Policy Brief

Circular economy modelling for EU decision-making

Linking models and data to support evidence-based circular economy and climate policy

Key messages

Beyond recycling
Current EU models underestimate the potential of higher-value circular strategies. The CircEUlar toolbox extends modelling to assess material demand reduction, product lifetime extension, reuse and repair.

Circular economy is missing from climate modelling
Climate models omit measures such as housing and appliance sharing, reduced car ownership and rebound effects, underestimating circularity's mitigation potential. Including these measures shows circular strategies can halve material demand and transform the embodied emissions of key sectors.

Circularity must be assessed as a system
Linking sectoral, economic and environmental models enables system-wide assessment of circular strategies across buildings, mobility and digitalisation.

Open and better data strengthens policy
Open data and transparent models improve representation of material stocks, consumer behaviour, stakeholder input and regional differences, strengthening the reliability and policy relevance of circular economy assessments.

Policy recommendations

Extend circularity beyond waste policy and modelling
- **Integrate higher-value circular strategies into transport, buildings and digital policy,** shifting the focus from recycling towards material demand reduction, lifetime extension, reuse, repair and asset utilisation. Require impact assessments to account for material flows, embodied emissions and infrastructure material demand. This will ensure their full climate and resource impacts are captured.

Adopt a systems approach to circular economy modelling
- **Apply the systems-based modelling approach already used for EU climate and energy policy to circular economy modelling.** Strengthen links between sectoral, economic and environmental models to enable system-wide assessment of circular strategies across buildings, mobility and digitalisation. This will improve the impact assessment of material demand, greenhouse gas emissions and cross-sector interactions, providing a stronger evidence base for policymaking.

Incorporate circular economy strategies into EU climate and energy modelling
- Systematically **incorporate demand-side and lifetime-extension strategies into the Commission's suite of linked models underpinning EU climate and energy policy**, including those supporting the 2040 climate target. Represent currently overlooked measures, such as building reuse, sharing and reduced car ownership. This will improve scenario analysis and estimates of material demand and greenhouse gas emissions.

Support open and harmonised data for circular economy
- Actors like Eurostat, the European Commission's Joint Research Centre and relevant research partners could build on EUBUCCO and other open datasets from CircEUlar to **establish a harmonised EU material stocks and flows observatory**. The observatory would track buildings, infrastructure and products; supporting reuse (e.g. vacant buildings) and reducing unnecessary new construction.

Policy context

The European Union (EU) positions the circular economy as a core pillar of its sustainability, resilience and competitiveness agenda. The Circular Economy Action Plan seeks to shift the EU from a linear "take–make–dispose" system towards a more circular and resource-efficient economy and is a key element of the European Green Deal. The Action Plan is complemented by several initiatives, including the Ecodesign for Sustainable Products Regulation, the European Steel and Metals Action Plan, and the Clean Industrial Deal.

The EU recognises the circular economy as central to reducing greenhouse gas (GHG) emissions and achieving climate neutrality by 2050. However, much of the policy landscape remains focused on waste and recycling rather than whole-system circularity [7]. This highlights **the need for robust quantitative evidence to support regulatory approaches**, including the forthcoming Circular Economy Act.

Why this matters

Despite recent progress, current EU-level modelling only partially represents circular economy strategies, limiting the evidence available to support policymaking. **Existing modelling** frameworks, therefore, **need to represent a broader range of circular strategies** while accounting for their technical and socio-economic feasibility. In contrast to energy modelling, **significant data gaps persist for material stocks and flows, limiting the accuracy and comprehensiveness of analyses** [1]. Addressing these gaps requires open access to data, starting with publicly funded datasets including those generated through EU-funded projects, alongside transparent models to improve reproducibility, verification, cross-country comparison and policy learning.

What the evidence shows

Beyond recycling: accounting for the full potential of circular economy strategies

Existing EU legislation remains primarily focused on recycling targets and end-of-life waste management. CircEUlar broadens the evidence base by assessing higher-value circular strategies that reduce material demand and extend product lifetimes.

CircEUlar extends circular economy modelling beyond recycling by applying the **Narrow-Slow-Close** framework [10]. This enables the assessment of strategies that reduce material demand through improved product design, material efficiency and lower activity levels (narrow), extend product lifetimes through repair, reuse, refurbishment and repurposing (slow), and recover materials through reuse and recycling (close). ››

The results reveal a clear hierarchy in mitigation potential. **Narrow strategies deliver the greatest climate benefits, followed by slow strategies, while close strategies – including recycling – provide comparatively smaller gains**. Fully realising the potential of the circular economy requires modelling frameworks and policies that prioritise higher-value circular strategies across transport, buildings, household appliances and digital technologies, complementing existing climate and waste policies.

Circular economy strategies interact across sectors, value chains and environmental systems. Assessing their impacts therefore requires an integrated modelling approach that captures material demand, economic activity, environmental impacts and climate outcomes within a single analytical framework.

CircEUlar provides a comprehensive ecosystem of interlinked models spanning buildings and household services, transport, digitalisation and material systems (Figure 1). The framework combines integrated assessment modelling (MESSAGEix-GLOBIOM [2]); detailed sectoral models for buildings, transport, materials and household appliances; industrial ecology models of material stocks and flows (MISO2, GLOMIS and EXIOfutures); environmental modelling (GAINS); and computable general equilibrium modelling (JRC-GEM-E3) – **all in dark blue**. Novel data sources, including EUBUCCO, consumer [12] and business [13] surveys, (**in light blue**) and stakeholder engagement input at key points [11] (**in green**), further strengthened the evidence base and supported scenario development and validation.

By linking these complementary models, CircEUlar quantifies how circular economy strategies influence material demand, product stocks and flows, greenhouse gas emissions, air pollution and wider economic outcomes under different transition pathways. This approach provides a more systemic quantitative assessment of circular economy strategies and their potential towards climate targets at the EU and global level.

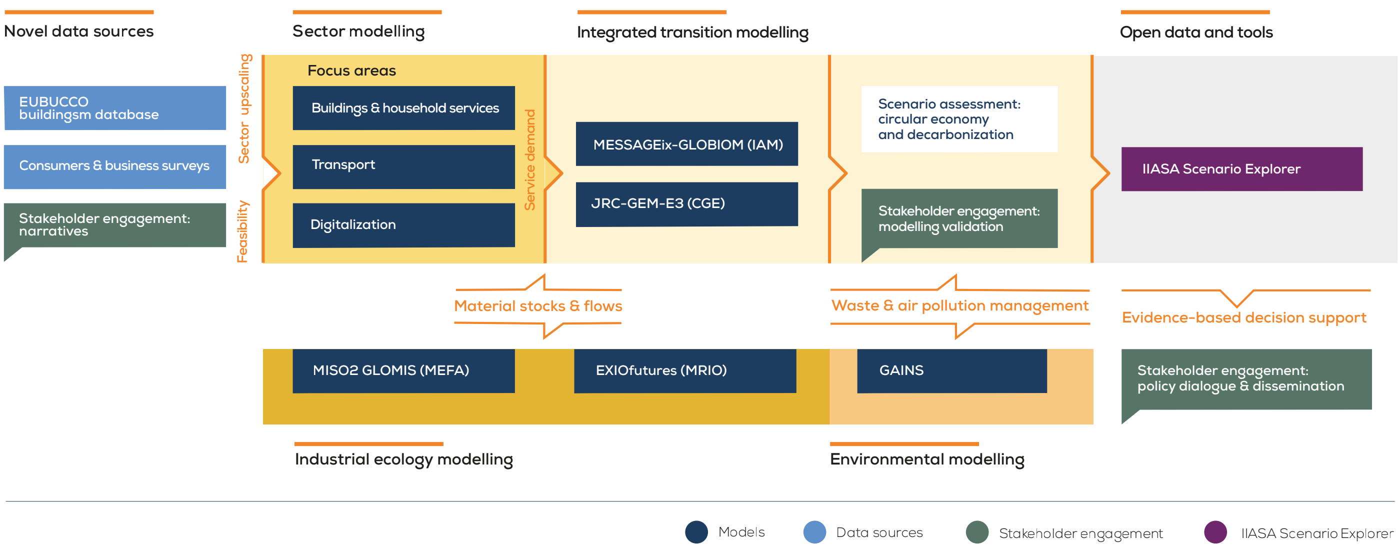

Figure 1. Overview of the CircEUlar modelling ecosystem – Systematic modelling approach to circular economy

Strengthening the EU toolbox with enhanced modelling capabilities

The European Commission uses a suite of linked models to support impact assessments for climate and energy policies, including the EU's 2030 and 2040 climate targets [8,9]. Integrating CircEUlar's modelling capabilities would strengthen its ability to assess circular economy strategies and their contribution to climate and energy objectives.

Figure 2 illustrates the potential linkages between the CircEUlar modelling ecosystem (**in green**; see **Figure 1** for more details) and the European Commission's climate and energy modelling toolbox (**in orange**), highlighting shared models (**in blue**).

Together, these linkages broaden the representation of these circular economy strategies and practices across the following areas:

- **Buildings** - Shared living space, reduced household appliance ownership and reuse of vacant buildings, supported by detailed building-and city-level modelling;
- **Transport** - Reduced car ownership, trade-offs between vehicle lifetime extension and electrification, transport infrastructure, and changes in vehicle material intensity;
- **Digitalisation** - Energy and material demand associated with data centres;
- **Material stocks and flows** - Improved assessment of material stocks and flows for electric vehicles, household appliances and data centres, supporting implementation of the Critical Raw Materials Act and the RESourceEU Action Plan;
- **Waste management** - New linkages between sectoral and waste management models improve assessment of how product design and use patterns shape end-of-life treatment and secondary material availability;
- **Industry** - Integration of bottom-up sectoral models with macroeconomic analysis to assess how circular strategies reduce demand for energy-intensive materials and products; and
- **Rebound effects** - Explicit assessment of rebound effects when evaluating the climate mitigation potential of circular economy strategies.

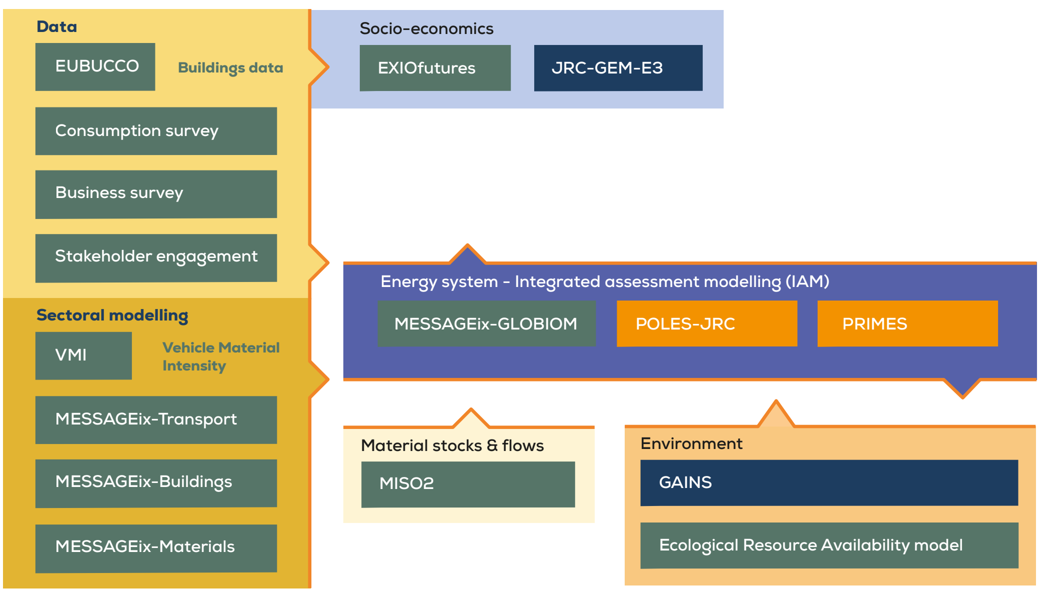

Figure 2. Linking CircEUlar modelling to EU modelling toolbox

CircEUlar modelling toolbox   EU modelling toolbox   Part of both modelling toolboxes

Towards improved representation of circular economy strategies in EU models

Current large-scale models represent only a limited set of circular economy strategies, focusing primarily on recycling and reuse. They also rely on simplifying assumptions that can overlook mass balances, thermodynamic constraints and interactions across sectors [4, 5, 6]. CircEUlar addresses these limitations by introducing **detailed modelling of material stocks and flows and extending model capabilities to represent strategies that narrow, slow and close material cycles**.

The EU's experience using models to inform climate and energy policy provides a strong foundation for circular economy modelling. As with climate modelling, these models are designed to explore the implications of different policy choices rather than predict precise outcomes. **Their results should therefore be interpreted alongside expert judgement and stakeholder evidence**.

The examples below illustrate how the CircEUlar enhanced modelling capabilities could strengthen the EU's modelling toolbox for circular economy policymaking, as shown in **Figure 2**.

Buildings

Current EU models have limited capacity to assess the reuse of vacant buildings and building lifetime extension (slow strategies) because they lack detailed information on building stocks and vacancy. Reusing existing buildings, however, could substantially reduce demand for new construction, along with the associated material use and greenhouse gas emissions.

CircEUlar addresses this gap by combining the **EUBUCCO** building database with **MESSAGEix-Buildings** to assess the reuse of vacant buildings and lifetime extension across Europe through stock-turnover modelling. The results show these circular strategies can reduce material-related embodied emissions in new constructions by 22% by 2050 compared with a reference scenario [14]. These findings provide a stronger evidence base for policies that promote building reuse and reduce unnecessary new construction [3].

Mobility

High-resolution modelling of transport infrastructure with GLOMIS enables assessment of the material stocks, flows and emissions associated with infrastructure expansion, maintenance and renewal. Linking this model with **MESSAGEix-GLOBIOM** [2] enables evaluation of the combined effects of demand and supply-side circular economy strategies. Without circularity measures, material stocks in EU mobility infrastructure could increase by almost 60% between 2024 and 2060. Meeting this demand would require around 1.8 Gt of annual material ›› inflows and generate 1.3 $GtCO_2$ of cumulative emissions. Integrating circularity measures reduces cumulative emissions by 40-45%, demonstrating that omitting circular economy strategies from current modelling underestimates their contribution to EU climate targets [15].

Improved open data and models

Gaps in data on material stocks and flows, together with limited information on behavioural and contextual factors, constrain the assessment of circular economy strategies. CircEUlar addresses these gaps by integrating existing and novel open datasets and models, improving transparency, reproducibility and robustness of circular economy assessments.
The open-source **EUBUCCO** database provides information on more than 320 million buildings across Europe, including building footprints, height, number of floors and use type. It is complemented by new datasets on consumer behaviours and preferences related to sharing, second-hand markets, modal shift and downsizing, enabling more realistic assessment of circular economy strategies by accounting for behavioural feasibility alongside technical potential [12, 13]. Key datasets and scenario results are also made openly available through **IIASA's Scenario Explorer**, enabling policymakers, researchers and other users to visualise, compare and explore scenarios through an intuitive web interface.

Circular economy modelling can be integrated incrementally into the EU's existing suite of linked climate and energy models, building on established modelling capabilities. This would strengthen evidence-based policymaking by providing a more comprehensive assessment of greenhouse gas emissions, material demand and circular economy strategies across sectors.

Research Methodology

CircEUlar models circular economy strategies through a structured three-stage process that integrates models, tools and data, supported by empirical analysis and stakeholder engagement, as depicted in Figure 1. The process begins with the establishment of a common modelling protocol and the development of scenario narratives to ensure alignment across the modelling ecosystem.

During the **Explore** stage, the models were improved to enable enhanced representation of a broader set of circular economy strategies across sectors and were individually parameterised, translating qualitative scenario narratives into quantitative model parameters. During the **Expand** stage, complementary models were progressively coupled within each focus area, integrating new datasets and evidence from empirical analysis, interviews and stakeholder dialogues to refine model parameters, assumptions and feasibility.

Finally, during the **Consolidate** stage, the linked models were integrated across focus areas and joint scenarios were developed, providing results on the potential and feasibility of circular economy strategies at the European level. This process was applied across the project's focus areas (buildings and household services, mobility, and digitalisation) and key sub-topics, including household appliances and waste.

Figure 1 provides an overview of the modelling ecosystem, while the references listed below provide further details on the individual models and datasets.

References

Numbers in brackets correspond to this reference list.

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[10] **Bocken et al. (2016).** Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering 33, 308–320. https://doi.org/10.1080/21681015.2016.1172124

[11] **Giorgi et al. (2026).** Final report on community building and events (CircEUlar Project Deliverable 1.2). https://zenodo.org/records/22115535

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[15] **Baumgart et al. (2026)**. Material and carbon implications of future mobility infrastructure expansion around the world, Journal of Industrial Ecology, 30, 1935–1949. https://doi.org/10.1007/s44498-026-00132-x

Models and tools

Sector modelling

- **MESSAGEix-Buildings building sector model:** https://doi.org/10.1007/s10584-021-03229-3
- **MESSAGEix-Transport transport sector model:** https://docs.messageix.org/projects/models/en/stable/transport/index.html
- **MESSAGEix-Materials industry sector model:** https://docs.messageix.org/projects/models/en/latest/material/index.html
- **GLANCE household appliances model:** https://doi.org/10.5281/zenodo.21542463

Integrated transition modelling

- **MESSAGEix-GLOBIOM integrated assessment modelling (IAM) framework:**
  - https://iiasa.ac.at/models-tools-data/messageix
  - docs.messageix.org/projects/models/en/stable/global/index.html
- **JRC-GEM-E3 computable general equilibrium (CGE) model:** https://joint-research-centre.ec.europa.eu/what-we-do/scientific-tools-and-databases/general-equilibrium-model-economy-energy-environment/overview-jrc-gem-e3-model_en

Industrial ecology modelling

- **MISO2 material stocks and flows model:** https://boku.ac.at/miso
- **GLOMIS:** https://link.springer.com/article/10.1007/s44498-026-00132-x
- **EXIOFutures:** https://zenodo.org/records/22707658

Environmental modelling

- **GAINS emission and pollution model:** https://iiasa.ac.at/models-tools-data/gains

Open data sources and tools

- **EUBUCCO buildings database:** https://eubucco.com
- **IIASA Scenario Explorer:** https://circeular.apps.ece.iiasa.ac.at

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CircEUlar project

CircEUlar is a Horizon Europe project (2022-2026) led by the International Institute for Applied Systems Analysis (IIASA) and involving 11 European partners. It develops integrated modelling frameworks and circular pathways for a net-zero economy, with detailed analysis of mobility and buildings as material-intensive demand sectors, and digitalisation as a potential enabler of circularity. Combining quantitative modelling, qualitative research, and stakeholder engagement, the project generates evidence to support Europe's climate and circular economy objectives. **Visit our website: https://circeular.org/**

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