INTEGRATE

DRIVING TRANSFORMATIONAL CHANGE

JISEA 2018 Annual Report

JISEA
Joint Institute for
Strategic Energy Analysis

INTEGRATING TECHNOLOGY AND ECONOMICS WITH COMPUTING TO ADVANCE THE ENERGY FUTURE

The work of the Joint Institute for Strategic Energy Analysis (JISEA) has always been about integration—the integration of energy, finance, and society. This nexus uniquely positions JISEA to provide objective, credible research and analysis that enable informed decisions. Integration, therefore, represents a fitting theme for our 2018 Annual Report.

During the past year, JISEA has advanced strategic dialogues at the forefront of our dynamic global energy economy. For example, we published a report exploring the market potential for battery-generator hybrids that combine energy generation and storage capabilities. We evaluated Mexico's smart grid deployment strategy for its planned 2030 power system. We hosted a lively discussion—and maybe a bit of a debate—to find common ground among renewable energy and oil & gas leaders during a time of unprecedented growth for both industries.

Looking forward, the theme of integration also resonates with exciting developments for JISEA in 2018. The National Renewable Energy Laboratory (NREL) created a new directorate combining its advanced scientific computing capabilities with its globally recognized analysis centers, including JISEA. This merger will expand JISEA's ability to model deeply complex and integrated energy systems, policies, and economies.

I joined NREL in late 2017 to lead the new integrated Scientific Computing and Energy Analysis Directorate, a role which unites my background in computational science, applied mathematics, and sustainable systems analysis. I believe that JISEA, in its new organizational home, is well-positioned to provide cutting-edge information as the global energy economy experiences transformational change. We look forward to working with JISEA's university partners and global affiliates to advance our shared goals at this exciting time.

Rob Leland

Associate Lab Director,
Scientific Computing and
Energy Analysis

A YEAR OF TRANSITION

2018 marks a transition year for JISEA. It has been my honor and pleasure to be the founding Executive Director and to work with an outstanding team of core staff, collaborating researchers, affiliates, supporters, and stakeholders over the past eight years.

JISEA was founded to bring extraordinary new knowledge to the dynamic world of energy and the role it plays in our economies. I'm extremely proud that we have built an organization that is recognized nationally and internationally as a thought leader and respected source of credible, objective analysis, information, and insights. We began and remain focused on our efforts to think and explore outside the normal boxes, as exemplified in our work on synergies among systems such as natural gas and renewables, and nuclear and renewables. Working with colleagues across the national lab complex, universities, and collaborating stakeholders, we have opened up new avenues for rethinking energy systems and the services and products they provide to societies.

Looking back across the accomplishments of JISEA since 2010, we reflect on more than 109 publications produced by numerous collaborators from across a broad network of collaborating institutions and affiliates—and an exceptional annual gathering of energy thought leaders that uniquely convenes a highly diverse set of experts.

We are also extremely pleased to have been able to support the Clean Energy Ministerial's 21st Century Power Partnership Initiative, in which we have built a strong international network of expertise, advanced knowledge through in-depth analysis, and comparative assessment across jurisdictions and country contexts—all while focusing on holistic, system-wide solutions. The advances in power sector transformation continue to build new knowledge, challenging us to continually ensure that our collaborative efforts remain on the leading edge, and to effectively communicate state-of-the-art to utilities, regulators, operators, ministries, and other key stakeholders.

Two years ago, we announced the addition of the Clean Energy Manufacturing Analysis Center as part of JISEA's portfolio and are extremely pleased that it, too, has firmly established a record of delivering unprecedented analysis and insights to the increasingly complex global supply chain for clean and advanced energy technologies.

I would also like to recognize and thank Bobi Garrett, Dan Arvizu, Robin Newmark, and Martin Keller for their vision, support, and leadership in establishing and enabling JISEA to thrive. Pat Statwick, our program administrator, also deserves special mention—her energy, expertise, and enthusiasm for excellence have been critical to JISEA's success.

I am thrilled to welcome the new Director of JISEA, Jill Engel-Cox, and look forward to supporting her and our worldwide network of experts and stakeholders to advance JISEA's efforts into this new phase. I will continue to support JISEA as the Deputy Laboratory Director for Scientific Computing and Energy Analysis, a new cross-cutting set of technical capabilities that will bolster the strategic positioning and growth of the entire laboratory.

Please join me in welcoming Jill, and join us in our collective commitment to continue advancing our collective thought leadership, strategic insights, and decision making on this dynamic and exciting path of energy transformation.

Douglas J. Arent

Founding JISEA
Executive Director

INTEGRATED SYSTEM ANALYSIS BRINGS PROSPERITY, RESILIENCE, AND SUSTAINABILITY INTO FOCUS

JISEA takes a broad, systems-level view of the world when analyzing pathways to a sustainable energy future. This approach allows our founding institutions and research affiliates to identify actionable strategies for achieving economic prosperity, human resilience, and environmental sustainability.

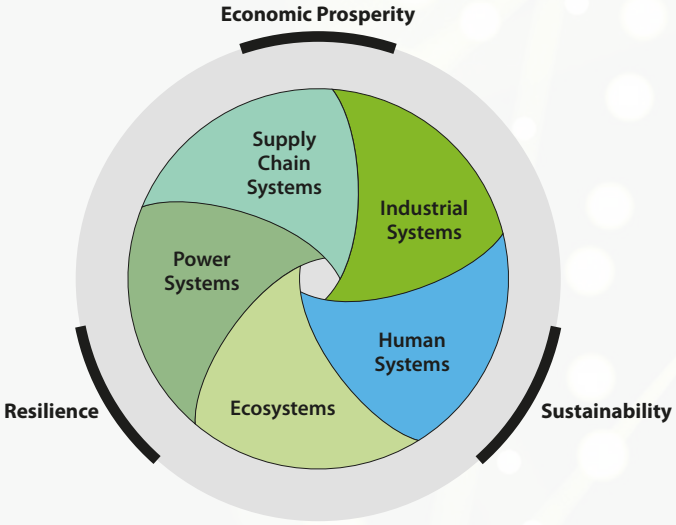
The future that we envision comes into greater focus when viewed across multiple, interconnected systems. Over the past year, JISEA has provided objective, data-based analyses across the following five systems:

Power systems
JISEA helped India, South Africa, Mexico, and China model and optimize the planned growth of their national power systems as part of the 21st Century Power Partnership for the Clean Energy Ministerial.

Supply chain systems
JISEA's Clean Energy Manufacturing Analysis Center (CEMAC) developed a framework for modeling the system dynamics of polysilicon as part of the global solar photovoltaic (PV) supply chain. CEMAC also quantified the supply chain costs for emerging energy technologies, including power electronics, carbon fiber, and geothermal power plant turbines.

Industrial systems
JISEA, CEMAC, and partners brought together leaders from the renewable, oil & gas, and nuclear sectors to identify ways their industrial systems could work synergistically. Workshop discussions spanned the integration of solar power into oil & gas operations, potential oil & gas sector investments into renewable technologies such as offshore wind, and opportunities to produce hydrogen as a clean fuel.

Human systems
JISEA leadership and collaborators published a new book, *The Political Economy of Clean Energy Transitions*, in a post-COP21 world. This free, downloadable e-book allows for the widespread dissemination of insights gained during an unprecedented era of mitigation policy experimentation.



JISEA's integrated systems analysis model

Ecosystems
JISEA combined satellite imagery with data analysis to quantify the lifetime land use impacts for generating electricity from natural gas. *Nature Energy* published the "cradle to grave" assessment, which enables accurate comparisons of land use requirements for renewable technologies with nonrenewable generation sources for the first time.

This annual report provides a deeper look at how JISEA advanced our understanding of these interconnected energy systems in 2017. Our findings make it increasingly clear how a prosperous, resilient, and sustainable energy future is on the horizon.

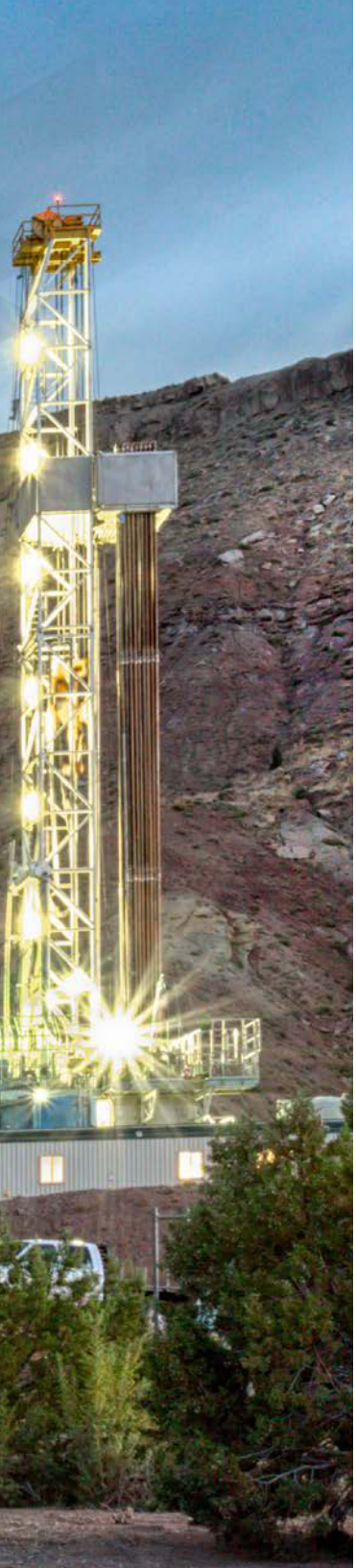
CONTENTS

INTEGRATED SYSTEMS SOLUTIONS

EVOLVING TOWARD INTERCONNECTEDNESS

The generation and use of energy in the buildings, industrial, and transportation sectors is continuously evolving. And JISEA with it. Over the past year, we have seen the buildings sector becoming more efficient with strategies that combine sensors, smart management systems, distributed energy generation, and storage. The transportation sector is becoming more technologically diverse with the rapid expansion of hybrid and electric vehicles (EVs) and the move to autonomous mobility options. The industrial sector is reducing emissions through efficiency improvements, smarter land use, and operational upgrades.

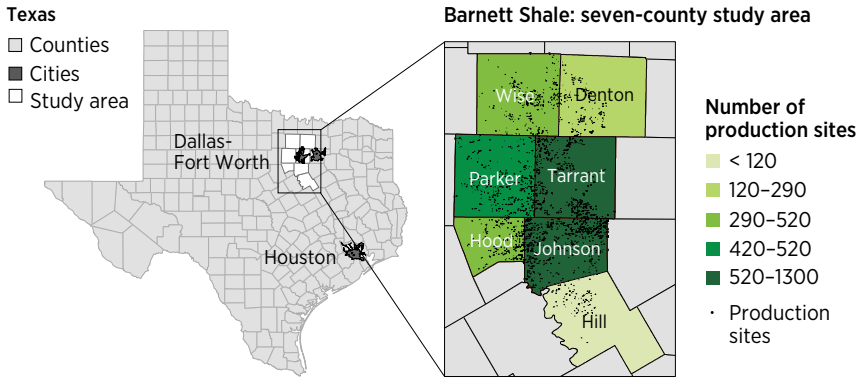
These changes are driven not just by environmental and energy security concerns, but also economics. The electricity-sector market share of natural gas and variable-generation renewables, such as wind and solar PV, continues to grow. Storage and hybrid storage-generator solutions are gaining traction due to enhanced services and affordability. These drivers of energy resilience and security motivate investment and utilization strategies for innovative energy generation and delivery assets.



ADVANCING OUR UNDERSTANDING OF NATURAL GAS

The rapid growth in unconventional natural gas production from shale has focused energy thought leaders on the safety, reliability, and sustainability of U.S. industry practices. Among them, JISEA analysts examined organizational practices among onshore oil and gas firms that engage in natural gas exploration, production, transmission, and storage. With the exception of several firms that set an example by implementing recommended policies and practices, the oil and gas industry has a valuable opportunity to embrace high-reliability organizational approaches to further advance safety and security, improve environmental practices, and continue to evolve the complex dynamics of the social license to operate.

This year, a separate JISEA study examined improved methods for estimating life cycle surface land-use intensity for nonrenewable electricity generation sources, such as natural gas, coal, and nuclear. Analysts were able to estimate the surface land-use intensity across the life cycle of electricity generated from natural gas using infrastructure inventories, satellite imagery, and well-level production data taken from approximately 500 sites in the Barnett Shale of Texas. When replicated for other gas-producing regions and different fuels, our approach offers a route to enable empirically grounded comparisons of the land footprint of energy choices.



Seven-county study area in the Barnett Shale play of Texas. The inset shows the production sites and their density from 2009 within the study area boundaries.

OIL & GAS AND RENEWABLES WORKING TOGETHER

Workshop participants from oil and gas and renewable energy tour NREL's Visualization Center.

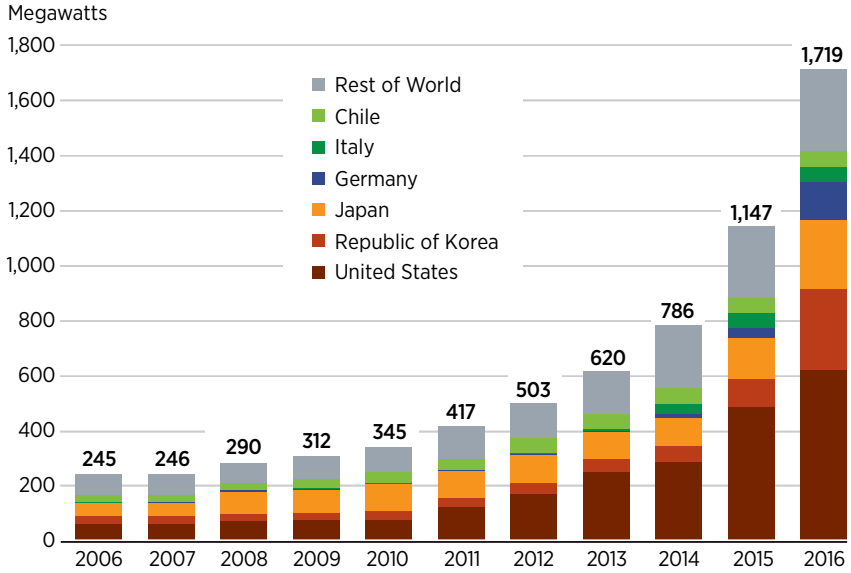
JISEA and the International Energy Agency's (IEA's) Gas and Oil Technologies Program sponsored a workshop to examine how the oil & gas industry can work with the renewable energy industry to continue to advance synergistic advanced energy solutions. The workshop allowed participants from both sides to come together and discuss topics including incorporating renewable generation into oil and gas operations, recovering waste heat and water more efficiently,

and optimizing the delivery of gas and renewable electricity for utilities. Oil and gas representatives expressed interest in incorporating renewables into their operational and financial portfolios, especially for synergistic technologies such as combining offshore oil and gas production with offshore wind power and solar thermal enhanced well field operations. Future conversations will continue to address the challenge presented by methane emissions from natural gas, a fuel that remains an important partner for integrating variable renewables.

THE EXPANDING ROLE OF BATTERY STORAGE HYBRIDS

Trends of increasing renewable energy, demand for resilience, need for flexibility, and improving economics drive a growing demand for combining battery storage capabilities with generators, or hybridizing a battery. JISEA set out to understand which markets are best suited for battery storage and storage hybrids, and how regulations and incentives can support or impede standalone installations. Our analysts found that hybridizing a battery leads to synergies that increase the value of both battery and generator. While cost declines are forecasted to drive a 22-fold increase in battery storage and hybrid system capacity in the United States over the next six years, market structures that do not adequately reward energy storage pose hurdles for the technology.

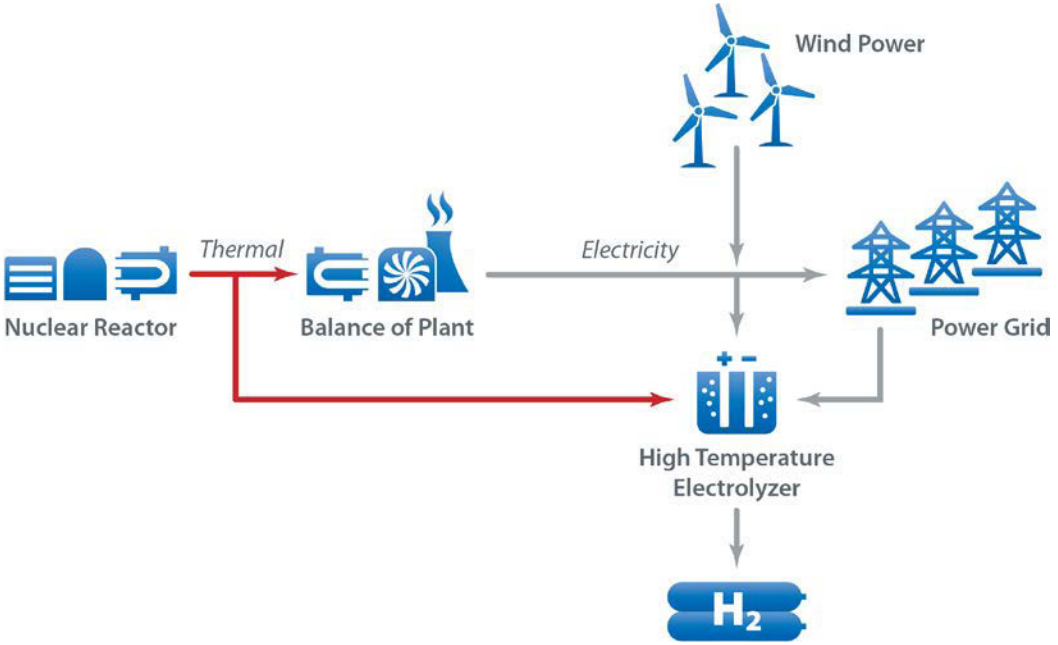
Global Grid-Connected Stationary Battery Storage Capacity by Country, 2006–2016



NUCLEAR-RENEWABLE HYBRID ENERGY SYSTEMS

The U.S. Department of Energy's H2@Scale Big Idea concept explores the potential for widescale hydrogen production and utilization to enable resiliency in the power generation and transmission sectors, while also stimulating diverse multibillion-dollar domestic industries, domestic competitiveness, and job creation. In this innovative climate, JISEA is examining the technical and economic aspects of nuclear-renewable hybrid energy systems (N-R HESs), which are physically coupled facilities combining nuclear and renewable energy sources to produce electricity along with other products such as thermal energy, hydrogen, and desalinated water. Working with colleagues at Idaho National Laboratory, JISEA researcher teams explored the economics of several N-R HES scenarios, determining that the economically optimal system configuration includes a nuclear reactor generating a thermal product such as steam or a heat transfer fluid. This configuration can generate zero-carbon, dispatchable electricity and provide zero-carbon energy for industrial processes at a lower cost than alternatives.

Nuclear-Renewable Hybrid Energy System High Temperature Electrolyzer Scenario



Electricity for the high temperature electrolyzer can be sourced from the nuclear reactor/thermal power cycle, the wind power plant, and/or the grid. Heat can only be sourced from the nuclear reactor.

Red arrows indicate flow of thermal energy and gray arrows indicate electricity.

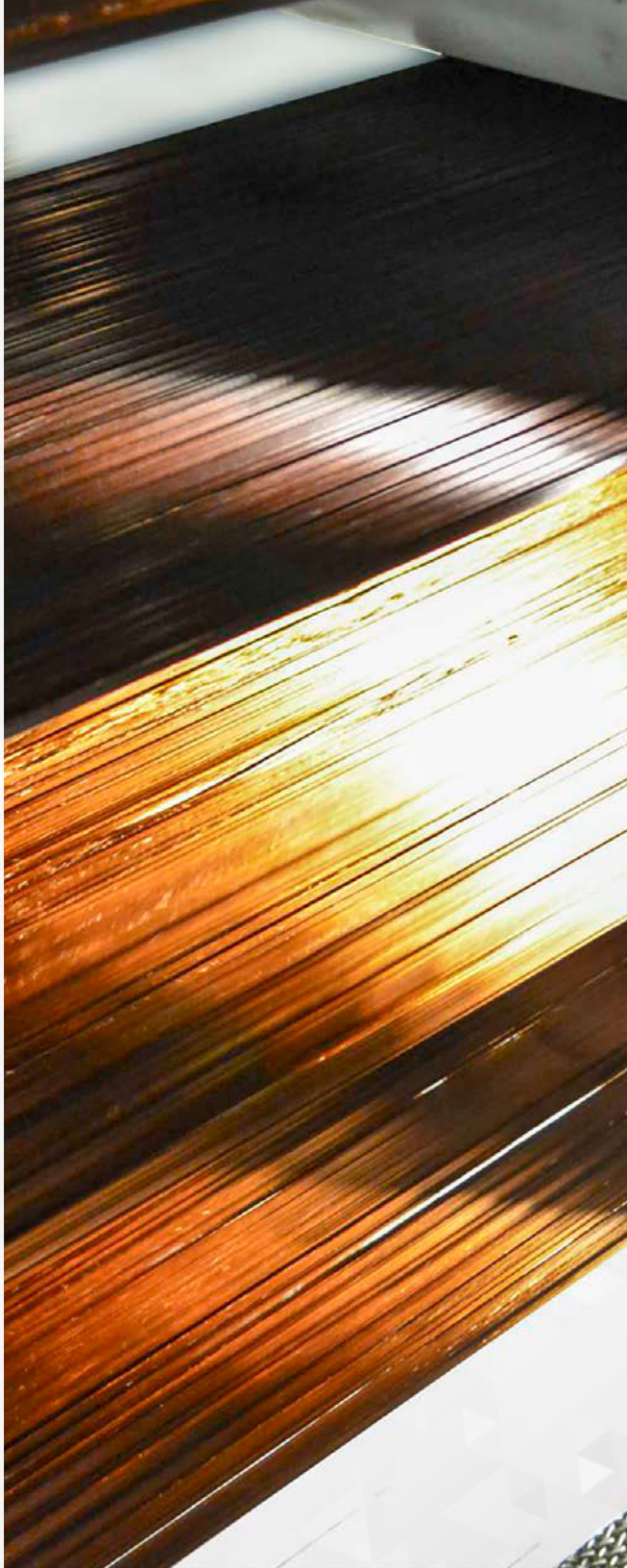
INTEGRATED SUPPLY CHAINS

TRANSITIONING TO A CLEAN ENERGY ECONOMY

Global supply chains exist at the foundation of a strong clean energy economy. As new energy technologies show potential for lower costs, higher efficiencies, and reduced footprints, JISEA's Clean Energy Manufacturing Analysis Center (CEMAC) works to analyze and quantify the supply chains from critical materials to final product. CEMAC's insights are key to informing research programs, international trade issues, and investment decisions.

With support from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (DOE EERE), CEMAC provides decision makers and industry leaders with detailed, bottom-up cost analyses of emerging global supply chains. This year, CEMAC analysts reported on manufacturing of power electronics, carbon fiber, lithium-ion batteries, geothermal power plant turbines, and the system dynamics of polysilicon for solar PV. Our findings on market conditions, potential applications, and energy savings demonstrate targeted areas where DOE EERE investments would have the most impact on competitiveness.

CEMAC Clean Energy Manufacturing Analysis Center

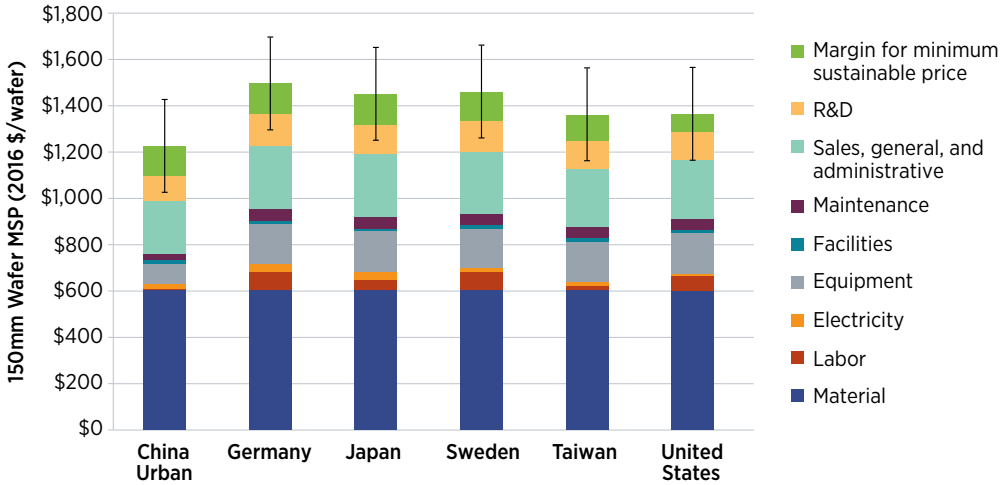


CARBON FIBER MANUFACTURING

Although global demand for carbon fiber is projected to grow more than 10% per year between 2015 and 2024, it is not clear where new manufacturing facilities will locate to meet this demand. CEMAC analysts provided valuable insights into global carbon fiber supply, demand, markets, and geographic distribution in four major market growth areas: aerospace, automotive, wind energy, and pressure vessels. A regional analysis shows the United States is currently competitive in these markets thanks to factors such as low utility costs. To maintain this position, CEMAC's work in this area aims to continue examining what national efforts support carbon fiber manufacturing, how these efforts and other factors influence manufacturing location decisions, and where opportunities exist to increase carbon fiber manufacturing and deployment.

WIDE BANDGAP SEMICONDUCTORS IN POWER ELECTRONICS

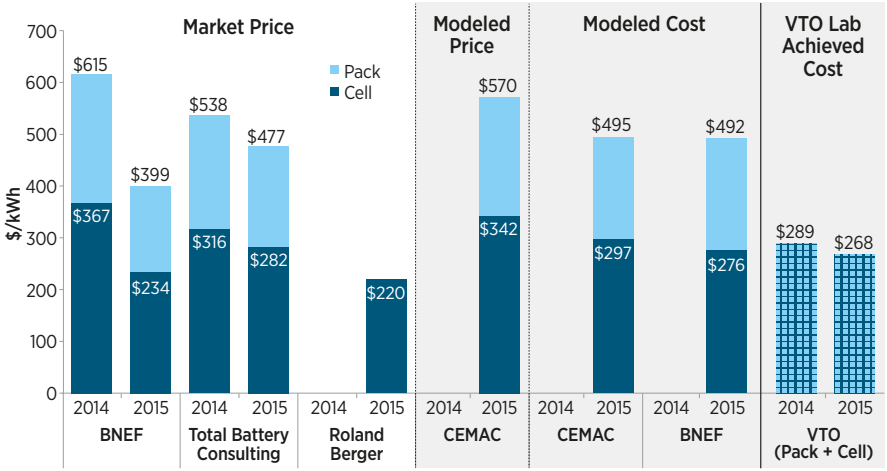
Rising U.S. energy demands are driving interest in new ways to increase the system efficiency of power electronics. Wide bandgap semiconductor devices, notably silicon carbide (SiC) devices, show potential to not only reduce the energy lost during power conversion, but do so with a smaller footprint, lighter weight, and lower system cost compared to traditional silicon devices. CEMAC's 2017 technical report on the subject states that wide bandgap semiconductor integration into motor drives stands to have the largest energy impact, followed by data centers, renewable generation, and hybrid/electric vehicles. While SiC is positioned to be the principal wide bandgap power device material for these markets within the next five years, future CEMAC work will focus on process heating, medical applications, grid/smart grid infrastructure, wireless charging, and MHz radio frequency devices, as well as the significant potential for gallium nitride (GaN) applications.



Breakdown of modeled regional manufacturing costs for 6-inch SiC wafers

COMPARATIVE COSTS OF LITHIUM-ION BATTERIES

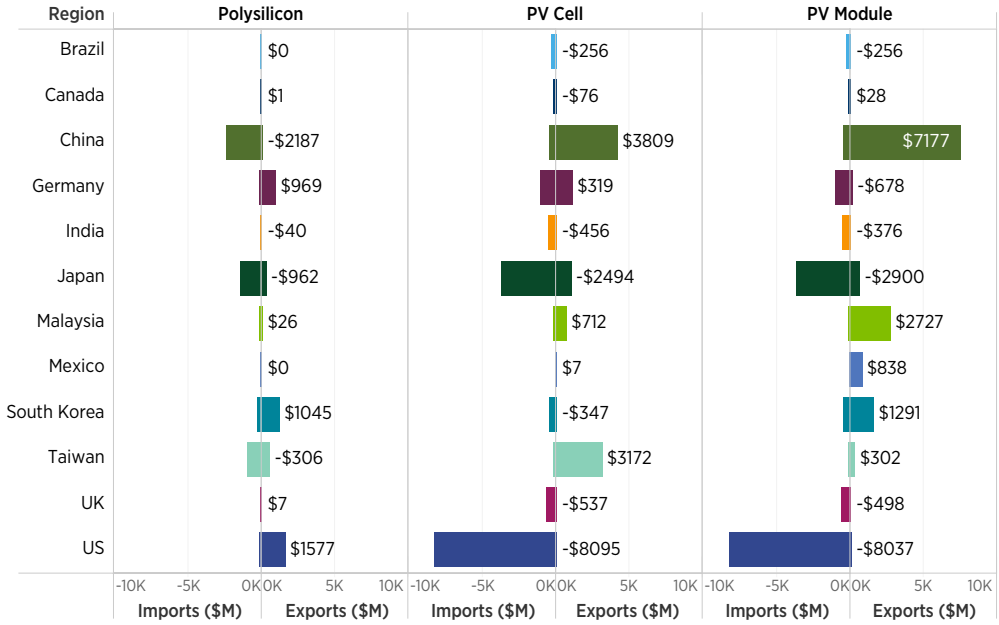
Technical papers, market research, and the media present a range of cost and price metrics when trying to assess the automotive battery market. This is in part because the technology is relatively new, and the shape, size, chemistry, and packaging differ between vehicles. CEMAC has worked to establish metrics for light-duty vehicle cell and cell pack market price, modeled price, modeled cost, and DOE's Vehicle Technologies Office (VTO) lab achieved costs. Our analysis suggests that market factors—not manufacturing cost considerations—currently influence pricing decisions. Comparing both the CEMAC and Bloomberg New Energy Finance (BNEF) cost modeling results to observed prices further indicates that manufacturers have sold at or even below their costs of production in recent years.



Estimated national prices and costs of light-duty plug-in hybrid electric vehicle cells and packs

SYSTEM DYNAMICS OF POLYSILICON FOR SOLAR PHOTOVOLTAICS

The significant price fluctuations of high-purity polysilicon, a key material in solar PV, have impacted the manufacturing capacity and cost of both polysilicon and solar panels. CEMAC's flagship report, "*Benchmarks of Global Clean Energy Manufacturing,*" identified balance of trade effects on upstream materials like polysilicon. CEMAC developed and validated an initial system dynamics framework to gain insights into the global trade in polysilicon. Analysts modeled three regions—China, the U.S., and the rest of the world—to understand the impacts of import duties and nonprice drivers on the relative volumes of imports and domestic supply. Future work aims to understand factors that contribute to thriving manufacturing environments.



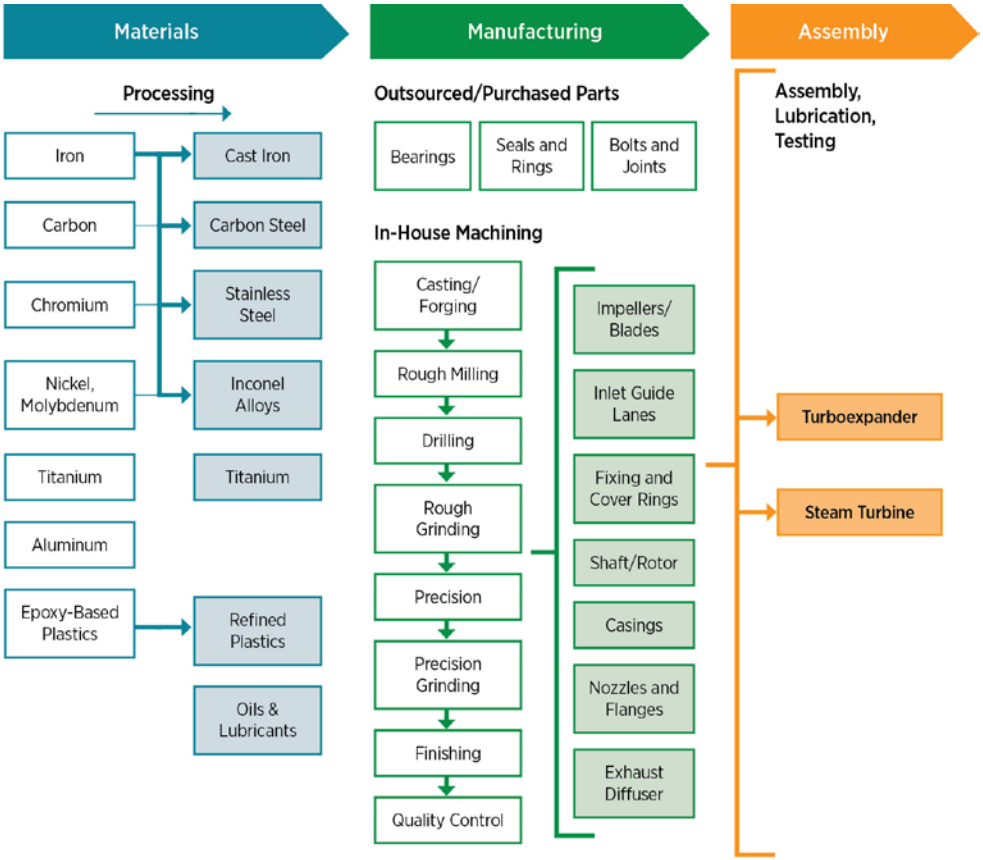
Balance of trade for the silicon PV supply chain, 2016

ENERGY INNOVATION CLUSTERS AND INFLUENCE ON MANUFACTURING

Innovation clusters—such as Silicon Valley—are geographic concentrations of specialized organizations of businesses, research institutions, and other entities related to a single technology. Because such clustering facilitates economic growth, governments have a renewed interest in understanding how to link clean energy innovation clusters and manufacturing. CEMAC analysts developed qualitative case studies on innovation clusters for three different clean energy technologies: solar PV clusters in California and the province of Jiangsu in China, wind turbine clusters in Germany and the U.S. Great Lakes region, and ethanol clusters in the U.S. Midwest and the state of São Paulo in Brazil. CEMAC's report identified several factors that may influence the geographic proximity of innovation activities and manufacturing. Future studies aim to utilize patent, trade, and market data to better quantify this relationship.

MANUFACTURING ANALYSIS ON GEOTHERMAL POWER PLANT TURBINES

Geothermal power plants in development worldwide are expected to create an annual average demand of 1 gigawatt (GW) for a diverse mix of geothermal turbine types. This growing market presents new opportunities for removing barriers to development, reducing plant capital costs, and optimizing financial models. CEMAC's geothermal turbine manufacturing analysis found that developer projects using custom turbines are resulting in higher manufacturing setup costs, longer lead-times, and higher capital costs. While standardizing the size of turbines could significantly lower manufacturing costs, the demand for high-volume production of one-size standard turbines remains insufficient.



Manufacturing process flow diagram for geothermal power plants

INTEGRATED POWER SYSTEMS

ADVANCING INTEGRATED POWER SECTOR INNOVATION

In 21st century power systems, electricity from diverse sources will be delivered through smart, efficient networks and balanced by a variety of flexibility options, such as demand response, storage, and smart EV charging. Developing such systems requires new global partnerships focused on technical excellence, targeted innovation, and smart policy and regulations, supported by sustained financial and political investment and ambitious public-private sector collaboration.

The 21st Century Power Partnership (Power Partnership), a multilateral initiative of the Clean Energy Ministerial (CEM), serves as a platform to advance integrated policy, regulatory, financial, and technical solutions in power markets around the globe. Over the past year, the Power Partnership has worked with dozens of technical partners, including the IEA, the International Renewable Energy Agency, GIZ, the Danish Energy Agency, the World Bank, and the World Resources Institute, to deliver world-class expertise and advance power system knowledge to key decision makers around the world. These collaborative partnerships delivered high-value insights for leaders of the 23 CEM countries and the European Union, which account for about 90% of global clean energy investments and 75% of global greenhouse gas emissions.

21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

ACCELERATING POWER SYSTEM TRANSFORMATION EFFORTS WORLDWIDE

The Power Partnership aims to accomplish four primary goals: support national policy and regulatory implementation, share knowledge and best practices, strengthen and disseminate tools, and bolster expert capacity. Along with performing analyses and convening multi-stakeholder knowledge exchanges, the Power Partnership provided in-depth technical assistance to five partner countries during the past year.

Brazil

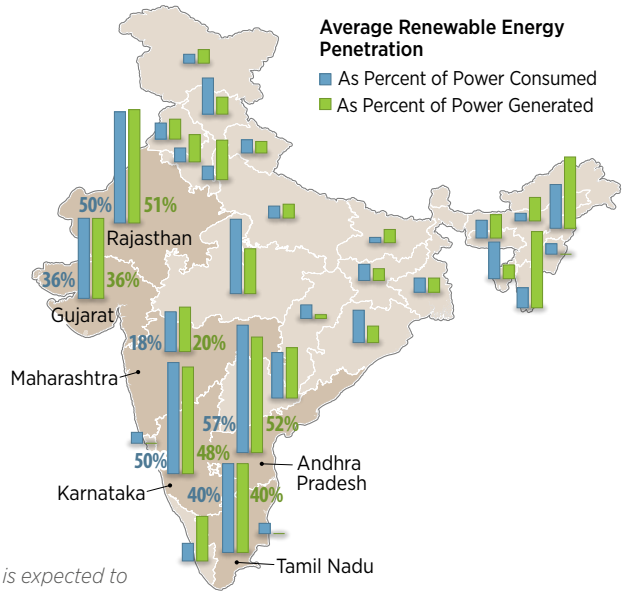
In mid-2017, Brazil became the newest member country of the Power Partnership. Dialogue is currently under way on priorities for collaboration.

China

The Power Partnership is working with China National Renewable Energy Centre, the Energy Research Institute, State Grid Corporation of China, the Danish Energy Agency, GIZ, and other institutions and international experts to build capacity for advanced grid modeling, planning, and operations in China. One year after joining the Power Partnership, the country hosted the 8th Clean Energy Ministerial meeting in Beijing in June 2017. In December, the Power Partnership hosted a webinar on power transformation activities in China, India, and the United States. The event was held in conjunction with a study tour by Chinese power system experts to visit North American power system operators and research institutes in December.

India

In India, the Power Partnership, working with USAID's Greening the Grid program, the World Bank, and other collaborators, focused on power system modeling support and training in tools that address critical needs associated with the government's established target of 175 GW of installed renewable energy capacity by 2022. The flagship "Greening the Grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. I—National Study," was released in June 2017. This work delivered unprecedented details and insights for power systems development and operations and was enthusiastically endorsed by the Ministry of Power of India as a flagship effort to advance their knowledge and decision making.



Renewable energy is expected to meet over 50% of electricity demand in three of India's 29 states by 2022.

Mexico

Now in its fourth year of deep engagement with key stakeholders in Mexico and other international experts, the Power Partnership published an additional technical report titled "Designing Distributed Generation in Mexico" in May 2017. This analysis outlines the foundational elements of distributed generation regulation and presents international experiences, objectives, and action items for the government to consider. In July 2017, material from the forthcoming Power Partnership technical report titled "The Status and Outlook of Distributed Generation Public Policy in Mexico" was presented at a public stakeholder meeting hosted by the *Secretaría de Energía de México* (SENER). In September 2017, SENER hosted a workshop on modeling tools in the energy sector at the Mexico International Renewable Energy Conference in Mexico City with the support of the Power Partnership.

South Africa

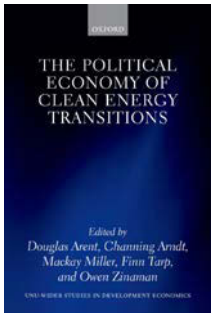
In April 2017, the Power Partnership hosted two Fellows from the Council for Scientific and Industrial Research at NREL. Fellows used the International Jobs and Economic Development tool to investigate the potential economic impacts of implementing the Integrated Resource Plan in South Africa. The Power Partnership's South Africa program also continued its technical partnership with Eskom to complete a comprehensive grid study analyzing the potential for the South African power system to reliably and cost-effectively integrate high penetrations of renewable energy.

ADVANCING GLOBAL THOUGHT LEADERSHIP

JISEA's publications have helped guide, influence, and inform global energy policy and investment decisions for almost 10 years. Recent publications produced by the Power Partnership present leading-edge analysis of market design and regulatory issues for clean energy and 21st century power systems.

The Political Economy of Clean Energy Transitions

Edited by JISEA Executive Director Doug Arent and Power Partnership Deputy Lead Owen Zinaman, this free, downloadable e-book explores the political and economic factors that influence clean energy and climate policy development. The book presents replicable case studies and lessons learned as well as up-to-date and forward-looking analysis with an intent to inform the decisions that shape the diverse pathways transitioning to a clean energy future.



Status of Power System Transformation

Jointly written by Power Partnership and IEA experts, this report provides an overview of current renewable integration and grid development trends across the globe. Power sectors around the world are undergoing significant change due to the rapid uptake of new supply- and demand-side technologies. While power system transformation is highly context specific, common themes are emerging. This report introduces a framework for assessing the status of power system transformation, then applies it to Indonesia, South Africa, Mexico, and Australia.

Low- and medium-voltage grids are transitioning from a paradigm of passively distributed power to customers and toward smarter, actively managed systems with bidirectional flows of power and data.

Policies for Enabling Corporate Sourcing of Renewable Energy Internationally

This Power Partnership technical report explores how the policy- and regulatory-enabling environment around the world plays a key role in shaping where and how corporations invest in renewables. Developed in support of CEM's Corporate Sourcing of Renewables Campaign, the analysis explores renewable energy procurement mechanisms globally and provides information on how to obtain quality and credible renewable energy transactions.

Collectively, corporate buyers have the potential to drive a sizable amount of new renewable energy development through private sector investment in both mature and nascent renewables markets.

Next-Generation Performance-Based Regulation: Emphasizing Utility Performance to Unleash Power Sector Innovation

Released in September 2017, this Power Partnership technical report analyzes how best practices and lessons gleaned from more than two decades of performance-based regulation in practice can be applied to design innovative programs for power system transformation. Today's average residential customer is increasingly able to control personal energy usage and even become a grid resource, something not contemplated in the 20th century era of large, centrally operated generating plants. This report advocates for performance-based regulation as a pathway for the reformation of hundred-year-old regulatory structures that can unleash innovations within 21st century power systems.

In restructured markets of the 21st century, the 20th century rules of separation and codes of conduct require attention and become more important than ever to align incentives properly and to avoid hidden incentives.

TEAM

FOUNDING PARTNERS

JISEA is operated by the Alliance for Sustainable Energy, LLC, on behalf of its founding partners.

NREL NATIONAL RENEWABLE ENERGY LABORATORY

COLORADO SCHOOL OF MINES

Colorado State University

MIT Massachusetts Institute of Technology

Stanford University

University of Colorado Boulder

CONTACT US

JISEA partners with numerous research affiliates and sponsors to analyze pathways to a sustainable energy future. To establish a new partnership with us, contact JISEA at **JISEA.Coordinator@nrel.gov** or visit our website: **www.jisea.org.**

JISEA PROGRAM COMMITTEE

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

William Boyd
Associate Professor of Law, University of Colorado

Robin Newmark
Executive Director for Strategic Initiatives, NREL

John Reilly
Co-Director, MIT Joint Program on the Science and Policy of Global Change; Senior Lecturer, MIT Sloan School of Management

Ron Sega
Vice President and Enterprise Executive for Energy and the Environment, Colorado State University and The Ohio State University

Dag Nummedal
Research Professor, Office of Research, and Department of Geology and Geological Engineering, Colorado School of Mines (retired)

John Weyant
Professor of Management Science and Engineering, Stanford University

JISEA ADVISORY COUNCIL

Joan MacNaughton, Chair, The Climate Group

Bill Ritter, Director, Center for the New Energy Economy, Colorado State University

Katherine Sierra, Non-Resident Senior Fellow, The Brookings Institution

CEMAC ADVISORY COMMITTEE

The Advisory Committee provides programmatic guidance to the Clean Energy Manufacturing Analysis Center. The CEMAC Advisory Committee is composed of experts from industry, trade associations, academia, and government as well as CEMAC management.

Allyson Anderson Book,
The American Geosciences Institute

Tom Catania, Chair, University of Michigan

Paul Camuti, Ingersoll-Rand

David Eaglesham, Pellion Technologies

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Swami Venkataraman,
Moody's Investors Service

Charles W. Wessner, Georgetown University

Joan Wills, Cummins Inc.

RESEARCH AFFILIATES

JISEA augments the capabilities of its founding institutions with those of leading analysis centers across the globe.

Rice University's Baker Institute Center for Energy Studies

BAKERINSTITUTE.ORG/CENTER-FOR-ENERGY-STUDIES

CES provides new insights on the role of economics, policy, and regulation in the performance and evolution of energy markets.

Carnegie Mellon University Department of Engineering and Public Policy

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The Department of Engineering and Public Policy, a unique department within the College of Engineering at Carnegie Mellon University, focuses on addressing technology-based policy problems.

Energy Institute at The University of Texas at Austin

ENERGY.UTEXAS.EDU

The Energy Institute is dedicated to broadening the educational experience of students by creating a community of scholars around energy issues of importance to Texas, the nation, and the world.

Eskom

ESKOM.CO.ZA

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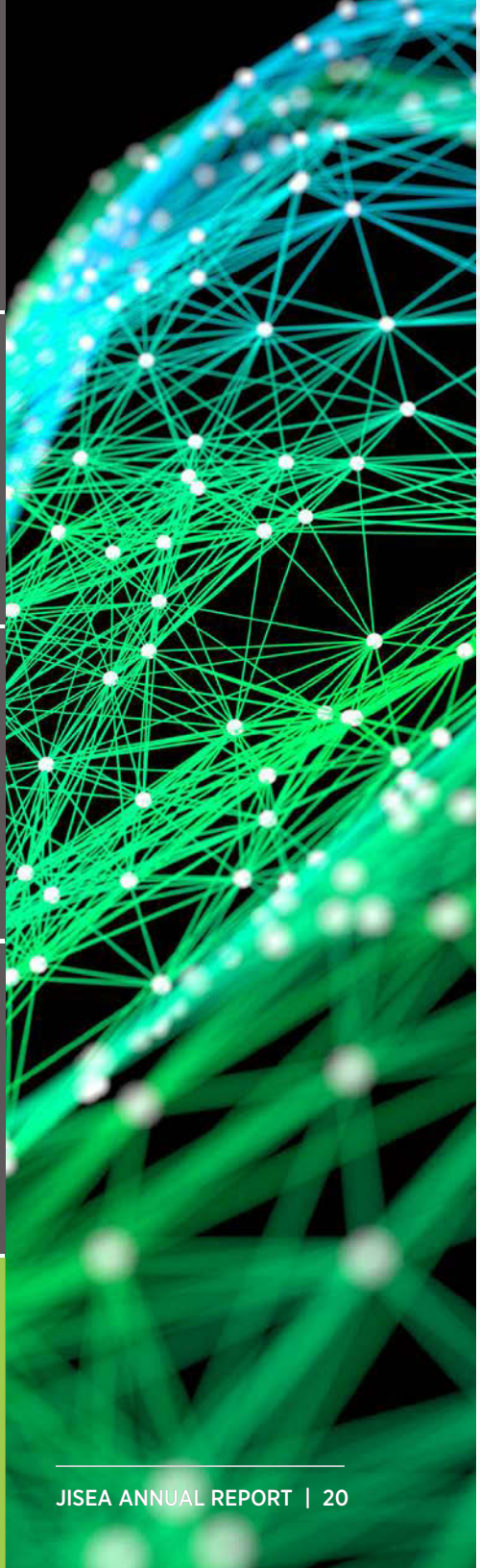

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