Engage

Accelerating the Transformation of the Global Energy Economy

JISEA 2021 Annual Report

JISEA

Joint Institute for
Strategic Energy Analysis

A YEAR OF THOUGHTFUL ENGAGEMENT

At the Joint Institute for Strategic Energy Analysis (JISEA), we work collectively and creatively with industry and government experts to study integrated technical, economic, and social aspects of the clean energy transition. This collaboration is where unique insight happens, and where I personally feel energized.

When JISEA transitioned to remote work with the global pandemic, we had to reconsider the way we engage with our research partners to stay connected. We learned that, like the grid, we are resilient.

This year we were able to continue thoughtful engagement with our global communities. We participated in national and international presentations and hosted virtual events that brought together people from the energy, water, food, policy, manufacturing, academic, mining, oil and gas sectors, and more.

JISEA analysts completed several large studies this year. We completed a multiyear research program on the natural gas-electricity interface. Supported by a consortium of sponsoring organizations and in partnership with academia and energy software experts, JISEA studied the potential benefits and trade-offs of enhanced coordination between the natural gas and electricity sectors.

Continuing JISEA's tenured research on how renewable energy systems can work with traditional nuclear and fossil energy, we explored the potential of nuclear energy to provide power system flexibility and studied how multi-input, multi-output, tightly coupled hybrid energy systems can provide power, heat, mobility, and other energy services synergistically.

Another major highlight this year was the release of our latest *Benchmarks of Global Clean Energy Manufacturing* report, which provides extensive insights into the supply chains of four clean energy technologies across 13 countries and 3 years.

From a global perspective, the energy transition accelerated both despite and due to the pandemic. The ways we use energy and move about the world shifted dramatically, illustrating the change and resilience that are possible.

This year certainly hasn't been what we expected, but it's been successful for JISEA and the clean energy transition. By engaging with our research partners in new ways, we've continued to make progress toward resilient, secure, and flexible energy systems. I thank you for your support, and I hope you enjoy reading about how JISEA's thoughtful engagement advanced our mission in 2020!

Jill Engel-Cox
JISEA Director

CROSS-CUTTING ANALYSIS FOR MODERN ENERGY SYSTEMS

Energy systems are evolving quickly. The integration of more clean energy generation, storage, and efficient end-use technologies is being driven by customer demand, lower cost, and the increased resilience and flexibility they can provide.

However, many challenges remain in front of us. For example, we must address the increase in penetration of variable generation, the increasing linkage between electricity and transportation infrastructure, and the continually evolving cybersecurity and natural disaster threats. Additionally, we must assess shortcomings in today's policies, procedures, and coordination among sectors to bridge the energy system of today with the modern one of tomorrow.

In the Energy Systems Integration (ESI) directorate at NREL, our research is focused on solutions that enable smooth transitions to modern energy systems that are secure, resilient, reliable, affordable, and clean. Our advanced energy research and analysis provide technically sound guidance to get there, supporting strategic energy planning, data-driven decision making, and reduced-risk project development.

It is this deep understanding of the challenges of today that informs our fundamental R&D that is shaping and building the new solutions for tomorrow.

This year we welcomed JISEA into the ESI directorate to leverage their unique analytical capabilities in high-impact, cross-cutting research. With industry and academic partnerships and a focus on leveraging diverse energy sources in the grid, JISEA is a natural fit within the ESI directorate.

Partnership has been a driving force within ESI since the beginning. This engagement has kept us aligned with industry concerns and questions to ensure we're pursuing research that makes an impact.

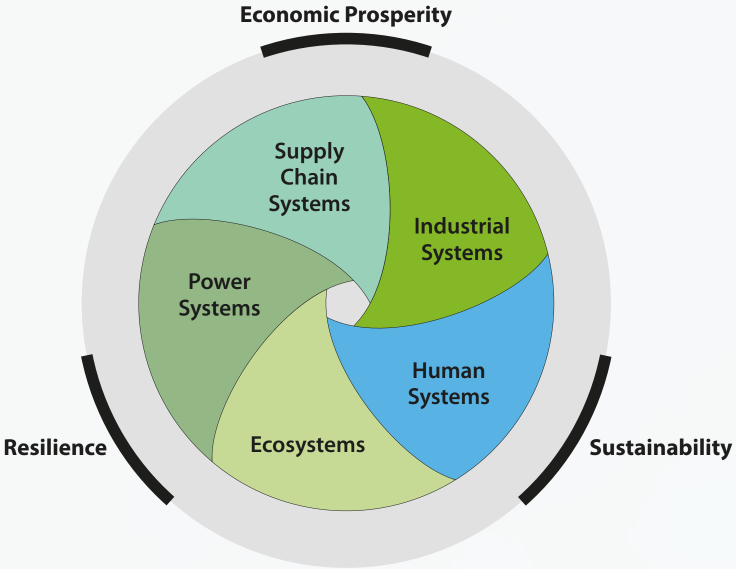
JISEA has been a model for industry partnerships with their collaborative workshops and research consortiums that bring together diverse experts. This engagement includes all voices in the clean energy transition to identify solutions that benefit stakeholders and the larger energy economy.

JISEA pushes the boundaries to ask the next biggest questions in the clean energy transition that other people aren't thinking of yet. This helps to identify and connect where the industry is going with new areas of research, ensuring that we're staying ahead of the curve. Stay tuned for exciting updates on this in 2021.

We are fortunate to have JISEA's cross-cutting expertise and forward-thinking approach to help optimize and integrate rapidly evolving energy systems. I'm thrilled by the success JISEA had in 2020, and I look forward to seeing how we can continue to shape modern energy systems in 2021.

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 provides 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 Water-Energy-Food Nexus**

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ENERGY SYSTEMS INTEGRATION AND TRANSFORMATION

ALIGNING MODERN DYNAMIC ENERGY SYSTEMS

A decarbonized grid may require new energy infrastructure and coordination among stakeholders to provide secure and resilient energy.

JISEA research is helping transition individual energy systems into integrated energy systems of the future to provide resilient, secure, affordable, flexible, and sustainable energy.

As jurisdictions and industries set ambitious decarbonization goals, energy systems are rapidly shifting to variable renewable energy sources. Natural gas continues to expand for power, heat, and feedstocks. New nuclear energy technologies may become more flexible. Electrification of transportation, homes, and industry is expected to expand.

This technology shift requires coordination of planning, regulation, and operations across diverse energy systems at scales ranging from individual customers to entire regions. However, energy systems have traditionally been designed as stand-alone systems with little or no dependencies.

Through a holistic research and analysis approach, JISEA is examining the value of all energy sources and mapping synergies to align today's dynamic energy systems through novel concepts and processes. By partnering with industry, we gain insight that informs and guides the implementation of feasible, real-world solutions.

INNOVATION IN NOVEL HYBRID ENERGY SYSTEMS

Considering energy sources independently and competitively can overlook synergies that could add value to the complex electric grid of the future.

JISEA analysts were part of a team from the U.S. Department of Energy's (DOE's) three applied energy laboratories—the National Renewable Energy Laboratory (NREL), Idaho National Laboratory (INL), and National Energy Technology Laboratory (NETL)—to develop novel concepts for multi-input, multi-output tightly coupled hybrid energy systems.

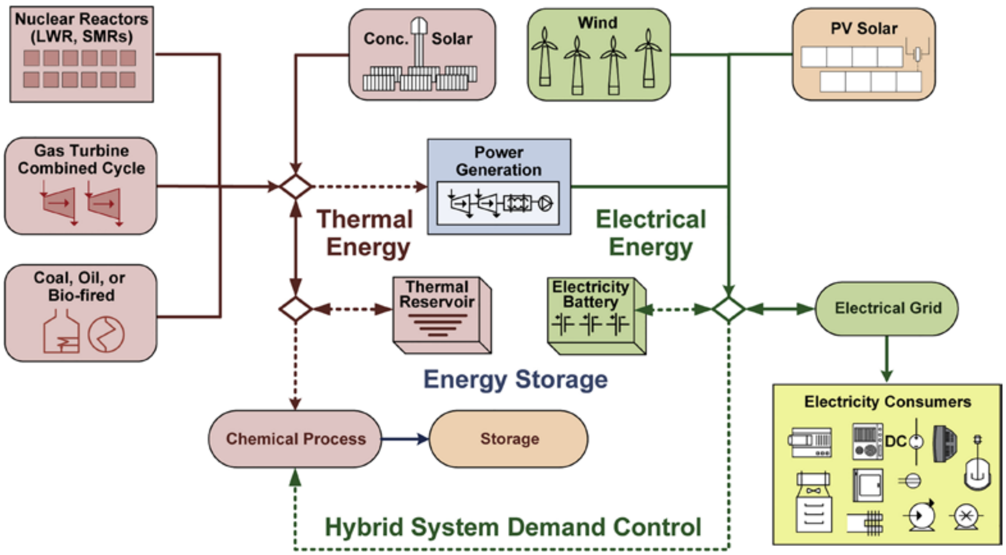
These system configurations include diverse energy generators—renewable, nuclear, and fossil with carbon capture—to synergistically provide power, heat, mobility, and other energy services.

For example, a hypothetical, tightly coupled industrial energy park could use heat and electricity from highly flexible advanced nuclear reactors, small-scale fossil generators, and renewable energy technologies to produce electricity and hydrogen from electrolysis. Depending on market pricing, electricity and/or heat could be sold to the grid, used on-site, or stored for later distribution and use. Energy output could also produce hydrogen or other valuable chemicals and products.

The diversity and interactions between multiple energy sources and applications can potentially increase the resilience, reliability, security, economics, affordability, flexibility, and sustainability of both the hybrid energy system and the overall energy system surrounding it.

The analysts also developed a new framework for engineering-based modeling and analysis to adequately study complex hybrid energy systems.

LEARN MORE: Multi-Input, Multi-Output Hybrid Energy Systems (www.doi.org/10.1016/j.joule.2020.11.004)



Novel hybrid system configurations combining fossil, nuclear, and renewable energy sources could provide multiple outputs ranging from power, heat, and clean water to fuels and chemicals—significantly contributing to wide-scale decarbonization efforts.

STRATEGIES TO SYNC UP THE NATURAL GAS AND ELECTRICITY SECTORS

Natural gas and electricity are becoming more interdependent with increasing installations of gas-fired generators, widespread availability of low-cost natural gas, and rising penetrations of variable renewable energy sources. The two systems weren't built to operate together, though, and this growing interdependence creates new challenges for both.

To address this, in 2015 the U.S. Federal Energy Regulatory Commission issued Order 809 to improve day-ahead and intraday coordination between the natural gas and electric sectors, with the goals of minimizing system operating costs and increasing reliability.

JISEA engaged with academia, commercial energy system modelers, and a consortium of sponsors in a year-long study on the operational costs and reliability of market-based coordination between natural gas and electricity systems. Analysts used real Colorado power and gas pipeline data provided by Kinder Morgan, Inc., and released a series of publications on their findings, culminating in a final synthesis report.

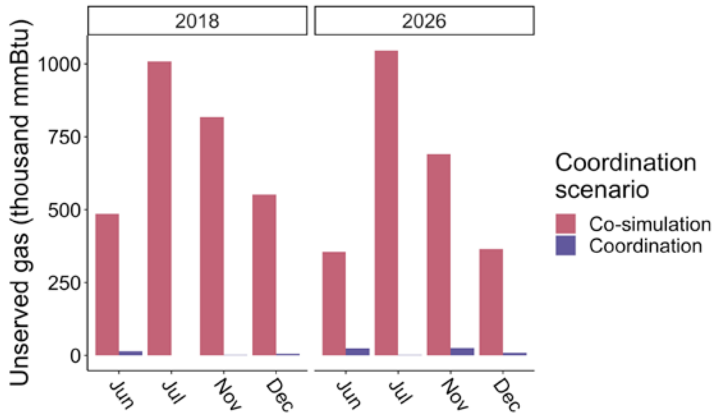
Coordination—both day-ahead and intraday—decreased the amount of natural gas that could not be delivered to customers due to a supply shortage or excess demand, referred to as curtailment or unserved gas. Currently, system operators pay for costly out-of-market interventions to manage gas curtailment. In intraday markets, coordination reduced curtailed natural gas by nearly 97% for the Colorado system without substantial cost increases.

Coordination can also support more renewables on the grid by relieving natural gas pipeline constraints and allowing greater flexibility to deliver gas when intermittent wind or solar aren't available.

LEARN MORE: Electric Power Grid and Natural Gas Network Operations and Coordination (www.nrel.gov/docs/fy20osti/77096.pdf)

Integrated Model of Natural Gas Pipelines and the Electricity Grid (www.nrel.gov/docs/fy20osti/76561.pdf)

"We know that the key attribute of our future electric grid is flexibility. JISEA's study advances the conversation by confirming that enhanced coordination between the gas and electric systems, including a shaped flow nomination, could facilitate higher levels of renewable penetration, in addition to other cost and efficiency benefits. This is an important contribution, and it was very rewarding to work with the JISEA team."
—Natalie Karas, Senior Director and Lead Counsel, Environmental Defense Fund's Energy Program



Total unserved natural gas (in thousand mmBtu) by week for the co-simulation and coordination scenarios; results are shown using ratable flows.

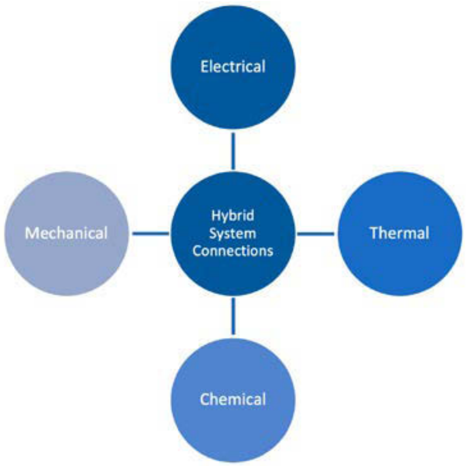
NUCLEAR-RENEWABLE SYNERGIES FOR CLEAN ENERGY SOLUTIONS

Since 2011, JISEA has analyzed the potential of nuclear-renewable hybrid energy systems to provide low-carbon electricity when the grid needs it and another commodity product, such as thermal energy or hydrogen, during other hours.

In 2020, Clean Energy Ministerial's (CEM's) Nuclear Innovation: Clean Energy (NICE) Future Initiative—a key program under the JISEA umbrella—conducted an international study on the potential of flexible nuclear energy on the grid. The study incorporated insight from more than 20 organizations worldwide.

JISEA analysts modeled future scenarios with available low-cost flexible nuclear energy and different levels of renewable energy penetration through 2050. Across all scenarios, the introduction of low-cost, flexible nuclear energy (more than just low-cost traditional nuclear) had the potential to reduce system costs, supported increased renewable capacity on the grid, and lowered atmospheric emissions.

LEARN MORE: Flexible Nuclear Energy for Clean Energy Systems (www.nrel.gov/docs/fy20osti/77088.pdf)



Integrated energy systems can support nuclear plant flexibility by redirecting excess steam, thermal energy, and/or electricity to coupled, nongrid applications. SOURCE: Suman, 2018

NICE Future
Nuclear Innovation: Clean Energy Future

JISEA @ CEM11: Exploring the Enabling Roles of Nuclear Energy in Clean Energy Systems

In September 2020, JISEA joined ministers from around the world for the virtual 11th Clean Energy Ministerial meeting, or CEM11. Founded in 2010, CEM facilitates global dialogue on high-level policy to share best practices for accelerating the clean energy transition.

At CEM11, JISEA led a session on the potential of nuclear energy in clean energy systems. During the session, NICE Future announced its international report on nuclear flexibility—a major part of the Flexible Nuclear Campaign for Nuclear Renewables Integration initiative.

Researchers in integrated energy systems, including JISEA Director Jill Engel-Cox (top left), discuss the enabling roles of nuclear energy at a side event during CEM11.

> “When we think outside of the box with nuclear energy, there are many valuable roles that it can play in harmony with renewables to add resilience and flexibility to the power grid.”
>
> *—Jordan Cox, JISEA nuclear analyst*

FLEXIBILITY OPPORTUNITIES WITH ELECTRIC VEHICLE CHARGING

With increasing adoption of plug-in electric vehicles (EVs), questions are growing around how to integrate them into the power system at least cost and whether they offer opportunities for flexibility.

At a virtual two-day workshop in April 2020, CEM convened 75 international experts from four of its work streams—21st Century Power Partnership (21CPP), Electric Vehicles Initiative, International Smart Grid Action Network Initiative, and Power System Flexibility Campaign—to discuss coupling the transportation and power sectors.

Experts emphasized that vehicle electrification is critical to the energy transition. Maximizing the benefits of EVs will require engaging stakeholders at all levels to consider EV users and their needs while also integrating EVs into the grid. This could require changes to regulation and market design in addition to technological innovation.

LEARN MORE: Electric Vehicle and Power System Integration (https://www.nrel.gov/docs/fy20osti/77494.pdf)

Vehicle electrification is a critical component of broader electrification trends and energy system transformation. Photo by Ellina Levina, International Energy Agency

21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

As part of an ongoing partnership between 21CPP and Brazil's Energy Research Office, *Empresa de Pesquisa Energética* (EPE), JISEA hosted three analysts from EPE for a weeklong technical exchange in February 2020 at JISEA'S home, the National Renewable Energy Laboratory in Golden, Colorado.

The exchange provided hands-on experience in energy planning, demand-side modeling, and computational tools to support power system transformation in Brazil.

The week included tours of NREL's best-in-class research facilities and technical discussions with NREL/JISEA analysts on wide-ranging topics, from energy storage to scalable infrastructure modeling to electric vehicle charging.

LEARN MORE: 21st Century Power Partnership (www.21stcenturypower.org)

NREL's Flatirons Campus provides the EPE team with on-the-ground experience to apply to their own renewable energy projects in Brazil.

ADVANCED MANUFACTURING AND CIRCULAR ECONOMY

DESIGNING SUSTAINABLE SYSTEMS FOR ENERGY MATERIALS

A circular economy for energy materials enables synergies across systems so energy materials can be reused, recycled, or repaired easily for multiple lifetimes.

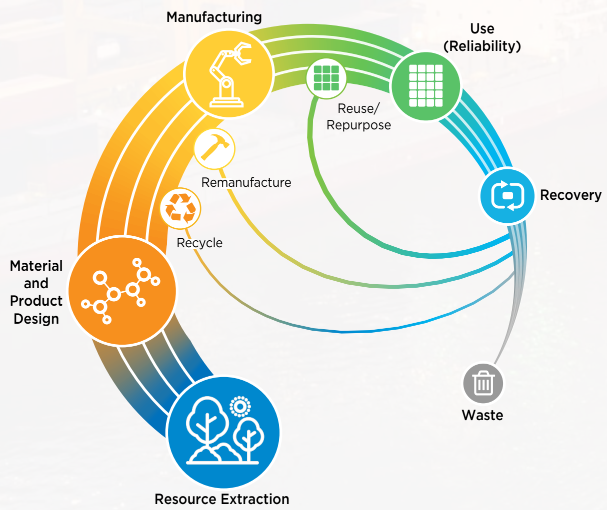
Traditionally, energy materials are brought to bear using a linear approach—materials are taken, products are made, and when products expire or break, they are disposed of. The process repeats.

While this can work for a little while, eventually it depletes finite resources, produces waste, and cannot be sustained long term. For example, retired solar photovoltaic (PV) modules could total 80 million metric tons of waste by 2050, or 10% of the world's electronic waste.

That's why JISEA is invested in research on the manufacturing of energy materials. Through life cycle assessments and supply chain and technoeconomic analyses, we're tracing energy technologies through their lifetimes, from extraction of raw materials to end-of-life management.

Through the Clean Energy Manufacturing Analysis Center (CEMAC), a key program under the JISEA umbrella, researchers assess and compare clean energy technology supply chains. This illuminates environmental and economic impacts, as well as intersections with other systems where synergies could take place.

Through this holistic approach, we work collectively to innovate upstream and prevent waste from the beginning.



A circular economy utilizes resources for as long as possible, extracts the maximum value during that time, and then recovers and regenerates products and materials. Illustration by Alfred Hicks, NREL

PROMISING APPROACHES FOR MANAGING RETIRED SOLAR PANELS

Currently, no standards or best practices exist for managing solar PV modules when they reach the end of their typical 30-year life span.

By engaging with solar manufacturers, JISEA analyzed the most promising approaches to recycling PV modules, focusing specifically on crystalline silicon, which is used in more than 90% of installed PV systems.

Crystalline silicon accounts for about half of the energy, carbon footprint, and cost to produce PV modules, but only a small portion of the mass.

Based on their findings, JISEA analysts recommended R&D on reducing recycling costs and environmental impacts while maximizing recovery of high-value silicon versus intact silicon wafers. The wafers have been touted as a good reuse option, but they often crack and aren't viable for direct reuse.

LEARN MORE: Research and Development Priorities for Silicon Photovoltaic Module Recycling To Support a Circular Economy (www.doi.org/10.1038/s41560-020-0645-2)

JISEA/NREL scientists Garvin Heath (left) and Timothy Silverman (right) visit Dlubak Glass in Ohio, the largest U.S. processor and recycler of glass in cars, computer monitors, TVs, and lighting. *Photo courtesy of Garvin Heath*

"PV is a major part of the energy transition. We must be good stewards of these materials and help develop a circular economy for PV modules."
—Garvin Heath, JISEA sustainability scientist

NEXT-GENERATION REFRIGERATION TO COOL THE PLANET

State of Alternative Refrigerants

Traditional refrigerants deplete the ozone layer and produce powerful atmospheric emissions. If it were released into the atmosphere, just one kilogram of the refrigerant R-410A, which is commonly used in U.S. home air conditioners, would result in the same greenhouse impact as two tons of carbon dioxide, or the equivalent amount released from an average car over six months. Refrigerant markets are now rapidly changing to transition to energy efficient, low-emissions alternatives.

In partnership with Oak Ridge National Laboratory and supported by the U.S. Department of Energy's Building Technologies Office, JISEA analysts studied the production, distribution, consumption, costs, and potential operating efficiency of alternative refrigerants in heating, ventilation, and air-conditioning systems. They found that certain alternative refrigerants work best for certain applications, but there are generally multiple viable options. For example, the alternative refrigerant HFO-1234yf is suitable for vehicle air-conditioning systems but is currently more expensive and flammable than its conventional counterpart, R-134a.

The United States has a positive outlook for its refrigerant market with a stable supply of the required chemical feedstock, existing refrigerant manufacturing capital, and experienced labor.

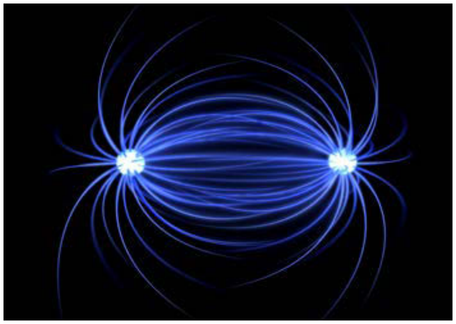
LEARN MORE: Refrigerants: Market Trends and Supply Chain Assessment (www.nrel.gov/docs/fy20osti/70207.pdf)

CEMAC Clean Energy Manufacturing Analysis Center

Cooling Potential of Magnets

Magnetocaloric refrigeration is an innovative technology that uses a water-based fluid and magnets instead of a traditional compressor and harmful refrigerants, offering an environmentally friendly, cost-effective alternative with the potential for 20%–30% energy savings.

To provide insight into magnetocaloric refrigeration's potential to reach commercial scale, JISEA studied the material supply chain, which showed the magnetocaloric materials themselves, while important, have several viable options. Lanthanum was the most viable magnetocaloric material for domestic commercialization.

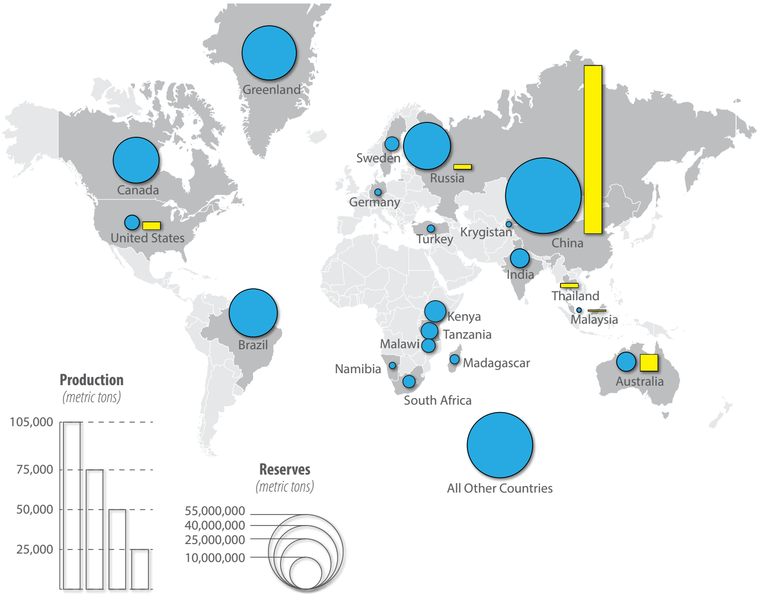


Magnetic refrigeration is a cooling technology that changes temperature by exposing a material to a magnetic field, also known as the magnetocaloric effect.

Lanthanum is used in batteries for electric vehicles, performs well in magnetocaloric refrigeration systems, and is relatively abundant and inexpensive compared to other magnetocaloric materials.

However, the global market for rare earth permanent magnets poses the biggest barrier to commercial production. China produces 80%–90% of the global supply, and competing uses, including wind turbines, steel production, and MRI machines, contribute to an expected supply shortage—estimates in the study suggest supply shortages are likely before 2030.

LEARN MORE: Critical Material Supply Chain Analysis: Magnetocalorics (www.nrel.gov/docs/fy20osti/75163.pdf)



Thanks to large natural reserves of rare earth elements and an established supply chain, China produces 80%-90% of the world's rare earth magnets. Australia is the second largest producer, and many countries have substantial reserves. *Illustration by Billy Roberts, NREL*

LEDS: A GLOBAL ENTERPRISE, A DOMESTIC MANUFACTURING WIN

The popular light-emitting diodes (LEDs) are projected to save 261 terawatt-hours of energy by 2030. Because of the growing prominence of LEDs, JISEA/NREL researchers performed techno-economic analysis of LED luminaires.

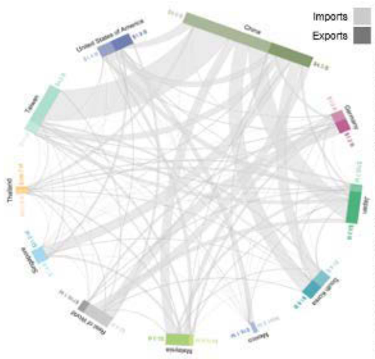
The study showed the majority of LEDs consumed in the United States are incorporated into lighting products. U.S. commercial lighting accounts for 50% of the overall lighting energy consumption and thus represents a huge potential for energy savings.

While the United States is not a dominant producer of LED die and packaging, it produces 77% of integrated luminaires for domestic consumption. In a case study on a U.S. value chain for a 2′x 2′ integrated luminaire, 65% of the value was added at the luminaire stage, which is manufactured domestically.

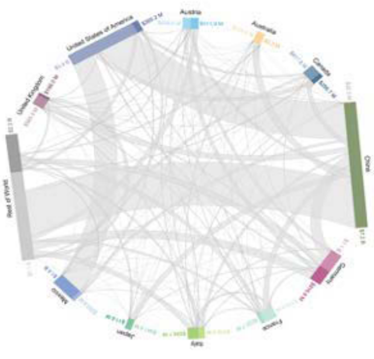
Additionally, although labor is cheaper in China, Mexico, and India, the study showed shipping costs negate significant savings and add considerable time to market—shining light on a win-win opportunity for U.S. energy consumption and economics.

LEARN MORE: Research Note: LED Lighting – A Global Enterprise (www.doi.org/10.1177%2F1477153520901757)

CEMAC
Clean Energy Manufacturing Analysis Center



Country	Imports	Exports
LED die/package trade flow		
United States	$1.4B	$1.9B
China	$8.8B	$4.3B
Germany	$1.0B	$1.2B
Japan	$766M	$3.3B
Malaysia	$434M	$2.3B
Mexico	$492M	$18M
Rest of World	$2.8B	$716M
Singapore	$1.4B	$31M
South Korea	$1.4B	$1.6B
Taiwan	$1.0B	$4.3B
Thailand	$482M	$296M
Luminaires trade flow		
United States	$3.9B	$365M
Australia	$453M	$9M
Austria	$405M	$412M
Canada	$611M	$256N
China	$33M	$7.2B
France	$704M	$221M
Germany	$1.1B	$917M
Italy	$318M	$584M
Japan	$342M	$11M
Mexico	$203M	$1.4B
Rest of World	$5.1B	$2.1B
United Kingdom	$586M	$169M



Trade flow wheels of CEMAC's analysis of the global LED supply chain show China is the largest exporter of LED die/package (left) and all luminaires (both LED and traditional).

"I love being able to connect advancements in basic science to industry through cost and supply chain analysis. . . . In this study I was surprised to learn that shipping cost and time had such a large impact."
—Samantha Reese, JISEA supply chain analyst

Samantha Reese, JISEA clean energy manufacturing analyst
Photo by Dennis Schroeder, NREL

GLOBAL CLEAN ENERGY MANUFACTURING DATA AND INSIGHTS

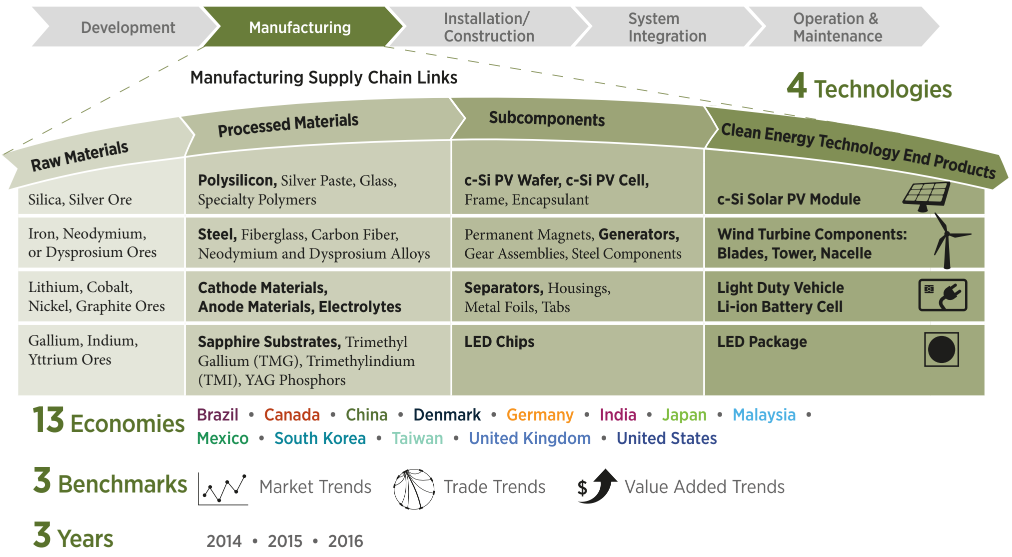
Many organizations have analyzed market aspects of clean energy manufacturing, but trade and value added are unique to CEMAC's *Benchmarks of Global Clean Energy Manufacturing* report.

Completed in 2020 and released in 2021, the updated report 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 3 years from 2014 to 2016.

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

The total value added from production of the four benchmark technologies across the 13 economies increased from $89.6 billion in 2014 to $102.4 billion in 2015 and then dropped to $87.3 billion in 2016, in part due to declining unit costs of clean energy technologies. China accrued the largest total value added from manufacturing the four clean energy end products analyzed, amassing three to four times more than the United States, Japan, and Germany accrued individually.

Value chain for clean energy technologies

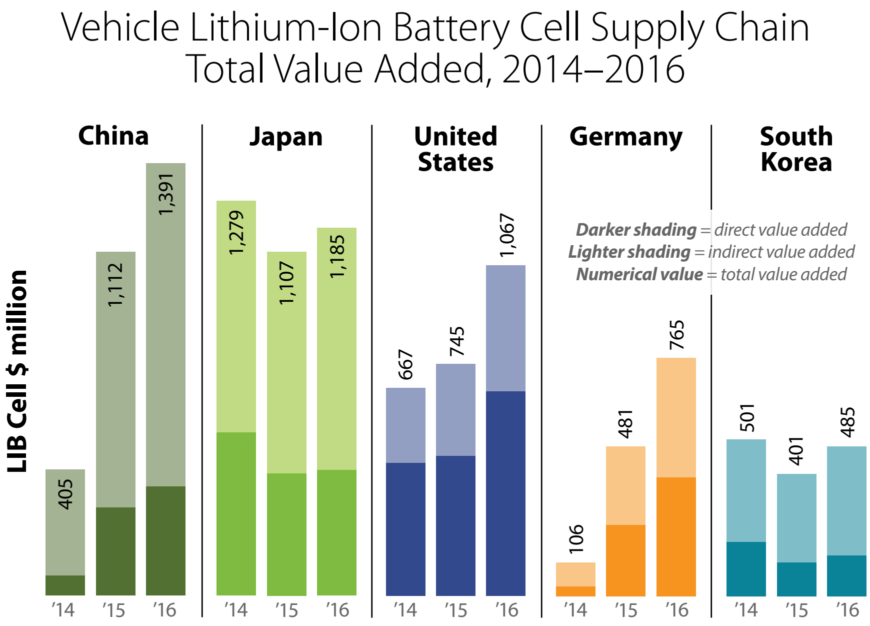


CEMAC analysis presented in the benchmarks report focuses on the manufacturing aspects of the larger clean energy value chain and examines each technology in terms of four manufacturing supply chain links: raw material, processed material, subcomponents, and end products.

All the analyzed economies accrued indirect value added from the global production of intermediate material, subcomponents, and services related to end product manufacturing of the four technologies in other economies. China was the largest supplier of these intermediates to all the other countries, contributing the most indirect value added to the other benchmarked economies.

Still, the greatest share of total value added to the benchmarked economies over the period generally came from domestic production of the technologies, including processing materials, manufacturing components, and providing services throughout the supply chain (indirect value added) rather than assembling the clean energy technology end products themselves (direct value added).

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



Source: *Benchmarks of Global Clean Energy Manufacturing, 2014–2016*, JISEA technical report (2021)

Analysts assessed total value added, indirect value added, and direct value added to benchmarked economies across the lithium-ion battery cell supply chain by individual technology component. The total value added from lithium-ion battery cells increased the most in Germany, China, and the United States from 2014 to 2016, as production ramped up to meet growing electric vehicle demand in those economies.

CLEAN POWER FOR INDUSTRY

DECARBONIZING INDUSTRIAL AND COMMERCIAL PROCESSES

A decarbonized industrial sector can improve efficiency of processes, reduce system operating costs, and lower atmospheric emissions.

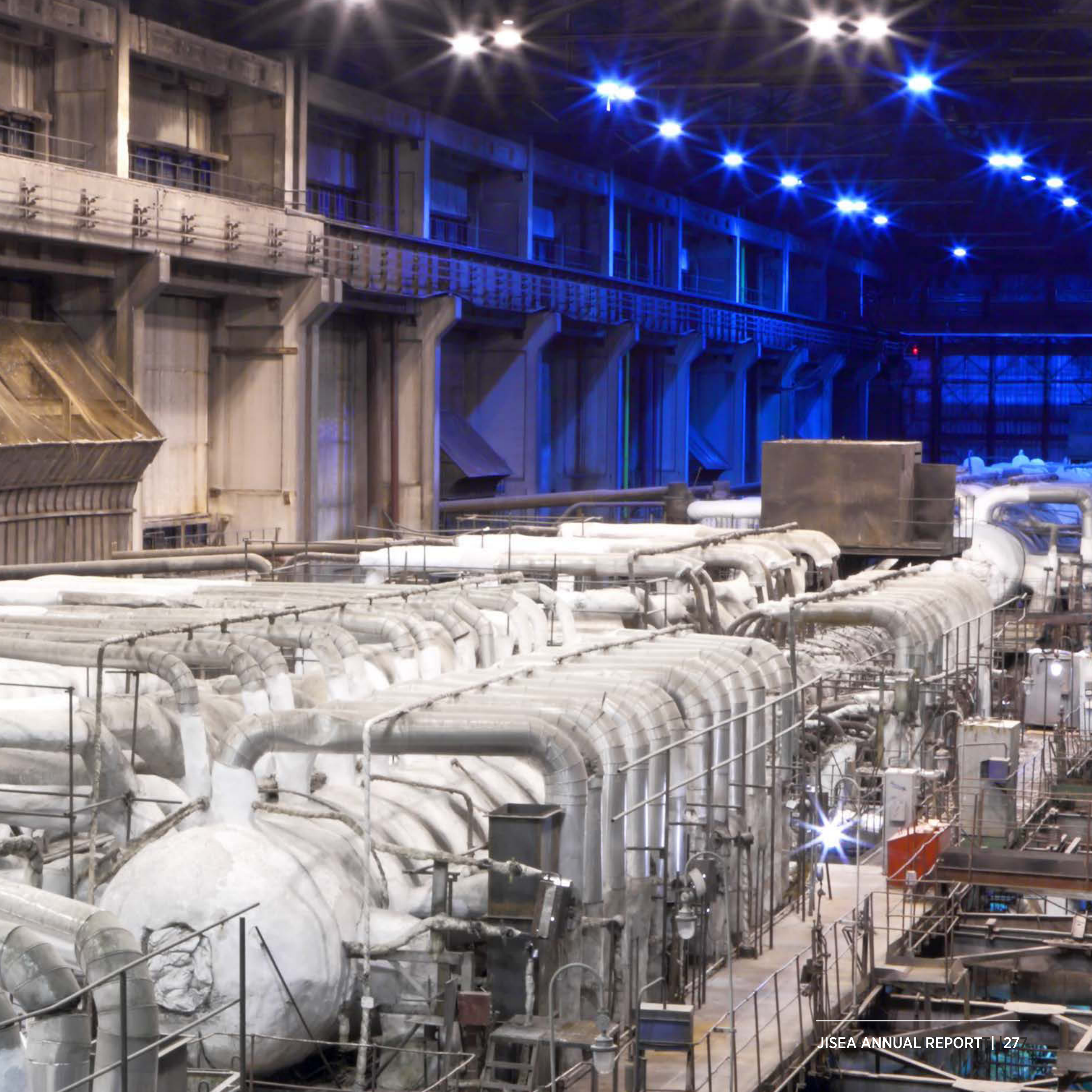
Industry accounts for one-third of U.S. energy use, according to the U.S. Environmental Protection Agency. The most energy-intensive processes transform raw materials into products like aluminum, chemicals, glass, metals, mining, and petroleum refining.

Industry is increasingly seeking ways to shift away from fossil fuels to reduce system costs and emissions, meet energy resilience goals, and take advantage of low-cost clean energy technologies. However, operational costs and risks can be barriers.

JISEA is breaking down barriers though ongoing engagement with industry to understand the diverse technical and economic considerations for integrating renewables into operations and identifying cross-cutting opportunities where solutions can help multiple partners.

Using state-of-the-art energy modeling, JISEA analyzes system performance, costs, and emissions for clean energy technologies when integrated into specific industrial applications across a variety of possible future scenarios.

Insights are helping businesses identify, evaluate, and implement clean energy solutions, providing new opportunities for industrial and commercial facilities to improve efficiency of their processes, decarbonize operations, and engage in the clean energy transition—ultimately benefiting the larger global energy economy.



CLEAN ENERGY IN NATURAL GAS WELL OPERATIONS

Could distributed solar PV, wind energy, and/or battery energy storage support natural gas well operations?

JISEA analysts performed techno-economic analysis on the potential of these technologies to provide cost savings, support resilience goals, and/or reduce emissions at hypothetical upstream well sites in the Marcellus Shale in Pennsylvania.

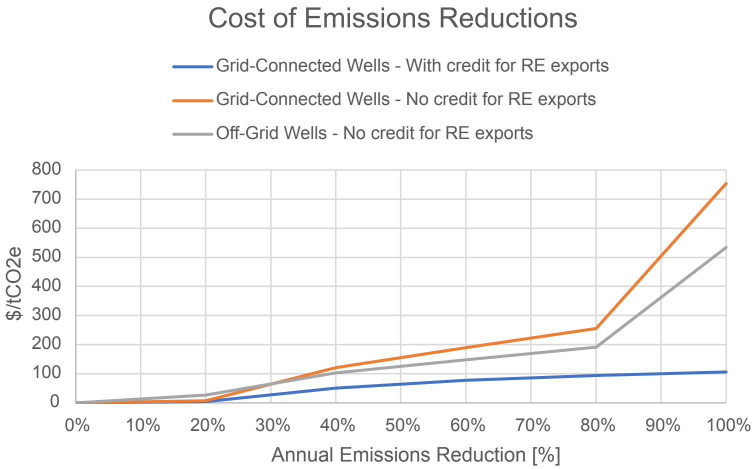
This study was inspired by workshops in 2019 with JISEA's oil and gas consortium—a group of businesses and organizations interested in integrating clean power into oil and gas operations. Dialogue focused on technologies, analyses, and policies related to the potential roles of renewables.

In this study, analysts used REopt, a renewable energy integration and optimization model, to simulate grid-connected and off-grid scenarios at the Marcellus Shale. Results indicated that solar PV could provide operational cost savings for both grid-connected and off-grid well sites while reducing site emissions by approximately 15%. Combinations of solar PV, distributed wind, and battery energy storage can support higher emissions reductions targets at costs competitive with those seen in existing, albeit limited, U.S. carbon markets, such as California's Low Carbon Fuel Standard.

This analysis was presented at the Institute of Electrical and Electronics Engineers' virtual International Systems Conference in August 2020.

LEARN MORE: Opportunities for Clean Energy in Natural Gas Well Operations (edas.info/manuscript/1135618352/final/1570645493.pdf)

Model simulations of the Marcellus Shale in Pennsylvania show solar PV could provide operational cost savings and reduce emissions by about 15%. *Photo from iStock 174940312*



Analysts assessed the cost of reducing carbon emissions associated with the electricity used to power wells across different scenarios.

CLEAN ENERGY IN INDUSTRIAL PROCESS HEAT APPLICATIONS

Most industrial process heat (IPH) demand is met with fuels such as natural gas, propane, or fuel-oil, which could be replaced or offset with renewable thermal energy systems and hybrid system configurations with thermal energy storage.

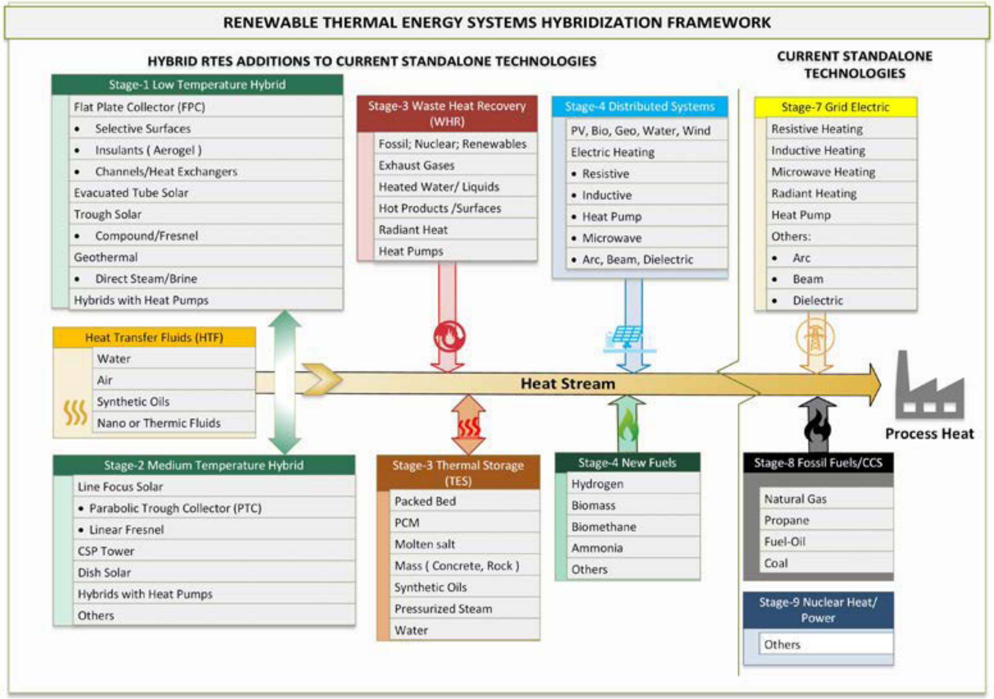
JISEA created a novel energy analysis framework for determining the right hybrid renewable technologies for certain IPH applications at specific sites to help industry understand the options.

Built from existing energy generation models, the framework simulates commercially available renewable heat technology configurations at different temperatures. JISEA analysts modeled three hybrid system configurations. Across all scenarios, the most suitable and cost-effective hybrid system was selected based on optimized field size and dispatch model, including levelized cost of heat calculations.

With continued research, this framework could become a complete renewable heat generation and cost analysis tool, providing a valuable tool for industry to decarbonize operations.

LEARN MORE: Renewable Thermal Hybridization Framework for Industrial Process Heat Applications (www.nrel.gov/docs/fy21osti/79675.pdf)

Renewable thermal energy systems could offset or replace fuel use to meet industrial process heat demand. *Photo from iStock 1127556526*



The renewable thermal energy hybridization framework shows possible combinations of energy sources in different stages to raise the temperature of the heat stream and meet industrial process heat demands.

CLEAN ENERGY IN MINING

Mining is one of the most energy-intensive industries in the world and relies heavily on fossil fuels. Energy makes up 15%–40% of mine operating expenses and generates significant quantities of emissions.

Mining is also a major source of raw materials for several high-demand products, including consumer electronics, electric vehicle batteries, and renewable energy technologies. With demand for these raw materials expected to increase over the coming decade, 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.

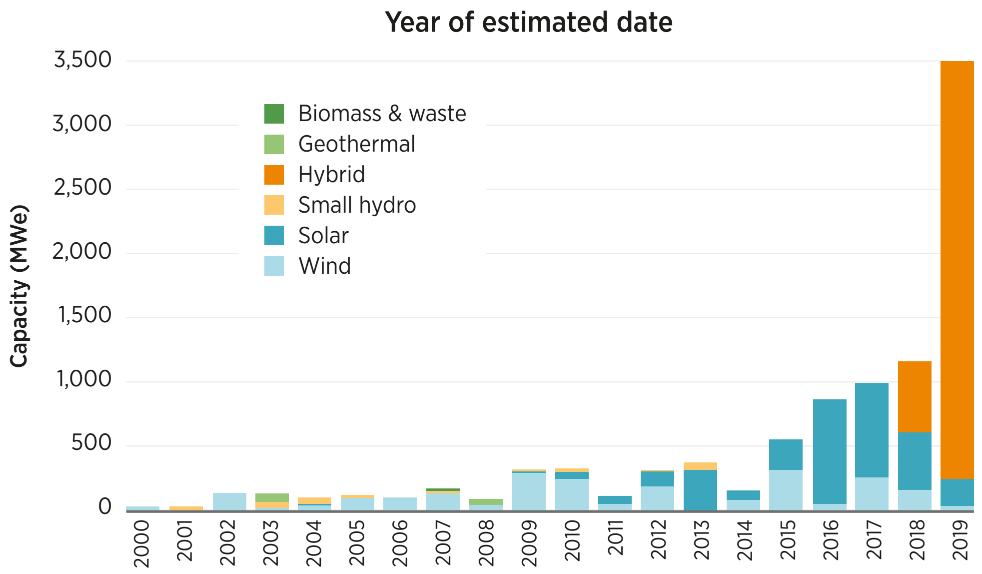
In 2019, JISEA hosted a workshop with the mining industry to understand questions or concerns related to adopting renewable energy in mining operations. This informed a research study completed in 2020 in partnership with Colorado School of Mines and Missouri University of Science and Technology detailing opportunities and challenges for integrating clean energy technologies into mining operations.

Findings indicated that renewable technologies can be integrated across the value chain—from extraction to processing to refining and beneficiation—but solutions are different for each stage and at varying levels of technology readiness.

Generally, greater adoption of renewables can 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, there are several integration challenges that need to be resolved. Optimizing storage with variable generation profiles, providing renewable heat for high-temperature refining processes, and switching out emissions-intensive feedstocks with more inert substitutes are all areas that require further research, development, demonstration, and deployment.

LEARN MORE: Integrating Clean Energy into Mining Operations: Opportunities, Challenges, and Enabling Approaches (www.nrel.gov/docs/fy20osti/76156.pdf)



A chart of the renewable projects associated with mining companies worldwide shows most of the systems in 2018 and 2019 were hybrids—included a combination of wind, solar, energy storage, or other technologies—and generally backed by fossil fuels to smooth the variability of the renewable energy generation.

SUSTAINABLE ENERGY OPPORTUNITIES IN THE FOOD SYSTEM

Addressing energy efficiency in the food system is an essential ingredient for decarbonization. In a 2020 report, the U.S Department of Agriculture estimated that the food system accounted for 11.5% of fossil fuel consumption and 18.1% of total greenhouse gas emissions in the United States.

In collaboration with our partner institutions NREL and Colorado State University, JISEA hosted a three-day virtual workshop in June with food industry experts, academia, and researchers to explore opportunities for energy efficiency in food systems.

The discussion focused on three energy-intensive areas: indoor agriculture, food processing, and food and beverage packaging. Attendees highlighted the need for more information on trade-offs of integrating clean power into operations and an analysis of the impact of size and location when siting facilities.

The workshop was part of a collaborative research project to explore ways to lower energy costs in food systems, reduce emissions, increase food production in areas with little or no access to grid electricity, and increase food resilience and security.

LEARN MORE: Read the full story at http://bit.ly/3imKBag.

Workshop participants pause for a photo during a breakout session.

SUSTAINABLE COMMUNITIES AT THE WATER-ENERGY-FOOD NEXUS

INCREASING RESILIENCE OF WATER, ENERGY, AND FOOD SYSTEMS

A resilient world can sustain adequate and affordable resources needed for communities to prosper, thereby bolstering security and reducing risk.

Given our burgeoning population, increasing urbanization, and warming planet, the global community faces unprecedented challenges securing sufficient water, energy, and food for all communities. These resources rely heavily on each other but are traditionally designed and managed independently.

No single policy or technology can address this challenge. The United Nations urges that we need an “integrated, forward-looking approach to water-energy-food security for 9.7 billion people” by 2050.

JISEA studies the water-energy-food nexus at local, national, and regional scales to understand dynamics between consumption and production and identify potential opportunities for enhanced efficiency to mutually benefit all systems.

Because multiple disciplines converge at the nexus of water, energy, and food, working collaboratively and collectively is more important than ever. Together, scientific understanding, data, and policy can support an integrated approach for sustainable management of water, energy, and food systems that fosters greater stability worldwide.

POLICY PRIORITIES AT THE WATER-ENERGY-FOOD NEXUS

JISEA collaborated with global experts on a policy brief for Think 20 (T20) Saudi Arabia—one of the premier engagement forums for G20 international leaders to discuss today's most important global issues. The brief, which provided recommendations for policy efforts within the water-energy-food nexus, was presented at a virtual conference in October.

In the paper, JISEA analysts suggested standardized assessments of the costs of water provision and benefits for society with desalination technologies, which could guide incentives for investing in new technology.

To ensure adequate nutrition while preserving resources, the analysts encouraged designing agricultural policy around both; existing food and crop pricing mechanisms only focus on caloric needs.

Finally, the authors suggested that the deployment of renewable energy technologies should consider land and water use, as well as agricultural production, to benefit the entire nexus.

Collectively, the authors' recommendations present a high-level approach for countries to develop a water-energy-food framework backed by cohesive data and coherent policy.

LEARN MORE: Integrated Nexus Policies for Sustainable and Resilient Energy, Water, and Food Systems (www.g20-insights.org/policy_briefs/integrated-nexus-policies-for-sustainable-and-resilient-energy-water-and-food-systems/)

Water, energy, and food heavily depend on one another but are traditionally managed independently. An integrated approach backed by data and policy could align the water-energy-food nexus. Photo from iStock 108310732

NEED FOR A HIGH-LEVEL, INTEGRATED APPROACH

Together, data and science can support water-energy-food decisions at all scales, from local energy and infrastructure problems to macroscale grid integration research. But expertise and data are currently siloed.

In a special issue on the water-energy-food nexus in *Frontiers in Environmental Science*, JISEA and academia shared a vision of high-level integration to achieve sustainability across the three sectors.

They reviewed existing approaches to the water-energy-food nexus and found many sophisticated techniques, practices, and models have been developed. However, they often focus on interactions between at most two of the sectors and refer to the nexus as a concept rather than an analytical sustainability approach.

To advance planning for the water-energy-food nexus, the analysts encouraged consolidating resources into a database. They also suggested national high-profile events could be good opportunities to develop a high-level policy road map or implementation plan that integrates existing approaches.

LEARN MORE: Achieving Water-Energy-Food Nexus Sustainability: A Science and Data Need or a Need for Integrated Public Policy? (www.doi.org/10.3389/fenvs.2020.00132)

Water, energy, and food have typically been designed as independent systems, but they are basic and interconnected necessities of life. JISEA analysts recommend a high-level, integrated approach to achieve sustainability across the three sectors. Photo from iStock 1284710627

JACK'S SOLAR GARDEN ENERGIZES BOULDER COMMUNITY

JISEA celebrated the opening of Jack's Solar Garden at a safe, socially distant gathering in fall 2020. Five acres of the Boulder, Colorado, farm will grow crops underneath elevated solar PV panels.

Dubbed "agrivoltaics," co-located agriculture and solar PV infrastructure have shown mutual benefits, including higher crop yields, lower water requirements, and greater efficiency of PV panels.

Jack's Solar Garden is the largest agrivoltaics project of its kind in the nation. It will partner with Sprout City Farms to produce food for a local Community Supported Agriculture program. In addition, Jack's Solar Garden is coordinating with NREL, Colorado State University, University of Arizona, and independent (or industry/private sector) researchers to study the impacts of different panel heights, panel spacing, and crop types grown underneath solar panels to inform agrivoltaics research.

JISEA first investigated agrivoltaics 7 years ago by leading a research project on co-located solar PV with aloe vera in India.

Today, JISEA/NREL analyst Jordan Macknick is leading the charge in this booming research area and coordinating 30 agrivoltaics research sites across the country as part of the U.S. Department of Energy's Innovative Site Preparation and Impact Reductions on the Environment project led by JISEA partners NREL and Colorado State University.

Folks safely mingle and learn about NREL and JISEA's work in agrivoltaics. Photo by Werner Slocum, NREL

JISEA Director Jill Engel-Cox speaks at the opening of Jack's Solar Garden. Photo by Werner Slocum, NREL

JISEA/NREL analyst James McCall envisions the future of agrivoltaics. Photo by Jordan Macknick, NREL/JISEA

TEAM

JISEA's extended interdisciplinary team. First row, left to right: Christina Simeone, Tim Coburn, Jeff Logan, Tisi Igogo. Second row, left to right: Megan Day, Liz Weber, Madeline Schroeder, Garvin Heath. Third row, left to right: Michael Martin, Steven Freilich, Jill Engel-Cox, Mark Ruth. Third row, left to right: Mark Jacobson, Anna Garcia, Darlene Steward. Not pictured: Jordan Cox, Jennifer Daw, Travis Lowder, Jordan Macknick, Kevin McCabe, James McCall, Ben McKenney, Gail Mosey, Emily Newes, Debbie Sandor.

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www.nrel.gov/docs/fy21osti/79675.pdf

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Integrated Nexus Policies for Sustainable and Resilient Energy, Water, and Food Systems

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edas.info/manuscript/1135618352/final/1570645493.pdf

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Valuing Intra-Day Coordination of Electric Power and Natural Gas System Operations

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CEMAC

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

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