Circomod Policy Brief 2:

Circular economy as a complementary tool for climate change mitigation

CIRCOMOD is an EU research project that develops integrated models, data and decision-support tools to assess how circular economy strategies can reduce greenhouse gas (GHG) emissions and material use at scale.

Executive summary

This brief is part of a series produced by the CIRCOMOD project, which models the contribution of circular economy strategies to climate mitigation across sectors and regions. The CIRCOMOD project organises circular economy (CE) action into three archetypes: narrowing strategies, which reduce demand for materials and services at source; slowing strategies, which extend the useful life of products and materials already in circulation; and closing strategies, which keep materials in use at end of life through recycling and recovery. This brief draws on modelling results from CIRCOMOD Deliverable 6.1 (integrated assessment modelling of CE impacts on climate mitigation) and Deliverable 6.2 (macroeconomic assessment using two computable general equilibrium models, GEM-E3 and ICES-CE).

This brief is addressed to climate and industrial policymakers at EU and national level, and to UNFCCC parties updating their Nationally Determined Contributions (NDCs).

KEY MESSAGES

1. Up to 21% of cumulative global industrial greenhouse gas (GHG) emission mitigation potential before additional climate policy could come from circular economy strategies, with around 93% of that potential attributable to 'narrowing' policies. This makes demand-side measures the most time-critical CE lever in the 2030 to 2050 window.

2. CE strategies retain near-term mitigation value under deep decarbonisation pathways, but the additional gain diminishes as climate policy ambition rises. The case for CE is sharpest in the next two decades, where it can moderate the speed and material intensity of the energy transition.

3. Around half of direct GHG emission and energy savings from CE policies are offset by rebound effects under current climate policy, driven by household spending reallocation toward other goods and services. The rebound is substantially reduced under a 2°C scenario, where carbon prices redirect that reallocation away from emission-intensive sectors. The economic effects of CE are model-dependent and addressed in full in Policy Brief 3; the climate case for CE is strongest when CE instruments are paired with carbon pricing.

Why now

Industrial decarbonisation pathways consistent with the Paris Agreement require deep emission reductions before 2050, but the supply-side technologies expected to deliver them face binding constraints in the 2030 to 2050 window. Hydrogen-based steelmaking, electrified high-temperature heat, and carbon capture and storage all depend on capital stock turnover, infrastructure build-out, and electricity system transformation that take time. CIRCOMOD modelling shows that CE demand-side measures can cut emissions in the near term by reducing how much new material enters the economy right away, rather than waiting for existing industrial assets to wear out and be replaced with cleaner alternatives.

This timing matters because national climate policy architectures are being set now. Parties to the Paris Agreement have submitted, or are completing, their third round of Nationally Determined Contributions, covering the period to 2035, and are now translating those targets into sectoral and industrial strategies. In the EU context, the Clean Industrial Deal and the entry into force of the new Emissions Trading System for emissions from fuel combustion in buildings, road transport and additional sectors (ETS2) in 2028 sharpen this window further. Across these processes, circular economy strategies need to be written into the climate policy toolkit – rather than being siloed in resource-efficiency and waste policy domains. Treating CE as an abatement instrument that brings significant benefits already in the short-term, rather than a long-run efficiency goal, changes what gets measured, what gets funded, and what gets counted toward national climate targets.

Demand-side strategies deserve greater attention in climate mitigation portfolios: the CIRCOMOD assessment finds that narrowing strategies are consistently the most effective and immediate circular economy measures. They are also the most challenging to implement, as they often require changes in infrastructure, urban planning, mobility systems, housing patterns, business models, and consumption practices.

What the models show

The CIRCOMOD models combine four biophysical frameworks (IMAGE, WITCH, RECC, TIMES) with two computable general equilibrium models (GEM-E3, ICES) to assess the climate mitigation potential of three CE archetypes at global and European scales: narrowing strategies, such as smaller dwellings, modal shift away from private cars, and product lightweighting; slowing strategies, such as extending the operational life of buildings and vehicles; and closing strategies, such as increased recycling of metals and plastics. The cross-model headline is that CE strategies could deliver up to 21% of cumulative **global** industrial mitigation potential before additional climate policy, with around 93% of that potential attributable to narrowing.

At the **European** level, cumulative emission savings under narrowing strategies range from around 1% to 10% of baseline emissions over the period 2025 to 2050, depending on the model. Narrowing produces the largest reduction in every model. Slow strategies, by contrast, can increase emissions in some sectors when they delay the substitution of carbon-intensive capital stock, a finding developed in detail in Brief 4 on Buildings and Transport. Closing strategies have limited additional impact on metals, where high recycling rates are already embedded in baseline scenarios, but retain substantial untapped potential for materials with low end-of-life recovery (such as plastics).

CE strategies also reduce primary material demand. Globally, CE measures cut final demand for aggregates by roughly 40%, manufactured materials by up to 36%, and metals by 35 to 40% by 2060; in Europe, reductions are larger, reaching 74% for manufactured materials and over 50% for metals. Narrowing strategies reduce sectoral demand for buildings by 30 to 50% and for cars by up to 50% by 2050. Policymakers should therefore consider material demand, recycling capacity, primary production emissions, trade dependencies, and regional production capacities as part of climate policy design. Brief 3 develops the interregional analysis and Global South implications.

Figure 1: Cumulative 2025-2050 CO2 emissions in the No_CE scenario, and emission savings (negative values) or additions (positive values) of CE scenarios compared to the No_CE scenario. Note: Narrow, Slow and Close scenario results for each isolated scenario shown here, not cumulative strategy effects as in a waterfall plot. "Energy Supply" includes electricity sector. AFOLU = Agriculture, Forestry and Other Land Use. "Other" includes difference of reported sectors to reported "Total" emissions by model. Empty plots mean no results reported/not explicitly covered in the model. Buildings sector in ICES comprises all private household consumption, including private cars, while Transportation excludes cars in ICES.

Source: CIRCOMOD D6.1, Figure 25

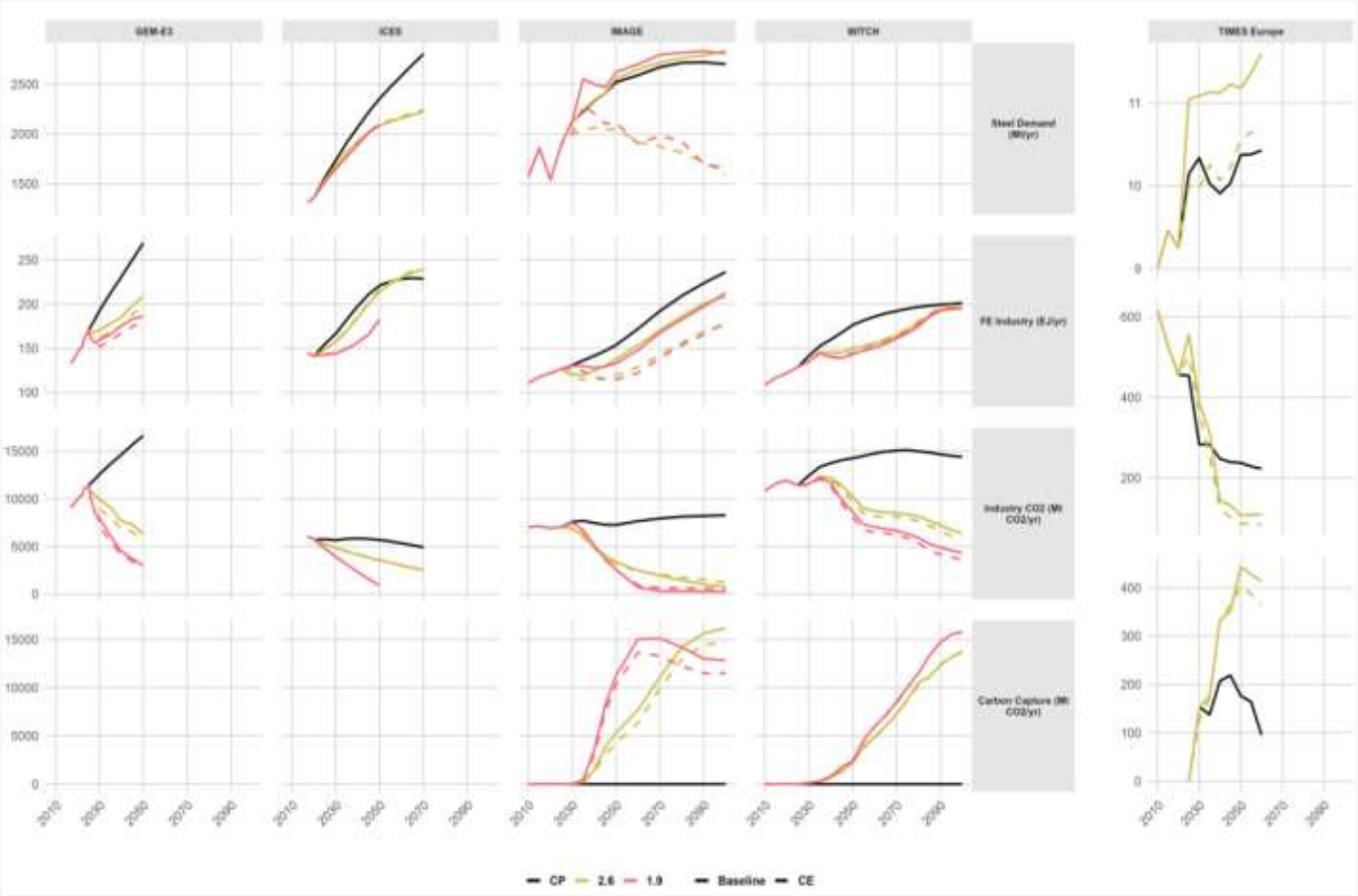

Figure 2: Effects of increased climate ambition on final material, industrial energy use, industrial CO2 emissions, and carbon capture requirements, with and without CE policies. Source: CIRCOMOD D6.1, Figure 11.

The contribution of CE strategies to emission reduction is largest where climate policy is weakest. In a world where countries implement only their current pledged policies – with shallow decarbonisation of energy systems and across the economy – CE strategies, particularly demand reduction, can account for up to 10% of total emissions savings. As climate policy becomes more ambitious and the energy system decarbonises, CE's share of total emissions savings falls, from up to 10% in the baseline to around 6% under a 2°C pathway (IMAGE). However, the contribution remains significant. CE continues to cut emissions that conventional supply-side measures struggle to reach, particularly in industrial processes and materials. CE and climate policy are complements, not substitutes.

Rebound effects offset approximately half of the direct emission and energy savings from CE policies under current climate ambition. The primary mechanism is household spending reallocation: money freed by CE-driven reductions in one area of consumption is redirected to other goods and services, which carry their own emissions footprint. Under a 2°C scenario, this effect is substantially smaller, as carbon pricing raises the cost of emissions-intensive goods economy-wide, limiting the extent to which redirected spending restores emissions.

Policy implications

First, CE is not a single policy lever. Narrowing, slowing, and closing strategies act on different parts of the material life cycle, operate on different timescales, and produce different – sometimes opposing – emission outcomes. Effective policy design needs to take these differences into account, while aggregate CE targets risk obscuring these differences.

Second, narrowing is the most time-critical CE lever in the 2030 to 2050 window. The modelling shows that it acts on material inflows in the year of implementation, before products and infrastructure reach end of life. Its potential is concentrated in high-income regions where service levels already exceed decent living standards thresholds (a regional pattern which Brief 3 develops in detail). The implication is that narrowing belongs in the same policy frame as energy-system mitigation, not in a parallel resource-efficiency package.

Third, slowing strategies only deliver mitigation if the assets being kept in use are already low-carbon. Extending the life of a well-insulated building or an electric vehicle avoids the emissions of manufacturing a replacement. Extending the life of a gas boiler or a combustion engine locks them in for longer. The same intervention produces opposite climate outcomes depending on what is being extended and when. Brief 4 develops this for buildings and vehicles. The broader implication: slowing strategies need to be sequenced carefully and paired with policies that first clean up the underlying stock.

Fourth, the mitigation case for closing strategies depends on where recycling rates currently stand. For major metals, end-of-life recovery is already relatively high, leaving limited room for further gains from increased recycling. Where recovery rates are low, the opportunity is much larger. Plastics illustrate the stakes: only around 14% of plastic waste is recycled at end-of-life in the EU. That gap means continued demand for virgin fossil-based feedstocks – a source of emissions that persists even as the energy system decarbonises, and that closing strategies are well positioned to address.

Finally, macroeconomic feedback effects qualify all the above. Under current climate policy, around half of the direct emission savings from CE measures can be offset by reallocation of freed household budgets toward emissions-intensive goods. The implication is that CE strategies cannot be relied on in isolation. Complementary policy, such as the EU emissions trading scheme (ETS2), product efficiency standards, and resource pricing, is needed to convert direct material savings into realised emission reductions. Consequently, policies generate 2.5 times greater emission reductions under a 2°C scenario than under current policies (ICES-CE), directly because higher carbon prices suppress spending reallocation toward emission-intensive goods.

Recommendations

The following recommendations address climate and industrial policy makers at national and EU level, and the UNFCCC process. Each is grounded in a specific CIRCOMOD finding.

Extend existing NDC accounting and long-term strategy frameworks to include demand-side CE measures, with narrowing strategies reported and quantified separately alongside supply-side mitigation. Current UNFCCC guidance on mitigation in NDCs already provides a framework for this, and the Global Stocktake has formally recognised demand-side options as part of the mitigation toolkit. Governments should integrate narrowing strategies into mitigation accounting on the same basis as energy-system and process-emissions measures, with quantified contributions reported in NDC documentation and updated in line with the five-year cycle. This determines what becomes investible.

Condition slowing instruments on the carbon intensity of the affected stock. Lifetime-extension subsidies, vehicle scrappage policy, and retrofit-versus-replacement guidance should reference the carbon intensity of the relevant stock segment, rather than treating lifetime extension as universally beneficial. EU institutions and member states already have the indicators required: ETS benchmarks provide carbon intensity data for industrial processes, Energy Performance Certificates under the EPBD cover buildings stock, and the EEA fleet CO_2 monitoring framework covers vehicles. Brief 4 considers buildings and transport sectors in detail.

Rebalance closing-strategy effort from high-recovery metals to low-recovery materials. Policy attention and funding for end-of-life infrastructure should shift toward plastics, aggregates, and other materials with low recovery rates, while maintaining the operational capacity needed to absorb growing metal scrap volumes. For plastics specifically, recycled content thresholds and collection targets calibrated to fossil feedstock displacement, not weight-based recycling alone, would address the lock-in effect identified by the modelling. One mechanism through which this reorientation could be supported is the calibration of EPR eco-modulation criteria under EU Packaging and Packaging Waste Regulation (PPWR) – weighting fee structures to reflect fossil feedstock displacement alongside existing post-consumer recyclate thresholds.

Integrate demand-displacement safeguards into the policy instruments that accompany CE measures, to convert material savings into realised emission reductions rather than household budget reallocation toward other emissions-intensive goods. Instruments already under development – such as ETS2, resource pricing, and material input standards – could be extended to function as guardrails for CE rebound. For the macroeconomic and distributional consequences of CE strategies, including employment effects, see Policy Brief 3.

Caveats

These findings carry important caveats. Results vary across model types because different models capture different things: some measure physical material and energy savings, others capture how the broader economy responds and can partially erode those savings. Both perspectives are valid; reported figures are ranges, not a single estimate.

Sectoral coverage is incomplete. Machinery, ICT infrastructure, and other smaller sectors are not modelled, so the emission reductions CE strategies could deliver across the full economy are likely higher than the figures presented here. On the other hand, these figures assume CE measures are fully adopted. In practice, demand-reduction strategies face the greatest behavioural and institutional resistance, so actual outcomes in practice might fall short of their full potential.

Further reading

CIRCOMOD Deliverable 6.1: Cross-model assessment of CE mitigation potential, global and EU scales.

CIRCOMOD Deliverable 6.2: Macroeconomic and trade effects of CE strategies.

CIRCOMOD Policy Brief 1: Tools and methods for policymakers and industry

CIRCOMOD Policy Brief 3: Circular economy, material demand, and the macroeconomics of decarbonisation

CIRCOMOD Policy Brief 4: Circular economy policy for buildings and transport in Europe.

IPCC Sixth Assessment Report, Working Group III, Chapter 11 (Industry): material efficiency and demand-side mitigation pathways.

About CIRCOMOD

CIRCOMOD is an EU research initiative that develops integrated models to quantify how circular economy strategies – such as material efficiency, product lifetime extension, reuse, and high-quality recycling – can reduce greenhouse gas emissions and resource use at scale.

By combining detailed data on material flows, real-world technologies, and economic dynamics, the project enables a system-wide assessment of the impacts of circular strategies across sectors and regions. The project ran from 2022 to 2026.

Further information

CIRCOMOD data hub:
circomod.eu/circomod-data-hub
Project website: circomod.eu

Contacts
Oreane Edelenbosch, o.y.edelenbosch@uu.nl
Detlef van Vuuren, Detlef.vanVuuren@pbl.nl