient education systems are preconditions for the target rather than optional additions. Türkiye’s emerging institutional framework, including the Ministry of National Education climate action plan spanning ten thematic areas, a health-sector climate curriculum grounded in a peer-reviewed pilot, and a National Climate Change Adaptation Strategy that names capacity-building and awareness as a stand-alone pillar across every economic sector, is presented as an operational template. This national evidence is read alongside international evidence on the persistent gap between agricultural knowledge and on-farm adoption, and on the global gap between curriculum reform, teacher readiness, and youth engagement that international frameworks have documented. The chapter closes with an action plan structured around four distinct meanings of “100%”. These are universal access, institutional coverage, priority-profession completion, and measurable behavioural change.

Keywords: Climate change education, Climate-resilient agriculture, Public awareness, One Health, Disaster and conflict resilience

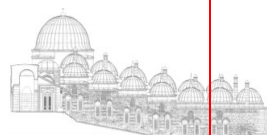


5.1 Introduction

The preceding chapters of this Action Plan address electrification, zero waste and methane, resilient buildings and cities, and green industrialization four transitions defined primarily by technology, capital, and regulation. This chapter addresses the transition on which all four ultimately depend: whether the people who operate, regulate, finance, and use these systems know what to do, trust the information available to them, and are able to act on it. The Intergovernmental Panel on Climate Change (IPCC) and the UNFCCC's Action for Climate Empowerment (ACE) framework identify education, training, public awareness, public participation, access to information, and international cooperation as the six elements without which mitigation and adaptation measures cannot be sustained at scale (UNESCO & UNFCCC, 2016; UNESCO, 2020). Twenty-nine years after ACE's predecessor was written into the 1992 UNFCCC text, this remains one of the least resourced and least measured dimensions of the multilateral climate regime.

The gap is between the existence of technology or practice and its adoption at the scale needed to matter. The Food and Agriculture Organization, the International Fund for Agricultural Development, and the Islamic Development Bank, mapping affordable and transferrable climate-smart technologies for smallholder farmers across ten countries including Türkiye, found that adoption remained limited wherever training and extension support were absent, regardless of how well a technology performed under trial conditions (FAO, IFAD, & IsDB, 2024). The same pattern recurs throughout this Action Plan: livestock manure acidification can cut methane emissions by 82–86% when slurry pH is held at or below 5.5, yet uptake stays low without accompanying training, permitting support, and regional adaptation, a finding echoed across the multidisciplinary literature on manure-management adoption (Larson et al., 2026). The lesson generalizes: no combination of subsidy, code, or carbon price closes the distance between a validated practice and a farm, a classroom, or a household unless education and extension close it first.

This chapter therefore proposes a fifth 2035 Global Implementation Target, to be read alongside the other four: that climate change and climate-resilient farming training reach 100% of society, children, young people, adults, farmers, teachers, public officials, health workers, private-sector employees, media professionals, and vulnerable groups by 2035. Section 2 sets out the scale of the global and Turkish education-action gap. Section 3 defines the technical scope of climate-resilient agricultural training. Section 4 addresses how education is delivered and, critically, how it is converted into adopted practice. Section 5 addresses climate education and skills development for children and young people specifically. Section 6 documents the institutional mechanisms already operating in Türkiye on which an implementation architecture can be built. Section 7 sets out an action plan, and Section 8 concludes.



5.2. The Global and National Education-Action Gap

The scale of the awareness and training deficit is best illustrated sector by sector. In agriculture, Türkiye withdraws approximately 77% of its total freshwater for irrigation, making the sector highly exposed to climate-driven water stress; the extent to which that exposure is managed depends on whether farmers have received training in deficit irrigation, sensor-based scheduling, and drought-adapted cropping, rather than on water availability alone (Angın, 2025). In food systems, TÜBA's assessment of food, water loss, and waste finds that approximately one-third of food produced worldwide is lost or wasted, representing not only the food itself but the land, water, energy, fertilizer, labor, and economic value embedded in it. Losses that are disproportionately concentrated at points in the supply chain (harvest timing, cold-chain handling, storage) where basic training and low-cost technology can deliver large reductions (Şahin & Erol, 2024). In genetic resources, the erosion of locally adapted seed varieties in favor of a narrow set of commercial cultivars removes exactly the drought- and heat-tolerant genetic material that climate adaptation will most need, a risk that is only avoided where farmers, breeders, and seed banks are trained and resourced to conserve it (Balkaya, 2024).

The gap is not confined to farmers. TÜBA's assessment of alternative food sources documents that sustainable production depends as much on educating producers and consumers, and on trustworthy labelling and effective oversight, as it does on developing the underlying technology itself (Şahin, 2024). TÜBA's review of microplastics and endocrine disruptors similarly finds that bringing scientists, public institutions, local government, civil society, media, and the public onto a shared evidence base measurably strengthens both scientific awareness and policy-making capacity. A template for climate literacy, as well as agricultural literacy, needs to be built (Aydın & Tayanç, 2024). Agricultural biodiversity compounds the exposure: continued reliance on monoculture increases vulnerability to pests, disease, and yield collapse under a changing climate, while erosion of the natural enemies and soil organisms that moderate these risks is itself accelerated by the practices of untrained producers (Asim et al., 2025; Çakmakçı, 2024; Köksel & Acar, 2024).

None of this is a uniquely agricultural problem. The One Health framework jointly adopted by the Food and Agriculture Organization, the World Health Organization, the World Organization for Animal Health, and the UN Environment Programme defines an integrated approach to sustainably balancing the health of people, animals, plants, and ecosystems (Erol, 2025). Climate change is one of the principal forces reshaping the zoonotic and vector-borne disease landscape that this framework exists to manage, through mechanisms ranging from deforestation and agricultural expansion to the geographic spread of disease vectors into previously unaffected regions (Timurkan, 2025). A health workforce, an agricultural



workforce, and a general public that have not been trained to recognize these interconnected risks cannot be expected to respond to them effectively, however sound the underlying science or policy may be.

5.3. Climate-Resilient Agricultural Training: Technical Scope

Climate-resilient farming training cannot be a single generic module; it must cover the full set of decisions a producer makes across a production cycle, adapted to regional climate, farm scale, and production system.

5.3.1. Water Management

Priority training includes drip and sensor-assisted irrigation scheduling, soil-moisture-based water budgeting, rainwater harvesting, crop-and-water planning for drought years, salinity and drainage management, and the safe use of treated wastewater in irrigation. Given that agriculture already accounts for roughly three-quarters of national freshwater withdrawals, water-efficiency training delivers among the highest returns of any single intervention available to the sector (Angin, 2025).

5.3.2. Soil Health

Soil-test-based fertilisation, organic-matter building, crop rotation and cover cropping, reduced tillage, and the safe agronomic use of compost, digestate, and biochar all depend on farmer training to be applied correctly; incorrectly dosed or poorly timed inputs can just as easily damage soil biodiversity as protect it (Turan & Kocaman, cited in Şahin & Erol, 2024); Çakmakçı, 2024). Soil biodiversity is itself a leading indicator of soil health and of the ecosystem's underlying productive capacity, reinforcing the case for treating soil-focused training as a climate as well as an agronomic priority.

5.3.3. Crop Production and Genetic Resources

Training should cover the selection of drought- and heat-tolerant varieties, region-specific sowing and harvest calendars, integrated pest management, agroforestry, crop diversification, and the conservation and use of local and traditional seed varieties. Local varieties constitute one of the most important structural indicators of agricultural biodiversity and a genetic reservoir for future climate adaptation; without producer training and institutional support for their multiplication and conservation, this reservoir continues to narrow even as the case for maintaining it strengthens (Balkaya, 2024; Şaylan, 2024).



5.3.4. Livestock and Poultry

Heat-stress monitoring and early warning, shading, ventilation and cooling system design, water and feed reserve planning, climate-adapted housing, precision feeding to reduce nitrogen excretion, manure and bedding management, and biogas, compost, and biochar utilization should all be covered, alongside vector and disease-risk monitoring consistent with the One Health approach (Erol, 2025; Timurkan, 2025). Precision livestock systems, sensors, automation, and AI-based monitoring of feed intake, animal health, housing conditions, and resource use can simultaneously raise productivity and reduce waste and emissions, but only where farmer training, affordable technology, and appropriate financing are available together. Technology alone is not enough to bring all of these benefits.

5.3.5. Digital and Precision Agriculture

The convergence of remote sensing and artificial intelligence, Geospatial Artificial Intelligence, or GeoAI now allows satellite constellations, unmanned aerial vehicles, and hyperspectral sensors to generate high-resolution, near-real-time data on vegetation health, water stress, soil moisture, and carbon stocks (Kavzoğlu, 2025). For smallholders in particular, mobile applications and SMS-based services can translate this data into actionable, localized advice on weather, market prices, and agronomic timing without requiring continuous internet access. The productivity and emissions gain available from these tools depend entirely on whether farmers, technicians, and extension officers have been trained to interpret and act on the outputs. The same conclusion applies to every other technology addressed in this Action Plan.

5.3.6. Economic and Social Resilience

Training in agricultural insurance and climate-risk finance, cooperative formation, income diversification, access to digital marketing platforms, and post-disaster recovery planning should accompany technical training rather than follow it; farmers who cannot finance a recommended practice, or who have no channel to market a diversified product, will not adopt it regardless of how well they understand it. Targeted support for women and young farmers is a further precondition for reaching the 100% coverage target this chapter proposes, since these groups are disproportionately underserved by conventional extension systems.

5.4. Building Educational Resilience Across Society

Universal coverage requires content adjusted to each group's role, risk exposure, and decision-making power, delivered through channels that reach people where they already are.



Table 5.1 Target Groups and Curriculum Content

Target Group	Priority Training Content
Pre-school and primary	Water, energy, nature, waste reduction, and food-waste awareness
Secondary school	Climate science, greenhouse gases, disaster risk, sustainable consumption
University students	Profession-specific climate risk, adaptation, carbon and resource management
Vocational and technical education (TVET) students and young farmers	Green skills for climate-adapted trades: renewable energy installation and maintenance, precision-agriculture and irrigation technician skills, veterinary and animal-health assistance, climate-resilient construction
Teachers	Climate science, applied pedagogy, and countering misinformation
Farmers	Water, soil, crop, livestock, fertiliser, energy, and disaster management
Agricultural engineers and veterinarians	Climate risk analysis, heat stress, disease, precision production, emissions
Public officials	Climate legislation, green budgeting, public investment, disaster preparedness
Local government	Local climate action plans, risk mapping, waste management
Private sector	Resource efficiency, supply chains, emissions, and climate risk
Health workers	Heat, air pollution, nutrition, and climate-sensitive disease
Media	Science-based climate communication and countering disinformation
Older adults and people with disabilities	Protection during heat, flood, fire, and emergencies
Consumers	Climate impacts of food, transport, energy, water, and waste choices

5.4.1. The Extension and Advisory Model

Reaching farmers at scale requires a standing advisory presence in every production region, not episodic training events. Regional climate advisory teams, agricultural engineers, veterinarians, technicians, and trained lead farmers should provide continuous support on regional climate risk, crop and breed selection, water and fertilizer management, meteorological early warning, agricultural insurance, and access to grant and investment programmes. Demonstration farms and farmer field schools, modelled on approaches such as FAO's Junior Farmer Field and Life Schools, allow producers to observe precision irrigation, soil conservation, low-emission manure management, climate-resilient varieties, livestock heat-stress management, renewable energy, and compost, biogas, and biochar production under their own local conditions are more effective delivery mode than classroom instruction alone.



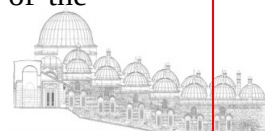
Delivery channels must combine digital and in-person methods: mobile applications, SMS and voice alerts, television and radio programming, farmer meetings, village visits, community education centers, printed guides, and materials in local languages and dialects. Digital access should complement, not substitute for, in-person training; rural areas without reliable internet access, older farmers, people with disabilities, and other disadvantaged groups require dedicated access models if the 100% coverage target is to be meaningful rather than nominal.

5.4.2. From Awareness to Adoption: Closing the Behavior Gap

Knowledge is necessary but not sufficient for behavior change. The manure-acidification case is instructive precisely because it is a technically well-validated, low-cost practice whose real-world adoption nonetheless remains limited wherever training, financing, simplified permitting, manure testing, and regional adaptation are absent (Larson et al., 2026). The same pattern is documented across the climate-smart agriculture literature more broadly (FAO, IFAD, & IsDB, 2024). Four design principles follow: training programmes should be explicitly linked to investment grants rather than delivered as a stand-alone activity; free technical advisory support should be guaranteed for small producers; certification should never be made the sole gateway to financial support, since this excludes exactly the producers most in need of assistance; and the real-world, on-farm performance of a promoted technology should be verified before it is scaled, rather than assumed from controlled trials. Because climate, farm size, production system, social structure, and economic capacity vary by region, a single national technology mandate applied uniformly to all producers is unlikely to deliver the results a regionally adapted approach can achieve.

5.4.3. Invasions and Armed Conflicts as an Environmental and Climate Resilience Crisis: Lessons from the Gaza Strip

The Israeli attacks on Gaza since October 2023 have become one of the greatest humanitarian disasters and genocide in history (Albanese, 2025). The number of Palestinians killed in the last 2.5 years has exceeded 72,000. Of those killed, 20,413 were children and 12,524 were women; 3,110 were healthcare workers, journalists, educators, and civil defense personnel. Hospitals were bombed, and the healthcare system collapsed as medicine and equipment were destroyed (TÜBA, 2023). The blockade made access to basic necessities almost impossible, leading to food and water crises. Universities and schools were bombed, and the remaining schools were converted into shelters, depriving hundreds of thousands of children of education. The constant bombardment and forced displacement deeply shook the social fabric and created psychological trauma. Climate education and disaster-preparedness programmes typically focus comprehensively on natural hazards such as earthquakes, floods, drought, while the devastating impact of armed conflict on environmental systems and climate resilience, comparable in scale to natural disasters, remains largely absent from education curricula. The United Nations Environment Programme's (UNEP) second assessment of the environmental impact of the



escalation of conflict in the Gaza Strip constitutes one of the most comprehensive contemporary scientific sources documenting the effects of a conflict on water resources, soil, biodiversity, marine ecosystems, the urban environment, and air quality (UNEP, 2025). This section summarises the report's principal findings to argue that armed conflict, like natural disasters, should be integrated systematically into climate and environmental education curricula, since both categories of shock threaten food, water, and health security through comparable mechanisms, and informing societies about these risks directly strengthens post-disaster environmental recovery capacity.

The impact on water resources and wastewater management has been dramatic. As of April 2025, only 9 of 54 storage and pumping facilities in Gaza remained operational, an 84% reduction in capacity; remaining desalination capacity stood at just 31% of pre-October 2023 levels, and none of Gaza's wastewater treatment facilities were operational. This collapse has produced a 36-fold increase in acute watery diarrhea cases and a 384-fold increase in acute jaundice syndrome (an indicator of hepatitis A), and poliovirus has re-emerged during the conflict (UNEP, 2025; Paris et al., 2025).

Biodiversity, soil, and land resources have suffered damage of a similar magnitude. Remote sensing assessments show that, as of May 2025, 97.1% of tree crops, 82.4% of annual crops, 95.1% of shrubland, and 89% of grassland/fallow land in Gaza had been damaged, rendering food production impossible at scale (UNEP, 2025; Yin et al., 2025). Soil has been contaminated by munitions, solid waste, and untreated sewage; vegetation loss and compaction from military activity have degraded soil structure, reducing infiltration capacity, increasing runoff and flood risk, and diminishing groundwater recharge. Wadi Gaza, a regionally significant wetland, has also suffered serious damage (UNEP, 2025).

Marine ecosystems have likewise borne the brunt of contamination: the conflict has all but eliminated the livelihoods of Gazan fishers, and the collapse of institutional capacity has left no effective control over contamination entering the food chain, leading to the consumption of poisonous fish. On the urban environment, an estimated 78% of all structures had been destroyed or damaged as of July 2025, and the volume of debris exceeded 61 million tons, twenty times the combined total generated by every previous conflict in Gaza since 2008, some of it contaminated with asbestos and industrial chemicals (UNOSAT, 2025; UNEP, 2025).

The collapse of solid waste management and dust from explosions have directly affected public health: more than 37,000 respiratory infection cases were recorded in June 2025 alone. At the time of writing, more than 500,000 people, in Gaza, were enduring famine conditions, with the remaining population facing emergency levels of hunger. The conflict has also produced the largest cohort of child amputees in modern history, and women and girls have faced disproportionate risks owing to the lack of access to safe water, sanitation, and hygiene facilities (UNEP, 2025).



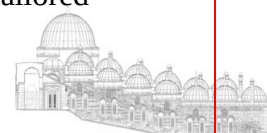
These findings show that armed conflict constitutes a systemic shock category, comparable in scale to natural disasters, that must be brought within the scope of climate and environmental education. UNEP's recommended approach of an early ecological and environmental health risk-screening exercise, identifying priority areas, science-based and inclusive planning, and engaging local expertise and institutions (universities, the private sector, non-governmental organizations), is directly consistent with the disaster and climate adaptation frameworks addressed for Türkiye in Section 6. Within the target of delivering climate change mitigation training to 100% of society, core knowledge on recognizing, monitoring, and remediating conflict-induced environmental destruction should be integrated into disaster management, public health, agriculture, and urban planning curricula, particularly for public officials, health workers, and professionals entering the humanitarian sector. This should be a natural part of the international peer-learning mechanism proposed under COP31 (see Section 7), ensuring that climate resilience education prepares society not only for natural hazards but also for human-induced systemic shocks.

5.5. Youth and Education

The target-group matrix in Table 5.1 already lists children, young people, and teachers as distinct rows. Meeting the 100% coverage target proposed in this chapter requires treating the education, skills, and civic-participation systems that serve the next generation as a strategic asset in their own right, not a subset of general public awareness. This section addresses five dimensions the target cannot be met without. The first is children and young people as a distinct constituency. The second is the role of teachers and vocational and technical education in delivering the curriculum this chapter proposes. The third is the emergence of green skills as the labour-market counterpart of climate-resilient training. The fourth is the case for meaningful rather than token youth participation. The fifth is the physical and institutional resilience of the education systems that must deliver all of the above while absorbing the shocks addressed elsewhere in this chapter.

5.5.1. Children and Young People as a Distinct Constituency

Global evidence indicates that the education-action gap identified in Section 2 is especially acute for the youngest learners. A UNESCO review of 100 national curriculum frameworks found that nearly half did not mention climate disruption at all, and a companion survey found that most young people could not explain the phenomenon in terms they had been taught (UNESCO, 2024a). Türkiye's own framework already treats children as a starting point rather than an afterthought. The Ministry of National Education's Climate Change Action Plan 2026-2030 (see Section 5.6.1) frames climate consciousness as a life culture to be internalised from early childhood. The National Climate Change Adaptation Strategy names children explicitly, alongside older adults, people with disabilities, and migrants, as a priority risk group for tailored



adaptation education (Republic of Türkiye, Ministry of Environment, Urbanisation and Climate Change, 2024). For rural children and young people specifically, this should include direct, sustained exposure to climate-resilient agriculture, delivered jointly by the Ministry of National Education and the Council of Higher Education through rural schools rather than treated as an urban curriculum extended outward. This is consistent with the Junior Farmer Field and Life Schools model already referenced in Section 4. Demonstration plots attached to rural schools give children and adolescents first-hand exposure to the same water, soil, and livestock practices set out in Section 3, rather than treating agricultural literacy as content reserved for adult farmers.

5.5.2. Teachers and Vocational and Technical Education

Curriculum reform delivers little without teachers who are prepared and confident to teach it. In the same UNESCO review, fewer than a quarter of teachers surveyed felt able to address climate action properly in the classroom (UNESCO, 2024a). This is a confidence gap that the Ministry of National Education's action plan explicitly targets through expanded teacher training and continuing professional development (see Section 5.6.1). This chapter treats that professional-development commitment as a precondition for every other target in the curriculum matrix, not a parallel activity. Vocational and technical education and training (TVET) institutions deserve equal weight alongside general schooling, since they are where much of the technical content addressed in Section 3 is actually taught to the workforce that will apply it, including irrigation technicians, veterinary and animal-health assistants, renewable-energy installers, and precision-agriculture operators. International guidance on greening TVET calls for climate and sustainability competencies to be embedded across vocational curricula, apprenticeships, and instructor training rather than added as a stand-alone module (UNESCO-UNEVOC & Cedefop, 2025). In Türkiye, this means extending the trainer-of-trainers model already used for agricultural extension (see Section 4.2) into agricultural, veterinary, forestry, and energy vocational high schools and community colleges, so that instructors themselves are certified in climate-resilient practice before their students are.

5.5.3. Green Skills for the Climate Transition

Green skills are commonly defined as the technical and transversal competencies, across all sectors and occupational levels, needed to adapt products, services, and processes to climate change and tightening environmental regulation (OECD & Cedefop, 2014). The International Labour Organization estimates that some 1.2 billion jobs, roughly 40% of global employment, depend on healthy ecosystems and a stable climate. It also estimates that a well-managed transition in green and blue energy alone could generate an additional 8.4 million jobs for young people worldwide by 2030 (ILO, 2022). Read against the technical training menu set out in Section 3, covering water management, soil health, precision and digital agriculture, and



livestock and poultry systems, green skills are simply the labour-market packaging of the same competencies. A young person trained to install and maintain sensor-based irrigation, or to operate biogas and biochar units, is acquiring a green skill and a climate-adaptation skill in the same act of learning. The implication for the action plan in Section 7 is that green-skills modules belong inside TVET qualifications, apprenticeships, and farmer field schools, not in a separate employment strategy disconnected from the agricultural and technical curriculum this chapter proposes.

5.5.4. Meaningful Youth Participation

Education and skills are necessary but not sufficient. Young people also need a genuine channel to shape the policies that will define their working lives, consistent with the “public participation” element of the ACE framework introduced in Section 1 (UNESCO & UNFCCC, 2016). At the multilateral level, YOUNGO has held official constituency status at the UNFCCC since 2009. The Presidency Youth Climate Champion function, established to broaden inclusive youth engagement within the COP process, offers Türkiye’s COP31 presidency a ready-made mechanism through which children’s and young people’s priorities can be escalated into the presidency’s own agenda (UNFCCC, 2024). Guidance on translating this into practice distinguishes meaningful from token participation on the basis of concrete safeguards. These include funded travel and accommodation, protection for participants under 18, translation support, and deliberate outreach to young people who are not already organised into national youth movements, since “youth” is too easily treated as a single homogenous voice (UNDP, 2022). Nationally, this argues for a standing youth advisory role in the climate-education monitoring system proposed in Section 7, so that the outcome indicators tracked there are reviewed by the young people they are meant to describe, and not only reported to them.

5.5.5. Climate-Resilient Education Systems

The institutions that deliver every target in this chapter should consider the issues addressed in this Action Plan. Resilience planning for schools, vocational institutions, and universities therefore belongs alongside curriculum reform rather than after it. UNESCO’s Greening Education Partnership organises this expectation around four action areas. These are greening schools, greening curriculum, greening communities, and greening teacher training and systems capacity, with an explicit ambition of bringing half of the world’s schools to a defined green-school standard by 2030 (UNESCO, 2024b). Türkiye’s own Ministry of National Education action plan already reflects this logic by including disaster and emergency preparedness and school physical infrastructure among its ten thematic areas (see Section 5.6.1), rather than treating school safety and climate curriculum as separate workstreams. Section 4.4 showed that armed conflict can destroy environmental and health infrastructure at a scale comparable to natural disasters. The same logic applies directly to education infrastructure. A climate-resilient



education system should plan for continuity of learning, hardened facilities, and the offline and low-bandwidth delivery channels described in Section 4.2, under both natural-hazard and conflict-driven disruption, rather than provisioning for one and improvising the other.

5.6. National Institutional Mechanisms: Türkiye's Emerging Framework

Türkiye's own institutional response, illustrates what a 100% coverage architecture can look like in practice and offers a transferable template for other COP31 Parties.

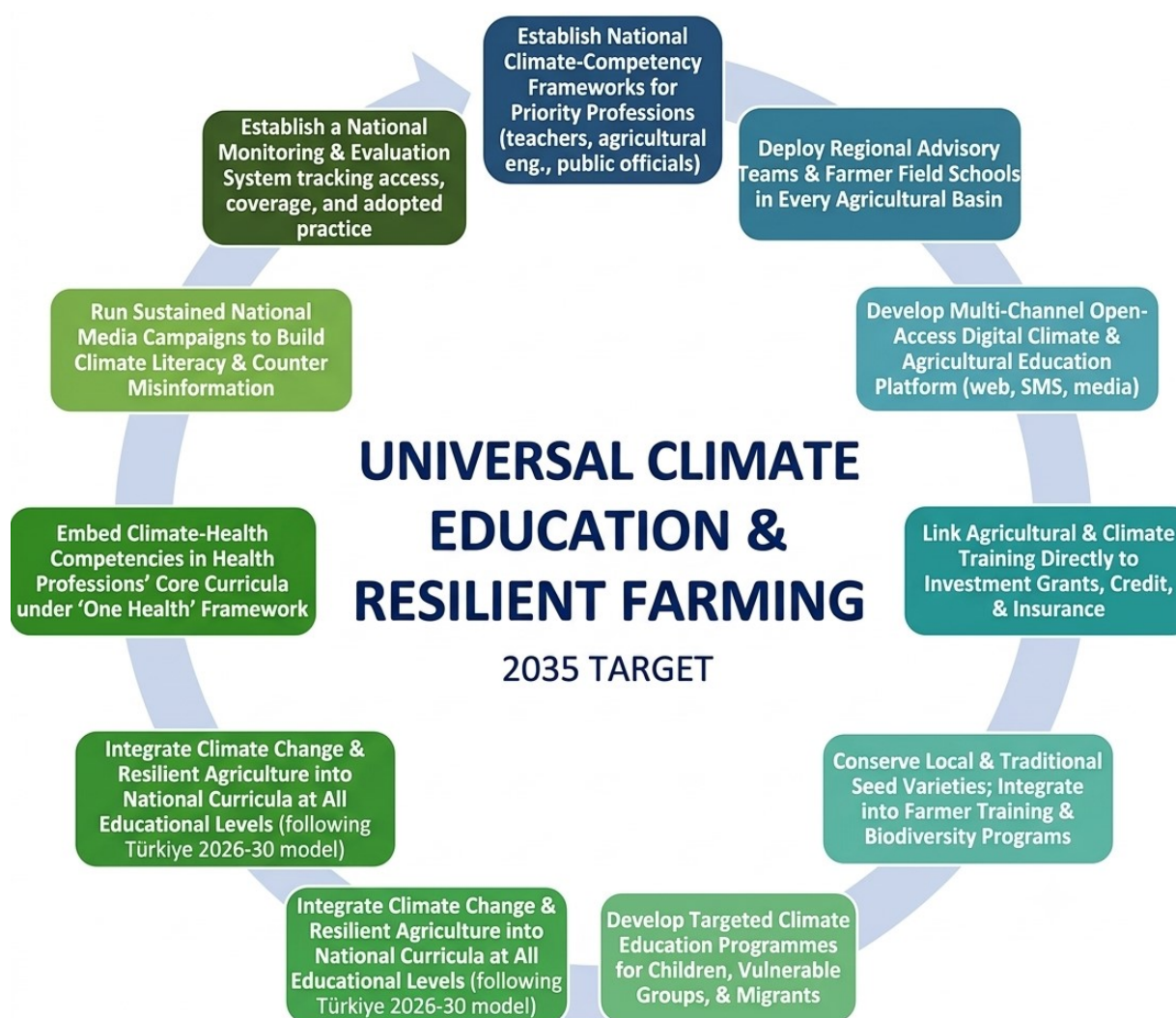


Figure 5.1 Possible action plans for climate education and resilient farming.



5.6.1. The Ministry of National Education’s Climate Change Action Plan 2026-2030

Building on an initial 2022–2025 action plan, Türkiye’s Ministry of National Education published a second “Climate Change Action Plan 2026-2030” within its broader Century of Türkiye Education Model, structured around ten thematic areas, including disaster and emergency preparedness, school infrastructure, dissemination of good practice, and international cooperation, comprising ten goals, thirty-three targets, and sixty-nine activities. The plan directs the revision of curricula around climate change, sustainability, and green transformation; expands teacher training in these areas; and promotes green-school practices covering energy, water, and waste management, including zero-waste systems, recycling, rainwater harvesting, composting, and agroecological activities within schools themselves. This represents one of the most systematic national attempts to embed climate literacy across an entire school system that any COP31 Party has yet documented (Republic of Türkiye, Ministry of National Education, 2026).

5.6.2. The National Climate Change Adaptation Strategy and Action Plan

Türkiye’s National Climate Change Adaptation Strategy and Action Plan treat capacity-building, cooperation, and awareness-raising as a stand-alone strategic pillar that cuts across every sector it covers. In agriculture, the plan sets a strategic goal of strengthening policy, legal frameworks, institutional capacity, cooperation, and awareness for sectoral adaptation, with an explicit action to scale up training, awareness, and capacity-building for agricultural stakeholders, delivered through national extension teams, private-sector field representatives, and lead farmers supported by trainer-of-trainers programmes, and reinforced through primary and secondary curricula developed jointly by the Ministry of National Education and the Council of Higher Education for rural and urban schools alike. Equivalent strategic goals and monitoring indicators exist for the energy, industry, tourism, and cross-cutting sectors, alongside biodiversity and ecosystem-services goals that explicitly recognize nature-based solutions as a foundation for adaptation. Monitoring indicators tracked under the plan include the number of training events and their participants, disaggregated by stakeholders as farmers, technical staff, managers, private sector, civil society, women, and vulnerable groups providing an existing, ready-to-use basis for the outcome indicators proposed in Section 7 (Republic of Türkiye, Ministry of Environment, Urbanisation and Climate Change, 2024).

5.6.3. Climate and Health Curricula: A One Health Approach

A peer-reviewed pilot curriculum designed to strengthen the resilience of the Turkish healthcare system through structured climate-and-health training demonstrates that integrating climate competencies into core health-professional education, rather than treating them as elective or supplementary content, is both feasible and measurable (Tanrıöver et al., 2025). This is



consistent with the One Health framework's premise that human, animal, and environmental health cannot be managed as separate domains (Erol, 2025), and with evidence that the geographic range of climate-sensitive vectors and zoonotic pathogens is expanding as the climate changes (Timurkan, 2025). A credible pathway to the 100% target this chapter proposes therefore requires health-workforce training to be developed in direct coordination with agricultural and general climate education, rather than as a parallel, uncoordinated track.

5.7. Action Plan for Universal Climate Education and Resilient Farming

Achieving 100% coverage by 2035 requires “100%” to be defined and pursued at four distinct levels simultaneously: universal access (every individual can reach free, comprehensible educational material); universal institutional coverage (every school, university, public institution, municipality, and agricultural extension unit is enrolled); universal priority-profession completion (teachers, public managers, agricultural advisers, and related professions complete training); and measurable adoption (the conversion of knowledge into changed practice is tracked in its own right, separately from training completion). The following actions operationalise this four-level definition.

- Integrate climate change and climate-resilient agriculture content into national curricula at every level of education, from pre-school to postgraduate study, following the model of Türkiye's Ministry of National Education Climate Change Action Plan 2026–2030.
- Establish national climate-competency frameworks for priority professions, teachers, health workers, agricultural engineers, veterinarians, and public officials, and embed them in core curricula, licensing, and continuing professional development.
- Deploy regional climate advisory teams and farmer field schools in every agricultural production basin, providing continuous, free technical support on water, soil, crop, livestock, and disaster management.
- Build a national, open-access digital climate and agricultural education platform, combined with mobile, SMS, radio, and television channels to reach areas without reliable internet access.
- Link agricultural and climate training programmes directly to investment grants, low-interest credit, and insurance products, rather than delivering training as a stand-alone activity disconnected from financing.
- Develop targeted programmes for children, older adults, people with disabilities, migrants, and other vulnerable groups, recognising that generic programming systematically underserves these populations.
- Conserve and multiply local and traditional seed varieties as a genetic reservoir for climate adaptation, integrating this work into farmer training and formal biodiversity conservation programmes alike.



- Integrate climate-health competencies into core curricula for all health professions, coordinated with agricultural and general climate education under a shared One Health framework.
- Run sustained national media and communication campaigns to build public climate literacy and counter misinformation, engaging media professionals as trained partners rather than passive channels.
- Establish a national climate-education monitoring and evaluation system that tracks access, institutional coverage, professional completion, and, as a distinct indicator, the conversion of training into adopted practice, disaggregated by age, gender, income, education level, region, and farm size.
- Embed green-skills modules into TVET qualifications, apprenticeships, and farmer field schools, aligning vocational curricula with the technical training menu set out in Section 3 rather than treating workforce skills and climate curriculum as separate programmes.
- Institutionalise safeguarded, meaningful youth participation in national climate-education governance, including through Türkiye’s COP31 Presidency Youth Climate Champion function and a standing youth advisory role in reviewing the monitoring indicators proposed below.

5.8. Conclusions

Climate education and climate-resilient farming training are not preparatory activities that precede the “real” work of decarbonisation, resource efficiency, and resilience addressed elsewhere in this Action Plan; they are the mechanism through which every other target in it becomes achievable. A more efficient building code, a more circular material standard, or a lower-methane waste system delivers no result if the people who must operate it do not understand it, do not trust it, or cannot afford to adopt it. The evidence assembled in this chapter, from Türkiye’s water-intensive agricultural sector, its documented food-loss burden, its eroding genetic diversity, and the persistent gap between validated technologies and their on-farm adoption, shows that this is not a marginal risk but the central operational constraint on the entire Action Plan.

Türkiye’s own emerging framework, ten-theme school climate action plan, a National Adaptation Strategy that treats capacity-building as a cross-cutting pillar with sector-specific training targets and indicators, and an early health-sector climate curriculum, demonstrates that the institutional building blocks for a 100% coverage target already exist and can be scaled rather than invented from scratch. What remains is to connect them: to fund training and technical assistance as an integral part of every investment programme in this Action Plan, to measure adoption rather than only attendance, and to treat every farmer, teacher, health worker, official, and household reached as a measurable unit of progress toward the same 2035 horizon that governs electrification, waste, buildings, and industry.



- Treat climate education and climate-resilient agricultural training as a fifth, equally weighted 2035 Global Implementation Target, not a supporting activity for the other four.
- Fund training and extension services as a mandatory, budgeted component of every technology and infrastructure investment addressed in this Action Plan.
- Build monitoring systems that separately track access, institutional coverage, professional completion, and adopted practice, since conflating these measures obscures where the real implementation gap lies.
- Prioritise regionally adapted delivery models over uniform national mandates, recognising that climate, farm scale, and social and economic capacity vary widely across producers and communities.
- Use Türkiye's COP31 presidency to establish an international peer-learning mechanism through which national climate-education and agricultural-extension frameworks can be compared, evaluated, and improved (UNFCCC, 2026).

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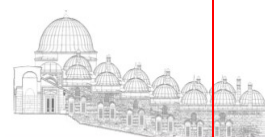
CHAPTER 6

CLIMATE IMPLEMENTATION BRIDGE

Abstract

The Climate Implementation Bridge (CIB) is the country-driven initiative developed under the COP31 Presidency to accelerate the translation of climate commitments into delivered outcomes. It is deliberately not a new fund, a new financing mechanism, an implementation agency or a coordination platform; it is a delivery instrument that improves the performance of the climate finance and implementation ecosystem that already exists. This chapter sets out the evidence base for that design choice and the operational structure through which it works. Global climate finance passed USD 2 trillion for the first time in 2024 and is estimated at USD 2.1 trillion in 2025, but annual growth has decelerated from 30% in 2021 to 6% in 2024 and an estimated 2-3% in 2025, against a requirement of at least USD 6.2 trillion a year by 2035. Of that finance, 85% is mobilised inside the countries where it is spent. The binding constraint is therefore not only the aggregate supply of capital but the country-level capacity to convert national priorities into portfolios that capital can be deployed into at an acceptable cost. Four constraints are quantified: pipeline attrition, with roughly 70% of projects in emerging market and developing economies never advancing beyond feasibility; the cost of capital, at 9.7-13.1% for utility-scale solar across the surveyed developing economies against 4.0-4.9% in Europe, the United States and China; currency mismatch, where hedging costs frequently offset the interest-rate advantage of foreign-currency lending; and scale mismatch, with 47% of city climate projects disclosed in 2024 costing under USD 1 million against investment thresholds that commonly begin at USD 1.5-7 million. CIB responds through three operational components: Robust National Architecture, Project Preparation and Finance Design. These are activated by country demand and delivered with existing partners including the NDC Partnership, UNDP, Climate Compatible Growth, the 2050 Pathways Platform, multilateral development banks and the climate funds. The chapter proposes a phased delivery path from COP31 in Antalya to 2035, a stakeholder map organised by function rather than by institutional category, and six actions for the COP31 negotiation and implementation agenda.

Keywords: Climate finance, Nationally determined contributions (NDC), Carbon pricing, Investable project portfolios, COP31



6.1. Introduction

The international climate regime has an implementation problem that is no longer primarily a problem of pledging. The UNEP (2025) Emissions Gap Report projects warming of 2.3-2.5°C on full implementation of nationally determined contributions (NDCs) and 2.8°C on current policies, an improvement of roughly 0.3°C on the previous year, of which methodological updates account for about 0.1°C and which the forthcoming withdrawal of the United States from the Paris Agreement is expected to erode by a further 0.1°C. The new NDCs themselves therefore move the projection very little. The 2025 NDC synthesis report records 64 new or updated NDCs submitted between 1 January 2024 and 30 September 2025, covering approximately 30% of global emissions in 2019, and projects 2035 emissions 17% (11-24%) below the 2019 level (UNFCCC, 2025a). Plans exist. Adaptation planning has advanced in parallel: as at 1 September 2025, 64 developing countries had submitted National Adaptation Plans (NAPs), among them 22 least developed countries (LDCs) and 14 small island developing States (SIDS), alongside 11 developed countries (UNFCCC, 2025b).

The financing picture has also improved in aggregate. Global climate finance crossed USD 2 trillion for the first time in 2024, with USD 2.1 trillion estimated for 2025 (Climate Policy Initiative [CPI], 2026). Mitigation finance reached USD 1.9 trillion in 2024, private flows exceeded USD 1.2 trillion at a compound annual growth rate of 19% between 2019 and 2024, and emerging market and developing economies (EMDEs) excluding China and the LDCs were the fastest-growing country grouping, at a 25% compound annual growth rate between 2022 and 2024.

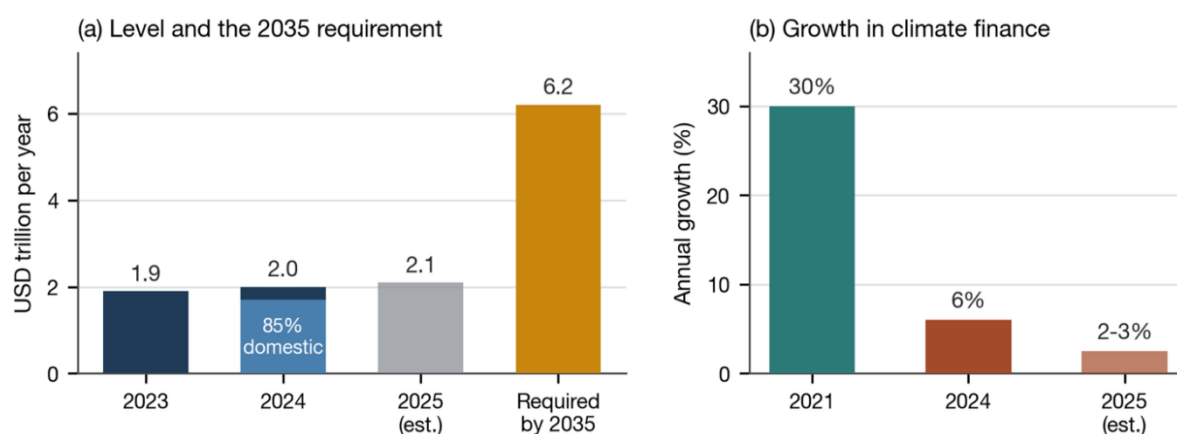
Two features of that aggregate should discipline how the problem is framed. The first is deceleration. Annual growth in climate finance has decelerated from a 30% surge in 2021 to 6% in 2024 and an estimated 2-3% in 2025, against a requirement of at least USD 6.2 trillion annually by 2035 (CPI, 2026). The Independent High-Level Expert Group on Climate Finance (IHLEG) puts the investment requirement for developing countries other than China at USD 2.3-2.5 trillion a year by 2030 (IHLEG, 2024), rising to USD 3.2 trillion a year by 2035 (IHLEG, 2025). Closing a gap of that size through incremental growth of the present trajectory is not arithmetically plausible.

The second is where the money actually comes from. More than USD 1.7 trillion was mobilised through domestic markets in 2024, or 85% of global climate investment (CPI, 2026). That share is not evenly distributed, and the distribution is itself the argument. In the three regions that mobilised the most climate finance, 89% was raised domestically; in regions containing more EMDEs the domestic share falls to 53%, and in Sub-Saharan Africa to 23%, with 77% coming from abroad (CPI, 2025). International climate finance to EMDEs was USD 196 billion in 2023, 78% of it from public actors. CPI's own prescription for regions with low domestic flows opens



with strengthening institutional capacity and policies, which is the content of Climate Implementation Bridge’s first component. The IHLEG’s own 2035 pathway assumes the same structure: of the USD 3.2 trillion required annually by 2035 in developing countries other than China, around 60% “could be financed internally,” leaving USD 1.3 trillion to be met from external sources. That is a sevenfold increase on the roughly USD 190 billion mobilised in 2022 (IHLEG, 2025).

This has a direct design implication. If the majority of climate investment is raised and deployed inside national financial systems, then the decisive constraint is the capacity of national institutions to originate, prepare, aggregate and de-risk investable propositions, and the terms on which domestic and international capital can meet them. International transfers matter, and they matter most where domestic capacity is weakest; but a design that treats the problem solely as a transfer problem addresses a minority of the flow. The IHLEG makes the connection explicit in noting that public, private and concessional sources are mutually supporting because together they “reduce risk and the cost of capital” (IHLEG, 2025). Cost of capital is the variable that determines whether a prepared project is financeable at all. Figure 6.1 presents both features together.



Sources: Climate Policy Initiative, *Global Landscape of Climate Finance 2026* (2024, 2025 estimate, growth rates, domestic share, 2035 requirement); *Global Landscape of Climate Finance 2025* (2023).

Figure 6.1 Global climate finance: level, composition and growth (CPI, 2026; CPI, 2025)

This is the gap the CIB addresses: not the absence of capital in the system, and not the absence of plans, but the absence of a reliable conversion process between the two at country level. The COP31 Presidency has been explicit that the response is not another funding vehicle. Presenting the COP31 Action Agenda at the Bonn Climate Change Conference in June 2026, COP31 President-designate Murat Kurum stated that the CIB “is not a new fund. It is not a new financing mechanism. Nor is it an alternative to existing initiatives,” describing it instead as a complementary initiative that supports the existing climate finance and implementation ecosystem and strengthens partnerships among actors (COP31 Presidency, 2026b). The English-language record of the same press conference reports the objective more briefly, as



supporting countries in turning their NDCs into investable project portfolios (COP31 Presidency, 2026c). Unveiling the initiative at the Climate Resilience Finance Summit during London Climate Action Week in June 2026, Minister of Treasury and Finance Mehmet Şimşek framed the objective as helping countries “move from climate plans to investment-ready projects and from financing needs to bankable pipelines,” and stated that the goal is not to create a new platform or institution (TRT World, 2026; Türkiye Today, 2026).

Section 6.2 sets out what CIB is and how it is structured. Section 6.3 provides the evidence base for the four constraints it is designed to relieve. Sections 6.4 to 6.8 address delivery, stakeholders, resourcing, actions and conclusions.

6.2. Content of the Action Plan

6.2.1. Defining the CIB

The Climate Implementation Bridge, developed under the COP31 Presidency, is a country-driven initiative designed to accelerate the translation of climate commitments into tangible outcomes. Countries have set ambitious goals through NDCs, NAPs and long-term strategies, but implementation continues to face limited institutional capacity, fragmented investment opportunities, and insufficient alignment between policy priorities and financing solutions. CIB addresses these by strengthening the connection between national climate priorities, investment opportunities, and financing partners (COP31 Presidency, 2026a).

The initiative is defined as much by what it declines to be. It does not create a new financing mechanism, a new implementation agency, or a new coordination platform. It functions as a practical implementation tool that improves how the existing climate ecosystem performs. Building on existing initiatives and delivery systems, it works in partnership with governments, international organisations, development banks, climate funds and private sector actors to support country-led implementation, and complements the work of institutions including the NDC Partnership, UNDP, Climate Compatible Growth (CCG), the 2050 Pathways Platform, the multilateral development banks (MDBs) and the climate funds. The stated aim is to help countries move from planning to implementation while explicitly avoiding duplication of existing mandates and structures (COP31 Presidency, 2026a).¹

¹ The word “mechanism” appears in Presidency texts in a non-technical sense. The April 2026 concept note refers throughout to “a mechanism to better connect national priorities with investment and delivery”, while stating in the same paragraph that it “is not a new climate fund, nor is it a replacement for existing coordination platforms or initiatives” (COP31 Presidency, 2026f). The sixth global implementation goal is stated as expanding the “CIB Mechanism” by 2035 (COP31 Presidency, 2026e), and the cooperation architecture page calls CIB “a pivotal mechanism” for the distribution of climate finance (COP31 Presidency, 2026d). All of these texts nevertheless describe CIB as complementary, and the later public description settles on “initiative” and “practical implementation tool”. This chapter follows the CIB’s own operational description, which states that CIB does not create a new financing mechanism and functions as an implementation tool within the existing ecosystem (COP31 Presidency, 2026a), consistent with the President-designate’s statement at Bonn that it “is not a new fund ... not a new financing mechanism” (COP31 Presidency, 2026b) and the Minister of Treasury and Finance’s statement in London (TRT World, 2026). The term “initiative” is therefore used throughout.



The Presidency's account of its wider cooperation architecture is consistent with this. There, CIB appears as one of four strategic pillars, alongside the Türkiye-Australia partnership model, the global sectoral alliances and the urban resilience workstream. It is described as a complementary initiative conceived to facilitate the transition of NDCs into "bankable, investment-ready projects aligned with international financial standards" (COP31 Presidency, 2026d). The reference to international financial standards is not incidental: it identifies the specific form the conversion has to take if capital is to be deployed against it, and it is the basis of Action 1 in Section 6.7.

This positioning is a substantive design choice, not presentational modesty. A new fund would compete for public and concessional resources that are already under pressure: public climate finance fell by around 13% between 2022 and 2023 amid constrained domestic budgets, and CPI notes that recently announced cuts to official development assistance raise the concern that public finance may decline further in the coming years (CPI, 2025). A new coordination platform would add a further interface to an ecosystem in which the multiplicity of finance providers, each with its own disbursement process, already raises transaction costs for recipients (CPI, 2024). CIB is designed to raise the throughput of the existing system rather than to enlarge its institutional surface area.

6.2.2. The Operating Principle: Country-Driven and Demand-Based

Support is shaped around the priorities and genuine demands defined by countries themselves, tailored to national circumstances, capacity and development goals, with national ownership at the centre of delivery (COP31 Presidency, 2026a). This is the entry condition for all CIB engagement, not one workstream among several. It has three practical consequences: CIB does not maintain a standing global project list; engagement begins from a government request tied to an existing NDC, NAP, long-term strategy or national development plan priority; and the sequence and intensity of the three operational components are set by what the requesting country actually lacks.

Demand of this kind is documented and unmet. The NDC Partnership has received more than 1,200 requests from nearly 80 countries for assistance in developing bankable projects, of which approximately half have been supported to date (RMI, 2025).

The concept note places particular weight on what that demand has to be aligned against. It prioritises "strict policy coherence between NDCs, NAPs, and National Development Plans, ensuring that climate targets are inextricably linked to sovereign macroeconomic strategies and positioned as drivers of economic growth" (COP31 Presidency, 2026f). That emphasis separates the initiative from project-level technical assistance. The unit of alignment is the national development and macroeconomic plan rather than the individual project. It also explains the order of the components. A portfolio that is coherent with a country's development plan is a different object from a portfolio that merely lists climate projects.



6.2.3. The Three Operational Components

The CIB delivers through three operational components. The Presidency’s concept note for the Implementation Forum session at the 2026 UNFCCC Climate Week names them as three mutually reinforcing components: Robust National Architecture (strategic diagnostics, capacity and digital infrastructure), Project Preparation (bankable and investable pipelines) and Finance Design (mobilizing private capital at scale). Together these “form an end-to-end implementation framework, connecting national strategies with concrete investments and results” (COP31 Presidency, 2026f). The published CIBdescription states the same structure in outcome terms: through its partnership-driven approach, CIB“supports stronger national implementation architecture, advances investment readiness, and facilitates financing partnerships needed to accelerate climate action and deliver measurable implementation outcomes” (COP31 Presidency, 2026a).

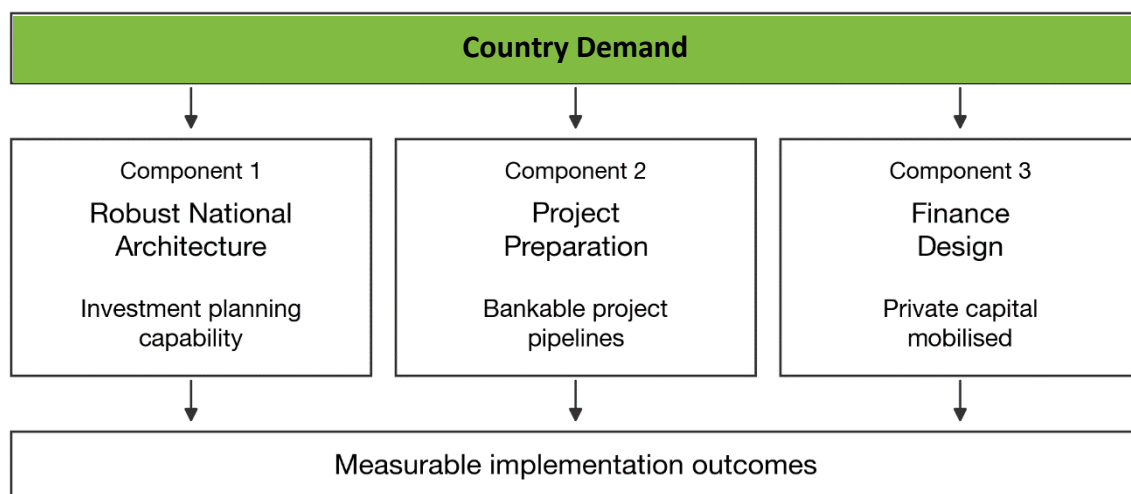
The Presidency’s five published core focus areas map onto the same three components, with country-driven demand-based support operating as the cross-cutting entry condition described above. Table 6.1 sets out the mapping, the function of each component and the outputs against which it can be assessed.

Table 6.1 CIB operational components, mapping to published focus areas, functions and outputs

Operational component (COP31 Presidency, 2026f)	Published focus area (COP31 Presidency, 2026a)	Function	Country-level output
<i>Entry condition:</i> country-driven, demand-based engagement	Country-Driven, Demand-Based Support	Engagement begins from a government request tied to an existing NDC, NAP, long-term strategy or national development plan priority; scope and sequencing set by national circumstances, capacity and development goals	Agreed scope of support and national counterpart designated
Component 1. Robust National Architecture <i>(strategic diagnostics, capacity and digital infrastructure)</i>	National Implementation Architecture	Strengthen data, modelling and institutional coordination capacity; build tools for evidence-based decision-making and mechanisms for cross-institutional cooperation	Functioning inter-ministerial coordination; investment planning capability located in a named institution; decision-grade data, diagnostics and digital infrastructure
Component 2. Project Preparation <i>(bankable and investable pipelines)</i>	Turning NDCs and NAPs into Projects; Bankable Project Pipelines	Translate NDC and NAP priorities into concrete, investment-ready and scalable project portfolios; support bankable, standardised and replicable pipelines through common appraisal criteria and readiness standards that reduce perceived risk	Structured project portfolio meeting public and private investor requirements; aggregated pipelines above minimum investable scale
Component 3. Finance Design <i>(mobilizing private capital at scale)</i>	Mobilising Finance at Scale	Bring together public, private and multilateral sources, including blended finance; position public resources to crowd in private capital	Financing partnerships matched to portfolio segments; de-risking and local-currency solutions arranged with the relevant institutions



The components are sequential in logic but not necessarily in time. A country with strong institutions and a weak pipeline enters at Component 2 (Project Preparation); a country with a prepared pipeline that cannot be financed on viable terms enters at Component 3 (Finance Design). The value of the design is that it does not assume every country presents the same deficit. Figure 6.2 shows the operating model.

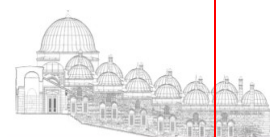


Source: Components per COP31 Presidency concept note (Yeosu, April 2026); focus areas and ecosystem per <https://cop31.tr/action-plan/caim>

Figure 6.2 Climate Implementation Bridge operating model (components per COP31 Presidency, 2026f; focus areas and ecosystem per COP31 Presidency, 2026a)

6.2.4. Boundaries of the Climate Implementation Bridge's Scope

Several agenda items of first-order importance to climate finance fall outside the Climate Implementation Bridge's scope and are addressed elsewhere in the multilateral process: reform of multilateral development bank capital adequacy; reallocation of IMF Special Drawing Rights; the architecture and replenishment of the Loss and Damage Fund; carbon market rules under Article 6; technology transfer and intellectual property arrangements; and sovereign debt restructuring, including debt-for-climate conversions. CIB interfaces with the outcomes of these processes, and a country portfolio may draw on instruments they produce, but it does not seek to determine them. Presenting them as CIB components would misdescribe both the initiative and the negotiation tracks in which they properly sit, and would make CIB's delivery contingent on reforms whose timetable it does not control.



6.3. Rationale

The design in Section 6.2 follows from four constraints that are separately documented and jointly binding. Each breaks a different link in the conversion from national priority to delivered asset. Relieving only one of them does not restore throughput.

6.3.1. Pipeline Attrition: Projects Do Not Survive Preparation

Roughly 70% of projects in EMDEs never move beyond the feasibility stage, and the rate is higher in Africa (RMI, 2025). The evidence from adaptation planning is consistent. Of the 64 developing countries with submitted NAPs as at 1 September 2025, 56 had a combined total of 113 single- and multi-country projects approved for implementation under the Green Climate Fund that explicitly align with NAP priorities. That total covers the full period since 2015 (UNFCCC, 2025b). Among the 22 LDCs with submitted NAPs, 20 accounted for 54 such projects. A decade of adaptation planning across 64 countries has produced approximately two GCF-aligned projects per country.

Institutional friction compounds this. The Green Climate Fund's revised Accreditation Framework, which went live on 31 October 2025, targets a reduction in the time required to accredit regional and national implementing entities from an average of 30 months to nine (Climate Home News, 2025). Separately, and on a different track, the Fund commits to completing its reviews of concept notes and funding proposals "in 9 months or less" (Green Climate Fund, 2025). The direction of reform is correct; the baseline indicates the scale of the delay that national entities have been absorbing.

Component 2 is directed at this link, and Component 1 at the institutional capacity that determines whether preparation can be sustained at all.

6.3.2. Cost of Capital: Viable Projects are Priced Out

Where projects do reach investors, the price of capital frequently determines viability. For utility-scale solar photovoltaic projects reaching final investment decision in 2021, the IEA Cost of Capital Observatory reports a nominal cost of capital of 4.0% in Europe, 4.3% in the United States and 4.9% in China, against 9.7% in Mexico, 9.9% in India, 10.0% in South Africa, 10.1% in Indonesia and 13.1% in Brazil (IEA, 2024).

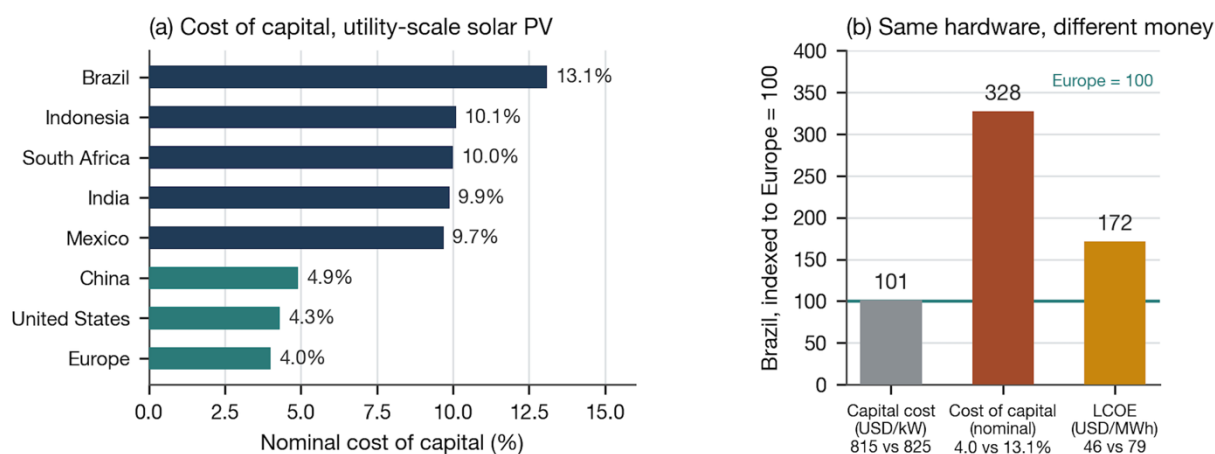
The comparison between Europe and Brazil isolates the effect, because it holds the technology constant. Capital costs per kilowatt were almost identical, USD 815 in Europe against USD 825 in Brazil. But the nominal cost of capital was 4.0% against 13.1%, and the resulting levelised cost of electricity was USD 46/MWh against USD 79/MWh (IEA, 2024). The equipment cost the same; the money did not, and the money is what made the electricity 72% more expensive.



The gap has not closed since. The IEA’s assessment of its 2024 survey is that the cost of capital for renewable power projects and batteries in EMDEs remains at least double that of advanced economies, with risk drivers pushing financing costs to two to three times advanced-economy or Chinese levels (IEA, 2025b).

The composition of that premium matters for what can be done about it. For solar PV, the country base rate accounts for 60-90% of total cost of capital in Africa, compared with 35% in China and 10% in advanced economies (IEA, 2025a). Most of the premium is therefore attributable to country-level and macro-financial risk rather than to technology or project-specific risk, which is precisely the category that project structuring, guarantees, blended concessional capital and credible national frameworks can address. In Kenya and Senegal, energy-sector businesses seeking domestic capital have faced rates above 15% with tenors too short for the assets being financed (IEA, 2025a). The same commentary records Kenya’s state utility delaying payments in 2023 because it could not source US dollars and euros. That is the currency constraint of Section 6.3.3 appearing inside an energy balance sheet.

Because renewable generation is capital-intensive and its levelised cost is dominated by financing charges, this differential is not a marginal consideration. It changes which projects clear an investment hurdle at all. Figure 6.3 presents the gap.



Sources: IEA, *Cost of Capital Observatory, Tools and analysis: “Breakdown of LCOE of utility-scale solar PV in selected countries, 2021”*.

Figure 6.3 Cost of capital for utility-scale solar PV, projects reaching final investment decision in 2021 (IEA, 2024)

6.3.3. Currency Mismatch: Hedging Cancels the Concession

Development and climate finance is frequently extended in foreign currency to borrowers whose revenues are in local currency. The resulting exposure is either carried unhedged, transferring balance-sheet risk to the borrower and ultimately to the sovereign, or hedged at a



cost that erodes the benefit of the loan. CPI's assessment is that commercial products to hedge currency risk are often costly for borrowers in EMDEs, and that hedge costs often fully offset the lower interest rates available on foreign-currency loans (CPI, 2023). Local capital markets in EMDEs can supply only about half of the funds required for the climate transition, so the exposure cannot simply be avoided by borrowing domestically.

Institutional solutions exist but are not at scale relative to the need. The Currency Exchange Fund (TCX), established in 2007 by a consortium of development finance institutions, governments and donors, offers hedges in currencies and tenors where commercial alternatives are absent. Working across more than 140 frontier and emerging market currencies, it had helped clients obtain more than USD 10 billion in local-currency funding by 2024 and had transferred over USD 3.5 billion of hedging exposure to private counterparties, on a capital base of USD 1.8 billion (OECD, 2025). Set against annual EMDE requirements measured in trillions, dedicated hedging capacity of this order is a small fraction of what a scaled climate programme would need. The implication is that local-currency structuring belongs in portfolio design from the outset, rather than being treated as a separate market to be tapped afterwards.

This constraint sits squarely within Component 3. It is also the constraint most often omitted from implementation proposals, because it is invisible at the level of headline commitments and appears only when a specific project is being priced.

6.3.4. Scale Mismatch: Projects Are too Small to be Financed

A large share of climate investment need arises at a scale below the minimum ticket size of the institutions that could finance it. Of more than 1,700 climate projects with cost estimates disclosed by local governments through CDP-ICLEI Track in 2024, 823 of them, or 47%, were reported to cost less than USD 1 million each (CDP, 2025). Against this, the Brazilian Development Bank applies a minimum investment threshold of approximately USD 7 million for municipal lending; the Climate Investment Funds' Smart Cities Program targets USD 30-100 million per participating city; multilateral development banks and international financial institutions engaging with the Covenant of Mayors - Eastern Partnership typically seek projects of at least EUR 5-15 million; and project preparation facilities that publish thresholds set minimums ranging from USD 1.5 million to USD 26 million depending on sector and stage (CDP, 2025).

The same pattern appears in the instrument mix. Between 2019 and 2022, the average ticket size was USD 3 million for grant-financed projects and USD 74 million for projects financed by low-cost debt, and small ticket sizes deter large institutional investors, leaving financing to public development finance institutions and aid agencies (CPI, 2024).



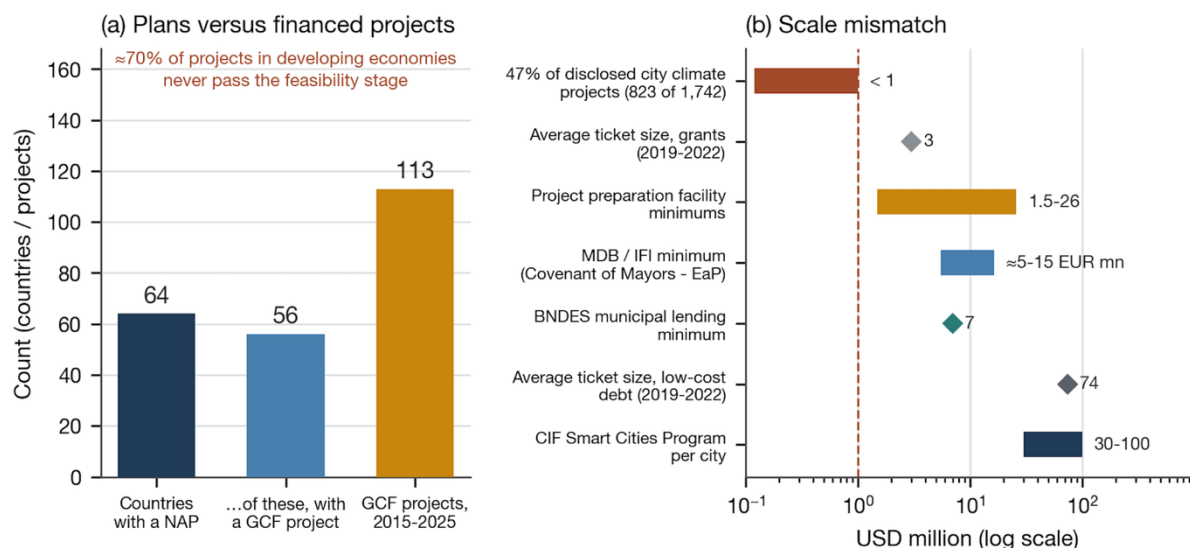
The response is aggregation: bundling projects to reach investable scale, reduce per-unit transaction costs and permit portfolio-level risk assessment. Sub-national governments are well placed to perform it, since they can consolidate fragmented municipal needs into coordinated pipelines. In February 2026, an investment roundtable convened by three Brazilian states presented a pipeline of approximately USD 1.4 billion built from nine developed project concepts, of which seven entered bilateral discussions with financiers (Climate Group, 2026). Aggregation is a core function of Component 2 and a precondition for Component 3. Table 6.2 consolidates the evidence.

Table 6.2 *Binding constraints, evidence and CIBresponse*

Constraint	Evidence	Source	CIB component
Pipeline attrition	~70% of EMDE projects never pass feasibility; 64 countries with NAPs yielded 113 GCF-aligned projects since 2015; GCF accreditation reform targets 30 → 9 months	RMI (2025); UNFCCC (2025b); GCF (2025)	Components 1 and 2
Cost of capital	Utility-scale solar cost of capital 9.7-13.1% across surveyed EMDEs vs 4.0-4.9% in Europe, the US and China; Europe vs Brazil: near-identical capital cost but 3.3× the cost of capital and 1.7× the LCOE; country base rate = 60-90% of cost of capital in Africa vs 10% in advanced economies	IEA (2024, 2025a, 2025b)	Components 1 and 3
Currency mismatch	Hedging costs often fully offset the lower rates on foreign-currency loans; local markets can supply ~50% of EMDE transition needs; TCX had enabled >USD 10 bn of local-currency funding by 2024 on a USD 1.8 bn capital base	CPI (2023); OECD (2025)	Component 3
Scale mismatch	47% of disclosed city climate projects cost < USD 1 mn; financing thresholds commonly USD 1.5-7 mn and above; average ticket size USD 3 mn (grants) vs USD 74 mn (low-cost debt)	CDP (2025); CPI (2024)	Component 2

Figure 6.4 shows the conversion funnel and the scale mismatch together.





Sources: UNFCCC, *National adaption plans, status as at 1 September 2025*; RMI (2025); CDP (2025), *Briefing on city project aggregation*; CPI (2024), *Understanding global concessional climate finance*.

Figure 6.4 From national plans to financed projects: attrition and scale mismatch (RMI, 2025; UNFCCC, 2025b; CDP, 2025)

6.3.5. Legal and Political Basis

CIB operates within the existing framework rather than seeking new mandates. Article 2.1(c) of the Paris Agreement commits Parties to making finance flows consistent with low-emission, climate-resilient development, and Article 9 defines climate finance obligations; the alignment of national climate priorities with investment decisions is a direct expression of the former. The first Global Stocktake and the UAE Consensus adopted at COP28 shifted the negotiation agenda towards implementation, and the New Collective Quantified Goal adopted at COP29 set a floor of USD 300 billion per year by 2035 within a broader call to scale finance to USD 1.3 trillion (UNFCCC, 2024). CIB is a means of improving the conversion rate of whatever those decisions ultimately deliver. Its rationale therefore does not depend on the level at which they settle.

6.4. Timeline

Sections 6.4, 6.6 and 6.7 are the working group's technical contribution, offered for the Presidency's consideration. They describe what the evidence in Section 6.3 implies for sequencing, resourcing and negotiation priorities; they do not report agreed CIB plans, and where the Presidency and its partners have already settled these questions, their decisions govern.



Table 6.3 Proposed CIB delivery phases and indicators, 2026-2035²

Phase	Focus	Milestones	Proposed indicators
Phase 1: Establishment (2026-2028)	Operationalising the initiative and demonstrating the model	CIB launched at COP31 Antalya; engagement protocol and common readiness criteria agreed with delivery partners; first cohort of requesting countries engaged; first aggregated portfolios structured and taken to market	Number of countries with an agreed scope of support; number of portfolios structured; median time from request to structured portfolio
Phase 2: Consolidation (2028-2032)	Standardisation and replication	Common appraisal and readiness standards adopted across participating partners; local-currency and de-risking solutions integrated into portfolio structuring as standard practice; aggregation applied at sub-national and sectoral level	Share of structured portfolios reaching financial close; volume of finance committed to CIB-supported portfolios; share of portfolios with local-currency or hedged structures
Phase 3: Scale (2032-2035)	Routine national capability	Robust national architecture functioning without external facilitation in participating countries; portfolio origination embedded in national investment planning cycles	Share of participating countries originating portfolios independently; share of NDC/NAP priorities covered by a financed or structured portfolio

CIB delivery is proposed in three phases anchored to the COP31 process, which convenes in Antalya from 9 to 20 November 2026. Phase indicators are framed around CIB's own delivery: countries engaged, portfolios developed, financing partnerships closed. They are not framed around global finance aggregates, which CIB influences but does not control. Table 6.3 sets out the phasing.

The sequencing reflects the logic of the components. Phase 1 establishes that the conversion process works in a defined set of countries. Phase 2 standardises it so that it can be replicated without bespoke effort in each case. Phase 3 transfers the capability to national institutions, at which point CIB's facilitation role in those countries should diminish. An instrument that does not plan for its own redundancy in the countries it works with has misunderstood the problem.

6.5. Stakeholders

CIB works through partnerships rather than through a new institutional structure, so the relevant question is not which organisations are associated with it but which function each performs against which component. Table 6.4 maps the ecosystem on that basis. The selection criterion is functional: an actor appears because it performs a task the components require, and because it is already mandated and resourced to perform it.

² The phases, milestones and indicators in this table are proposed by the working group as a delivery framework for CIB. They are not projections of global climate finance volumes and are not drawn from an external forecast. Baseline values for the constraints CIB addresses are given in Section 6.3 with their sources.



Table 6.4 CIB stakeholder ecosystem by function

Component	Function required	Actors performing it
<i>Entry condition</i>	Define and prioritise national demand; designate counterpart; hold ownership of scope	Requesting national governments, typically finance/treasury, planning and environment/climate ministries acting jointly
Component 1. Robust National Architecture	Strategic diagnostics; institutional coordination; data, modelling and digital infrastructure; investment planning capability	NDC Partnership; UNDP; Climate Compatible Growth; 2050 Pathways Platform; national statistical and planning institutions; national academies and research institutions (including TÜBA in the Turkish context)
Component 2. Project Preparation	Project origination and structuring; common appraisal and readiness criteria; aggregation to investable scale; preparation finance	Project preparation facilities; MDBs and national development banks; the climate funds (GCF, Adaptation Fund, GEF, Climate Investment Funds); sub-national and municipal authorities as aggregators; sectoral line ministries
Component 3. Finance Design	Capital provision; risk mitigation and credit enhancement; currency risk management; investability signalling	MDBs and development finance institutions; local and regional financial institutions; export credit agencies; guarantee providers; currency hedging providers such as TCX; institutional investors; credit rating agencies and financial regulators
Cross-cutting	Transparency, measurement and learning	UNFCCC Secretariat; COP31 Presidency; data and research organisations

Three points on the composition. First, the actors named in Component 1 are those the Presidency has explicitly identified as institutions whose work CIB complements (COP31 Presidency, 2026a); their inclusion follows from that positioning, not from a fresh allocation of roles. Second, Component 3 includes categories of actor that are frequently absent from climate finance stakeholder maps but determine whether a transaction closes: export credit agencies, credit rating agencies, financial regulators and local financial institutions. The Minister of Treasury and Finance specifically called on these actors to take an active role alongside the MDBs when presenting the initiative (TRT World, 2026; Türkiye Today, 2026). Third, the ecosystem is not fixed: because engagement is country-driven, the operative set of partners differs by country and by portfolio, and the map above should be read as the population from which a country-specific configuration is drawn. The working configuration is observable: the Presidency's Implementation Forum session on the design convened Climate Compatible Growth, the NDC Partnership, UNDP, the GEF, the Green Climate Fund, the Asian Development Bank, UNEP, the Global Capacity Building Coalition and the Pacific Resilience Facility alongside the COP30 Presidency and the UNFCCC secretariat, with government participation from developing countries (COP31 Presidency, 2026f).



Two features of how that ecosystem works follow from the country-driven principle and distinguish CIB from a conventional governance chart. Partners contribute across the process, not at a handover point. The table assigns each actor to the component where its contribution is decisive, but the engagement is continuous rather than sequential. A national development bank that will ultimately lend into a portfolio has an interest in how the appraisal criteria are set under Component 2 and in whether the institutional capacity exists under Component 1; a rating agency's view of a portfolio structure is more useful while the structure is being designed than after it is presented. The components describe where a contribution bites, not a relay in which each actor appears once and withdraws.

The configuration is assembled per country, not applied as a template. Because the entry condition is a government request shaped by national circumstances, the partner set is composed for that request. Which line ministries participate, which development bank leads, whether local financial institutions or export credit agencies are central, and whether hedging capacity is needed at all are country questions answered during engagement. CIB's coordination task is to convene the configuration a given country needs from partners already active in it. That is the difference between mobilising an existing ecosystem and constituting a new governance structure.

When presenting the initiative, the Minister of Treasury and Finance identified five areas as requiring resilience investment: water management, climate-smart agriculture, sustainable land use, resilient infrastructure and healthy ecosystems (Türkiye Today, 2026). These indicate the kinds of configuration that early engagements are likely to need, and which line ministries and specialist institutions they would draw in. They are an indication of demand, not a declared CIB portfolio list.

6.6. Budget and Financing

CIB's resourcing question is distinct from the climate finance gap it helps to close, and conflating the two has been a persistent source of confusion about the initiative. CIB does not hold, disburse or intermediate capital. It requires resourcing for facilitation: technical assistance to national institutions under Component 1; project preparation and structuring support under Component 2; and transaction facilitation under Component 3. Existing partners already fund these categories. CIB's incremental cost is therefore a coordination and technical assistance cost rather than a capital cost. Project development typically represents a small share of total project cost while determining whether the remainder is ever committed; the constraint on preparation is chronic underfunding rather than an inability to identify need, as the record of 1,200 unmet and partially met requests to the NDC Partnership demonstrates (RMI, 2025).

The financing that CIB is designed to unlock comes from three sources already present in the system:



- **Domestic capital**, which accounted for more than USD 1.7 trillion, or 85%, of global climate investment in 2024 (CPI, 2026). Its regional depth varies sharply, from 89% of flows in the three largest recipient regions to 53% in regions containing more EMDEs and 23% in Sub-Saharan Africa (CPI, 2025). Component 1 and the local-currency work under Component 3 are directed at this pool, and are worth most where it is thinnest.
- **Private capital**, which exceeded USD 1.2 trillion globally in 2024 and grew at 19% annually from 2019, with commercial financial institutions reaching USD 572 billion (CPI, 2026). Component 2's standardisation and aggregation work is what makes this pool addressable at the project level.
- **Public and concessional capital**, including the climate funds and MDB resources. Because public climate finance fell by around 13% between 2022 and 2023 and further decline is a live concern given announced cuts to official development assistance (CPI, 2025), the priority for concessional resources is to be positioned where they change the terms of a transaction: preparation, first-loss, guarantees and hedging. They should not be substituted for commercial capital.

Two allocation principles follow. Grant and concessional resources should be directed to project preparation and to risk mitigation, where the effect on subsequent commercial capital is greatest and where the shortfall is best evidenced. And in adaptation and in the most debt-constrained countries, support should remain grant-weighted, because instruments that add to debt service in countries already allocating a substantial share of public revenue to it will not produce net implementation.

6.7. Action Plan

Six actions are proposed to give CIB operational form through the COP31 process. Each is scoped within the three components and does not extend CIB into negotiation tracks it does not own. As with Section 6.4, these are proposals from the working group rather than a record of decisions already taken.

Figure 6.5 sets the six actions against the components they work through and the constraints they are meant to relieve.





Figure 6.5 Six proposed actions for the Climate Implementation Bridge, mapped to components and constraints (working group proposal)

Action 1

Adopt a common readiness and appraisal standard

Agree, with the MDBs, the climate funds and the project preparation facilities, a shared set of readiness criteria and appraisal requirements so that a portfolio prepared once can be presented to multiple financiers without restructuring. This directly targets the transaction costs created by a multiplicity of providers each operating its own process (CPI, 2024); it is the precondition for the standardised, replicable pipelines described in the Presidency’s focus areas (COP31 Presidency, 2026a); and it is what gives operational content to the requirement that projects be “aligned with international financial standards” (COP31 Presidency, 2026d).

Action 2

Establish a country engagement protocol

Define how a country request is received, scoped, matched to delivery partners and tracked, with a published median time from request to structured portfolio. The protocol should route requests to existing partners by default and record where no partner has capacity, so that unmet demand becomes visible rather than being absorbed silently, as a substantial share of the 1,200 requests to the NDC Partnership has been (RMI, 2025).



Action 3

Build aggregation into portfolio structuring

Adopt aggregation as a standard step rather than an exception, with explicit support for sub-national and sectoral bundling to lift projects above the minimum investable thresholds documented in Section 6.3.4. Given that 47% of disclosed city climate projects fall below USD 1 million against thresholds that commonly begin at USD 1.5-7 million (CDP, 2025), aggregation is the difference between a real need and a financeable one.

Action 4

Integrate currency risk management into portfolio design

Treat local-currency financing and hedging as a design parameter at the point of structuring rather than as a downstream problem for the borrower, working with hedging providers, national development banks and local financial institutions. Where hedging costs would fully offset the concessionality of a foreign-currency loan (CPI, 2023), the structure should be reconsidered before the transaction is presented rather than after.

Action 5

Address the cost of capital through the components that can move it

Since the country base rate accounts for 60-90% of the solar PV cost of capital in Africa against 10% in advanced economies (IEA, 2025a), the largest available reductions come from credible national frameworks and offtake arrangements (Component 1), standardised structuring that lowers perceived project risk (Component 2), and guarantees, first-loss capital and credit enhancement (Component 3). Engaging credit rating agencies and financial regulators on how CIB-standard portfolios are assessed is part of this action.

Action 6

Publish delivery transparently

Report against the indicators in Table 6.3 through existing UNFCCC and Presidency reporting channels: countries engaged, portfolios structured, financing partnerships closed, and time from request to structured portfolio. Because CIB's claim is that it improves the throughput of the existing system, that claim should be falsifiable against published delivery data.



6.7.1. Türkiye's Contribution under the COP31 Presidency

COP31 is led under a shared arrangement in which H. E. Murat Kurum serves as COP31 President-designate and Chris Bowen as COP31 President of Negotiations, and the Presidency identifies the institutional cooperation framework established between Türkiye and Australia through the preparatory process as the first of its four strategic cooperation pillars (COP31 Presidency, 2026d). CIB is a Presidency initiative in that shared sense, and the contribution described here is Türkiye's within it rather than a separate national programme.

Türkiye's contribution to CIB follows from the Presidency rather than from a separate national structure. It has three elements. First, convening: the Presidency provides the political weight, visibility and access that bring delivery partners and financiers to the same table, which was the explicit basis of the Minister of Treasury and Finance's call to export credit agencies, credit rating agencies, regulators and local financial institutions in London (TRT World, 2026). Second, demonstration: Türkiye's own experience in aligning climate objectives with investment planning, including its 2053 net-zero target and its sovereign and participation-finance green issuance, provides a working reference for the Component 1 and Component 3 questions that partner countries face. Third, scientific input: TÜBA's assessment of new energy technologies, which spans renewables, hydrogen, storage, smart grids and carbon capture alongside energy policy and innovation strategy (TÜBA, 2025), together with its work on circular production and green transition alignment (TÜBA, 2023), provides an evidence base for the technology and production dimensions of portfolio development, and the Academy's working groups can supply the independent scientific assessment that Component 1's evidence-based decision-making requires.

6.8. Conclusions

The gap between climate commitments and delivered outcomes is not primarily an information gap or, at the margin now binding, an aggregate capital gap. Global climate finance passed USD 2 trillion in 2024, 85% of it mobilised domestically, while roughly 70% of projects in developing economies never advance beyond feasibility and a decade of adaptation planning across 64 countries has produced approximately 113 GCF-aligned projects. Capital and plans coexist with a conversion process that fails.

The CIB is designed against that diagnosis. It is a country-driven initiative, activated by national demand, that works through three operational components, Robust National Architecture, Project Preparation and Finance Design, to raise the throughput of the climate finance and implementation ecosystem that already exists. It is not a fund, not a financing mechanism, not an implementation agency and not a coordination platform, and the decision not to be any of these is what allows it to complement rather than compete with the NDC Partnership, UNDP, Climate Compatible Growth, the 2050 Pathways Platform, the MDBs and the climate funds.



The constraints it must relieve are specific and measurable: attrition in project preparation, a cost of capital two to three times advanced-economy levels driven predominantly by country-level risk, currency mismatch that cancels the value of concessional lending, and a scale mismatch between where climate investment need arises and where financing thresholds begin. These are unglamorous constraints, and they are absent from most high-level climate finance proposals precisely because they only become visible at the point where a specific project is priced. They are also the constraints a delivery instrument can actually act on.

The test of CIB is equally concrete. Not how much finance is pledged, but how many countries convert a national priority into a structured portfolio, how quickly, on what terms, and how much of that portfolio reaches financial close. Reporting against those measures would establish COP31's claim to be an implementation COP. It would also make the claim disprovable, which is the more demanding and the more useful standard.

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CHAPTER 7

CONCLUSION

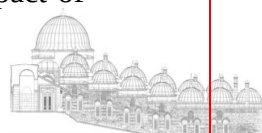
The six chapters of this Synthesis Report examine various aspects of the global climate transition, including power, waste, cities, industry, people and finance. However, they all reach the same conclusion: the technical and economic pathways to achieving the COP31-2035 Global Implementation Goals are well defined and, in most cases, are already underway. Nevertheless, the current pace of progress still falls short of what is required by the science and the targets. Closing this gap requires accelerating the deployment of existing solutions, backed by the financial and institutional capacity to implement them at a country level. The evidence assembled on electrification, zero waste, methane reduction, climate-resilient cities, green industrialisation, climate education and the Climate Implementation Bridge (CIB) is summarised below, together with each chapter's outlook for the road to 2035.

7. 1. Electrification

Electricity already accounts for around 21% of global final energy consumption. Yet it powers sectors representing over 40% of the global economy and demand is growing at roughly four times the rate of overall energy demand. This will add nearly 1,000 TWh a year until 2035. The report's central finding is that increasing electricity's share of final consumption to 35% by 2035 is technically feasible and economically advantageous. This would require the share of renewable energy in generation to rise from around one-third to over half, unabated fossil fuel generation to fall from 59% to around 13%, and roughly USD 3.3 trillion in annual energy investment to continue tilting towards grids, storage, and end-use electrification. Looking to the future, the chapter makes it clear that the transition will not happen by itself. Closing the electrification gap for the 730 million people who still do not have access to electricity, building the grid flexibility and critical mineral supply chains that the system needs and sequencing investment ahead of demand rather than behind it are all conditions that depend on each other.

7.2. Zero Waste and Methane Reduction

Global municipal solid waste (MSW) is projected to grow from 2.56 billion tonnes in 2022 to 3.86 billion tonnes by 2050. The waste sector currently accounts for around 20% of global anthropogenic methane emissions, primarily from the anaerobic decomposition of organic waste in landfills. Türkiye's scenario-based life cycle assessment demonstrates the impact of



sustained investment in waste recovery: the sector's carbon intensity decreased from 351 kg CO₂-eq per tonne of waste in 2014 to 61 kg CO₂-eq per tonne in 2021 and is projected to reach a net-negative value of -175 kg CO₂-eq per tonne by 2035 under the national 60% recovery target. Nevertheless, the findings presented in this chapter indicate that, despite this considerable decarbonisation, achieving the COP31 goal of halving waste generation growth by 2035 in Türkiye will require not only continued investment in waste recovery but also a structural shift from waste management to resource management, built on circular economy principles, waste prevention, source separation, and the integration of the waste sector into climate policy frameworks.

7.3. Climate Resilient Cities

Buildings and construction account for around 37% of global CO₂ emissions, 28% of final energy consumption, and nearly half of global material extraction. Meanwhile, global floor area reached 273 billion m² in 2024 and continues to expand by more than 5 billion m² a year. Since 2015, energy use intensity in buildings has improved by only about 1% annually, which is well short of the 2.5–3% a year required by a Paris-aligned pathway. This is the basis for the COP31 target of reducing building energy use intensity by at least 25%, and preferably 35%, by 2035. This chapter frames efficiency and resilience as inseparable, proposing nearly zero-energy codes for new construction and the deep renovation of 2–3% of existing buildings annually. Other measures include heat pumps, thermal storage and AI-supported building operation. These must be paired with resilience measures for urban heat, critical-facility energy security and the water–energy nexus. This is particularly urgent for informal settlements and hot-climate cities, as the choices made this decade will determine the outcomes for generations of future buildings.

7. 4. Green Industrialisation: Circular Material Utilisation

Industry accounts for almost 37% of global final energy consumption and around 24% of energy-related CO₂ emissions. Meanwhile, annual global material extraction has more than tripled since 1970, rising from approximately 30 billion tonnes to over 106 billion tonnes by 2024. The COP31-2035 target is to increase the utilisation of circular materials to at least 15% by 2035 through cleaner production, industrial symbiosis, digital manufacturing, and the integration of renewable energy into industrial processes. This chapter frames this target as part of a broader transformation, rather than a standalone solution. It calls for coordinated investment in advanced recycling infrastructure, digital monitoring of material flows and supportive regulation. It argues that circular material utilisation only delivers its full climate value when pursued alongside industrial decarbonisation and resource efficiency measures, not instead of them.



7.5. Raising Awareness and Education on Climate Change

This chapter considers climate education and climate-resilient agricultural training to be the foundation upon which the other four areas ultimately depend. The technology, capital and regulation addressed elsewhere in the report will only deliver results if those operating, financing, regulating and using these systems are knowledgeable and capable. The COP31 target is to ensure that climate change and climate-resilient farming training reaches 100% of society by 2035. This will be achieved through formal education, professional extension services, and lifelong learning, paying particular attention to children, teachers, and vocational and technical education. As a working template, this chapter presents the institutional groundwork of the Republic of Türkiye, which includes a Ministry of National Education climate action plan spanning ten thematic areas, a piloted health-sector climate curriculum, and a National Adaptation Strategy that identifies capacity building as a stand-alone pillar. The chapter's forward-looking framework breaks down the ambitious 100% target into four measurable dimensions: universal access, institutional coverage, priority profession completion, and demonstrated behavioural change.

7.6. Climate Implementation Bridge (CIB)

Global climate finance surpassed USD 2 trillion for the first time in 2024, reaching an estimated USD 2.1 trillion in 2025. However, its annual growth rate has slowed sharply from 30% in 2021 to approximately 6% in 2024, with an expected further decline to 2-3% in 2025. This falls well short of the estimated annual requirement of at least USD 6.2 trillion by 2035. Rather than the global supply of capital, which is already 85% mobilised domestically, the chapter identifies the binding constraint as the country-level capacity to convert national priorities into investable project portfolios. In emerging and developing economies, roughly 70% of projects never advance beyond the feasibility stage. The cost of capital for utility-scale solar is 9.7–13.1% in developing economies, compared to 4.0-4.9% in Europe, the United States and China. Furthermore, 47% of the city climate projects disclosed in 2024 fell below the USD 1-1.5 million scale required by most investment vehicles. The CIB's approach is deliberately institutional rather than financial. Rather than establishing another fund, the CIB proposes strengthening national architecture, project preparation, and financial design through existing partners, such as the NDC Partnership, UNDP, and multilateral development banks. The CIB's phased delivery plan runs from COP31 in Antalya through to 2035.



7.7. Looking Ahead

Read together, the six chapters provide a comprehensive overview of a single delivery challenge, offering six different perspectives. This includes the physical transition, such as electrifying demand, decarbonising waste, retrofitting cities, and closing material loops in industry. These changes are technically achievable within the COP31-2035 timeframe using existing technologies and practices that are already being implemented to some extent. The difference between today's trajectory and the 2035 goals is not so much invention as acceleration: doubling the pace of building renovations, tripling the rate of circular material use, halving waste generation growth and achieving universal climate literacy, all within the same decade. The CIB chapter explicitly states what the other five imply: the constraint is increasingly one of country-level capacity to prepare investable projects and secure affordable capital rather than of aggregate global ambition or available finance.

Foreword of this report, TÜBA contextualises this body of evidence within a broader commitment to science diplomacy, interdisciplinary collaboration and the ethical, human-centred application of artificial intelligence in response to climate change. On this basis, the Academy presents this report as a scientific foundation for the decisions to be made at COP31 in Antalya and during the subsequent decade of implementation. The report's overarching, forward-looking message is clear: the 2035 goals can only be achieved if the acceleration outlined in each chapter begins now and is sustained throughout the current decade, while being matched by the financing architecture described in the final chapter.



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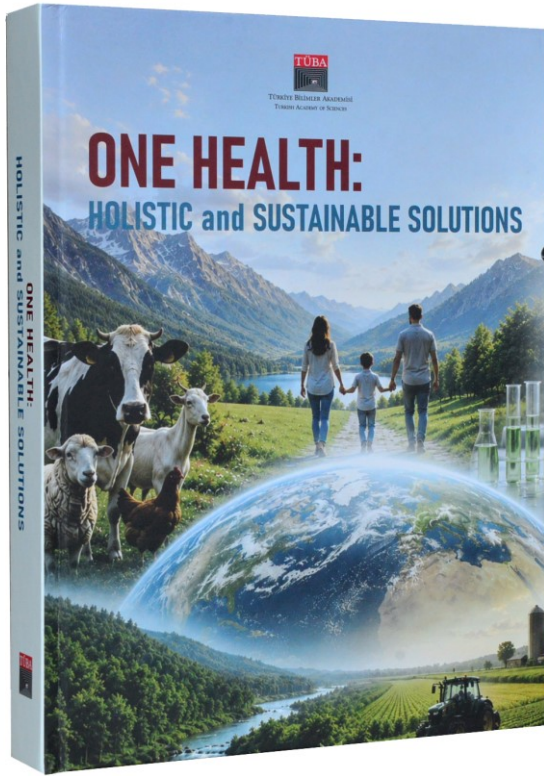
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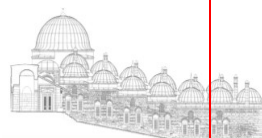
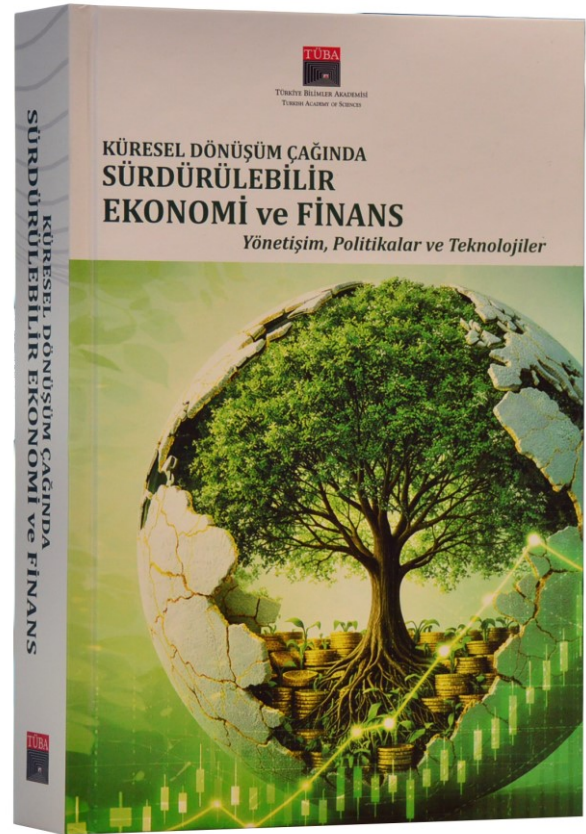


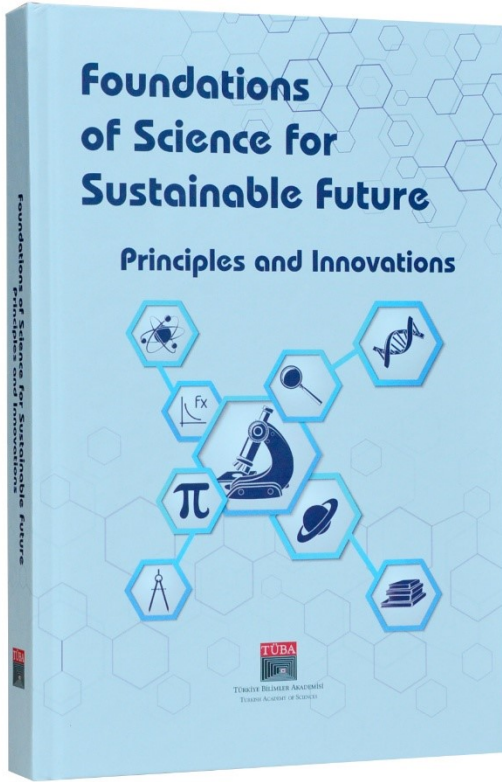


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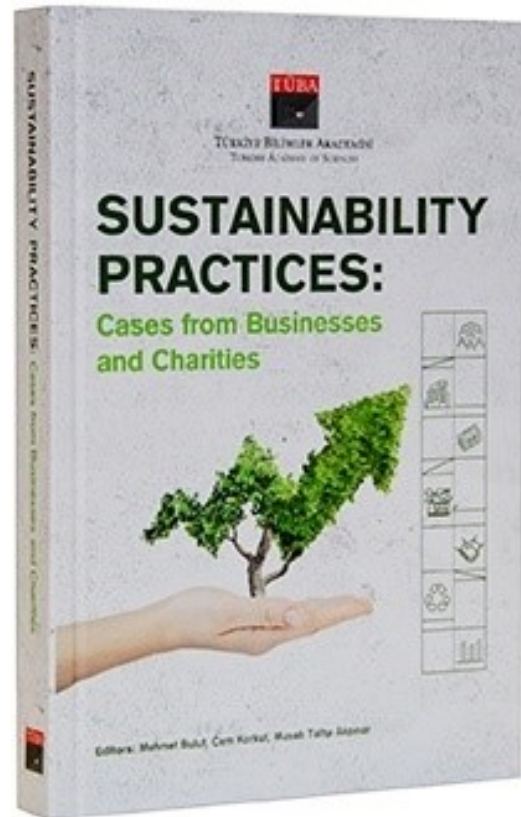


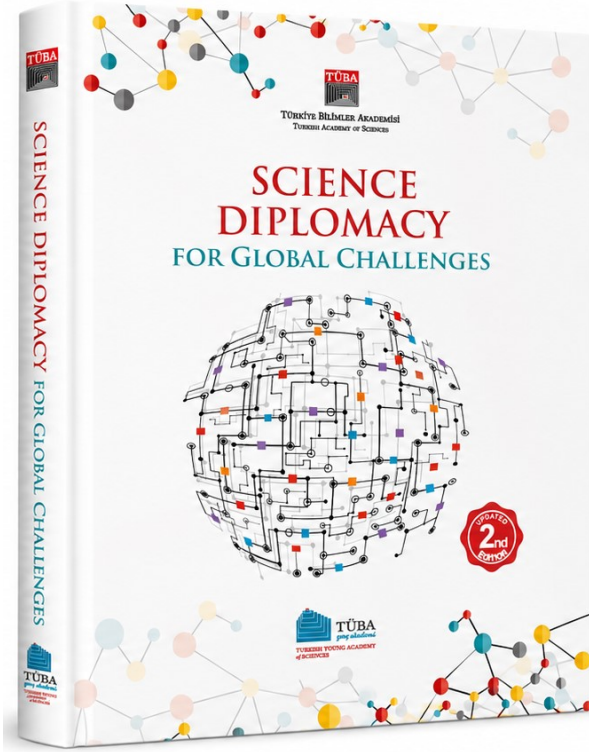


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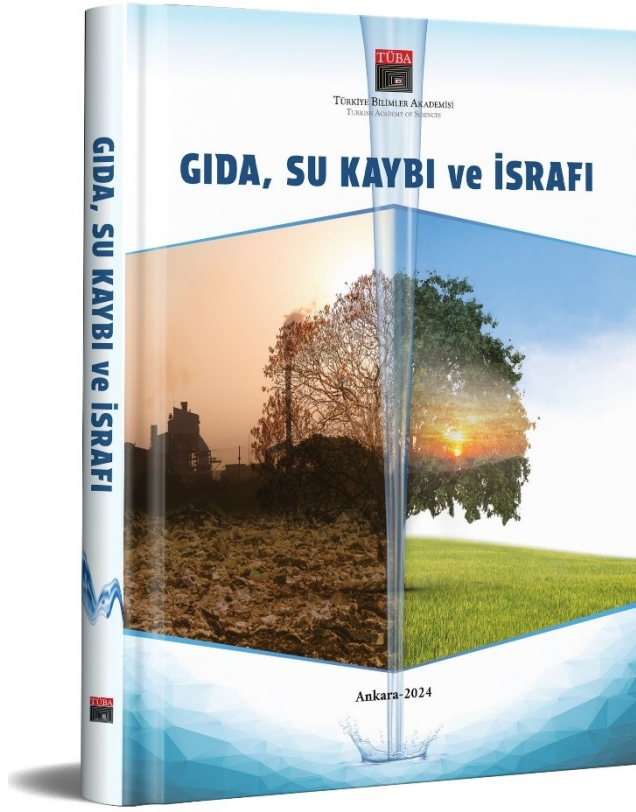


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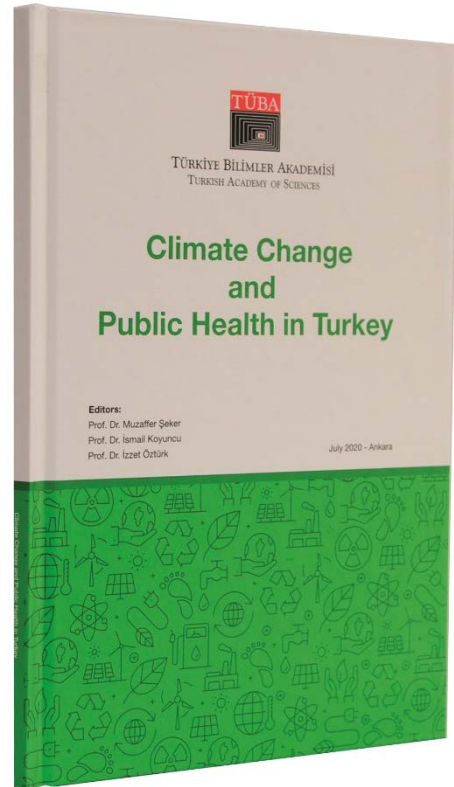




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Notes

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Ahead of COP31, the Turkish Academy of Sciences (TÜBA) prepared this synthesis report, which brings together the collective expertise of 17 scientists from TÜBA Working Groups. Comprising seven chapters, the report charts a science-based path from electrification and zero waste to climate-resilient cities and green industrialisation. It explores how education, technology and artificial intelligence can accelerate climate resilience worldwide. Based on rigorous research, the report provides specific policy recommendations for the COP31 Action Agenda. The report reflects TÜBA's commitment to evidence-based climate science and international cooperation. Designed for scientists, policymakers and diplomats, the report calls for a global consensus based on shared responsibility. As Türkiye prepares to host COP31 in Antalya, this report serves as a scientific guide for climate action. It affirms that, as with lasting peace, lasting sustainability depends on unity across nations and disciplines.



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