From Silos to Synergy: Identifying a Roadmap for Cross-Sector Research to Accelerate the Clean Energy Transition

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National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
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Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5400-91793
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Suggested Citation
Sharda, Shivam, Venu Garikapati, Tim Laclair, Nicole Viz, Katelyn Stenger, Bingrong Sun and Mark Ruth. 2024. *From Silos to Synergy, identifying a Roadmap for Cross-Sector Research to Accelerate the Clean Energy Transition*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-91793. https://www.nrel.gov/docs/fy25osti/91793.pdf.

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National Renewable Energy Laboratory
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Golden, CO 80401
303-275-3000 • www.nrel.gov

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by NREL's Internal Planning and Assessment (P&A) Effort. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

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Preface

The global transition to clean energy is one of the most important challenges of our time. Improving energy security, reducing energy burden, and fostering economic growth is very likely to require coordinated efforts across multiple sectors—transportation, energy, buildings, industry, and more. This report, *From Silos to Synergy: Identifying a Roadmap for Cross-Sector Research to Accelerate the Clean Energy Transition*, seeks to break down the silos that have traditionally separated these sectors, exploring the synergies and collaborations necessary to drive innovation and accelerate the deployment of sustainable solutions.

Drawing on insights from a diverse group of experts spanning energy systems, mobility systems, renewable technologies, grids, and urban planning, this report outlines key challenges, opportunities, and actionable pathways for cross-sectoral technology adoption research. By integrating perspectives from various domains, we aim to create a comprehensive vision for advancing decarbonization across sectors, while also addressing equity, economic, and technological challenges.

As clean energy solutions continue to evolve, it is clear that no single sector can achieve the level of transformation required. The future of energy systems are likely to be defined by the interconnection of technologies and the integration of new business models and policy frameworks. This report presents a roadmap for advancing this transition, offering key takeaways and next steps to promote an ecosystem of collaboration that drives sustainable energy outcomes. We hope this document serves as both a foundation and a call to action for researchers, policymakers, industry leaders, and stakeholders to work together in forging a cleaner, affordable, and more resilient energy future.

Acknowledgments

The authors would like to extend their heartfelt gratitude to the following individuals for their valuable time, insights, and feedback on the topic of cross-sectoral technology adoption: Alison Holms, Ashreeta Prasanna, Bryan Palmintier, Janet Reyna, Rawad El Kontar, Elisabeth Graffy, Kenneth Kelly, Eric Wilson, Jeffrey Gonder, Stacey Rothgeb, Paritosh Das, Jenny Sumner, Nadia Panossian, Carishma Gokhale-Welch, John Farrell, Thomas Bowen, Zahra Fallahi, Julia Sullivan, Sika Gadzanku, Korbaga Woldekidan, Otto Van Geet, Craig Simmons, Kim Trenbath, Paul Torcellini, Nate Blair, Chris Gearhart, Jeff Cook, Brittany Smith, Jibo Sanyal, Matteo Muratori, Elaine Hale, Arthur Yip, Catherine Ledna, Melissa Rossi, Patrick Walsh, Eric Lockhart, Alexis Zubrow, Casey Roepke, Kristen Ardani, and Samantha Sekar. The authors would also like to thank Panos Datskos, and Kristen Ardani, for supporting the pursuit of this idea as well as the development of this white paper. Overall, the collective guidance on the synergies between sectors has been instrumental in shaping the vision of this project.

List of Acronyms

DOE	U.S. Department of Energy
NREL	National Renewable Energy Laboratory
EV	Electric vehicle
GHG	Greenhouse gas emissions
LA 100	The Los Angeles 100% Renewable Energy Study and Equity Strategies
PV	Photovoltaics
ATB	Annual Technology Baseline
URDB	Utility Rate Database

Executive Summary

National blueprints for the transportation (U.S. Department of Energy, 2023), building (U.S. Department of Energy, 2024), and grid/electricity (U.S. Department of Energy, 2021) sectors call for ambitious reductions in greenhouse gas emissions by 2050 through adoption of various technologies. These include adoption of zero emission vehicles, increased investment in transit and active mobility, and strategies to reduce emissions across multiple modes, including freight in the transportation sector; accelerating adoption of energy-efficient appliances such as heat pumps, and highlighting the need to retrofit existing infrastructure in the building sector; and incentivizing energy storage and solar photovoltaics (PV) in the electricity sector.

However, the fact that adoption of all these technologies is interlinked as a household-or firm-level decision is often overlooked. Similarly, there is currently limited exploration on how the adoption of technologies across these sectors will impact net energy demand. This can be attributed to reasons such as the (i) traditionally siloed nature of research, (ii) lack of integrated data and models, and (iii) lack of interest from stakeholders including utilities. These gaps represent a substantial barrier to accelerating the clean energy transition. A more integrated, cross-sector approach to research is needed to better understand these interactions, identify synergies across sectors, and determine how best to deploy and operate clean energy technologies to maximize environmental and economic benefits.

This planning and assessment study by an interdisciplinary team of researchers aims to identify needs, challenges, and opportunities in cross-sector research to accelerate the decarbonization goals across the sector specific blueprints and aligns closely with NREL's Integrated Energy Pathways critical objective. Through in-depth one-on-one and group discussions with twenty-two NREL researchers across transportation, buildings, solar, and grid domains, the study identifies potential synergies to facilitate the development of interdisciplinary tools, models, and other capabilities to better understand cross-sector interactions.

Summary of key next steps:

1. Interoperability and data standardization for cross-sector analysis
2. Strengthen partnerships with utilities to align energy policies and practices with decarbonization goals
3. Address equity and accessibility as equally important considerations in the clean energy transition
4. Expand innovative funding mechanisms for cross-sector research such as city-specific plans (like LA100) or technology office analysis (like DOE's Standard Scenarios).

From the discussions, data standardization and quality emerged as a priority theme, with study participants advocating for a centralized database to enhance data consistency and accessibility across sectors. Active engagement and collaborations with utilities and public utility commissions was also identified as important to align energy policies with decarbonization

goals. However, challenges with data sharing, privacy, and the integration of diverse data sources need to be addressed to leverage these opportunities.

The study also points to the importance of equitable access to clean energy technologies. This includes developing tools and metrics that evaluate the affordability and accessibility of clean energy technologies such as electric vehicles (EVs), photovoltaics (PVs), and energy-efficient homes. Targeted incentives and support for low- and moderate-income households and multi-family homes are essential to overcome financial barriers and promote widespread adoption. The inclusivity of clean energy transition programs can be supported on the frontend through tracking adoption rates by income level and providing tailored guidance to households on technology adoption pathways, and on the backend through informing utilities and energy offices on household adoption patterns.

This effort identifies the value of a holistic, cross-sector approach to clean energy transition research and other decarbonization efforts that accounts for the interdependencies between the transportation, buildings, and energy sectors. By breaking down research silos and encouraging interdisciplinary collaboration, clean energy transition researchers can better address the complexities of the energy transition, ensuring that the United States meets its decarbonization targets in a sustainable, equitable, and cost-effective manner.

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1 An Integrated Cross-Sectoral Path to a Decarbonized Future

The national blueprints for decarbonizing the transportation, buildings, and electricity sectors call for ambitious reductions in greenhouse gas (GHG) emissions by 2050 through adoption of various technologies. Strategies suggested to achieve the decarbonization goals include adoption of electric vehicles (EVs) and enhancing transit services in the transportation sector; adoption of heat pumps and other energy-efficient appliances in the buildings sector; and accelerated solar photovoltaics (PV) adoption as well as energy storage in the electricity sector.

While the sector-specific decarbonization strategies are well-formulated, the interactions and interdependencies between sectors—especially in the adoption of technologies like EVs, PVs, and smart building systems—pose significant challenges that could serve as barriers to achieving the decarbonization goals. For example, deploying EVs and smart building technologies can lead to more heterogeneous electricity demand, stress grid assets, and challenge grid operations. Integrating these technologies may require substantial changes in electricity generation, distribution, and management—including a shift from centralized generation to a decentralized, flexible grid. Similarly, integrating EVs and PVs simultaneously into the grid makes it challenging to assess shifts in electricity usage patterns. Grid operators and planners need a more comprehensive, integrated view of cross-sectoral technology adoption curves to help them predict and manage peak loads effectively.

Complicating matters even further is the fact that these sectors and technologies interact with consumers in numerous (and often confounding) ways. Adoption of these technologies is ultimately a household-level decision (Sharda et al. 2024), and cross-sectoral technology interactions can impact the attractiveness of individual technologies to consumers. To accelerate progress toward the nation's decarbonization goals, it is essential to transcend the sectoral boundaries when assessing consumer behaviors and attitudes/perceptions towards a technology. For example, households equipped with smart energy management systems can optimize energy use by coordinating EV charging with solar energy production, ultimately reducing costs and enhancing efficiency.

There is limited understanding of these and other cross-sector interactions and interdependencies for various reasons, including the traditionally siloed nature of research and the lack of integrated data and models. Furthermore, there is a lack of holistic capabilities—such as integrated approaches, cross-disciplinary collaborations, and adaptive policy frameworks—to address the complex interdependencies among different sectors. These gaps represent a substantial barrier to accelerating the clean energy transition. A more integrated, cross-sector approach to research is needed to better understand these interactions, identify synergies across sectors, and determine how best to deploy and operate clean energy technologies to maximize environmental and economic benefits.

Efforts like the RiDER project are attempting to established links between the dGen, REopt, and SAM models for power system planning in the face of increasing renewable technology adoption, unpredictable outages, and demand changes (Mirletz et al. 2023)—albeit with a unidimensional line of communication between these tools. Dsgrid aggregates output data from

existing sector models (e.g., ResStock, ComStock, EVI-Pro) into a single platform, but does not capture underlying behavioral or adoption pattern interactions between sectors (Hale et al. 2023). Several cross-sector research efforts (Panossian et al. 2022; Wilson et al. 2019; Muratori and Yip 2024; Sharda et al. 2024; Viz et al. 2024) have identified gaps and emphasized the need for more comprehensive models that address sectoral interdependencies, but each of these studies also encounters limitations in scope. These include focusing on either technological impacts or data aggregation without fully exploring the inter-sectoral behavioral dynamics essential for an integrated clean energy transition. This planning and assessment effort identifies gaps, challenges, and opportunities in cross-sector research, with an aim of accelerating decarbonization goals across sectors while being cognizant of the constraints as well as impacts of these technologies on the electric grid. As such, the topics covered through this effort align closely with NREL's Integrated Energy Pathways critical objective.

2 Findings and Key Themes

The interdisciplinary team of researchers from across NREL—with expertise in transportation systems planning, electrical engineering, residential modeling and scaling, and energy storage—collaborated to identify needs, challenges, and opportunities in cross-sector clean energy transition research. The team conducted the research in two phases, using a mixed-methods approach. In Phase I, one-on-one interviews were held with twenty-two researchers from the buildings, grid, solar, accelerated deployment, and transportation sectors to gather insights on their experiences, challenges, and perspectives related to cross-sector research. These interviews were guided by three key questions to understand needs, challenges and opportunities in cross-sectoral research as summarized in Figure 1. In Phase II, the team facilitated one in-person and one virtual group discussion, where researchers from various sectors collaborated to address specific cross-sector challenges and explore synergies. Responses were collected using sticky notes and Google Jamboard, grouped into themes, and further discussed to identify a roadmap for cross-sectoral research.

The needs identified in Phase I included:

- Interdisciplinary modeling approaches that consider the interconnectedness of various sectors such as transportation, buildings, and energy systems
- Improved understanding of consumer behavior and preferences, particularly in low-income and disadvantaged communities, to support technology adoption and an equitable clean energy transition
- Models that incorporate socio-economic factors and policy levers while addressing barriers to technology adoption from multiple perspectives
- A comprehensive tool to guide consumers and households on technology adoption pathways that minimize their costs and energy consumption
- Enhanced approaches to optimize grid infrastructure and manage energy demand
- Research on grid integration strategies, smart grid technologies, and infrastructure upgrades
- More engagement with utilities to tap the potential of grid-interactive buildings to support grid resiliency and load management
- Research efforts that engage and empower communities, build local capacity, promote energy literacy and transparency, and enhance participation in decision-making processes
- Collaborative efforts between academia, research institutions, government agencies, and utility companies, such as partnerships, knowledge sharing platforms, and interdisciplinary research.

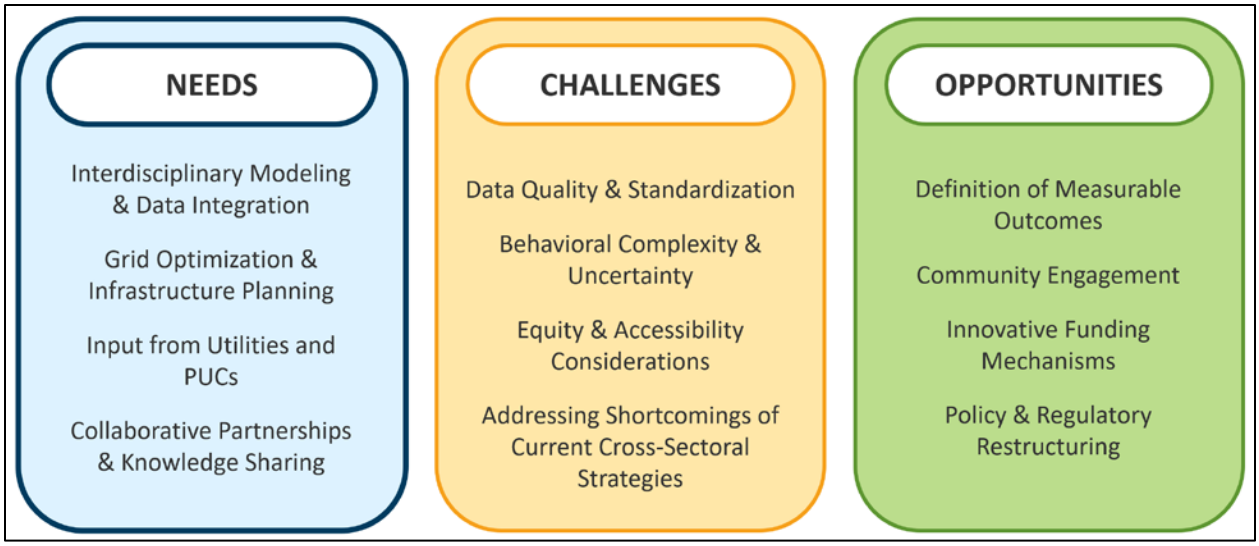

Figure 1. Summary of Research Needs, Challenges, and Opportunities

Challenges discussed in the one-on-one conversations included:

- A lack of standardized data sets and data sharing protocols hindering the development of robust cross-sector models and analysis
- Limited funding opportunities for cross-sector research
- Enhanced collaboration within U.S. Department of Energy (DOE) offices and State Energy Offices could be further strengthened by aligning priorities and addressing challenges in securing funding for joint (or cross-sectoral) initiatives
- Renewable energy integration is challenged by grid limitations, rate design, and regulatory constraints.

One-on-one discussions uncovered these concrete opportunities:

- Interdisciplinary research and collaborative partnerships spanning engineering, social sciences, economics, and policy could lead to breakthroughs in understanding complex energy systems and developing holistic solutions
- Research can be more impactful by defining and quantifying measurable outcomes, such as metrics related to energy efficiency, grid benefits, and consumer acceptance of transportation and buildings technologies
- Social equity can be enhanced through research efforts that engage and empower communities, build local capacity, promote energy literacy and transparency, and increase participation in decision-making processes.

Building on the needs, challenges, and opportunities discussed in Phase I, Phase II discussions identified the following synergies by NREL researchers (see Figure 2 highlighting virtual participation) to facilitate cross-sector research:

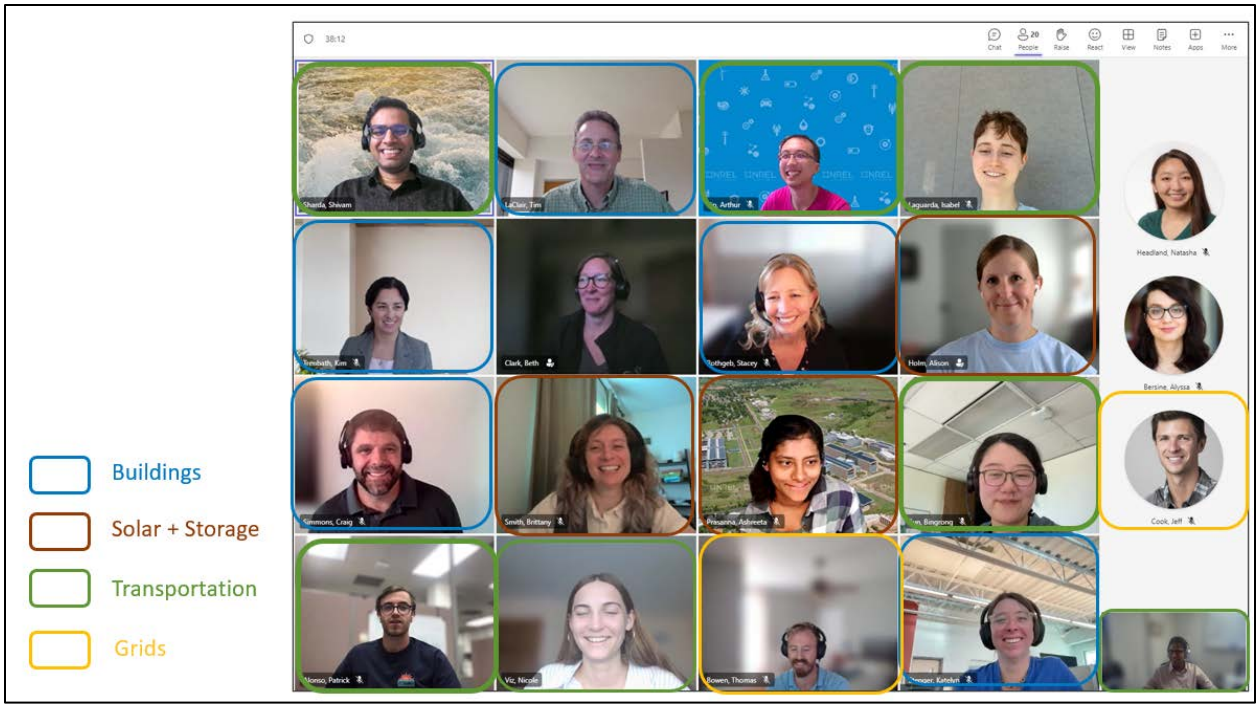

Figure 2. Group Photo from Virtual Panel Discussion in Phase II

Build Multi-Sector Tools from the Ground Up: Single-sector tools often fail to capture the complexities and interdependencies of a multi-sector energy landscape, which may challenge demand-side dynamics. The group discussion revealed a tendency in the research community to "patch together" existing tools from multiple sectors rather than creating new, interdisciplinary tools tailored to integrate insights from various fields. There was a consensus on the value of developing these new tools from a bottom-up approach, despite the challenges of securing funding through multiple DOE offices. Researchers noted that a similar question is being explored as part of the DECARB project, and there is agreement on the need to integrate single-sector tools. However, participants highlighted the difficulties in merging multiple tools into a cohesive framework due to differing embedded assumptions, resolutions, and data standards. To address this challenge, the development of a mechanism designed to reconcile these differences in assumptions and spatial-temporal resolutions across existing tools is crucial.

Map Interdependencies Among Sectors and Technologies: Participants suggested an explicit mapping of interdependencies to clearly show how actions in one sector can impact other sectors. In other words, sectors pairing and the implications of coupling them might be articulated through interdependency mapping. Such mapping can help researchers, utilities, consumers, and other stakeholders understand the relevant interactions and tradeoffs. For example, with a better understanding of the tradeoffs between costs and carbon emissions, consumers and policy makers can make informed choices that align with both economic and environmental objectives. A researcher studying residential solar adoption might benefit from an interdependency map that describes the extent to which EV adoption impacts the local grid. For a consumer considering purchasing an EV, an interdependency map could show how home charging would impact their electricity bills and energy consumption. Interdependency mapping would likely increase the effectiveness and accuracy of research tools.

Increased Understanding of Consumer Decision-Making Processes: This could enable design and implementation of more energy solutions that align with consumer preferences, increasing adoption. While cost reigns supreme in making a purchase decision for many of these technologies, it is critical to develop context-aware technology adoption prediction models to enable the generation of more realistic adoption curves. For example, an apartment dweller might be more inclined to adopt EVs compared to PVs (due to the challenges involved in powering an individual and rented unit in a multi-family dwelling using PVs). Similarly, while rural residents might have an aversion to EVs (due to range anxiety or other issues), presenting EVs as an energy storage solution in addition to a mobility solution might increase their value proposition.

Data Standardization and Data Quality: There was immediate consensus among participants that data standardization and quality are crucial to effective cross-sector clean energy research. Establishing a master relational dataset—perhaps hosted in a centralized location such as DOE's Livewire Data Platform—could significantly enhance data accessibility and consistency across various sectors. Since it might be aspirational to create a comprehensive dataset spanning all of these sectors, it might be realistic to identify sector-pairs that would most benefit from such a dataset as the first step in the process. Such a database would allow for integration of diverse datasets, ensuring that all stakeholders are working with the same high-quality information. Additionally, developing a set of reasonable default variables, values, assumptions, and scenarios, akin to how the NREL's Annual Technology Baseline (ATB) standardizes sector-specific energy technology cost and performance metrics, could possibly be synergized and extended to multiple sectors to ensure consistency in analyses and decision-making processes. High resolution across multiple data sources and tools is essential for producing accurate and actionable insights. Meeting participants discussed the need for increased data granularity as well as thorough documentation to ensure that all variables and assumptions are clearly defined and understood.

Collaboration with Utilities: Many participants agreed that collaboration with utilities is essential to advancing the clean energy transition, since utilities play a pivotal role in implementing and managing energy programs. Tools like the Utility Rate Database (URDB), which standardizes and provides access to rate data, exemplify how shared resources can enhance transparency and support energy planning. A marketplace of utility program data that includes performance and outcomes could greatly enhance transparency, facilitate sharing of best practices and innovation, and lead to more effective, scalable energy solutions. Furthermore, cooperation among researchers, energy planners, private utilities and public utility commissions is critical for accurately determining planning needs and available resources. Cultivating such collaboration was also identified to be challenging as utilities and utility commissions devote most of their time to ensuring smooth day-to-day operations. They also typically have data sharing and privacy concerns and lack the bandwidth and budget to establish a program data marketplace. The potential for shared benefits, however, should encourage both parties to find a solution to these challenges. By working together, these entities can ensure that energy policies and programs are aligned with current energy demand, consumer needs, and sustainability goals, fostering a more resilient, efficient energy infrastructure.

Strategies to Support an Equitable Clean Energy Transition: Participants highlighted that evaluations of clean energy costs and incentives should fully consider the needs and preferences

of property owners. By incentivizing the owners to adopt sustainable technologies so that they can both directly enjoy and share the benefits with their tenants, a more equitable distribution of benefits can be achieved. Special attention should be given to low- and moderate-income communities and multi-family dwellings, where the financial barriers to energy upgrades are often higher. Tailored incentives and support for these groups can help ensure that the benefits of clean energy—such as reduced utility bills and improved living conditions—are accessible to all, fostering greater inclusivity and fairness in the clean energy transition. Researchers across the board agreed that a potential way to promote equity through multi-sector research could be to improve the tracking of clean energy adoption by income level. These data could help pinpoint disparities and inform targeted interventions.

Developing household guidance tools tailored to the needs of lower-income households can empower them to participate in the clean energy transition. Such tools can offer practical advice and financial assistance for navigating the complexities of energy upgrades. For example, a resource could be developed to track available technology incentives at utility, city, state, and federal levels and provide information about cost effectiveness and payback periods.

Effective community engagement is also essential for successful clean energy transition, especially in overcoming barriers related to inconvenience and short consumer attention spans. To engage communities meaningfully, it is important to start by understanding the root causes of their concerns and identifying any critical non-energy needs that may be affecting their willingness or ability to participate. For example, a household with mold problems or a leaky roof will likely want to address those issues before adopting rooftop solar. By addressing these fundamental issues first—whether they relate to economic, social, or logistical challenges—clean energy programs can foster trust and buy-in, support community well-being, and make the energy transition smoother and more impactful for all involved.

Funding and Collaborative Models: When advocating for cross-sector research in the clean energy transition, participants from several research areas said that it may be effective to demonstrate the tangible benefits to stakeholders at the outset. By using case studies and storytelling, the real-world impact of integrated research across sectors like transportation, residential energy, and grid management can be vividly illustrated. These narratives can effectively convey how cross-sector approaches lead to more comprehensive solutions, greater efficiency, and enhanced sustainability. It can also be beneficial to identify and engage with the stakeholders who stand to benefit the most from this research—such as policymakers, utilities, and large-scale energy consumers. By prioritizing these stakeholders in outreach efforts, the momentum for cross-sector research can be built more rapidly, driving broader adoption and collaboration.

Finally, participants discussed potential pathways to accelerate cross-sector research. One researcher suggested an incremental approach—starting with a focus on pairs of interacting sectors and later expanding to multi-sector interactions. Aligning various research team programs with sector interactions and proposing coordinated scopes to clients and sponsors could streamline efforts and enhance effectiveness. Furthermore, simultaneously engaging multiple DOE programs and State Energy Offices in the conversation of cross-sector research will help researchers to better understand these stakeholders' viewpoints, and to address concerns they may have in supporting research that extends beyond the immediate charter of individual offices.

Collaborating with climate-interested foundations and organizations could provide additional funding and support, facilitating a more holistic approach to energy research and innovation.

3 Conclusions and Next Steps

This report identifies several key insights that serve as a foundation for advancing a decarbonized future. First, there is a pressing need for interdisciplinary collaboration among stakeholders across transportation, buildings, and energy sectors to foster synergies and drive comprehensive solutions. Second, understanding consumer behavior and preferences is critical for effectively implementing new technologies, as these insights will inform strategies that enhance adoption and acceptance. Third, addressing equity and accessibility issues would ensure that all communities, particularly those historically marginalized, can participate in and benefit from the clean energy transition. Lastly, establishing standardized data frameworks will be essential for tracking progress and guiding decision-making across sectors.

Based on these insights, the following actionable research agenda is proposed:

1. **Interdisciplinary Collaboration:** Initiate a series of workshops and collaborative research projects that bring together experts from transportation, energy, grid, and buildings sectors to identify specific synergies and co-develop solutions. Stakeholders involved would include research and academic institutions, industry leaders, policymakers, and community organizations.

2. **Consumer Behavior Research:** Conduct focused studies on consumer preferences and behaviors related to the adoption of clean technologies. This could involve surveys, focus groups, and pilot programs to gauge acceptance and identify barriers. Collaboration with behavioral scientists, market researchers, and local governments will be essential in this phase.

3. **Equity Assessments:** Develop a framework for assessing the equity implications of new technologies and policies. This could involve creating metrics to evaluate access to clean technologies and their affordability for low-income communities. Engaging with community organizations and advocacy groups will ensure that diverse perspectives are included in this research.

4. **Standardized Data Frameworks:** Work towards establishing unified/coordinated data-sharing that facilitates access to relevant data across sectors. This initiative would involve partnerships with governmental agencies, utility companies, and data analytics firms to ensure comprehensive and standardized data collection and dissemination methods.

Implementing this research agenda will require sustained engagement with stakeholders, continuous funding support, and a commitment to adaptive learning as new challenges and opportunities arise in the transition to a decarbonized future. This study was intended as an initial exploratory step to advance cross-sector research. To keep the momentum going, it is important to have ongoing discussions about this important topic. Quarterly meetings of cross-sector researchers and brown bag seminars with DOE offices can convene interested parties and increase connectedness and transparency. These actions are likely to support the creation of a resilient, equitable, and sustainable energy landscape that benefits all sectors of society.

References

U.S. Department of Energy. 2024. *Decarbonizing the U.S. Economy by 2050: A National Blueprint for the Buildings Sector.* https://www.energy.gov/eere/decarbonizing-us-economy-2050-national-blueprint-buildings-sector.

U.S. Department of Energy. 2023. *The U.S. National Blueprint for Transportation Decarbonization: A Joint Strategy to Transform Transportation.* DOE/EE-2674. https://www.energy.gov/eere/us-national-blueprint-transportation-decarbonization-joint-strategy-transform-transportation.

U.S. Department of Energy. 2021. *Solar Futures Study*. GO-102021-5621. https://www.energy.gov/articles/doe-releases-solar-futures-study-providing-blueprint-zero-carbon-grid

Sharda, Shivam, Venu Garikapati, Konstadinos Goulias, Janet Reyna, Bingrong Sun, Anna Spurlock, and Zachary Needell. 2024. "The electric vehicles-solar photovoltaics Nexus: Driving cross-sectoral adoption of sustainable technologies." *Renewable and Sustainable Energy Reviews* 191 (March 2024): 113172. https://www.sciencedirect.com/science/article/abs/pii/S1364032123010304.

Mirletz, Brian, Michaela Sizemore, Paritosh Das, & Jane Lockshin. 2023. "Linkages Between NREL's dGen, REopt, and SAM Models." https://www.nrel.gov/docs/fy23osti/86898.pdf

Hale, Elaine, Henry Horsey, Brandon Johnson, Matteo Muratori, Eric Wilson, et al. 2018. "The Demand-side Grid (dsgrid) Model Documentation." Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71492. https://www.nrel.gov/docs/fy18osti/71492.pdf

Panossian, Nadia, Matteo Muratori, Bryan Palmintier, Andrew Meintz, Timothy Lipman, and Keith Moffat. 2022. "Challenges and Opportunities of Integrating Electric Vehicles in Electricity Distribution Systems." *Current Sustainable/Renewable Energy Reports* 9: 27-40. https://link.springer.com/article/10.1007/s40518-022-00201-2.

Wilson, Eric, Chioke Harris, Joseph Robertson, and John Agan. 2019. "Evaluating energy efficiency potential in low-income households: A flexible and granular approach." *Energy Policy* 129 (June 2019): 710-737. https://www.sciencedirect.com/science/article/abs/pii/S0301421519300527.

Muratori, Matteo and Arthur Yip. 2024. "Projecting Electric Vehicle Electricity Demands and Charging Loads." Presented at EVS37 (International Electric Vehicle Symposium & Exhibition), Korea, April 23-26, 2024. NREL/PR-5400-89775. https://www.nrel.gov/docs/fy24osti/89775.pdf.

Viz, Nicole, Shivam Sharda, Venu Garikapati, Katelyn Stenger, Konstadinos Goulias, Christopher Hoehne, and Elisabeth Graffy. 2024. “Triple Effect Economics: How Do Electric Vehicles, Solar Photovoltaics, and Work-from-Home Transform Electricity Costs?” Preprint available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4878805.