EMPOWER

2022 ANNUAL REPORT

Accelerating the Transformation of the Global Energy Economy

JISEA

Joint Institute for Strategic Energy Analysis

A YEAR OF TRANSITION

2022 is a transition year for JISEA. It has been my honor and pleasure to serve as Joint Institute for Strategic Energy Analysis (JISEA) director over the past four years.

I'm extremely proud that JISEA is seen nationally and internationally as a thought leader and respected source of credible, objective analysis, information, and insights. We were founded on the principle of thinking outside the box to create new synergies across systems such as natural gas, nuclear, and renewables, and their relationship to land, water, industry, and society. We remain committed to that vision today.

This year we launched the JISEA Catalyzers initiative to empower communities and stakeholders in their energy transitions. Each Catalyzer convenes experts working within specific areas of clean energy research to discuss capabilities, challenges, best practices, and future needs. By enhancing connections across the energy research ecosystem to meet emerging challenges, the JISEA catalyzers are launching new, crosscutting capabilities at the National Renewable Energy Laboratory (NREL) to achieve clean energy goals at speed and scale—providing incredible value given the fast pace of clean energy research today.

Since I joined JISEA in 2015 as director of the Clean Energy Manufacturing Analysis Center, the energy transition has rapidly picked up pace. As of December 2020, more than 260 U.S. large corporations and 200 cities and counties have pledged to meet 100% of their electricity needs with renewable energy over the next few decades. Twenty percent of U.S. electricity supply now comes from renewable energy, and the cost of clean energy technologies continues to drop.

Still, technical and economic challenges will need to be overcome to achieve 100% renewable energy power systems across the entire United States. So the work continues.

I am thrilled to welcome Dr. Elizabeth Doris as the new director of JISEA. She will step into this role in October when she completes a special assignment with the U.S. Department of Energy as senior advisor on energy and environmental justice for the Office of Energy Efficiency and Renewable Energy.

Dr. Doris brings extensive expertise in policy and analysis to JISEA and has worked at NREL since 2005, most recently as laboratory program manager for state, local, and tribal governments—in addition to leading several other large initiatives. I'm confident Dr. Doris will advance JISEA's thought leadership, strategic insights, and collaboration during this dynamic and exciting time in the energy transition.

Until October, JISEA's core team will continue to support and expand the institute's impactful analysis, with Emily Newes, group manager of integrated modeling and economic analysis in NREL's Strategic Energy Analysis Center, serving as interim JISEA director. I will continue to partner with JISEA and NREL in a smaller capacity as a research advisor.

Jill Engel-Cox
JISEA Director, 2018–2022

EMPOWERING STAKEHOLDERS AND DECISION MAKERS

To navigate the complexity of the clean energy transition, we need leading-edge, multidisciplinary research. JISEA is an important vehicle for this work.

With strong industry and academic partnerships and a focus on leveraging diverse energy sources, JISEA contributes unique expertise to NREL. The institute creates forums for discussion to map new collaborations among stakeholders who wouldn't otherwise connect.

JISEA organizes discussion via technical workshops, research consortiums, and, new this year, the JISEA Catalyzers initiative, which I'm particularly excited about.

The catalyzers are helping NREL stay ahead of the research curve. Insights from the inaugural Sustainable Communities Catalyzer and Energy and Atmospheric Systems Catalyzer are informing new research capabilities at the laboratory.

For example, the Sustainable Communities Catalyzer, which empowers local energy transitions, will graduate this coming year to become a new NREL-led strategic training program for NREL staff who engage with communities to support their energy planning. This new program will build on—and create institutional structure for—the growing body of community-focused work NREL is leading. This includes creating opportunities for collaboration among researchers and staff, developing best practices, and helping inform capability build-out, as well as supporting a new group on this topic.

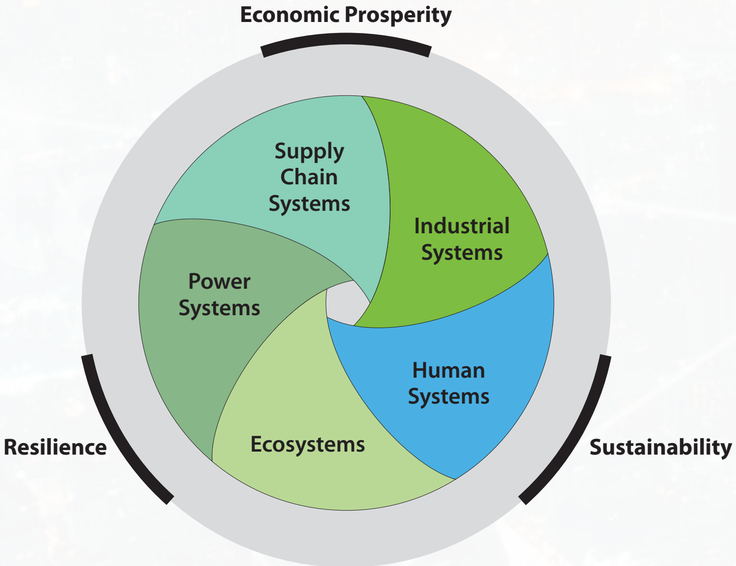
A new catalyzer on green computing will kick off this spring. As demand for high volumes of data processing, data analysis, and artificial intelligence grow, and computing systems permeate many aspects of modern society, computing has become a burgeoning consumer of energy and source of carbon emissions. The Green Computing Catalyzer will help advance green computing as a salient research domain at NREL and explore pathways to more energy-efficient computing.

While we will miss Dr. Jill Engel-Cox's leadership as director of JISEA, we are thrilled to welcome her in her new role as research advisor for the Energy Systems Integration directorate, where she will bring her deep expertise in analysis to help guide this growing area of work. Dr. Engel-Cox will continue to lead some research projects within JISEA and participate in international engagements.

I know Dr. Elizabeth Doris will do an excellent job carrying on JISEA's mission. The institute's cross-cutting expertise and forward-thinking approach are more important than ever, and I look forward to seeing how JISEA can continue to shape modern energy systems in 2022.

Juan Torres
Associate Laboratory Director
Energy Systems Integration

OUR MISSION



The Joint Institute for Strategic Energy Analysis (JISEA) provides leading-edge, objective, high-impact research and analysis to guide transformative global energy investment and policy decisions.

Through strategic insights and worldwide dialogue, JISEA explores the intersections of the environmental, social, financial, technological, and political elements of energy systems on the path to a clean energy economy. JISEA's work informs innovative solutions that advance the goals of sustainability, economic prosperity, and resilience.

JISEA research and analysis provide decision-making support to industry, the financial sector, and government with a focus on the following strategic areas:

- **Energy Systems Integration and Transformation**
- **Advanced Manufacturing and Circular Economy**
- **Clean Power for Industry**
- **Sustainable Communities at the Energy-Water-Food Nexus**

CONTENTS

ENERGY SYSTEMS INTEGRATION AND TRANSFORMATION

MAXIMIZING THE VALUE OF DIVERSE ENERGY SOURCES

Decarbonized energy systems require new planning and operation at multiple scales to ensure clean, reliable, and affordable energy.

Today's energy system has grown to include many formerly separated systems.

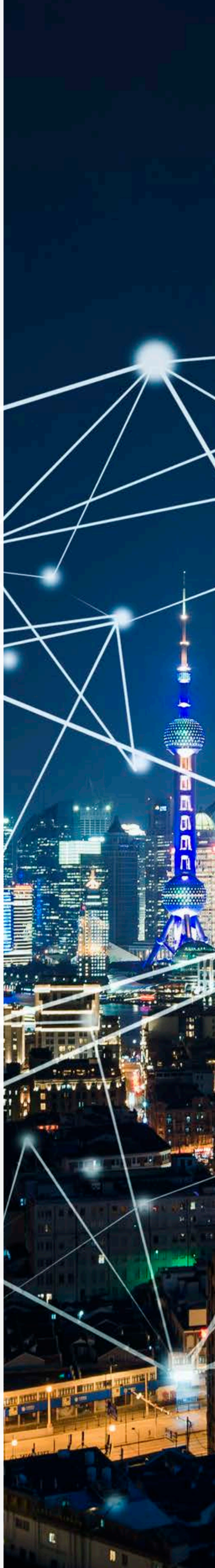
This shift is due to many factors: more variable renewable generation, greater use of natural gas, new nuclear energy technologies, heightened need to decarbonize the grid, and increased electrification across sectors.

To maximize the value of each energy source and ensure clean, reliable, and affordable energy, we need new ways to plan and coordinate operations.

New strategies must consider technical and nontechnical solutions, including everything from installing electric vehicle (EV) charging systems that minimize the need for expensive grid upgrades to better incorporating demand response opportunities into grid operations.

JISEA leads analysis of energy systems across multiple pathways and timescales to make planning and operations decisions easier for decision makers and stakeholders. Because solutions can range from simple to highly complex and impact stakeholders in unique ways, JISEA studies energy challenges holistically rather than looking at each system in isolation.

This work is supporting the design of more flexible, integrated energy systems.



INDUSTRY PROVES TO BE A PROMISING PROSPECT FOR GRID FLEXIBILITY

Industrial manufacturing consumes approximately one-third of energy in the United States and worldwide. Because much of that energy is provided directly by combustion, electrification of industry could potentially increase the electric load. If some industrial electricity demand could be time-shifted, industry could be an important contributor to grid flexibility.

Through a partnership with NREL and GE Energy Consulting, JISEA studied four energy-intensive industries with and without paired energy storage over several years to identify under what circumstances industry can profitably provide grid services.

The team studied chlor-alkali and electric arc furnaces, which are established electricity-intensive industries, and methane pyrolysis and direct air capture, which are emerging industries with electrification potential.

Across the industries, JISEA found demand flexibility could be profitable for industry with large behind-the-meter batteries that cost less than $250 per kilowatt-hour. If battery prices continue to fall along the learning curve of the last decade, use of batteries to manage electricity loads could become profitable for industrial customers long before 2050.

LEARN MORE: Opportunities for Industry to Provide Grid Flexibility While Increasing Profitability (www.nrel.gov/docs/fy21osti/75784.pdf)

Optimal Net Present Values in Millions of Dollars Across Years and Battery Prices

	2019	2050 High	2050 Medium	2050 Low
Chlor-alkali	-$1.90	-$0.50	$2.60	$17.50
Electric arc furnaces	-$4.00	-$0.80	$11.60	$45.20
Methane pyrolysis	-$0.04	-$0.00	-$0.10	$0.40
Direct air capture	-$8.10	-$2.40	-$0.50	$35.60

Optimal net present values were negative across all industries using 2019 electricity and battery prices but became meaningfully positive for 2050 across medium and low battery cost projections.

PATHWAYS FOR A CLEAN, SUSTAINABLE POWER SYSTEM IN THE YUCATAN PENINSULA

The Yucatan Peninsula, the easternmost region of Mexico comprising three states, is facing an energy crisis due to scarce natural gas supply, insufficient transmission capacity, and increasing electricity demand. The highest national electricity prices, state climate goals, and seasonal blackouts have jump-started planning for a more resilient energy system.

The Yucatan Peninsula has rich, untapped solar and wind resources and is actively investigating how to deploy utility- and distributed-scale renewables, energy efficiency programs, and sustainable transportation.

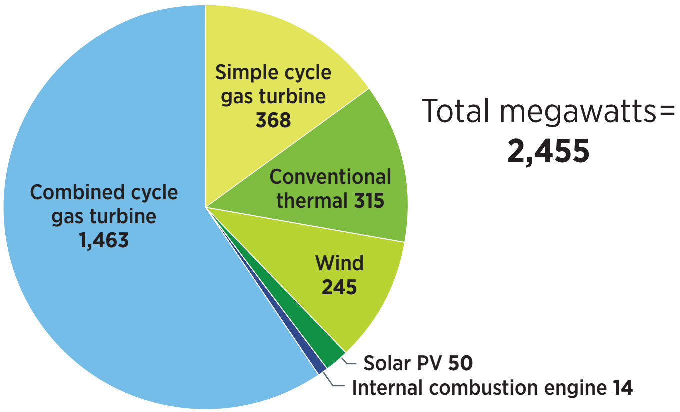
As part of the 21st Century Power Partnership (21CPP)—a key program under the JISEA umbrella—JISEA studied possible pathways the Yucatan Peninsula can take to develop a clean, sustainable power sector. The analysis included policy and program solutions as well as partnership opportunities with 21CPP.

21CPP supports the Yucatan Peninsula with data gathering, capacity building, modeling and analysis, and program and policy setting—all with the goal of helping the region best utilize resources to meet electricity needs while also enhancing energy efficiency and sustainability.

LEARN MORE: The Yucatan Peninsula Energy Assessment: Pathways for a Clean and Sustainable Power System (www.nrel.gov/docs/fy21osti/79680.pdf)

Evaluación Energética de la Península de Yucatán: Vías para un Sistema Energético Limpio y Sustentable (www.nrel.gov/docs/fy21osti/81142.pdf)

Yucatan Peninsula Power Generation Mix (Net Megawatts)



21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

"We're living in a turning point where big decisions need to be made and big investments need to be made for transformation in the power sector to help mitigate climate change. By working with developing countries, I contribute a small part to supporting those decisions and needs."

—Riccardo Bracho, JISEA international energy analyst

ACTIONS TO ENABLE FLEXIBLE NUCLEAR ENERGY

The Clean Energy Ministerial's (CEM's) Flexible Nuclear Campaign is helping countries quantify the economic benefits of advanced nuclear. As part of the campaign, the Nuclear Innovation: Clean Energy Future (NICE Future) initiative evaluated case studies on the potential role of flexible nuclear energy in meeting long-term clean energy goals.

To help guide the research, the NICE Future initiative convened a virtual workshop in April 2021 with more than 50 experts from a dozen countries. Participants discussed and identified barriers to deploying flexible nuclear energy. The workshop improved understanding of the diverse innovations, challenges, and opportunities for flexible nuclear energy deployment globally.

LEARN MORE: Actions to Enable Flexible Nuclear Energy (www.nrel.gov/docs/fy21osti/80146.pdf)

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

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.

PATHWAYS TO NET ZERO USING NUCLEAR INNOVATION

In partnership with the United Kingdom Department for Business and Energy and Industrial Strategy, NICE Future published diverse perspectives from policy leads around the world on pathways to net zero using nuclear innovation.

The publication, which falls under the Flexible Nuclear Campaign, highlights different paths participant countries are taking to reach their clean energy goals with the help of nuclear innovation. It also provides perspectives on how nuclear energy could contribute more to reducing emissions.

LEARN MORE: Pathways to Net Zero Using Nuclear Innovation: International Perspectives on the Role of Nuclear Energy and Innovation in Reaching Our Climate Targets (www.nice-future.org/assets/pdfs/nice-future-pathways-june2021.pdf)

JISEA @ CEM12: FLEXIBLE NUCLEAR ENERGY AND THE JOURNEY TO NET ZERO

From May 31 to June 6, 2021, JISEA and the NICE Future initiative hosted several events at the all-virtual 12th Clean Energy Ministerial Meeting (CEM12).

Founded in 2010, CEM facilitates global dialogue on high-level policy to share best practices for accelerating the clean energy transition. This year, NICE Future and JISEA partnered on events with environmental nonprofits TerraPraxis, Third Way, and ClearPath to highlight nuclear energy's contributions to the clean energy transition.

LEARN MORE: The CEM12 Outcomes Report (NICE Future side events featured on pages 57, 62, and 71). (www.cleanenergyministerial.org/events-cem/12th-clean-energy-ministerial-cem12)

> **"Nuclear energy can offer innovative, flexible, and integrated solutions, in partnership with renewable energy, to be considered by countries around the world."**
>
> *—Jordan Cox, JISEA/NREL analyst*

CEM12 convened representatives from more than 30 countries and international organizations to discuss how clean energy can support the global energy transformation to zero-emission societies and economies.

The NICE Future initiative also participated in the 2021 United Nations Climate Change Conference (COP26), presenting at a side event that explored how nuclear technologies can help meet UN Sustainable Development Goals and support economies in a just transition to a resilient carbon-free future. Photo by Sarbojit Pal, CEM

RENEWABLE ENERGY PLANNING IN THE KINGDOM OF SAUDI ARABIA

The Kingdom of Saudi Arabia is building its renewable energy capacity as part of a larger plan to diversify local energy sources, stimulate economic development, and enhance environmental sustainability. To realize this vision, the kingdom needs planning tools and models.

King Abdullah City for Atomic and Renewable Energy (K.A. CARE)—the independent entity that supports sustainable development of the energy sector in the kingdom—partnered with JISEA to understand what it needs to plan for its increasing renewable energy projects.

JISEA led analysis of K.A. CARE's current renewable energy planning capabilities and compared various planning tools. The high-level gap analysis provided the Kingdom of Saudi Arabia with a road map to advance its renewable energy capacity.

ADVANCED MANUFACTURING AND CIRCULAR ECONOMY

ENSURING RESOURCE SUSTAINABILITY IN A DECARBONIZED ECONOMY

A circular economy for energy materials would conserve valuable materials and prevent waste.

The traditional linear approach to producing energy materials involves taking materials, making and using products, and disposing of them when they break or expire. This approach depletes scarce critical materials.

A circular approach to producing energy materials, on the other hand, designs, manufactures, uses, and manages technologies at end of life to preserve and maximize valuable resources—reducing supply chain limitations and preventing waste. A circular approach also ensures that the materials needed for rapid deployment of clean energy technologies are available, which is important to be able to decarbonize economies.

JISEA conducts social, economic, and regulatory analyses of potential pathways to a circular economy for energy materials. This includes using innovative models and research capabilities to trace environmental and economic impacts of energy technologies through their life cycles, from extraction to end-of-life management.

Through this work, we are helping create design frameworks that increase reuse or recyclability to extend technology lifetimes and recover valuable materials—a sustainable strategy in the long term.

NOVEL MODELING CONSIDERS HUMAN BEHAVIOR IN THE FATE OF AGING SOLAR PANELS

By 2050, there could be 10 million metric tons of solar photovoltaic (PV) systems reaching the end of their lifetimes in the United States alone[1]—the weight of 30 Empire State Buildings.

To maximize the value of solar PV materials and minimize waste, there is growing interest in sustainable end-of-life PV options. Most research thus far has focused on the technical and economic potential of recycling or reusing PV materials, but it doesn't consider how social behavior factors in.

JISEA and NREL partnered on a study funded by the U.S. Department of Energy Advanced Manufacturing Office and Office of Management Strategic Programs Division to apply agent-based modeling to end-of-life PV management for the first time. The new modeling approach helps elucidate how people make decisions about recycling or reusing PV modules—marking a major shift in how we think about circular economy strategies.

JISEA/NREL found recycling costs and advice from peers factor into decisions about whether to recycle solar panels. Reuse could be an option if people perceive new and used solar panels as having equal value, but it would compete with recycling strategies.

LEARN MORE: Role of Social Factors in Success of Solar Photovoltaic Reuse and Recycle Programmes (doi.org/10.1038/s41560-021-00888-5)

1 IRENA and IEA-PVPS (2016), "End-of-Life Management: Solar Photovoltaic Panels," International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems.

THE GLOBAL STATE OF CLEAN ENERGY MANUFACTURING

JISEA's Clean Energy Manufacturing and Analysis Center is one of a few organizations to study trade and value added from clean energy manufacturing.

CEMAC's *Benchmarks of Global Clean Energy Manufacturing, 2014–2016* report, released in 2021, provides data and insights on four leading clean energy technologies: wind turbine components, crystalline silicon solar PV modules, vehicle lithium-ion battery cells, and LED packages, in 13 economies over three years (2014-2016).

Technologies were assessed in terms of common points of reference, or benchmarks, including market characteristics, global trade flows, and manufacturing value added.

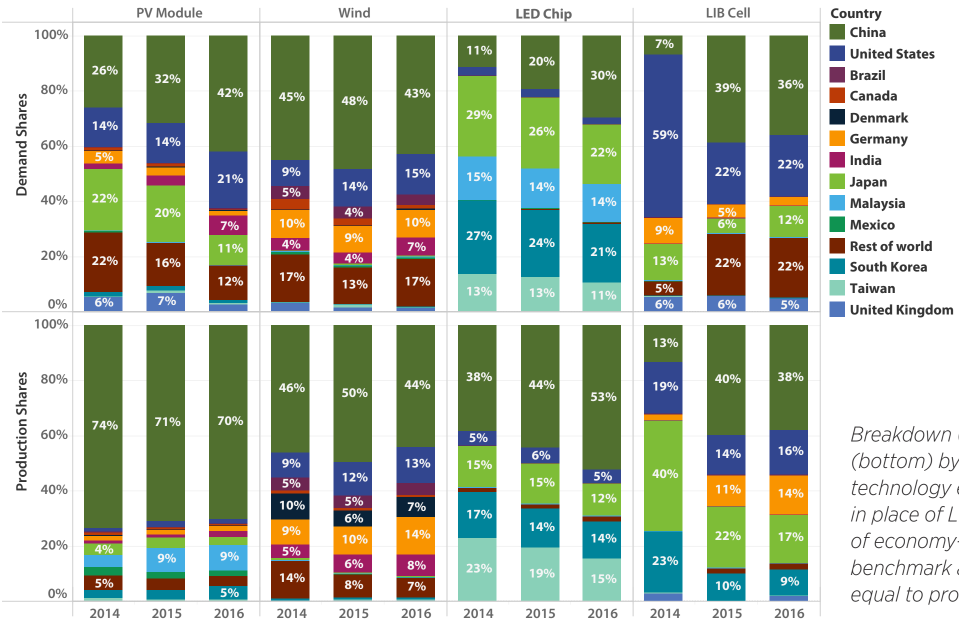
The benchmarked economies gained the most value from domestic processing of raw materials, manufacturing of intermediate components, and providing services throughout the supply chain (indirect value added).

The economies gained less value from manufacturing the clean energy technology end products themselves (direct value added).

LEARN MORE: Benchmarks of Global Clean Energy Manufacturing, 2014–2016 (www.nrel.gov/docs/fy21osti/78037.pdf)

Benchmarks of Global Clean Energy Manufacturing, 2014–2016, Research Highlight (www.nrel.gov/docs/fy21osti/79692.pdf)

Clean Energy Technology End Product Global Demand and Production Shares by Economy, 2014–2016



Breakdown (in %) of global demand (top) and production (bottom) by economy for benchmarked clean energy technology end products. Note that LED chip data are presented in place of LED package data. (Due to a lack of availability of economy-specific demand data for LED packages, the benchmark analysis assumes that demand for LED packages is equal to production throughout the report).

COBALT SUPPLY CHAIN ANALYSIS LINKS ELECTRIC VEHICLE MANUFACTURING AND DEPLOYMENT

Cobalt is considered a critical raw material and is used in many sectors, from electronics to health care. It's also an essential component of most lithium-ion batteries used in electric vehicles. Electra Battery Materials expects global cobalt demand to climb 30% by 2025.

The increasing demand for cobalt has raised questions about the larger EV manufacturing supply chain—how will increased EV deployment impact mineral production and vice versa?

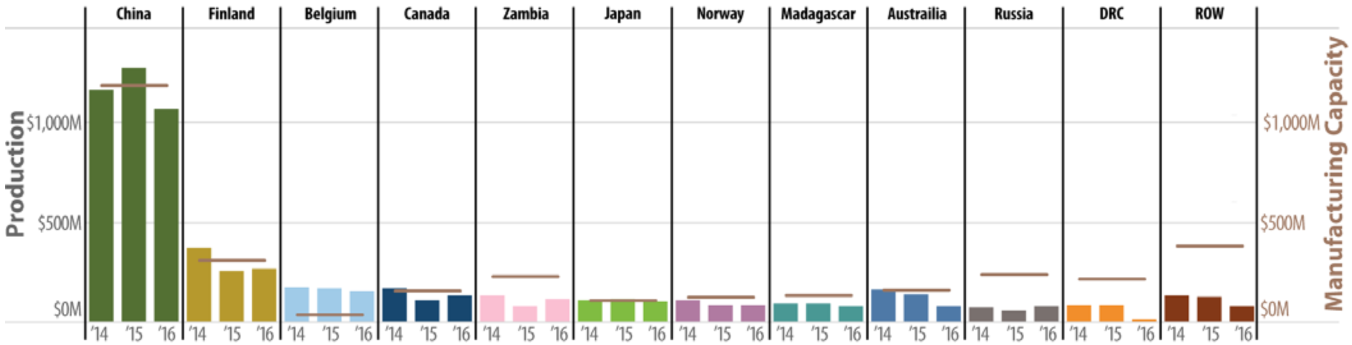
Raw materials are notoriously difficult to study due to lack of upstream data and challenges with tracking them through the manufacturing supply chain. For the first time, JISEA applied methodology from its *Benchmarks of Global Clean Energy Manufacturing* report to the cobalt supply chain.

Results show the value added to benchmarked economies from 2014 through 2016 from mining, processing, and refining cobalt for clean energy manufacturing. Of the benchmarked economies, Canada and the United States were the only two that accrued direct value from cobalt mining; China, Japan, and Canada were the only economies that accrued direct value from domestic cobalt refining.

LEARN MORE: Benchmarks of Global Clean Energy Manufacturing, 2014–2016 (pages 67–72) (www.nrel.gov/docs/fy21osti/78037.pdf)

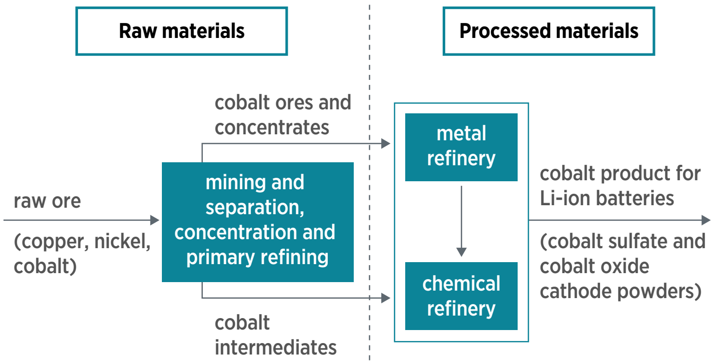
Cobalt Supply Chain Analysis Links Electric Vehicle Manufacturing and Deployment, JISEA story (www.jisea.org/20210518.html)

Refined Cobalt Production and Manufacturing Capacity for Each Economy, 2014–2016



Refined cobalt production (colored bars) and manufacturing capacity (brown lines) with data shown on different scales. All data are in US$ (2014).

Cobalt Supply Chain for Lithium-Ion Battery Manufacturing



The cobalt supply chain encompasses mining, ore processing to produce concentrates and intermediates, and metal and chemical refining to extract precursor materials.

CLEAN POWER FOR INDUSTRY

DECARBONIZING INDUSTRIAL PROCESSES

Technology and policy could establish cleaner industrial processes and advance the transition to a low-carbon economy.

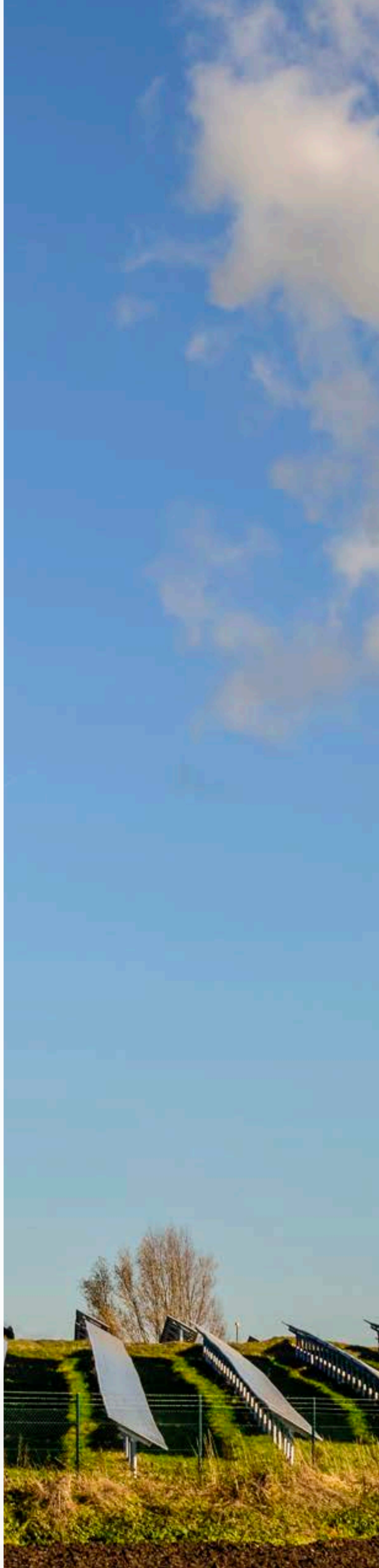
Industrial manufacturing is necessary for products and materials we use every day. It's also a major source of employment for many countries worldwide.

At the same time, industry accounts for one-third of global greenhouse gas emissions—the highest of any economic sector. The iron and steel, chemicals and plastics, and cement industries alone account for 55% of industrial emissions.

Therefore, industrial sector decarbonization is essential to achieving climate change goals. Technology and policy could help establish cleaner industrial processes and boost progress toward a low-carbon economy.

JISEA partners with industry to study opportunities to profitably incorporate cleaner technologies into industrial processes, lowering emissions while still delivering the same product. Some of the solutions JISEA explores include energy efficiency improvements, electric production of heat, the use of hydrogen and biomass as feedstock or fuel, and carbon capture, utilization, and storage.

JISEA analysis is helping inform industry decision-making and can be scaled up to help address larger sectorwide challenges.



MOVING TOWARD RENEWABLE ENERGY IN MINING

Mining is one of the most energy-intensive industries in the world and relies heavily on fossil fuels. Mining is also a major source of raw materials for several high-demand products, including consumer electronics, EV batteries, and renewable energy technologies.

With increasing demand for raw materials, there is an industrywide trend toward declining ore grades—which increases the energy intensity per ton of ore extracted—and a global push for cleaner industries.

As part of a JISEA research consortium with mining industry experts, JISEA studied opportunities and challenges for integrating clean energy technologies into mining operations.

JISEA found greater adoption of renewables could benefit mining companies by lowering their emissions, improving their operating margins, hedging against fossil fuel price volatility, and improving their social license to operate. However, many technical integration challenges still need to be resolved. Future research could focus on specific opportunities to integrate clean energy.

LEARN MORE: Integrating Renewable Energy into Mining Operations: Opportunities, Challenges, and Enabling Approaches (www.doi.org/10.1016/j.apenergy.2021.117375)

"The mining industry is ramping up deployment of clean energy, but there are opportunities to go beyond just wind, solar, and battery solutions at extraction sites. With many of the largest companies adopting net-zero goals, transformative technologies such as hydrogen applications, zero-emissions process heating, and sustainable shipping fuels will play significant roles. This is the R&D frontier that will require collaboration and scale-up today to deliver deep decarbonization."

—Travis Lowder, JISEA/NREL analyst

CLOSING THE METHANE GAP IN U.S. EMISSIONS INVENTORIES

Methane, a primary constituent of natural gas, can intentionally and unintentionally be emitted into the air during oil and natural gas production.

The U.S. Environmental Protection Agency (EPA) estimates methane emissions from oil and natural gas production in its annual Greenhouse Gas Inventory. The inventory informs policy design, cost analysis, formulation of oil and gas leak detection and repair programs, and life cycle assessment research.

However, estimates in the Greenhouse Gas Inventory have consistently been lower than site-level field measurements. To help close the methane gap JISEA, Stanford University, Colorado State University, and NREL partnered on a study funded under a JISEA sponsorship agreement with Novim—a nonprofit that provides independent, nonadvocacy data, information, and knowledge on important national and global issues.

The team used a new, bottom-up analytical approach to estimate emissions at the most detailed level and scale up, using the most comprehensive data set of publicly available, component-level direct emissions measurements developed to date.

The research found that the biggest gaps in estimates between the new approach and the Greenhouse Gas Inventory came from unintentional equipment leaks and venting from storage tanks. The differences reflect the quality of the data sources—the research team used a larger data set with more recent measurements that accurately represent today's conditions. Unlike much of the methane research to date, this new approach is compatible with Greenhouse Gas Inventory requirements and, therefore, could enable the EPA to update its methods to improve accuracy.

LEARN MORE: Closing the Methane Gap in U.S. Oil and Natural Gas Production Emissions Inventories (www.doi.org/10.1038/s41467-021-25017-4)

CLEAN ENERGY INTEGRATION IN OIL AND GAS OPERATIONS

As the U.S. energy system transitions to lower-carbon energy sources, the oil and gas industry is becoming more interested in exploring decarbonization opportunities, increasing operational resilience, and conserving high-value resources.

JISEA completed two case studies on the potential benefits of incorporating clean energy technologies in two parts of the oil and gas value chain: oil fields and compressor stations.

This work was sponsored by a JISEA oil and gas consortium including ConocoPhillips, Baker Hughes, Extraction Oil & Gas, Kinder Morgan, and the Interstate Natural Gas Association of America Foundation. The consortium seeks to understand site-specific energy consumption, prices, and opportunities for clean energy integration.

JISEA first modeled the technoeconomic potential of solar PV, wind, and battery energy storage at an all-electric compressor station in West Texas owned by Kinder Morgan. As modeled, smaller renewable energy systems can be cost-effective, increase resilience, and reduce emissions.

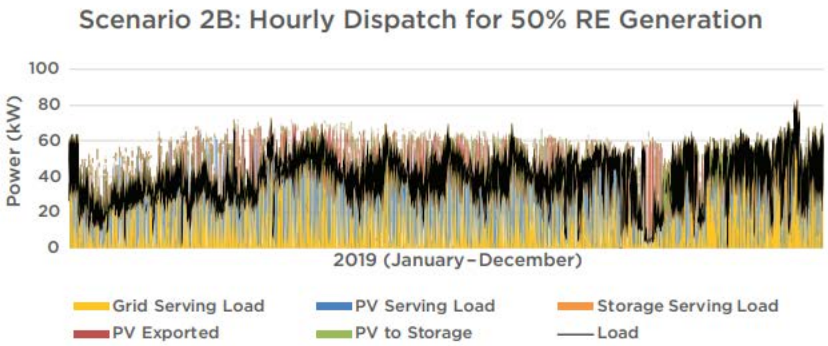
In the second case study, JISEA modeled clean energy options for a ConocoPhillips oil field in the Delaware Basin—part of the larger Permian Basin that produces about 40% of U.S. oil.

Much like compressor stations, oil field operations could benefit most from smaller renewable energy technologies that generate 5% of the site's load; larger PV systems currently would not be economic at the site level. However, larger systems could be economic in other areas, depending heavily on electricity rates.

LEARN MORE: Clean Energy Integration in Natural Gas Compressor Station Operations (www.nrel.gov/docs/fy21osti/80540.pdf)

Integration of Clean Energy into Oil Field Operations (www.nrel.gov/docs/fy22osti/81107.pdf)

Hourly Dispatch of Solar PV and Battery Storage for 50% Renewable Energy Generation



A solar PV and battery storage system at an oil field site would be dispatched throughout the year. PV generated above site load could be exported to the utility or curtailed.

Compressor stations play an important role in transporting natural gas from the well to end users by sustaining the pressure and flow of natural gas. Note the pictured compressor station was not the one modeled in the study. Photo from Kinder Morgan

SUSTAINABLE COMMUNITIES AT THE ENERGY-WATER-FOOD NEXUS

INCREASING RESILIENCE OF ENERGY, WATER, AND FOOD SYSTEMS

The energy-water-food nexus refers to the interconnected nature of these systems, such that demands often impact one another.

For example, the world's power supply is still dominated by fossil-fuel-based, nuclear, and hydroelectric power plants, which require a reliable supply of water. Efforts to meet energy, water, and food demands have historically been siloed despite their strong interdependence.

As population growth, urbanization, and climate change increase, so does the demand for the competing uses of energy, water, and food. Therefore, a more holistic approach is needed to avoid straining any one of the systems and meet global demands sustainably.

JISEA studies the energy-water-food nexus using a comprehensive approach that integrates multiple disciplines (social, economic, environmental, and more) to understand the full scope of benefits, demands, and impacts of the collective system.

Through this work, JISEA is helping identify innovative technology and policy solutions that make the best use of resources to sustainably meet the interdependent demands of energy, water, and food.

ANAEROBIC DIGESTION OFFERS MANY BENEFITS FOR COLORADO DAIRIES

In 2019, methane emissions from livestock manure accounted for about 9.5% of U.S. methane emissions, with beef and dairy cattle emitting more than any other domestic animal.

Anaerobic digestion, the process through which bacteria break down organic matter in the absence of oxygen, can produce energy in the form of biogas, improve air and water quality, and reduce overall greenhouse gas emissions.

Through a partnership with the Colorado Department of Agriculture and the Colorado Energy Office, JISEA conducted a case study on the potential benefits of implementing an anaerobic digestion system at Aurora Organic Dairy High Plains Farms in Gill, Colorado. The farms encompass 6,000 acres and have about 13,000 cows, 80% of which are producing milk at any given time.

JISEA modeled an anaerobic digestor system at the farms with a combined heat and power system that operates on the produced biogas. As modeled, the digester system would reduce emissions from manure management in liquid lagoons by 5,700 metric tons of CO_2 per year.

The system could also produce enough energy to meet all the farms' electricity and heating demands, including providing electricity and winter heating for the biogas digesters, with enough excess capacity to export 1 to 2 megawatts back to the grid. Alternatively, upgrading the biogas to renewable natural gas would produce the equivalent of 1.34 million gallons of gasoline per year and could avoid 12,000 metric tons of vehicle CO_2 emissions annually.

LEARN MORE: Anaerobic Digestion Implementation at Dairies in Colorado (www.nrel.gov/docs/fy21osti/80381.pdf)

"At JISEA, we are not focused on just one element of clean energy transition, we have the opportunity to think about intersections that haven't already been explored."

—Liz Weber, JISEA program manager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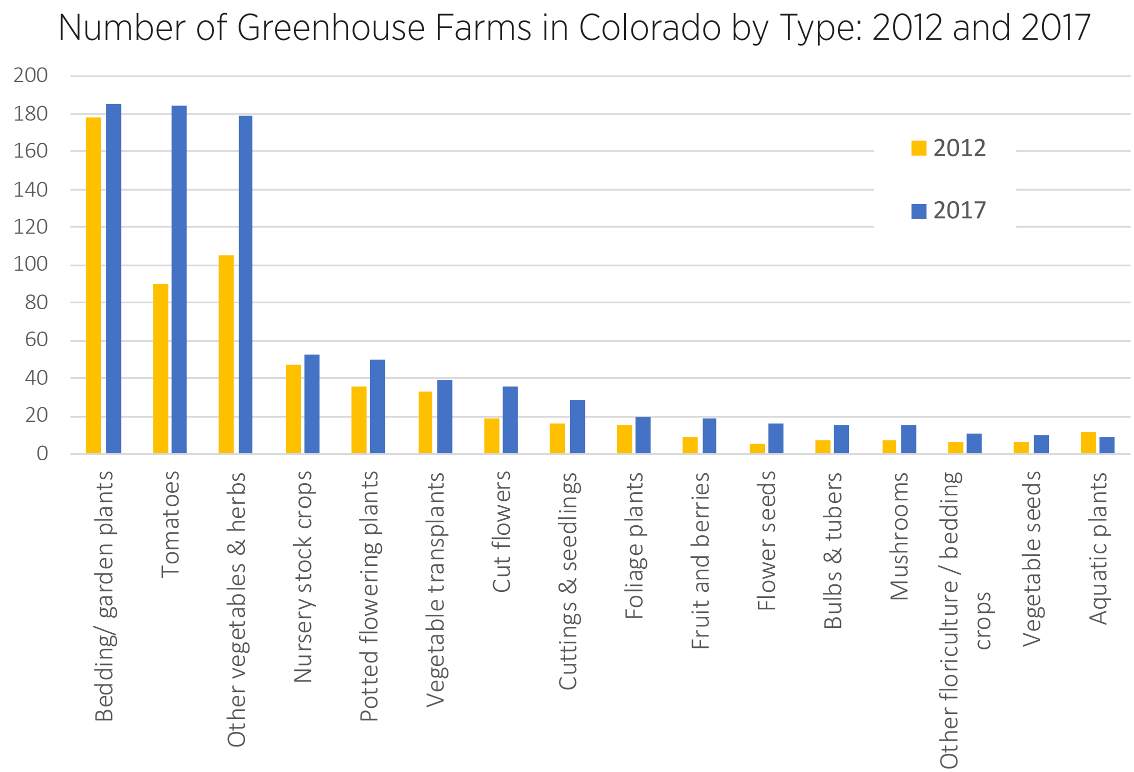
SOLAR ENERGY PROVIDES A PROMISING SOLUTION FOR COLORADO GREENHOUSES

Agricultural greenhouses can offer a wide range of environmental, economic, and resilience benefits, but they often require careful control and optimization of internal environmental conditions to maximize crop productivity. Regulating temperature, lighting, humidity, and ambient CO_2 concentrations can be energy-intensive processes.

JISEA partnered with the Colorado Department of Agriculture and the Colorado Energy Office to review the potential for solar energy to provide heat, electricity, and backup power at four Colorado greenhouses: Altman Specialty Plants, Gunnison Gardens, Welby Gardens, and Zapata Seeds.

Because the greenhouses all have unique energy and agricultural needs, JISEA found there are no one-size-fits-all solutions. Rather, JISEA found different combinations of solar PV and solar thermal technologies at each Colorado greenhouse could reduce operating costs, improve farm competitiveness, and improve the sustainability and resilience of agricultural yields. Each solution could include an appropriate combination of passive and active design and technologies based on factors such as structural design, operations, or internal and external climate conditions.

LEARN MORE: Renewable Energy for Heat & Power Generation and Energy Storage in Greenhouses (www.nrel.gov/docs/fy21osti/80382.pdf)



Number of greenhouse farms in Colorado by type in 2012 (yellow bar) and 2017 (blue bar). Statewide data is from the United States Department of Agriculture Census of Agriculture 2017 Report.

CO-BENEFITS AND IMPACTS OF FLOATING SOLAR PHOTOVOLTAICS

Floating solar PV has emerged as a promising use of PV due to land-use constraints, but there has not been in-depth analysis of the technology's co-benefits and impacts on energy, water, and food systems.

JISEA and NREL partnered to address this informational gap through an in-depth literature review of suggested co-benefits of floating PV systems.

The review confirmed some of the suggested benefits of floating PV systems, such as panel efficiency and reduced land usage, are supported by research. Other benefits, however, such as improved power quality and reduced curtailment, are not supported by research.

The findings indicate more data collection and research are needed to better quantify the water-related and broader economic, environmental, social, sustainability, justice, and resilience co-benefits and impacts of floating PV systems.

LEARN MORE: Benefits and Critical Knowledge Gaps in Determining the Role of Floating Photovoltaics in the Energy-Water-Food Nexus (doi.org/10.3390/su13084317)

JISEA CATALYZERS

CATALYZING CLEAN ENERGY RESEARCH CAPABILITIES

The JISEA Catalyzers initiative is a highly interdisciplinary program that brings together experts within specific research areas to discuss capabilities, establish best practices, and identify future research needs.

The initiative was launched in May 2021 and is operated in partnership with NREL. Each catalyzer is incubated for one to two years before transitioning into a new NREL-led program.

The vision for the Catalyzers initiative took shape as the depth and scope of clean energy research expanded drastically—calling for new capabilities to answer more complex questions.

JISEA kicked off the initiative with two inaugural catalyzers focused on energy and atmospheric systems and sustainable communities. Both were inspired by emerging capabilities at JISEA/NREL and areas of growing importance within the energy transition.

Since launching, the catalyzer teams have hosted workshops and presentations, contributed to research projects, and conducted studies to establish robust networks of experts within the two topic areas. These research communities are now identifying the next biggest questions they should be thinking about and the resources needed to answer them.

Together, the catalyzers are establishing new research capabilities that will support diverse stakeholders and advance the energy transition.

ENERGY AND ATMOSPHERIC SYSTEMS CATALYZER

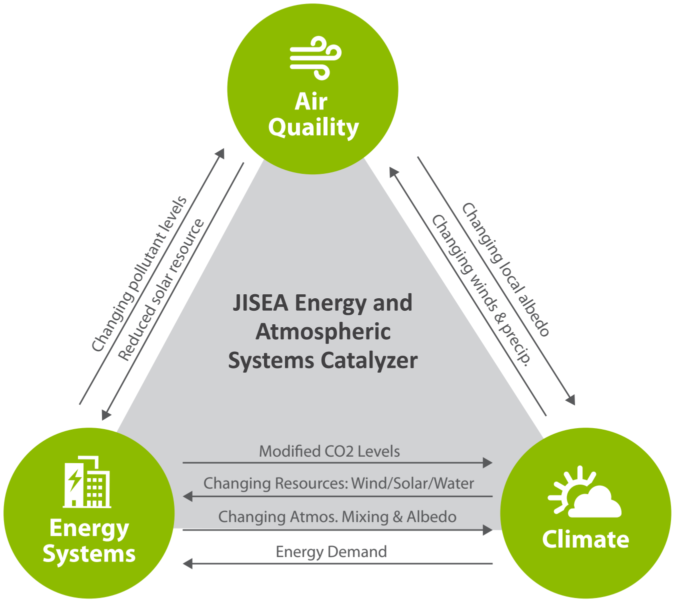
The Energy and Atmospheric Systems Catalyzer explores multidirectional relationships across climate, air quality, and energy systems for sustainable future energy systems.

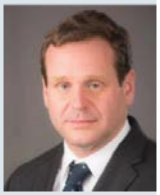
Through this catalyzer, JISEA is connecting researchers in many disciplines across the institute and NREL—from computational science to energy analysis to sustainability—to understand the breadth and depth of this capability.

Researchers affiliated with the Energy and Atmospheric Systems Catalyzer have participated in many research projects, from a study on the effect of wildfires on air quality to an effort to build a global air quality model.

This year, the catalyzer also tracked and quantified emissions from energy technologies, which is important for lenders, utilities, and lawmakers to make policy, planning, and investment decisions. The team updated prior harmonization of around 3,000 life cycle assessments on utility-scale electricity generation technologies, including storage technologies for the first time.

LEARN MORE: Life Cycle Greenhouse Gas Emissions from Electricity Generation: Update (www.nrel.gov/docs/fy21osti/80580.pdf)

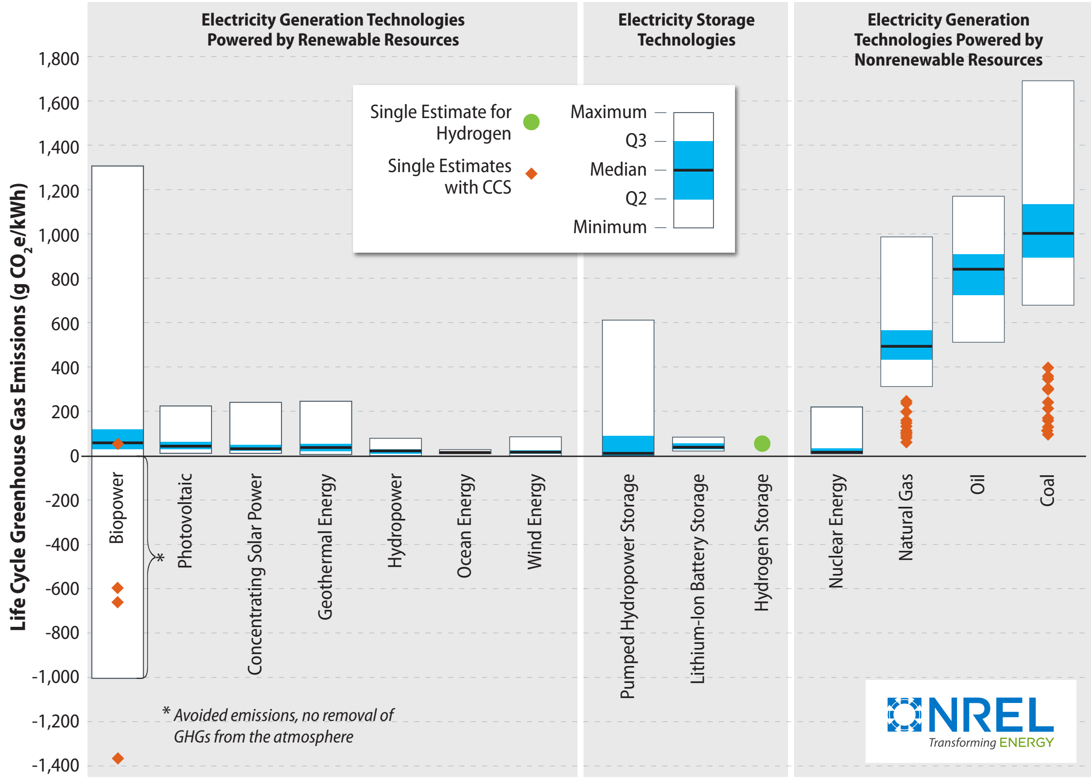




"NREL researchers have been looking at interactions between the atmosphere and energy systems from so many dimensions, from air quality impacts of new energy technologies to the effect of climate change on renewables to looking at the impact of wildfires on power generation. And yet NREL is not seen as an atmospheric sciences lab. Our job at the catalyzer is to bring together researchers at the lab in air quality, atmospheric systems, and climate to establish a baseline for the types of analyses we can conduct and create a vision for those capabilities moving forward."

—Michael Martin, Energy and Atmospheric Systems Catalyzer co-lead

Life Cycle Greenhouse Gas Emission Estimates for Selected Electricity Generation and Storage Technologies, and Some Technologies Integrated with Carbon Capture and Storage



	Biopower	Photovoltaic	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Pumped Hydropower Storage	Lithium-Ion Battery Storage	Hydrogen Storage	Nuclear Energy	Natural Gas	Oil	Coal
Estimates	276 (+4)	46	36	35	149	10	186	16	29	1	99	80 (+13)	24	164 (+11)
References	57 (+2)	17	10	15	22	5	69	4	3	1	27	47 (+11)	10	53 (+9)

Comparison of published estimates of life cycle greenhouse gas emissions for biomass, solar (PV and concentrating solar power), geothermal, hydropower, ocean, wind (land-based and offshore), nuclear, oil, and coal generation technologies as well as storage technologies. Note: The number of estimates is greater than the number of references because many studies considered multiple scenarios. Numbers reported in parentheses pertain to additional references and estimates that evaluated technologies with carbon capture and storage.

SUSTAINABLE COMMUNITIES CATALYZER

The Sustainable Communities Catalyzer puts communities at the front of the energy transition.

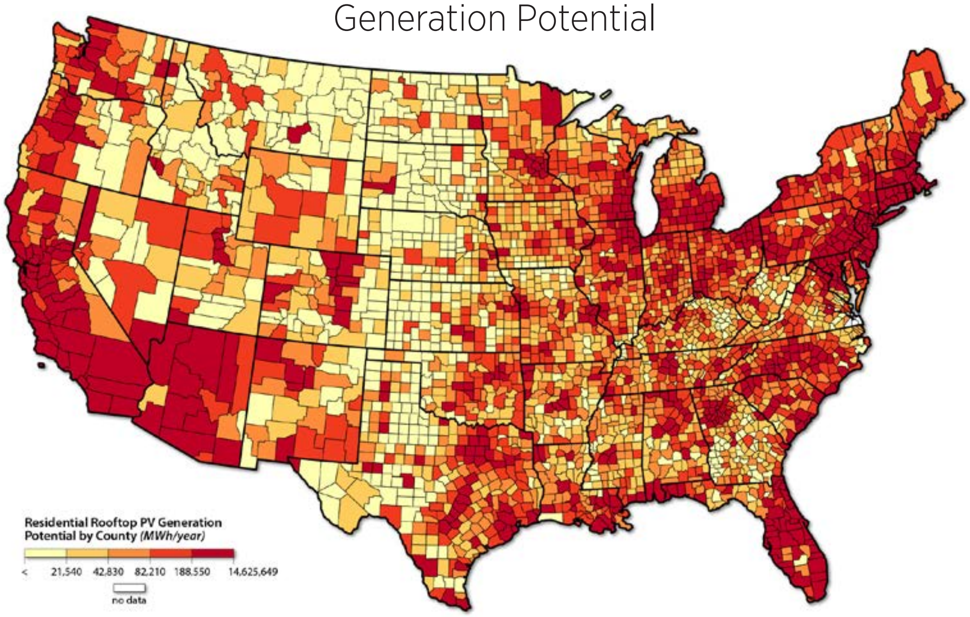
Using world-class modeling and computational capabilities, the Sustainable Communities Catalyzer studies pathways for communities to achieve sustainable clean energy transitions—with a focus on rural and disadvantaged communities.

Since launching, the Sustainable Communities Catalyzer has met with groups of experts in sustainable energy planning and is working directly with several communities to analyze their energy questions.

Using the State and Local Planning for Energy Platform, an NREL tool that supports local energy planning and decision-making, the team performed new energy justice analyses. The team intersected data on energy burden, environmental hazard exposure, income, and education with areas of high technical renewable generation potential and low levelized cost of energy. The resulting data set enables the addition of equity considerations in clean energy investments and program participation.

After a successful year, the Sustainable Communities Catalyzer will be graduating into a new NREL-led program—elevating it as an important area of expertise within the energy transition.

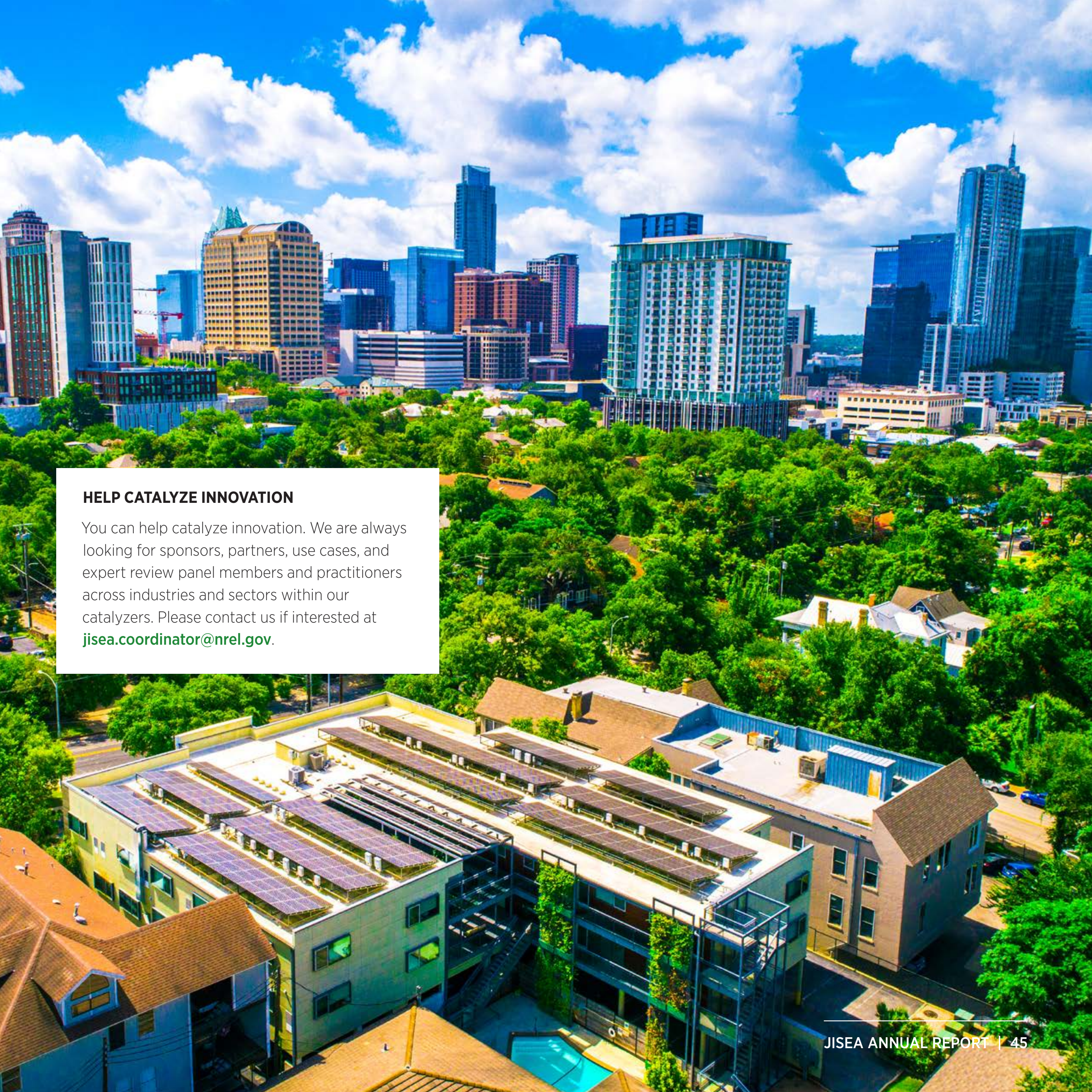
County-Level Residential Rooftop PV Annual Technical Generation Potential



Comparing generation potential and levelized costs across wind and solar energy technologies can help inform state and local energy planners seeking to prioritize local renewable energy generation.

"We couldn't have done this research without the JISEA Catalyzers initiative. We have a lot to offer communities, but the catalyzer has allowed us to pause, bring together the people involved, and conduct new analysis to inform work moving forward with new insights."

—Megan Day, Sustainable Communities Catalyzer lead



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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**.

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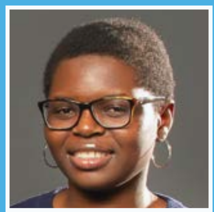
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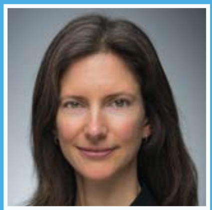
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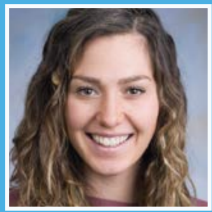
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JISEA's Program Committee provides guidance on program direction to the executive director and reviews JISEA's research agenda, priorities, and research program plan.

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Role of the Social Factors in Success of Solar Photovoltaic Reuse and Recycle Programmes

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Life Cycle Greenhouse Gas Emissions from Electricity Generation: Update

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Clean Energy Integration in Natural Gas Compressor Station Operations

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Closing the Methane Gap in U.S. Oil and Natural Gas Production Emissions Inventories

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Renewable Energy for Heat & Power Generation and Energy Storage in Greenhouses

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Anaerobic Digestion Implementation at Dairies in Colorado

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Applied Energy Tri-Laboratory Consortium Workshop Report

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Approaches for Integrating Renewable Energy Technologies in Oil and Gas Operations

www.nrel.gov/docs/gen/fy21/79081.pdf

Benefits and Critical Knowledge Gaps in Determining the Role of Floating Photovoltaics in the Energy-Water-Food Nexus

www.doi.org/10.3390/su13084317

CEMAC

https://www.jisea.org/manufacturing.html

Benchmarks of Global Clean Energy Manufacturing Research Highlight, 2014–2016

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The Yucatan Peninsula Energy Assessment: Pathways for a Clean and Sustainable Power System

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