PIVOT

2023 Annual Report

Powering the Transformation of the Global Energy Economy

JISEA

Joint Institute for Strategic Energy Analysis

PIVOTING TO NEW CLEAN ENERGY CHALLENGES

It's a thrill to offer my letter at such a transitional time in the energy sector. With new major public and private investments in clean energy, climate and geopolitical shifts, and the development of innovative research methodologies and partnerships, there is a palpable pivot in clean energy's role in the global energy system. That's at the heart and the theme of this year's annual report: pivoting to the next generation of clean energy challenges and building innovative, rapid, and inclusive approaches to overcome them.

We are starting with pivoting our research focus. Emerging trends in society, technology, and the environment are raising questions as to how clean energy will continue to meet growing needs in a sustainable and equitable way. So, in addition to the Joint Institute for Strategic Energy Analysis's (JISEA's) longstanding and successful focus on hard-to-decarbonize industries like manufacturing and agriculture, we are expanding our area of work to include investigating clean energy challenges around climate adaptation, technological advancement, and workforce development.

To better address these challenges, we are diversifying the voices on our University Program Committee. JISEA leverages partnerships to identify and seed investment in emerging challenges while pushing the boundaries of innovation in applied scientific research to provide more value to the field and the world. This requires bringing to the table diverse, multidisciplinary voices to widen our perspectives and expand our thinking as to how solutions to these challenges can be developed. We are excited to welcome Dr. Sonya Smith, professor and director of the Atmospheric Sciences Program at Howard University, to the committee and look forward to the new insights she will provide and the partnership we will build between JISEA and Howard University.

Along with diversifying our partners, we are also adding new voices internally. Over the last year, we integrated JISEA with the American-Made program. American-Made is powered by the U.S. Department of Energy (DOE) and administered by the National Renewable Energy Laboratory (NREL), and aims to accelerate the clean energy economy through prizes, networks, teaming, vouchers, and training. American-Made will connect JISEA with stakeholders, partners, and communities to help develop the strategy for growing the clean energy workforce, building programming that supports training solutions and informs technology, research, and analysis gaps.

Thanks to JISEA Founder Doug Arent, former Director Jill Engel-Cox, and NREL's visionary leadership, JISEA has always been a home for the development and testing of innovative solutions. Our pivot will help increase the scope of our work, as well as the mechanisms driving these solutions. We hope this pivot motivates you to start, continue, or reinvent your relationship with JISEA. This annual report reflects the groundbreaking work we can achieve when we work together, and I look forward to accomplishing even more in the coming year.

Elizabeth Doris
Center Director
Joint Institute for Strategic Energy Analysis

LEADING THE GROWTH OF NEW CAPABILITIES

JISEA was initiated in 2011 with the goal of leveraging diverse partnerships to address challenges at the edges of NREL's mission space—defining future work areas for NREL and our partners.

JISEA's success in this mission is seen in its robust portfolio of research on supply chain resilience and sustainability. This work positioned NREL and our partners as leaders in this space as public health and geopolitical disruptions to supply chains left industries and communities struggling to recover. NREL's expertise in rare materials constraints and more continues to inform clean energy manufacturing strategy, helping to strengthen these supply chains.

It is also seen in JISEA's early investments in computable general equilibrium modeling, in partnership with Colorado State University. This work has provided proof of concept for larger-scale economic modeling capabilities that are now in use throughout NREL's flagship projects in Los Angeles, Puerto Rico, and the Navajo Nation.

Our tradition of looking ahead to emerging challenges to clean energy transformation and building the capabilities needed to tackle them continues even as JISEA pivots in the coming year to asking new questions at the intersection of a changing economic, environmental, and security climate.

Addressing these challenges requires an expanded, diverse set of partners. One example of this is JISEA's integration with American-Made and its prize, voucher, and training networks. As a part of JISEA, American-Made not only helps identify on-the-ground knowledge regarding novel solutions to clean energy challenges, but also engages a broader constituency, serving as a force for promoting diversity, equity, and inclusion in clean energy research and innovation.

Even as it expands, JISEA is not wavering from its core mission. Investments continue in thought-leading research capabilities and building connections needed to solve multidisciplinary challenges through the Catalyzers initiative.

JISEA's Sustainable Communities Catalyzer and recently launched Green Computing Catalyzer target areas that are emerging priorities for NREL. This year, we will see the addition of new catalyzers that will continue to influence the future direction and investments of the lab.

As Dr. Elizabeth Doris reaches the 6-month mark at the helm of JISEA, I am excited by the steps she is taking to position the organization for bigger impact while staying true to JISEA's roots. I am confident JISEA will produce transformative work in the coming year that will prepare NREL and the world for facing future energy challenges.

Juan Torres
Associate Laboratory Director
Energy Systems Integration

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PIVOTING FORWARD

JISEA is NREL's center for launching new research domains addressing future challenges to the clean energy transition. Through innovative approaches, JISEA serves as an engine for collaboration to build expertise and capabilities around complex, multidisciplinary issues that the world will face in the decades to come.

The work included in this year's annual report reflects JISEA's achievements using our high-impact research and analysis to guide transformative global energy investment and policy decisions in:

Energy Systems Integration and Transformation

Advanced Manufacturing, Circular Economy, and Clean Power for Industry

Sustainable Communities at the Energy-Water-Food Nexus

EXPANDING OUR EXPLORATORY AREAS

As a future-looking organization, our priority areas evolve with changes to the clean energy ecosystem. Working with our network of partners, we have identified an expanded set of exploratory areas that encompass upcoming challenges in the clean energy space. These exploratory areas will guide our research and network development over the coming year as we work to build a foundation for future long-term investment and research.

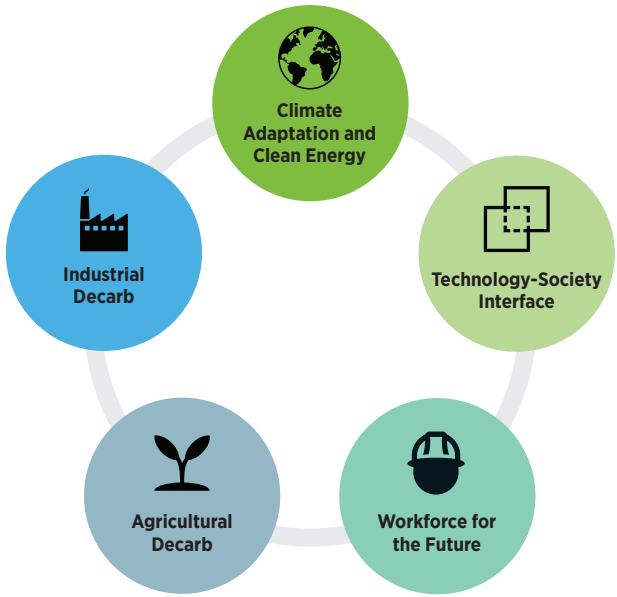
Climate Adaptation and Clean Energy Intersections
The effects of climate change on the efficiency, security, and resilience of the energy system

Technology-Society Interface and the Clean Energy Transformation
The societal implications of advanced clean energy technology

Clean Energy Workforce
The scale and scope of future clean energy workforce needs

Agricultural Decarbonization and the Food-Energy-Water Nexus
The clean energy opportunities and implications in the agricultural sector

Industrial Decarbonization
The development of sustainable, energy-efficient industrial processes



AMERICAN-MADE PROGRAM JOINS JISEA

Along with expanding our focus areas, we are also expanding as an organization with the addition of the American-Made program. The American-Made program was developed in partnership with DOE and is focused on accelerating the clean energy economy through prizes, teaming, vouchers, and training. These programs, led by Group Manager Debbie Brodt-Giles, highlight real-world technology challenges and gaps in the clean energy economy and address them by advancing technology innovation and community development.

JISEA and the American-Made program operate under the same approach to solving complex challenges—connecting researchers, innovators, and partners, and fostering a flexible innovation environment to produce insights, research, and solutions. American-Made builds and utilizes a robust network that includes nearly 400 clean energy industry partners and the DOE national laboratories to help accelerate innovation, partnerships, businesses, and jobs. Through these networks, and through the accessibility of the prize programs, American-Made also develops a diverse new generation of the clean energy workforce, one of JISEA's priority areas.

400+
Network Members

$150M
Cash Prizes and Team Support

300+
Teams Funded

The coming year will bring a variety of new prizes from American-Made, and as this partnership continues to strengthen, we look forward to even greater success fast tracking on-the-ground solutions to clean energy challenges.

LEARN MORE: American-Made Program Website (americanmadechallenges.org)

"We have seen immense growth over the past five years, and now we have technology and community-based prizes that cover nearly every technology office at DOE. What makes me most proud is hearing from innovators that the process was relatively easy and highly impactful to building their technologies, business, and solutions. We are changing the way government thinks about innovation and R&D, opening doors to working with national labs, and accelerating getting funding into the hands of real people who are making a true impact on our clean energy future."

—Debbie Brodt-Giles, Group Manager for Prizes, Networks, and Vouchers

U.S. Secretary of Energy Jennifer Granholm announces the winners of the Community Clean Energy Coalition Prize in Puerto Rico. The Community Clean Energy Coalition Prize helps community coalitions—made up of nonprofits, city governments, school systems, and other community organizations—come together to develop a strategy to address a local clean energy opportunity or inequity. Photo from DOE

ENERGY SYSTEMS INTEGRATION AND TRANSFORMATION

OPTIMIZING ENERGY SYSTEMS WITH DIVERSE ENERGY SOURCES

Decarbonized energy systems require strategic coordination to integrate in a way that ensures reliable and affordable energy.

To meet the needs of a growing market share of clean energy technology, a strategic transition from individual to integrated systems is required.

Integrating energy systems maximizes the value of each energy source and ensures clean, reliable, and affordable energy. Coordinating this integration relies on expert analysis of the policies and mechanisms that govern various energy systems and their intersections, and often requires the development of novel approaches that are suited to the new dynamics of integrated systems.

Over the past year, JISEA has provided analysis and thought leadership on a variety of scales to advance synergistic solutions that integrate renewable and conventional energy technologies.

JISEA analysts worked at the country level to determine the effects of real-world policy decisions on energy system costs and consumption. Analysts also worked to quantify the economic benefits of the integration of nuclear energy in various countries.

JISEA's work also included developing innovative tools for advancing decarbonized systems, including proposed financing mechanisms adapted for hybrid energy systems and an evaluation tool for determining the appropriate policy for decarbonizing transportation systems through traffic decongestion.

By working in energy systems integration and transformation, JISEA helps equip decision-makers and stakeholders with the insight needed to make impactful policy and process decisions that align with their energy goals. The result is a push toward energy systems that benefit from the unique advantages of their diverse energy sources.

ANALYZING POLICY IMPACTS ON MEXICO'S POWER SYSTEM

Under the legal framework of the 2013 energy reform, and the subsequent 2014 Electric Industry Law, Ley de la Industria Eléctrica (LIE), Mexico operates its power system utilizing "economic dispatch." In practice, this means the National Energy Control Center, Centro Nacional de Control de Energía, ranks power generation plants on a "merit order" from lowest to highest variable costs, allowing the lowest-cost generator to provide power at any time.

However, the enactment of new amendments to the LIE would fundamentally alter the commitment and dispatch framework of the power system by prioritizing state-owned power plants.

As part of the 21st Century Power Partnership (21CPP), JISEA analyst Riccardo Bracho led an analysis of Mexico's power system under these new amendments to better understand the potential implications to production costs and power sector emissions. The analysis modeled four scenarios, including a reference scenario of the old commitment and dispatch framework and three additional scenarios of various potential changes arising from the amendments aimed at operating the power system with larger proportions of state-owned utility power supply.

21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

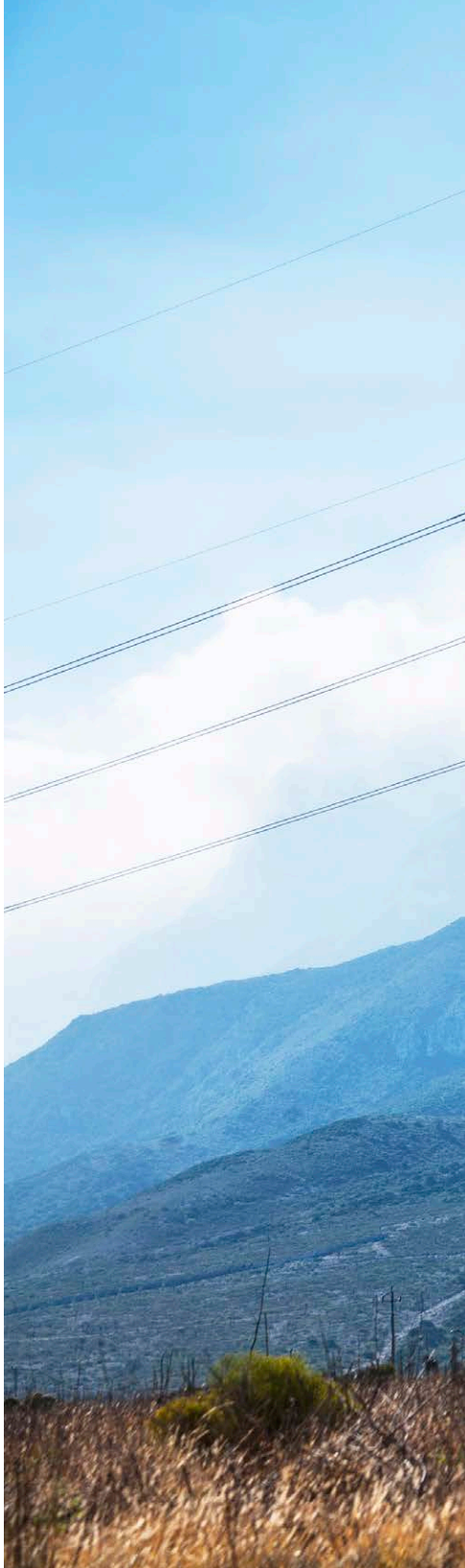
About the 21st Century Power Partnership

21CPP is a Clean Energy Ministerial (CEM) program operating under JISEA that works to advance global clean energy transformation. The program focuses on in-country technical assistance in Mexico, South Africa, India, and China, working to inform policy and disseminate tools.

The study concluded that prioritizing state-owned power plants for Mexican power generation would lead to increased variable electricity production costs, as well as increased consumption of fossil fuels and increased carbon dioxide, sulfur dioxide, and nitrogen oxides emissions.

This study contributed to 21CPP's overall goal of supporting Mexico's energy system transformation by providing analysis-based insights to better inform policymakers, regulators, and system operators.

LEARN MORE: Impacts Analysis of Amendments to Mexico's Unit Commitment and Dispatch Rules (https://www.nrel.gov/docs/fy22osti/81350.pdf)



HIGHLIGHTING NUCLEAR POWER'S BENEFITS TO LOCAL ECONOMIES

The integration of clean energy systems not only advances decarbonization goals, but can also benefit the communities the systems serve by driving economic growth. The Nuclear Innovation: Clean Energy Future (NICE Future) initiative published a technical fact sheet summarizing the benefits nuclear energy development can create for local economies.

NICE Future
Nuclear Innovation: Clean Energy Future
An Initiative of the Clean Energy Ministerial

The fact sheet explored case studies of job creation by nuclear energy programs in three countries with long-standing nuclear power plants and a mature supply chain to support nuclear energy—France, South Korea, and the United States. The case studies highlighted the creation of thousands of direct jobs at facilities, indirect jobs at associated operations, and induced jobs that support a growing workforce (i.e., health care and service industry jobs).

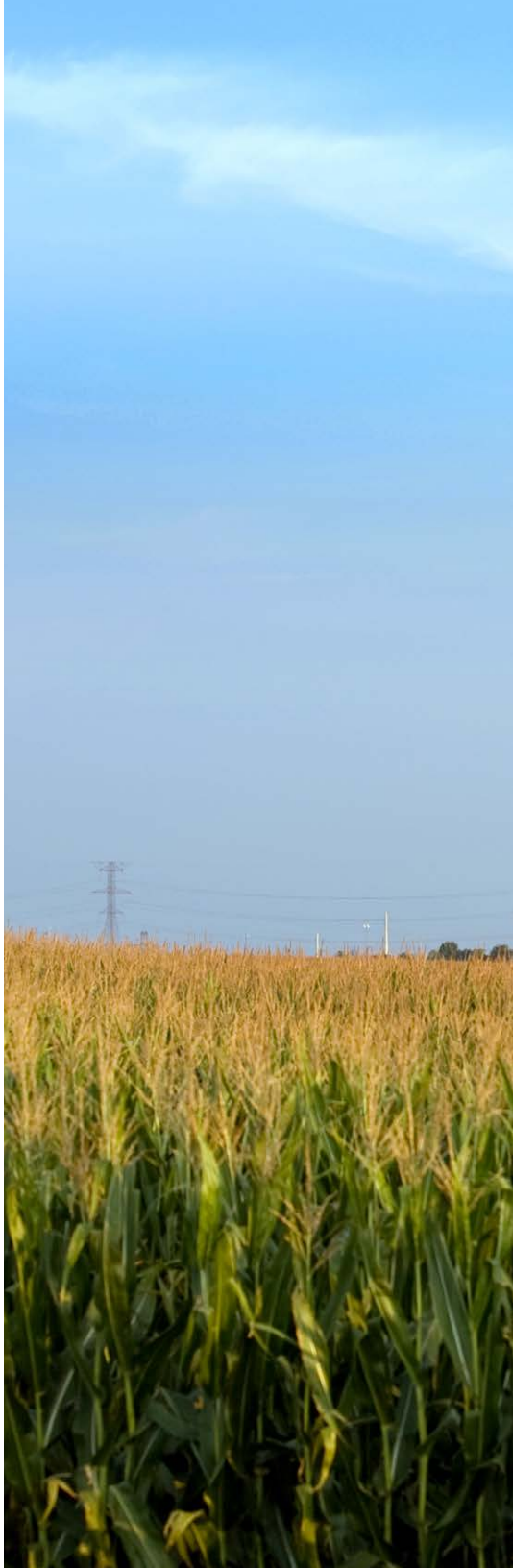
In addition to showcasing job creation, the fact sheet also demonstrated that nuclear energy often protects against energy price volatility and can provide more dispersed community-level impacts with the construction of smaller power plants.

Through this resource, JISEA analysts sought to provide stakeholders with a holistic understanding of the economic benefits of nuclear energy systems, including those provided directly by nuclear energy and those that arise when nuclear power supplements existing energy systems.

About the Nuclear Innovation: Clean Energy Future Initiative

The NICE Future Initiative leads global conversation on the potential roles of nuclear energy in future clean energy systems. NICE Future is an international initiative of the Clean Energy Ministerial and is operated by JISEA, which implements activities based on guidance from CEM, the United Nations, and NICE Future partners and stakeholders.

LEARN MORE: Nuclear Energy—Providing Power, Building Economies (https://www.nrel.gov/docs/fy22osti/82419.pdf)



DEVELOPING TOOLS FOR QUANTIFYING TRAFFIC CONGESTION AND EMISSIONS

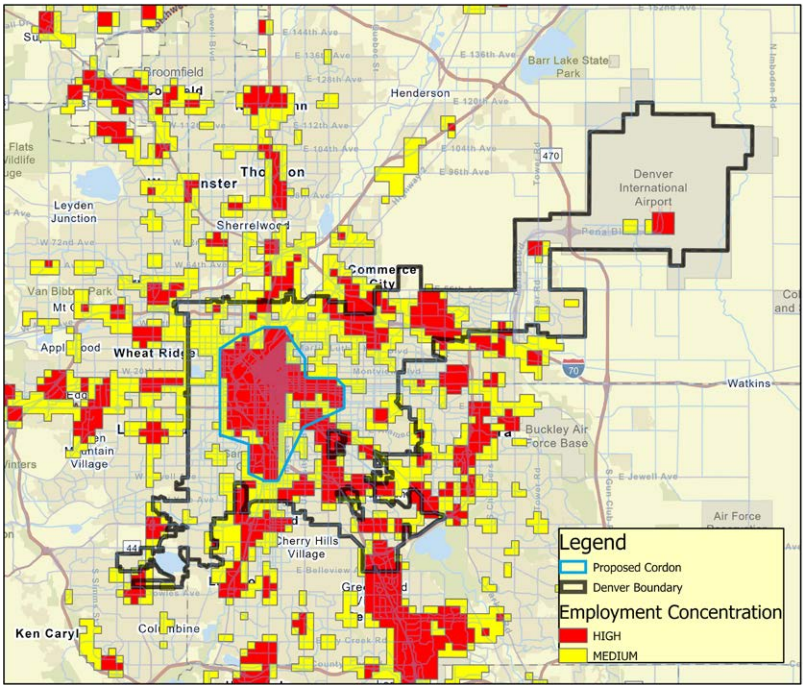
Traffic congestion is a significant source of air pollution emissions and negatively impacts economic productivity and quality of life. Yet as cities investigate ways to reduce congestion and mitigate its impacts, financial constraints often prevent them from identifying the most promising policy strategies.

To address this barrier, JISEA partnered with NREL researchers to develop an open-access method for quantifying the net income, traffic mitigation, and avoided pollution emissions from a cordon-based traffic congestion pricing policy. Under such a policy, travel demand is reduced by requiring drivers to pay a toll to enter designated congested "cordon" areas. The evaluation method, called Cordon Screen, used a case study of modeled implementation in the Denver metropolitan area and validated results against real-world cordon pricing program outcomes.

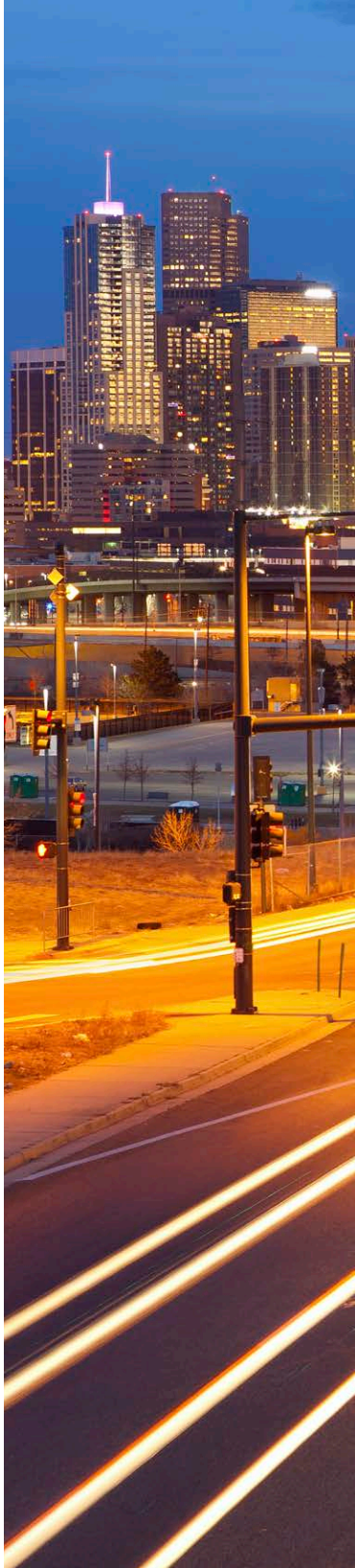
JISEA analysts work to inform policy that supports energy transformation at a variety of levels. At the municipal level, the common challenge of limited financial resources hindering policy analysis drove the analysts to develop innovative new methods using well-known software tools and limited user-supplied data requirements.

Through further stakeholder input and refinement, Cordon Screen could serve as a low-cost, open-source planning tool for major cities in the United States.

LEARN MORE: Cordon Screen: A Cordon-Based Congestion Pricing Policy Evaluation Method for U.S. Cities (https://doi.org/10.1080/10962247.2022.2100510).



Proposed cordon area in Denver, CO, based on predicted increases in traffic congestion, forecasted population growth, and geographic concentration of employment.



"JISEA's partnerships with universities help students network with leading clean energy researchers. My JISEA internship helped me get a full-time job at NREL by connecting me with NREL staff and giving me the opportunity to collaborate on research topics that supported the completion of my Ph.D."

—Christina Simeone, Former JISEA Intern

ADAPTING FINANCING MECHANISMS FOR FULLY INTEGRATED HYBRID ENERGY SYSTEMS

Along with analyzing various energy systems integration policies and scenarios, JISEA analysts also provide insights through thought leadership on energy systems integration approaches and challenges.

In an article published in the *Journal of Renewable and Sustainable Energy*, JISEA analysts reviewed fully integrated hybrid energy systems (HES) and proposed three principles to help financing mechanisms better capture the value of these systems.

The first principle focused on incorporating more diverse metrics to inform real financing costs of these systems. It suggested the combination of unique benefits conferred by the variety of technologies fully integrated HES represent can be better accounted for through metrics like resilience, environmental gains, and energy efficiency.

Principle two suggested the variety of energy generation technologies within HES enable the system to shift between energy products on short timescales, which could reduce a facility's vulnerability to short-term price volatility. It also suggested HES can further reduce financial risk by spreading ownership across multiple companies with diverse needs for the various energy products produced by the system.

Principle three suggested that by pairing first-of-a-kind facilities with more established technologies, fully integrated HES can reduce the financial risk to the facility overall while also playing an important role in demonstrating the feasibility of new energy technologies.

Adapting financial mechanisms is important to the proliferation of fully integrated HES. In this article, JISEA analysts leveraged their understanding of the properties of fully integrated HES to provide perspective on effective ways to adapt the mechanisms that finance them.

LEARN MORE: Principles To Adapt Financing Mechanisms for Fully Integrated Hybrid Energy Systems (https://doi.org/10.1063/5.0118251)

ADVANCED MANUFACTURING, CIRCULAR ECONOMY, CLEAN POWER FOR INDUSTRY

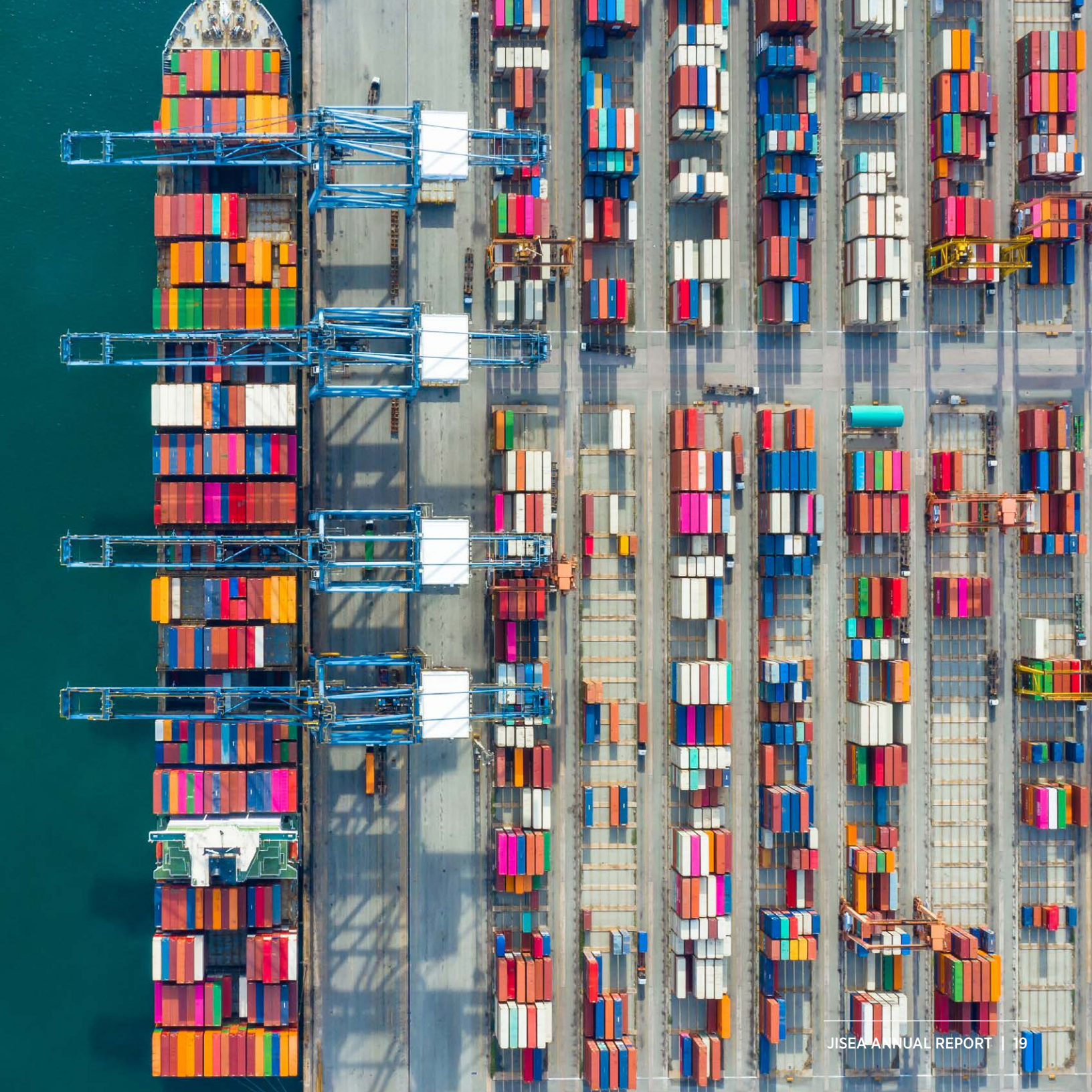
ADVANCING RESILIENT SUPPLY CHAINS AND RESOURCE SUSTAINABILITY

Strengthening supply chains requires a thorough understanding of clean energy manufacturing and recycling processes, as well as the regulatory and economic frameworks under which they operate.

Shifting geopolitical dynamics have placed a greater emphasis on building resilient, sustainable, and affordable clean energy supply chains. Achieving this requires a better understanding of the vulnerabilities of clean energy supply chains and ways government stakeholders and investment mechanisms can address them. There must also be a transition toward more decarbonized and circular manufacturing processes that promote the recovery of materials as well as meet corporate and regulatory environmental and social standards.

This past year, JISEA continued to serve as a leader in global supply chain and manufacturing research by providing the insights needed to guide this transition. JISEA analysts investigated domestic and global clean energy supply chains to identify opportunities for improvement. They also studied and proposed less energy-intensive industrial systems, more effective recycling processes, and more energy-efficient buildings.

Another important aspect of decarbonizing industrial processes—and an emerging field of clean energy analysis—is the focus on green computing. Advanced computing is becoming a critical component of industry. It is also a growing source of energy consumption. After announcing green computing as a focus area at the 2022 JISEA Annual Meeting, JISEA launched the Green Computing Catalyzer, working to analyze potential pathways to reduce the environmental impact of computing.



INFORMING POLICY ACTIONS TO STRENGTHEN U.S. CLEAN ENERGY SUPPLY CHAINS

Achieving 100% clean energy by 2035 in the United States will require astonishing growth in clean energy technologies. Domestic production of these technologies will need to scale in a reliable and sustainable way that is protected against production shortages, trade disruptions, and natural disasters.

To inform policy actions needed to strengthen America's energy supply chains, JISEA researchers supported deep-dive studies on supply chains for solar photovoltaics (PV), wind, grid energy storage, semiconductors, and water electrolyzers and fuel cells. These studies looked into the various stages of the supply chain, including materials extraction, refining, processing, fabrication, assembly, transportation, installation, and decommissioning.

Analysts then examined potential policy- and innovation-based methods for addressing supply chain concerns, such as resource concentration outside of the United States, workforce and logistics issues, decreased U.S. manufacturing capacity, and more.

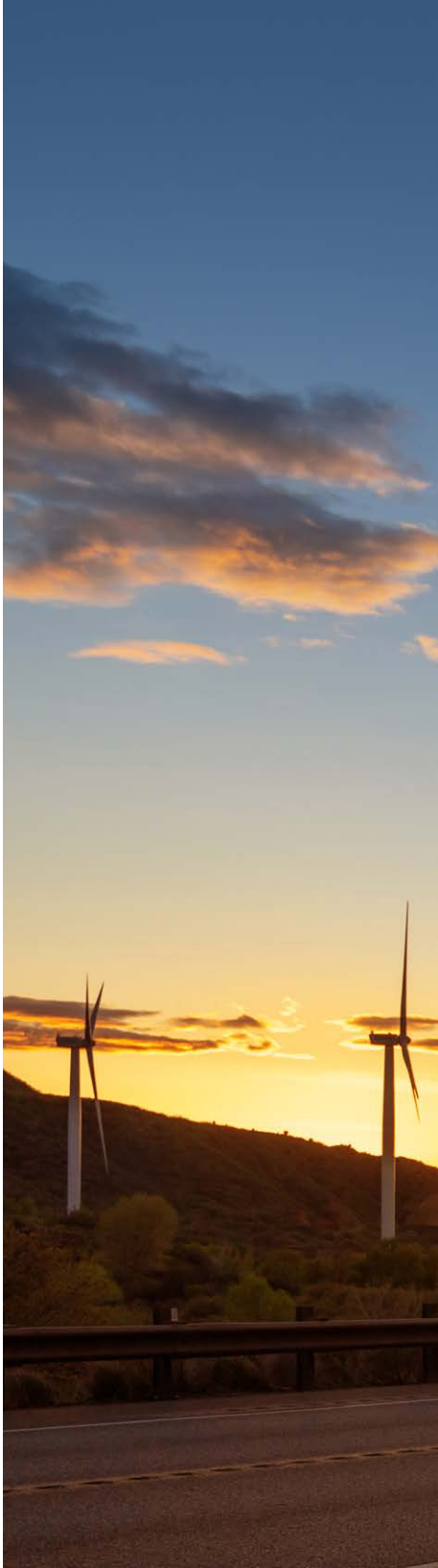
The resulting reports were led by DOE and NREL, and provided policy insights informing a comprehensive federal plan to build an energy sector industrial base. The federal strategy outlines actions designed to support domestic manufacturing, promote more equitable distribution of clean energy benefits, and provide economic value to families and businesses through cost management and job creation.

Along with reducing the carbon footprint of manufacturing at a facility level, addressing vulnerabilities of the supply chain as a system is important to creating strength and sustainability. The study applied JISEA and NREL expertise in supply chain and manufacturing research to provide the hard data and analysis needed to inform balanced policy decisions at the highest level.

LEARN MORE: NREL-Authored Clean Energy Supply Chain Analysis Reports (https://www.nrel.gov/news/program/2022/nrel-authored-clean-energy-supply-chain-analysis-reports.html)

"In order to slow the advance of climate change, the nation and the world will have to speed up the manufacturing of clean energy technologies. At the same time, we need to make the entire cradle-to-grave process of producing, deploying, and decommissioning those technologies equally sustainable."

—Jill Engel-Cox, Former JISEA Director



ASSESSING COSTS TO IMPROVE PHOTOVOLTAIC RECYCLING PROCESSES

An effective recycling process for renewable energy technology materials is an important factor in the overall sustainability of a technology's pathway. To transition to a more sustainable, circular economy, technologies must have an effective recycling process that is cost-competitive with disposal. An efficient, cost-effective recycling process has yet to be established for crystalline silicon photovoltaic (c-Si PV) modules, and a lack of cost estimates plays a role.

In this study, JISEA analysts filled that knowledge gap by developing detailed estimates of seven types of capital and operating costs, as well as estimates of revenue from recovered materials, for two proposed recycling processes for c-Si PV modules.

Analysts then used those results to propose a novel recycling process that shows the value of these types of techno-economic analyses to informing the development of processes that minimize costs based on the available options. A key insight they uncovered was that increasing the purity of and identifying higher-value markets for recovered materials helps reduce net costs and increase recycling rates in voluntary markets.

Promoting a sustainable, circular economy for renewable energy materials relies on being able to assess the costs of processes to ensure that sustainable end-of-life options are also cost-competitive ones. In this study, JISEA analysts outlined important revenue metrics and cost drivers to help inform this analysis.

LEARN MORE: Technoeconomic Analysis of High-Value, Crystalline Silicon Photovoltaic Module Recycling Processes (https://doi.org/10.1016/j.solmat.2022.111592)

PROVIDING EXPERT COMMENTARY ON SUPPLY CHAIN CHALLENGES

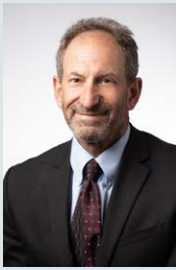
JISEA shares its expertise in supply chain analysis through thought leadership in academic journals as well as in industry media.

In a guest commentary in *Financier Worldwide*, former JISEA Director Jill Engel-Cox and Doug Arent, NREL's Executive Director for Strategic Public-Private Partnerships and the founder of JISEA, reviewed the characteristics of clean energy supply chains that call for new approaches to investment and policy by industry and government decision-makers.

The column highlighted the need to invest in domestic manufacturing to avoid the risks associated with supply chain links that are reliant upon a single country or region. The authors also discussed economic opportunities that can accelerate research and investment in a way that meets global sustainable development goals and environmental, social, and governance standards.

Lastly, the column discussed how new clean energy technology requires innovative ecosystems and partnerships to bring about the shift in the manufacturing capabilities and commercial processes needed for development.

LEARN MORE: Global Energy Supply Chains Shifting From Fuels to Tech (https://www.financierworldwide.com/global-energy-supply-chains-shifting-from-fuels-to-tech#.Y9NDAOzMJhF)



"What makes JISEA unique is its ability to recognize and organize networks around emerging clean energy challenges that have yet to register on the global radar. JISEA builds a foundation for significant, yet underrepresented areas of research so the clean energy ecosystem is prepared to respond when these challenges become a mainstream priority."

—Doug Arent, JISEA Founder

IMPROVING CLEAN ENERGY MANUFACTURING MODELING

In evaluating the value of clean energy technologies, it is important to consider the environmental and social benefits they have along the various segments of their supply chains. While many assessment models for research design and manufacturing decisions exist, they do not place enough emphasis on these benefits.

To address this gap, JISEA partnered with NREL to review the current limitations of techno-economic assessment (TEA) and life-cycle assessment (LCA) models, and to consider emerging modeling options that could better represent environmental and social performance.

Analysts concluded that using TEA and LCA models in tandem provides a fuller picture because they bring complementary measures of economic and environmental impact. However, neither approach considers societal impact. Additionally, analysts found that current options for incorporating societal factors, such as social LCAs, are a helpful start, but until the metrics can be better standardized and comparable, there is still room for improvement.

LEARN MORE: Techno-Economic, Environmental, and Social Measurement of Clean Energy Technology Supply Chains (https://doi.org/10.1002/amp2.10131)

JISEA LAUNCHES GREEN COMPUTING CATALYZER

As demand for high volumes of data processing, data analysis, and artificial intelligence (AI) increases, computing systems have become burgeoning consumers of energy and contributors of carbon emissions.

To understand how to design, manufacture, use, and dispose of computers with minimal environmental impact, JISEA launched the new Green Computing Catalyzer—the third catalyzer in the JISEA Catalyzers initiative, a program that is accelerating the clean energy transition through collaboration.

The Green Computing Catalyzer was announced at the 2022 JISEA Annual Meeting and launched in May 2022 to analyze potential pathways to reduce the environmental impact of computing and advance green computing as a salient research domain at NREL. The annual meeting presentation covered NREL's history in green computing, including taking steps to efficiently capture waste heat from NREL's high-performance computing system. The presentation also identified AI as a significant and growing component of energy use for computing.

Over the next few years, the Green Computing Catalyzer will explore strategies for increasing the energy efficiency of computing beyond relying on transistor-level process improvements. The project aims to publish real-world energy measurements for energy-intensive computing applications, bring attention to the rising energy consumption of computing, and demonstrate how meaningful efficiency gains can be attained through algorithmic optimization.

Publishing data sets of energy measurements from salient and emerging computing applications will put concrete figures to the growing energy demands of computing and raise awareness among industry and researchers.

Through the Green Computing Catalyzer, JISEA and NREL analysts will develop a baseline of existing research within green computing, build a network of experts, and identify needs for further research, knowledge sharing, and collaborations in the field.

LEARN MORE: Green Computing Catalyzer Annual Meeting Kickoff Presentation (https://www.nrel.gov/docs/fy22osti/82594.pdf)

"Computing's rapidly increasing energy consumption and increasingly limited switch-level efficiency gains mean now is the time to address computing energy efficiency through improved management, software, hardware, and architectural approaches. In the Green Computing Catalyzer, we highlight this urgent need; the potential impacts on science, industry, and society; and provide a road map and example of how we can mitigate the escalating energy demands of computing."

—Charles Tripp, Green Computing Catalyzer Lead

Help Catalyze Innovation

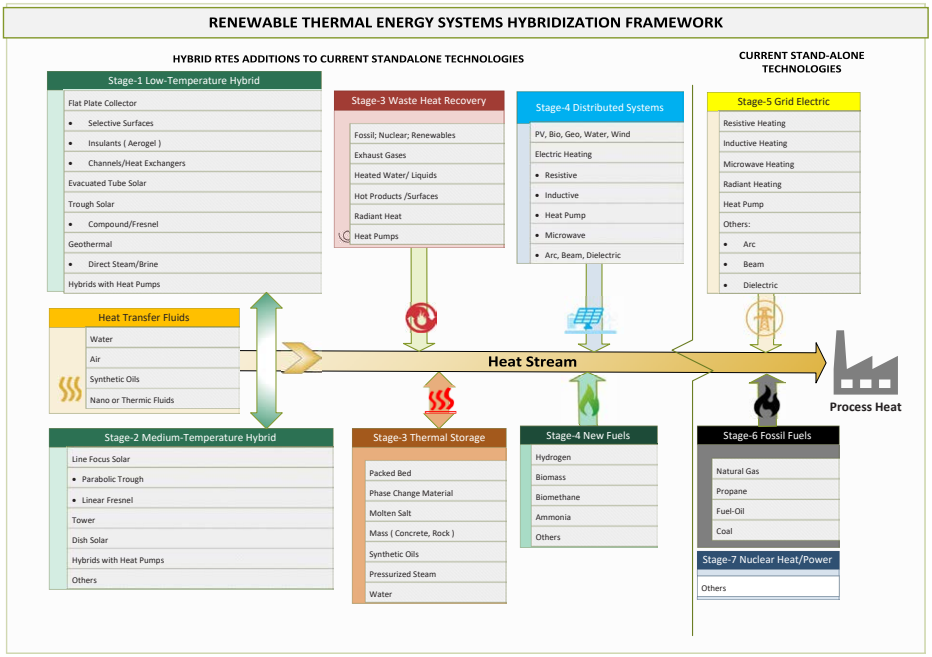
You can help catalyze innovation. We are always looking for sponsors, partners, use cases, and expert review panel members and practitioners across industries and sectors within our catalyzers. Please contact us if interested at **jisea.coordinator@nrel.gov**.

BUILDING A FRAMEWORK FOR HYBRIDIZING RENEWABLE THERMAL ENERGY SYSTEMS

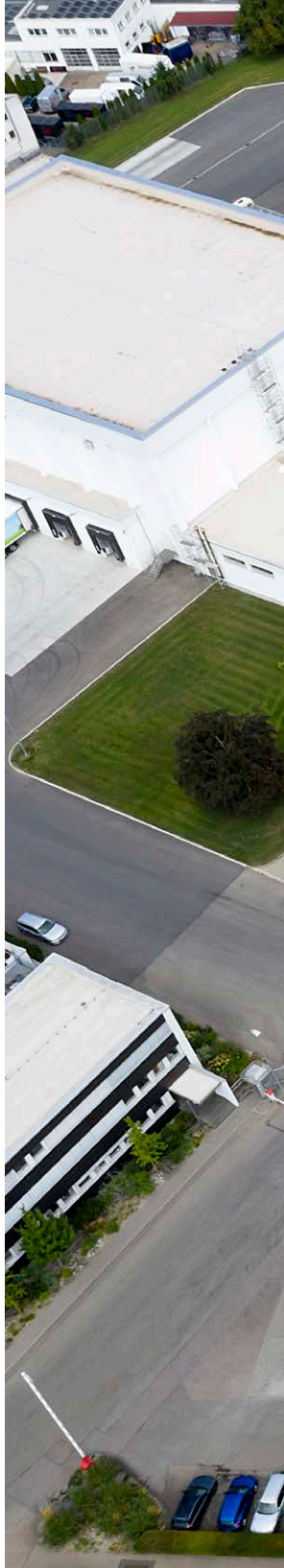
When working to improve the energy efficiency of industrial processes, there needs to be an effective way to determine the best combination of renewable technologies for a given industrial application. In the case of industrial process heat applications, well-established tools are available for modeling single renewable systems; however, none of these tools are capable of hybrid renewable thermal energy system (RTES) modeling.

To develop an initial modeling framework for hybrid RTES at different temperatures or combinations of technologies, JISEA analysts expanded on existing tools, including NREL's System Advisor Model. Analysts developed initial models to test three hybrid RTES scenarios based on commercially available solar heat technologies that are suitable for integration with conventional natural gas combustors on industrial sites.

The framework in this study set in motion a long-term project that concluded this past year in a three-part final report series on characterization, challenges, and modeling. The final study included analyses of thermal demands of U.S. industry, relevant hybrid RTES configurations, challenges and supporting policies, energy yield and performance modeling, and proposed development of a user decision tool. This work exemplifies how JISEA advances industrial decarbonization through early investment in the development of tools that adapt to the growing presence of renewable technology systems in industrial processes.



Overview of the RTES hybridization framework showing possible combinations of renewable and other sources in stages to raise the temperature of the heat stream to meet industrial process heat demands.

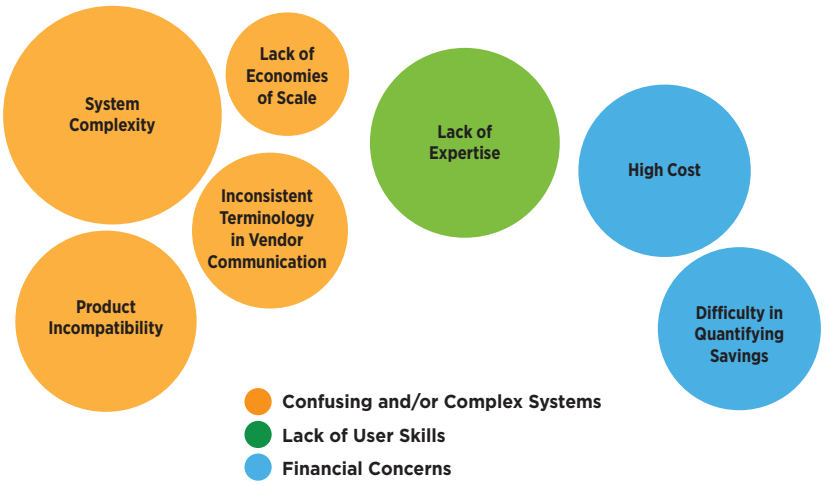


ADVANCING A SUSTAINABLE U.S. COMMERCIAL BUILDING STOCK

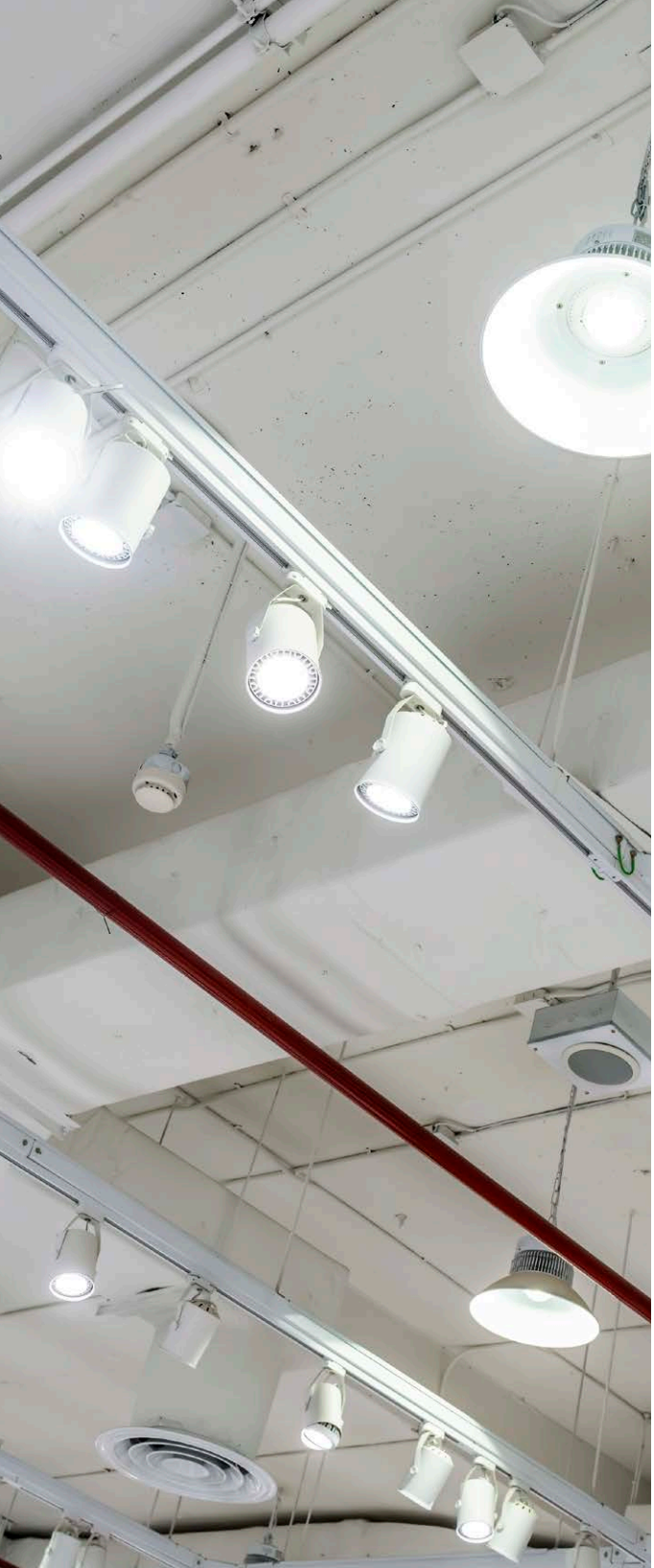
Building sensors and controls are automated systems that can regulate a building's heating, ventilation, and air conditioning system; lighting; and more to increase energy efficiency. Only 13% of buildings under 50,000 square feet have the technology—meaning more than 75% of the U.S. commercial building stock has untapped efficiency potential. To better understand what is fueling this untapped potential, JISEA studied barriers and drivers of adopting commercial building sensors and controls systems. This work, which was done in partnership with NREL, falls under JISEA's Clean Energy Manufacturing Analysis Center (CEMAC).

CEMAC
Clean Energy Manufacturing Analysis Center

JISEA found that the biggest drivers are the automated features and operational insights. Building owners like that the technology allows them to automate building schedules, seasonal changes, and more, as well as access metrics, including energy consumption or occupancy patterns.



Barriers to implementing commercial buildings control systems fell into three categories.



JISEA also found three key barriers to adoption: the systems can be confusing and/or complex, owners do not have the skills or expertise to use the systems, and owners cannot justify the upfront cost. Knowing cost can be a barrier to adoption, JISEA created a complete cost breakdown for multiple building sensors and controls systems. JISEA found 50%–75% of the cost of these systems comes from the specialized labor.

While industrial processes are an important target for decarbonization, the commercial buildings themselves can also be a source of increased energy efficiency. JISEA's analysis of barriers and drivers sheds light on the potential for adoption of building sensors and control systems.

LEARN MORE: Commercial Building Sensors and Controls Systems — Barriers, Drivers, and Costs (https://www.nrel.gov/docs/fy22osti/82117.pdf)

Commercial Building Sensors and Controls Systems — Barriers, Drivers, and Costs, Research Highlight (https://www.nrel.gov/docs/fy22osti/82750.pdf)

About the Clean Energy Manufacturing Analysis Center

Through JISEA's collaborative research and network development approach, CEMAC developed NREL's technical expertise on clean energy supply chains and manufacturing. CEMAC's analyses and insights inform choices to promote economic growth and the transition to a clean energy economy.

PARTNERING TO ACCELERATE DEPLOYMENT OF NET-ZERO TECHNOLOGIES

Following the proceedings of the 26th United Nations Climate Change Conference (COP26) in Glasgow, Scotland, JISEA partnered with NREL and 11 other research and technology organizations on an international research project to analyze approaches from oil and gas producing regions as they transition to net-zero integrated energy systems.

Led by the Net Zero Technology Centre, this report outlined eight global priorities for driving the innovation of net-zero technologies, including infrastructure development, novel materials, energy efficiency, standardization, venting/flaring and fugitive emissions, decarbonization of power, testing and demonstration facilities, and use of data and sensors. The partnership institutions, representing eight countries, agreed on five proposed actions to address them, including:

1. Establishment of collaborative 'Hydrogen Hub' demonstration facilities to reduce low-carbon hydrogen production cost
2. Establishment of a collaborative carbon capture, utilization, and storage demonstration facility to reduce costs of CO_2 capture for power generation and reformed hydrogen production
3. Establishment of a joint Open Innovation Competition to fund disruptive floating offshore wind substructure demonstrations, to achieve at-scale deployment and reduced levelized cost of electricity to reduce floating offshore wind cost
4. Aligned planning for international 'Super Grids' of electrical infrastructure to enable optimized electricity transport routes
5. Establishment of an international collaborative working group to drive implementation of shared data trusts for technology development purposes to drive efficiency improvements.

The goal of these actions is to accelerate technology innovation and deployment internationally and achieve net zero as quickly, efficiently, and affordably as possible. JISEA and NREL's leadership in the U.S. clean energy ecosystem, along with JISEA's expertise in clean energy supply chain analysis, contributed to the insights of this work and helped establish a framework for the development of future international collaborative efforts to reach net-zero goals.

LEARN MORE: Closing the Gap: A Global Perspective (bit.ly/3l22iCm)

ANALYZING SUCCESSFUL CLEAN ENERGY COMMERCIALIZATION PATHWAYS

For technologies to advance from concepts in the research lab to viable commercial products, many obstacles must be overcome. To replicate proven pathways for future clean energy technologies, the critical period between research demonstrations and first commercialization is important to understand.

JISEA partnered with NREL and the DOE Office of Energy Efficiency and Renewable Energy to study this critical period by analyzing case studies of successful first commercialization of four clean energy technologies, including thin film solar photovoltaics, wind turbine blades, dual-stage refrigeration evaporators, and fuel cells for material-handling equipment.

The review of the case studies found that three characteristics were common among all four technologies.

The first characteristic was the presence of conducive research infrastructure and public-private partnership models. Each case study featured different variations of public-private partnerships that promoted technological development through the exchange of research capabilities, funding, and facilities.

The second common feature among the technologies was a high degree of alignment among government regulations, research and development (R&D) priorities, and market forces. When clean energy technologies fall at the nexus of these three forces, their commercialization pathways are often supported and accelerated by government programs and industry partners.

Finally, each case study highlighted compatibility between timescales required for R&D, product development, and addressable opportunities. New technologies found success when they were timed with an increased market need, whereas technologies that provided energy efficiencies compared to incumbents found success when they were incorporated into established products to boost competition.

This study set the groundwork for a new generalizable approach to understanding success factors in commercialization. While every technology is developed under different regulatory and financial ecosystems, this study revealed that productive interactions between innovative businesses and government have repeatedly led to successful first commercialization of clean energy technologies.

LEARN MORE: Clean Energy Technology Pathways From Research to Commercialization: Policy and Practice Case Studies (https://doi.org/10.3389/fenrg.2022.1011990)

SUSTAINABLE COMMUNITIES AT THE ENERGY-WATER-FOOD NEXUS

INCREASING SUSTAINABILITY AND RESILIENCE IN LOCAL COMMUNITIES

Equitable deployment of clean energy technology requires collaboration at the community level and analysis to inform local decision-making.

Scaling clean energy integration, electrifying economies, and transforming energy systems will have major impacts on land use, economies, people, and the environment. These changes occur at the community level, and it is important that communities have the information they need to make informed decisions and ensure the energy transition's benefits and burdens are shared equitably.

This past year, JISEA made several advances in the sustainable community space thanks to the dedicated work of the Sustainable Communities Catalyzer. The Sustainable Communities Catalyzer was formed to advance the understanding of social, economic, environmental, and land use impacts of clean energy transitions and map pathways for sustainable, equitable transitions with a focus on rural and disadvantaged communities.

Analysts in the Sustainable Communities Catalyzer partnered with NREL and other energy planning experts to conduct analyses of clean energy potential and consumption at the local level, and to develop data and resources to support equitable community energy planning.

Along with the collaboration driving the Sustainable Communities Catalyzer, the 2022 JISEA Annual Meeting provided an opportunity for experts in the sustainable communities and agricultural decarbonization fields to connect and share insights from their work. Through two topic panels, JISEA analysts discussed work in agricultural energy efficiency and community resilience, facilitating network development in these areas and the exploration of complex and intersectional clean energy challenges.

ADVANCING EQUITABLE RENEWABLES DEPLOYMENT

Renewable energy development can bolster local economies through job creation, tax revenues, and lower energy costs, but communities that need these benefits the most often see less deployment. JISEA, in partnership with NREL, intersected data on disadvantaged community indicators and renewable energy generation potential to identify where deployment could have the biggest local impact. This work is part of JISEA's Sustainable Communities Catalyzer that is helping identify pathways for sustainable clean energy transitions with a focus on rural and disadvantaged communities.

Using a suite of models, JISEA and NREL created a new data set that intersects energy burden, environmental hazard, and sociodemographic data with county-level technical generation potential and levelized cost of energy for multiple renewable energy technologies.

JISEA and NREL found that counties with mining, quarrying, and oil and gas extraction tend to have greater opportunity for wind energy and utility-scale solar. Counties with larger concentrations of minority individuals tend to have relatively lower-cost opportunity for commercial and residential rooftop solar, and counties with more individuals who have less than a high school education tend to have relatively lower-cost opportunity for utility-scale solar.

Counties that are closer to traffic or higher concentrations of diesel pollution tend to have greater opportunity for commercial and residential rooftop solar. Counties with higher ozone concentrations tend to have greater opportunity for utility-scale solar and land-based wind, in addition to having relatively lower-cost commercial and residential solar opportunities. Finally, counties with higher respiratory hazard from air toxics tend to have relatively lower-cost geothermal opportunities.

JISEA's analysis of these indicators can enable consideration of equity metrics in state and federal renewable energy infrastructure investments and programs seeking to prioritize investments in disadvantaged communities. It can also inform local jurisdictions' prioritization of energy economic development and job creation efforts by elucidating their relative strengths or weaknesses in clean energy development potential.

LEARN MORE: Intersections of Disadvantaged Communities and Renewable Energy Potential: Data Set and Analysis to Inform Equitable Investment Prioritization in the United States (https://doi.org/10.1016/j.ref.2022.02.002)

LEARN MORE: Equitable Energy Investment Prioritization Data Set (https://data.nrel.gov/submissions/175)

Sharing the Insights

Along with the rigorous work that goes into conducting these analyses, the Sustainable Communities Catalyzer engaged with different audiences to spread the insights it uncovered. This study was presented several times to audiences made up of fellow researchers, local sustainability coordinators, and federal program administrators and contractors, ensuring the data were accessible to the decision-makers who need them.

LEARN MORE: Intersections of Disadvantaged Communities and Renewable Energy Potential: Analyses to Inform Equitable Investment Prioritization—Presentation (https://www.nrel.gov/docs/fy22osti/81527.pdf)

EMPOWERING LOCAL ENERGY PLANNING

Communities often have ambitious clean energy goals. However, the disconnect between the local renewable energy generation potential and costs, and community goals and aspirations can hinder local communities in realizing their clean energy vision. For example, many communities want to focus primarily on rooftop solar to meet their local electricity needs, but some areas may have low PV potential compared to their local electricity consumption.

To help bridge this gap, analysts from JISEA and NREL used data from NREL's State and Local Planning for Energy (SLOPE) platform—a tool developed by DOE and NREL—to compare annual technical generation potential and levelized costs of renewable energy technologies to modeled electricity consumption in every county in the contiguous United States.

Community engagement on renewable energy siting at the Islesboro, Maine, Energy Jamboree. Photo by Bryan Bechtold, NREL 69875

Technologies analyzed include utility, residential, and commercial PV systems, land-based wind, and concentrating solar power (CSP).

Study results revealed the potential of local renewable energy generation to meet local energy demand is not solely determined by the local solar or wind resource—some lower-resource areas have higher potential, and costs can depend on local factors such as land-use patterns and local markets.

As modeled, land-based wind and utility-scale PV have the highest technical generation potential and are more cost-effective than rooftop PV. If counties developed all suitable rooftops with solar PV, they could generate a median of 45% of residential electricity consumption from residential rooftops and 35% of commercial electricity consumption from commercial rooftops. Overall, land-based wind could produce local electricity for the lowest cost, followed by utility-scale PV, commercial rooftop PV, CSP, and residential rooftop PV. These findings help communities understand the need to take a holistic, multitechnology, multiscale, and sometimes regional approach to achieving local clean energy goals.

This work is also part of the JISEA Sustainable Communities Catalyzer, which is helping map pathways for sustainable, local clean energy transitions.

LEARN MORE: Local Power: Comparing County-Level Renewable Energy Potential to Consumption Using the SLOPE Platform (https://www.nrel.gov/docs/fy22osti/81378.pdf)

IDENTIFYING BEST PRACTICES FOR COMMUNITY ENERGY PLANNING

More than 180 communities in the United States have committed to transition to 100% clean energy by 2050 or sooner. At the same time, some local communities are pushing back on the changes in land use and the development needed to transition to clean energy.

Building on decades of work to advance state, local, and tribal energy transitions, JISEA's Sustainable Communities Catalyzer published a community energy planning best-practices guide to support practitioners at NREL and beyond.

The guide offers five key best practices for community energy planning based on interviews with seasoned NREL practitioners and a literature review on equitable community energy planning:

1. Do your homework in preparation for community interactions.
2. Be humble, authentic, and honest in interactions with community members.
3. Respect community agency in every step of the process.
4. Meet the community where they are.
5. Democratize participation.

These steps enhance practitioners' capabilities in supporting community energy planning processes by building trust with the community and establishing a foundation for meaningful collaboration. This guide was developed through the Sustainable Communities Catalyzer and leverages its network of thought leaders who are committed to advancing more equitable participation in the clean energy transition.

LEARN MORE: Community Energy Planning: Best Practices and Lessons Learned in NREL's Work with Communities (https://www.nrel.gov/docs/fy22osti/82937.pdf)

"As community clean energy opportunities scale rapidly with the Inflation Reduction Act and Bipartisan Infrastructure Law, Sustainable Communities Catalyzer analysts delivered three publications, a data set, two trainings, and two keynote speakers to advance capabilities at NREL and beyond to support sustainable, equitable, local energy transitions. We are seeing the need and the impact for these resources made possible by JISEA."

—Megan Day, Sustainable Communities Catalyzer Lead

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https://www.nrel.gov/docs/fy22osti/80683.pdf

Local Power: Comparing County-Level Renewable Energy Potential to Consumption Using the SLOPE Platform

https://www.nrel.gov/docs/fy22osti/81378.pdf

Renewable Thermal Hybridization Framework for Industrial Process Heat Applications

https://dx.doi.org/10.1063/5.0085805

A Critical Review of the Circular Economy for Lithium-Ion Batteries and Photovoltaic Modules - Status, Challenges, and Opportunities

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NREL/MK-6A42-84806 | April 2023
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