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Perspective

Climate mitigation models need to become circular – let's start with the construction sector

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Circular Economy (CE) is presented today as the way forward to achieving a sustainable and carbon-neutral society. Yet, circularity assessment tools such as Life Cycle Assessment (LCA), Material Flow Analysis (MFA), and Supply and value-chain analysis are currently disconnected from the models used to advise bodies that steer sustainability-driven policies like the Intergovernmental Panel on Climate Change (IPCC). Climate mitigation models (henceforth climate models) are used in policy discussions and international negotiations to track GHG emissions and identify pathways towards a low-carbon economy. One example is the JRC-EU-TIMES model developed by the International Energy Agency or the PRIMES model, which is the backbone of the energy and climate policy of the European Union (EU). These climate models are inherently suitable for representing only linear patterns of economic activity, where GHG emissions are modelled per economic sector (primary energy resource extraction, final energy generation, energy, and materials used in industry, buildings, etc.). But current climate models lack modelling resolution and flexibility to account for the Green Transition measures required e.g. Fit for 55 or RePowerEU goals. Upstream and downstream supply chains are poorly represented, indirect GHG emissions are seldom included (McDowall et al., 2018), and common CE measures – such as extending product lifetime, resource sharing models, and feedback loops of materials and goods - are not considered. This means that, for example, for the cement sector, GHG emissions associated with the production stage are seen by climate mitigation models as the sole responsibility of the cement industry. However, a reallocation of building materials from concrete to raw materials, for example, can provide carbon storage and sequestration, and consequently pledges a reduction of GHG emissions. In addition, citizen behaviour is poorly understood and quantified regarding construction materials CE practices of reuse, recycling, and sharing (Wijkman, 2019).

Thus, **current climate mitigation models cannot account for materials' circularity** or interconnected resource needs despite improvements in this direction. Existing Integrated Assessment Models (IAM) for climate mitigation modelling, such as IMAGE, MESSAGE and WITCH-GLOBIOM, have been powerful tools for improving our understanding of the climate change problem and the potential pathways to deal with it as in IPCC AR5. However, IAM cannot perform integrated

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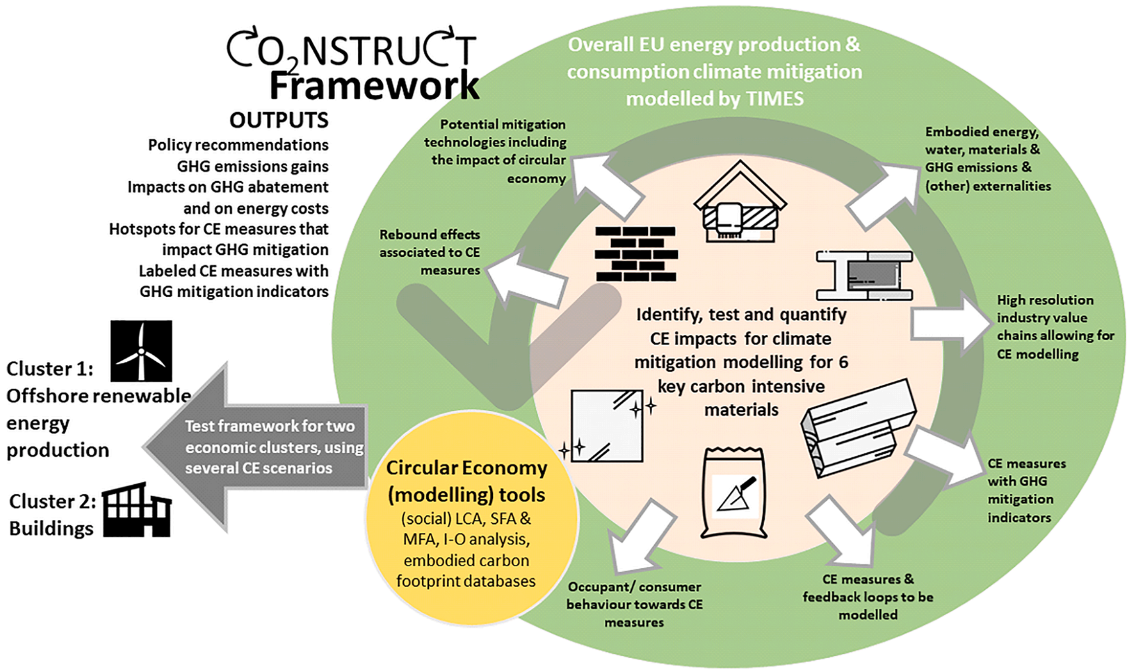

Fig. 1. Conceptual CO_2NSTRUCT circular climate mitigation modelling framework.

resource assessment and modelling (Bazilian et al., 2011) since they often focus on a single resource or are applied on an aggregated scale. On the other hand, existing technology energy-climate mitigation models (such as TIMES) have been linked to other tools/methods to investigate connections between energy and other systems (Luderer et al., 2019), but such efforts did not: (i) address trade-offs and benefits across technologies life cycle; (ii) consider materials value chains nor the possibility for closing loops, (iii) quantify effects on optimal decarbonization pathways regarding additional economic/social aspects (e.g., investment needs, energy prices). In consequence, climate mitigation models are inherently linear, and/or do not have sufficient technical detail to adequately capture value chains and feedback loops inherent to CE options. Embodied energy, water, and emissions are not considered while modelling climate mitigation pathways. Related or changing impacts on – sometimes remote – water resources are in their infancy (Schomberg et al., 2021). CE rebound effects and cradle-to-cradle analysis are not accounted for, as well as changes to more circular consumption patterns (e.g. sharing). This limits our capability to understand and quantify the extent to which CE practices contribute to achieve a carbon-neutral economy. In short, climate mitigation models need a major leap to **address these CE technical aspects**, such as a higher level of technical detail to adequately represent CE measures and integrate feedback loops which characterise CE practices.

Policy actions supported by well-grounded application of Circular Economy practices for climate mitigation are important for any economic/industrial sector. But because the construction sector is transversal to most economic sectors, being both the (i) consumer of services and intermediate products (such as raw materials, chemicals, or electrical equipment), and (ii) producer of goods (housing, products, renewable energy infrastructure, and even Blue Economy industries), we can use it as blueprint for the coupling of CE into climate mitigation. Using carbon-intensive and environmental impactful **construction materials** (Bazilian et al., 2011) such as cement, steel, brick, glass, bio-based, and insulation materials as proxy, we can characterize specific feedback-loops stemming from CE practices along their value-chains and quantify their impacts. Optimistic estimates predict 80% CO_2 emission reductions if material efficiency is increased, but this number lowers to 53% for the construction sector. To accurately predict these estimates, we need to integrate CE into climate mitigation in a better, more holistic way, by **transforming linear models used for policy support into circular models**. And to do so, we need to **bridge the gap between energy-climate mitigation modelling and CE analytical tools used for cradle-to-cradle assessments** (e.g., LCA, MFA, Supply, and value-chain analysis). The new Horizon Europe project CO_2NSTRUCT aims to do this by using the core concepts of Material flows, closed-loop supply chains, CE rebound effect, and Citizens/Consumer behaviour, bringing them together with the TIMES energy-climate mitigation model (Fig. 1). The project will also develop a strategy to quantify citizen behaviour and key stakeholder opinion on six construction materials CE measures and incorporate its results in the new circular climate mitigation framework. It aims to the engagement of key stakeholder and citizens by considering their feedback on needed actions to integrate CE into climate mitigation actions and by conduction various engagement activities throughout the project development. Using the construction sector as proxy, CO_2NSTRUCT will create the imprint to shift linear climate mitigation models into circular, hopefully allowing for a more accurate CE accounting across another economic sectors.

Authors' statement

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Declaration of Competing Interest

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Data Availability

No data was used for the research described in the article.

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