

Decarbonizing Tomorrow: Technological, Behavioral, and Policy Solutions to Climate Change

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Introduction

Climate change is among the most urgent global challenges of the 21st century, causing rising sea levels, extreme weather events, and biodiversity loss. Tackling this crisis requires both immediate and long-term interventions. Fortunately, an expanding body of research has revealed a set of powerful technological and behavioral strategies that, if widely adopted, can help stabilize global temperatures and avert catastrophic outcomes. This essay explores four major solution pathways: decarbonized transportation, green buildings and integrated infrastructure, carbon capture technologies, and behavior-policy synergy. Supported by advanced engineering and policy frameworks, these solutions offer a realistic route to net-zero emissions by mid-century (Larsen et al., 2022).

1. Decarbonizing Transportation: The Role of Electric Vehicles

The transportation sector is a major emitter of greenhouse gases, accounting for roughly 24% of global CO₂ emissions. A key solution is the widespread adoption of battery electric vehicles (BEVs), especially when powered by low-carbon electricity grids. According to Agoro (2025), EVs can reduce lifecycle emissions by more than 70% in California, compared to internal combustion engine vehicles when powered by renewable energy.

Globally, policy incentives are accelerating the transition toward low-emission transportation. In the United States, the Inflation Reduction Act (IRA) is projected to significantly boost the adoption of electric vehicles by offering a comprehensive suite of tax credits and subsidies. These provisions are expected to increase the share of electric vehicles in new car sales to between 19% and 57% by 2030, compared to just 12% to 43% without the IRA (Larsen et al., 2022). However, several obstacles still impede the widespread adoption of electric vehicles, including high initial costs, inadequate charging infrastructure in rural regions, and continued range anxiety among consumers.(Boppana, 2023).

Nonetheless, advances in smart charging, bidirectional power flow (vehicle-to-grid), and solid-state battery technology continue to increase the feasibility and sustainability of EVs as a long-term transportation solution.

2. Green Buildings and Energy-Integrated Infrastructure

Buildings contribute nearly 40% of global energy use and carbon emissions. Improving building efficiency and transitioning to net-zero energy systems is crucial. One solution is integrating photovoltaic/thermal (PV/T) systems, which combine electricity generation with solar thermal collectors. These technologies allow buildings to simultaneously meet heating and power needs while reducing carbon footprints (Kazem et al., 2023).

Emerging research also suggests integrating Direct Air Capture (DAC) systems into indoor air systems to capture CO₂ directly from buildings. López et al. (2024) explore how DAC-integrated green buildings could improve indoor air quality while contributing to urban climate goals. This co-benefit strengthens the case for cities to incentivize building retrofits and intelligent climate-aware urban planning.

In parallel, studies on hydrogen-based energy systems highlight the importance of thermally resilient infrastructure. (Goren et al., 2024) emphasize that processes like methane steam reforming for hydrogen production require stable, efficient, and heat-tolerant systems. These findings reinforce the broader importance of engineering building components that can support high-performance, low-emission energy technologies across both residential and industrial contexts.

3. Carbon Capture and Direct Air Capture (DAC) Technologies

Carbon Capture and Storage (CCS) and Direct Air Capture (DAC) are two emerging technologies crucial for addressing residual emissions and legacy CO₂ already in the atmosphere. While CCS is more mature and often integrated into power plants or industrial sites, DAC is increasingly being seen as a long-term pillar of negative emissions strategies.

Innovations in adsorbent materials, such as amine-functionalized solid sorbents, are making DAC more energy-efficient and scalable (Ayeleru et al., 2023). Küng et al. (2023) outline a roadmap to reduce DAC costs, a milestone for mass deployment. Mobile DAC systems, such as rail-based air capture, offer novel deployment models that allow flexibility and integration with underutilized energy sources like stranded renewables (Bachman et al., 2022).

International case studies also illustrate the integration of CCS with hydrogen fuel production, as seen in Thailand, where industrial clusters are using carbon capture to decarbonize heavy industries (Chantanakome, 2025). Still, storage availability, regulatory frameworks, and public acceptance remain key barriers to scaling these solutions (Sovacool et al., 2022).

4. Policy and Behavioral Change: Completing the Picture

While technology offers enormous mitigation potential, human behavior and institutional policy determine its adoption rate. For example, behavioral shifts such as reducing red meat consumption, avoiding frequent air travel, and adopting energy-saving habits can collectively reduce personal carbon footprints (Ivanova et al., 2020).

At the systemic level, governments must enact policies such as carbon pricing, green subsidies, and regulatory standards. The success of the IRA in the U.S. and the EU's Emissions Trading Scheme are prime examples of how coordinated action can drive change. Moreover, public awareness campaigns and climate education in schools have been shown to foster long-term environmental stewardship (Carmichael, 2019).

Equally important is the global equity in deploying negative emission technologies such as DAC, which must be affordable and scalable in resource-abundant regions to maximize their climate mitigation potential (Breyer et al., 2020).

Conclusion

Solving climate change demands a systemic, multi-faceted response that integrates advanced technology, robust policy, and cultural transformation. From electric vehicles and zero-carbon buildings to scalable carbon capture and behavioral shifts, each solution plays a vital role. The challenge now lies not in identifying solutions but in coordinating their deployment at the necessary speed and scale. If we act collectively and urgently as research and innovation continue to progress, the path to a livable climate future becomes increasingly achievable.

Reference

- [1] Agoro, H. (2025). *Comparative Study of EV and Internal Combustion Engine (ICE) Vehicles*.
- [2] Ayeleru, O. O., Modekwe, H. U., Onisuru, O. R., Ohoro, C. R., Akinnawo, C. A., & Olubambi, P. A. (2023). Adsorbent technologies and applications for carbon capture, and direct air capture in environmental perspective and sustainable climate action. *Sustainable Chemistry for Climate Action*, 3, 100029.
<https://doi.org/10.1016/j.scca.2023.100029>
- [3] Bachman, E., Tavasoli, A., Hatton, T. A., Maravelias, C. T., Haites, E., Styring, P., Aspuru-Guzik, A., MacIntosh, J., & Ozin, G. (2022). Rail-based direct air carbon capture. *Joule*, 6(7), 1368–1381. <https://doi.org/10.1016/j.joule.2022.06.025>
- [4] Boppana, V. R. (2023). *Climate Tech: Pioneering the Path to a Sustainable Future* (SSRN Scholarly Paper No. 5005716). Social Science Research Network.
<https://doi.org/10.2139/ssrn.5005716>
- [5] Breyer, C., Fasihi, M., & Aghahosseini, A. (2020). Carbon dioxide direct air capture for effective climate change mitigation based on renewable electricity: A new type of energy system sector coupling. *Mitigation and Adaptation Strategies for Global Change*, 25(1), 43–65. <https://doi.org/10.1007/s11027-019-9847-y>
- [6] Carmichael, R. (2019). *Carmichael, R. (2019) Behaviour change, public engagement and Net Zero. A report for the Committee on Climate Change. Available at*
<https://www.theccc.org.uk/publications/> and
<http://www.imperial.ac.uk/icept/publications/>.

- [7] Chantanakome, W. (2025). Carbon Capture, Usage, and Storage (CCUS) Implications in Thailand. In *Energy Transition and Carbon Neutrality in ASEAN* (pp. 69–89). https://doi.org/10.1142/9789811288050_0003
- [8] Goren, A. Y., Dincer, I., Gogoi, S. B., Boral, P., & Patel, D. (2024). Recent developments on carbon neutrality through carbon dioxide capture and utilization with clean hydrogen for production of alternative fuels for smart cities. *International Journal of Hydrogen Energy*, 79, 551–578. <https://doi.org/10.1016/j.ijhydene.2024.06.421>
- [9] Ivanova, D., Barrett, J., Wiedenhofer, D., Macura, B., Callaghan, M., & Creutzig, F. (2020). Quantifying the potential for climate change mitigation of consumption options. *Environmental Research Letters*, 15(9), 093001. <https://doi.org/10.1088/1748-9326/ab8589>
- [10] Kazem, H. A., Al-Waeli, A. H. A., Chaichan, M. T., & Alnaser, W. E. (2023). Photovoltaic/thermal systems for carbon dioxide mitigation applications: A review. *Frontiers in Built Environment*, 9. <https://doi.org/10.3389/fbuil.2023.1211131>
- [11] Küng, L., Aeschlimann, S., Charalambous, C., McIlwaine, F., Young, J., Shannon, N., Strassel, K., Nichole Maesano, C., Kahsar, R., Pike, D., Spek, M. van der, & Garcia, S. (2023). A roadmap for achieving scalable, safe, and low-cost direct air carbon capture and storage. *Energy & Environmental Science*, 16(10), 4280–4304. <https://doi.org/10.1039/D3EE01008B>
- [12] Larsen, J., King, B., Kolus, H., Dasari, N., Hiltbrand, G., & Herndon, W. (2022). *A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy*

Provisions in the Inflation Reduction Act.

https://policycommons.net/artifacts/2649285/a-turning-point-for-us-climate-progress_inflation-reduction-act/3672158/

- [13] López, L. R., Dessì, P., Cabrera-Codony, A., Rocha-Melogno, L., Kraakman, N. J. R., Balaguer, M. D., & Puig, S. (2024). Indoor CO₂ direct air capture and utilization: Key strategies towards carbon neutrality. *Cleaner Engineering and Technology*, 20, 100746. <https://doi.org/10.1016/j.clet.2024.100746>
- [14] Sovacool, B. K., Baum, C. M., Low, S., Roberts, C., & Steinhauser, J. (2022). Climate policy for a net-zero future: Ten recommendations for Direct Air Capture. *Environmental Research Letters*, 17(7), 074014. <https://doi.org/10.1088/1748-9326/ac77a4>

Statement on AI use

GenAI Declaration

Jinyu LIN

I acknowledge the below use of ChatGPT (<https://chatgpt.com>) to refine the academic language, coherence, and clarity of my own work on 11 April 2025 for the below submission. I instructed ChatGPT to “Enhance the clarity, coherence, and conciseness of the essay while improving logical flow and readability.” The output (screenshots) were then further refined to ensure precise academic expression and alignment with my original intent.

这段话写的有些冗杂，读起来不太流畅，请帮我改成更流畅的句子：
However, the widespread adoption of electric vehicles still faces several challenges, including high upfront costs, insufficient charging infrastructure, especially in rural areas, and persistent range anxiety among consumers.

当然可以，下面是一个更流畅、简洁的版本：

However, the widespread adoption of electric vehicles remains hindered by high upfront costs, limited charging infrastructure—particularly in rural areas—and ongoing consumer concerns about driving range.

如果你想要语气更正式或书面一些，也可以试试这个版本：

However, several obstacles still impede the widespread adoption of electric vehicles, including high initial costs, inadequate charging infrastructure in rural regions, and continued range anxiety among consumers.

需要我根据上下文进一步优化语气或风格吗？

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修改：尽量减少材料的介绍，要切合这一段内容的主题，请在这一段后面加上该段文本的简短描述：

2. Green Buildings and Energy-Integrated Infrastructure
Buildings contribute nearly 40% of global energy use and carbon emissions. Improving building efficiency and transitioning to net-zero energy systems is crucial. One solution is integrating photovoltaic/thermal (PV/T) systems, which combine electricity generation with solar thermal collectors. These technologies allow buildings to simultaneously meet heating and power needs while reducing carbon footprints (Kazem et al., 2023). Emerging research also suggests integrating Direct Air Capture (DAC) systems into indoor air systems to capture CO₂ directly from buildings. Dessì et al. (2024) explore how DAC-integrated green buildings could improve indoor air quality while contributing to urban climate goals. This co-benefit strengthens the case for cities to incentivize building retrofits and intelligent climate-aware urban planning.

当然可以！以下是你所提供段落的**修改版**，我已将 Goren et al. (2024) 的研究结果合理融入，并保留原段落结构的连贯性。材料技术的描述被简化，同时与**绿色建筑与能源系统集成**的主题保持紧密相关。

✅ **修改后段落：**

2. Green Buildings and Energy-Integrated Infrastructure

Buildings contribute nearly 40% of global energy use and carbon emissions. Improving building efficiency and transitioning to net-zero energy systems is crucial. One solution is integrating **photovoltaic/thermal (PV/T)** systems, which combine electricity generation with solar thermal collectors. These technologies allow buildings to simultaneously meet heating and power needs while reducing carbon footprints (Kazem et al., 2023).

I understand that GenAI can be used as a tool and is not a substitute for doing my own work. I acknowledge that any violation of academic honesty policies may result in disciplinary action.”