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van Heerden, Rik; Edelenbosch, Oreane Y.; Daioglou, Vassilis; Le Gallic, Thomas; Baptista, Luiz Bernardo; Di Bella, Alice; Colelli, Francesco Pietro; Emmerling, Johannes; Marangoni, Giacomo; More Authors

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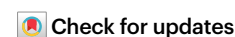
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Demand-side policies can significantly reduce emissions from energy use in buildings and transport

Rik van Heerden, Oreane Y. Edelenbosch, Vassilis Daioglou, Thomas Le Gallic, Luiz Bernardo Baptista, Alice Di Bella, Francesco Pietro Colelli, Johannes Emmerling, Panagiotis Fragkos, Robin Hasse, Johanna Hoppe, Paul Kishimoto, Florian Leblanc, Julien Lefèvre, Gunnar Luderer, Giacomo Marangoni, Alessio Mastrucci, Hazel Pettifor, Robert Pietzcker, Pedro Rochedo, Bas van Ruijven, Roberto Schaeffer, Charlie Wilson, Sonia Yeh, Eleftheria Zisarou & Detlef van Vuuren



Large emission reductions in buildings and transport are possible by integrating demand-side strategies to electrify energy use, improve technological efficiency, and reduce or shift patterns of activity. With enabling policies and infrastructures, final energy users can make significant contributions to climate goals, particularly through widespread deployment of heat pumps and electric vehicles.

BASED ON: Van Heerden, R. et al. *Nat. Energy* <https://doi.org/10.1038/s41560-025-01703-1> (2025).

The policy problem

The Paris Agreement sets a goal to keep global warming well below 2°C. However, model projections show that this goal is unlikely to be met with current climate policies and actions, indicating a need for additional strategies to further reduce greenhouse gas (GHG) emissions. Alongside technological supply-side solutions to transition away from fossil fuels, for example with the adoption of renewable energy sources in electricity generation, demand-side strategies involving energy users in sectors like buildings and transport can contribute significantly to emission reductions. Direct emissions from energy use in buildings and transport account for over 20% of global GHG emissions. In buildings, measures such as electrifying energy use through heat pumps, improving insulation, and reducing energy demand through behavioural shifts can significantly lower emissions. Similarly, in transport, electrifying vehicles, enhancing efficiency, and promoting mode shifts to public transit or active modes like cycling can drastically reduce emissions. Determining the most cost-optimal and effective policy mix is a complex systems problem.

The findings

Our analysis shows that a comprehensive set of measures involving end users can reduce sectoral CO₂ emissions by 51–85% in buildings and 37–91% in transport by 2050, compared to a scenario based on current policies (Fig. 1). Electrifying energy end-use and switching to alternative fuels delivers the largest emission reductions, though also leads to increases in

electricity demand. Reducing or changing energy-using activities including travel distances and mode choices can reduce energy demand and ease pressure on the electricity supply. So too can using more efficient technologies. The combination of all measures leads to significant further emission reductions, despite some offsetting interactions such as the reduced emission-reduction potentials of heat pumps when homes are better insulated. It is important to note, however, that the successful implementation of these policies depends on multiple conditions, such as broader societal support, which was not explicitly considered in this study.

The study

Our study uses quantitative scenarios generated with global integrated assessment models (IAMs) that are specifically designed to capture the interactions within and between the energy system, the economy, and the environment. We developed three scenarios that each capture the impact of a specific strategy targeting energy use. In the first scenario end users reduce or change energy-using activities, in the second they adopt more efficient technologies, and in the third they switch to electrification or alternative energy carriers as substitutes to fossil fuels. Using a structured questionnaire, we also gathered inputs from policymakers and experts in demand sectors to refine the scenarios. We quantitatively

Messages for policy

- Developing targets and corresponding policies to increase the share of electricity and sustainable fuels in energy-using sectors globally will yield significant emission reductions, especially in the medium term.
- Adopting a mix of policy measures, including both technological solutions and in support of behavioural changes, can alleviate the burden of mitigation on energy supply and infrastructure.
- End-use policies, such as efficiency improvements and promoting electrification, mostly interact synergistically with minimal trade-offs. A coordinated mix of these policies accelerates decarbonization.
- Transformative changes in buildings and transport can significantly reduce emissions. Key actions include electrification, smarter use of space, better insulation, enhanced vehicle efficiency, less driving, more biking, and better public transport.

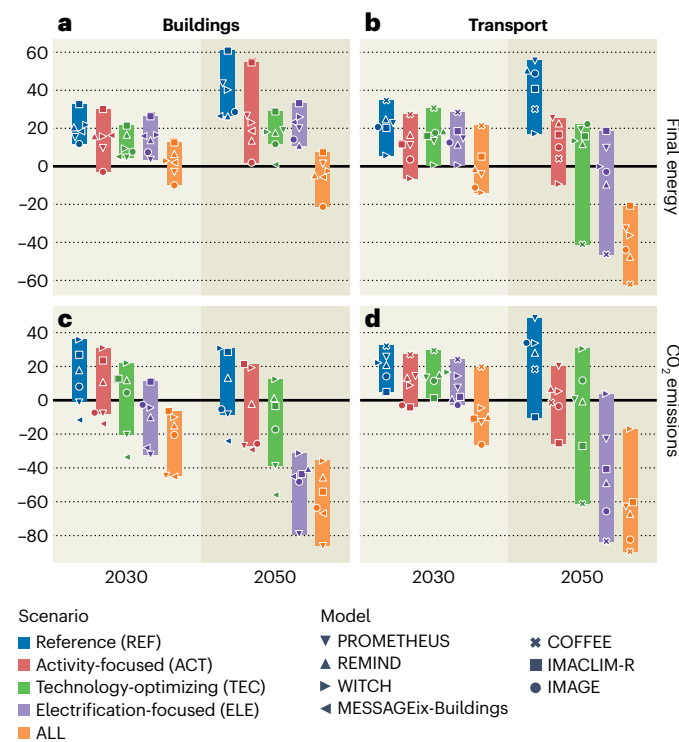


Fig. 1 | Change in global final energy use and direct CO₂ emissions from fuel combustion in the buildings and transport sectors. a–b, Final energy use in buildings (a) and transport (b). **c–d**, CO₂ emissions from buildings (c) and transport (d). The figure shows model results for five scenarios: a business-as-usual reference (REF), reducing or changing energy-using activities (ACT), adopting more efficient technologies (TEC), switching to electrification or alternative energy carriers as substitutes to fossil fuels (ELE), and a combined scenario (ALL) integrating ACT, TEC, and ELE. All scenarios have current policies implemented. Markers indicate individual model results and bars depict the model ranges. Figure adapted from R. van Heerden et al. *Nat. Energy* <https://doi.org/10.1038/s41560-025-01703-1> (2025); Springer Nature Ltd.

interpreted and quantified the scenarios through 2050 using seven IAMs. Finally, we compared the resulting emission reductions per strategy across the set of models and scenarios and analysed the results to better understand the main factors driving these reductions.

Rik van Heerden ¹, Oreane Y. Edelenbosch ^{1,2}, Vassilis Daioglou ^{1,2}, Thomas Le Gallic ^{3,4}, Luiz Bernardo Baptista ⁵, Alice Di Bella ^{6,7,8}, Francesco Pietro Colelli ^{6,7,9}, Johannes Emmerling ^{6,7}, Panagiotis Fragkos ¹⁰, Robin Hasse ^{11,12}, Johanna Hoppe ^{11,12}, Paul Kishimoto ¹³, Florian Leblanc ¹⁴, Julien Lefèvre ¹⁵, Gunnar Luderer ^{11,12}, Giacomo Marangoni ^{6,7,16}, Alessio Mastrucci ¹³, Hazel Pettifor ¹⁷, Robert Pietzcker ¹¹, Pedro Rochedo ¹⁸, Bas van Ruijven ¹³, Roberto Schaeffer ¹⁵, Charlie Wilson ^{13,17}, Sonia Yeh ¹⁹, Eleftheria Zisarou ¹⁰ & Detlef van Vuuren ^{1,2}

¹PBL Netherlands Environmental Assessment Agency, The Hague, The Netherlands. ²Copernicus Institute for Sustainable Development, Utrecht University, Utrecht, The Netherlands. ³Ecole des Ponts Paris Tech, Centre International de Recherche sur l'Environnement et le Développement (CIRED), Nogent-sur-Marne, France. ⁴SMASH – CIRED, Nogent-sur-Marne, France. ⁵Centre for Energy and Environmental

Economics (Cenergia), Energy Planning Program (PPE), Coppe, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil. ⁶CMCC Foundation – Euro-Mediterranean Center on Climate Change, Lecce, Italy. ⁷RFF-CMCC European Institute on Economics and the Environment, Milan, Italy. ⁸Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy. ⁹Department of Economics, Ca' Foscari University, Venice, Italy. ¹⁰E3M-Modelling, Athens, Greece. ¹¹Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany. ¹²Global Energy Systems Analysis, Technische Universität Berlin, Berlin, Germany. ¹³Energy, Climate, and Environment Program, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. ¹⁴CNRS, CIRED, Nogent-sur-Marne, France. ¹⁵AgroParisTech, CIRED, Nogent-sur-Marne, France. ¹⁶Faculty of Technology, Policy and Management, Delft University of Technology, Delft, The Netherlands. ¹⁷University of Oxford, Environmental Change Institute, Oxford Centre for the Environment, Oxford, UK. ¹⁸Research and Innovation Center on CO₂ and Hydrogen (RICH Center) and Management Science and Engineering Department, Khalifa University, Abu Dhabi, United Arab Emirates. ¹⁹Chalmers University of Technology, Gothenburg, Sweden.

✉ e-mail: rik.vanheerden@pbl.nl; o.y.edelenbosch@uu.nl

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Further reading

- IPCC in *Climate Change 2022: Mitigation of Climate Change* (eds Pörtner, H.-O. et al.) Ch. 5 (Cambridge Univ. Press, 2023). **This chapter provides an extensive literature overview of demand-side mitigation measures and their estimated impact.**
- Creutzig, F. et al. Demand-side solutions to climate change mitigation consistent with high levels of well-being. *Nat. Clim. Change* **12**, 36–46 (2022). **This article shows that demand-side mitigation options can reduce emissions while simultaneously improving well-being.**
- Hill, G., Heidrich, O., Creutzig, F. & Blythe, P. The role of electric vehicles in near-term mitigation pathways and achieving the UK's carbon budget. *Appl. Energy* **251**, 113111 (2019). **This article demonstrates that accelerating electric vehicle uptake in passenger transport is important to achieve climate targets after 2030 in the UK.**
- Padovani, F., Sommerfeldt, N., Longobardi, F. & Pearce, J. M. Decarbonizing rural residential buildings in cold climates: A techno-economic analysis of heating electrification. *Energy Build.* **250**, 111284 (2021). **This article demonstrates that sustainable heating electrification is techno-economically viable in rural, residential buildings in cold climates.**

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Competing interests

The authors declare no competing interests.