Exploring Opportunities for Collaboration among U.S. University Energy Institutes

The Academic Energy Institute Landscape and Prospects for Forming a Network

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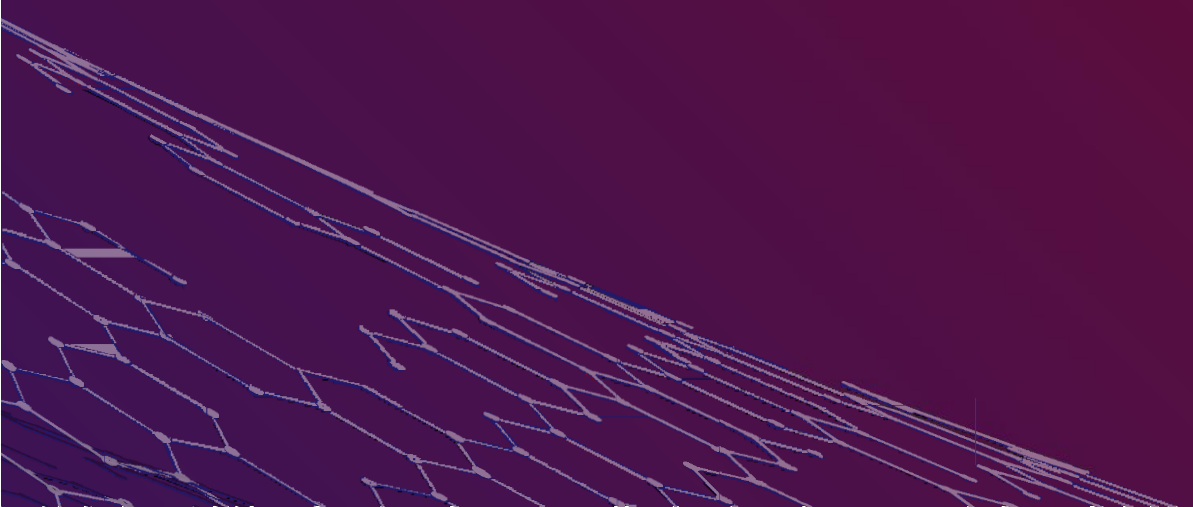

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Please do not distribute or reproduce this report, or any part thereof, without the authors' written permission. The report is intended for attendees of the 2019 University Energy Institute Leadership Summit and participants in our surveys. A peer-reviewed publication is forthcoming. For questions, please contact the Wilton E. Scott Institute for Energy Innovation, Carnegie Mellon University, at scottinstitute@andrew.cmu.edu.

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Executive Summary

This study reviews the status of U.S. academic energy institutes and explores potential opportunities and challenges surrounding the formation of a collaborative network of these institutes. Between 150 and 200 institutes anchored to universities across the U.S. are working to solve the world's energy and environmental challenges. This work is motivated by the realization that most of these institutes do not engage one another through formal and consistent collaboration around what are likely many shared points of interest. Based on the notion that a large and potentially formal organization of institutes could benefit the energy community, this study examines current institute focuses and potential areas of collaboration. Specifically, this work explores the following questions:

- What are the missions, specializations, and strategies of U.S. university energy institutes?
- What is the current and potential future role of energy institutes in higher education?
- What benefits and challenges could energy institutes and their stakeholders encounter in joining an organized network?
- How should a hypothetical, future network be governed and administered? How should it function? How could it be funded sustainably?

To better understand the energy institute landscape, we surveyed institute leaders about their missions, research focuses, collaborations with academic and non-academic stakeholders, and initial impressions of a future, hypothetical network. In another survey, we asked stakeholders about their current interactions with institutes and about their expectations of a proposed network. Drawing in our survey findings, we convened energy institutes leaders in Pittsburgh, PA (September 2019) for a two-day summit comprising roundtable discussions and networking opportunities. Discussions were intended to explore aspects of a proposed network's potential goals, funding sources, educational offerings, and organizational frameworks. After analyzing survey data and observing interactions at the summit, we present the following five key findings:

(1) At least 157 university energy institutes in the U.S. are advancing energy-related research and education. The number of U.S. energy institutes has grown substantially in the past decade. Today, institutes are spread across 128 universities, 111 cities and towns, 45 states and Washington D.C. Thirty-nine institutes are in the Northeast, 27 are in the Midwest, 48 are in the South, and 43 are in the West. These institutes are anchored to universities with student enrollments ranging from less than 1,000 to over 100,000.

(2) Many academic energy institutes overlap in their focuses and interact with one another and stakeholders but not with a larger network of institutes. Institutes whom we surveyed identified research, education, and professional training among their most important strategic focuses. Nearly all institutes indicated they had interacted with stakeholders, including industry and policymakers, and most institutes indicated interacting informally with other institutes. At the summit, institutes suggested that a network could incorporate into its vision and mission the following keywords: Energy, education, policy, research, institute, and industry. Few institutes who attended our summit had worked formally within larger academic energy institute groups but many were eager to understand how to collaborate further.

(3) A network could facilitate communication and collaboration among institutes and stakeholders, offer a common core of energy-related skills and topics in higher education, and impact energy policy. Summit participants suggested that a network could facilitate the sharing of best practices, data, intellectual property, job opportunities, and papers among institutes. Through a network, institutes could co-write funding proposals, co-sponsor events, and work with government and industry. Summit participants suggested that, to engage stakeholders, a network could create an affiliate program that matches stakeholders with academic experts based on shared goals and interests. Summit participants identified business, engineering, environment, management, science, systems, law, and sustainability as key topics that could contribute to an energy-related "common core" in higher education and suggested that institutes could share course resources, such as notes and syllabi, through a repository. Institute leaders also suggested that a network could serve as a collective voice to impact public policy.

(4) In general, institutes willing to join a network would want to increase their research funding and impact national policy. Most institutes suggested they would financially support a network. All institutes whom we surveyed indicated they would consider joining a network, and nearly three-quarters of institutes indicated they would financially contribute to a network. Seventy-six percent of institutes identified more research funding as one of the most important benefits they would want to receive from a network, and 68% of institutes ranked bigger impact on national policy as one of the most important benefits. When asked to identify challenges associated with joining a network, institutes ranked differing interests or goals, lack of funding, and lack of central management among the most considerable challenges. In general, institutes preferred that a network be national in scope and suggested that a network, if formed, share research initiatives, a website portal, an industry membership program, a mission statement, and a dedicated secretariat.

(5) Of the external 48 stakeholders whom we surveyed, over 90% indicated they would interact with a network. However, less than half of stakeholder respondents suggested they would financially support a network. Most stakeholders identified more collaborations with academia as the most important benefit they would want to receive from a network. Stakeholders also identified bigger impact on national policy, more collaborations with industry, and reduced time to bring technologies to market as important potential benefits. If they were to join a network, stakeholders indicated they would participate in events hosted by a network and share knowledge with a network. However, only 42% of stakeholders whom we surveyed indicated they would financially support a network. Stakeholders identified differing interests or goals and lack of funding as considerable challenges they would encounter in joining a network.

The energy institute landscape is rapidly evolving and offers collaborative opportunities that might be leveraged soon to enhance research, education, and professional opportunities for students, staff, and faculty. Based on our findings, we recommend hosting an additional meeting to further determine how institute commonalities and complementary strengths could be used to forge partnerships and decide on practical next steps for growing and strengthening collaborations. Forming a steering committee, crafting vision and mission statements, creating a web presence, and gathering additional stakeholder input are recommended next steps.

Chapter 1

Background and Study Definition

Outlining the University Energy Institute Landscape

Introduction

University energy institutes are hubs for energy and environmental research, education, and outreach. Per our assessment, at least 157 U.S. university energy institutes of varying sizes and specializations are working to solve the world's energy and environmental challenges. Appendix A lists U.S. energy institutes identified to date. These institutes conduct research, often in partnership with industry, policymakers, and other stakeholders, to better understand and impact the energy landscape. Most institutes adopt an interdisciplinary approach to their work, drawing on the sciences, engineering, and humanities to solve energy challenges and inform public and private decision-making. Because these institutes are anchored to universities, institutes have access to high-quality faculty and fellows who can readily communicate and collaborate across departments and disciplines.

Despite sharing interests, institutes do not widely and regularly collaborate with one another. There are examples of alliances among institutes, corporations, and government,[1] and between two or three institutes at different universities,[2] co-participation in or co-sponsorship of events by university energy institutes or initiatives,[3] meetings of the academic energy education community,[4] and research partnerships among institutes at the same university.[5] However, there is currently no national consortium or network that regularly communicates and facilitates sustained collaborations among academic energy institutes. Prior reviews indicate that energy institutes share similar focuses and activities. The Colorado School of Mines, whose study provided the impetus for this work, reviewed 36 energy institutes and found that 84% of them hosted guest lectures, colloquia, or symposia, and 39% published working papers or research online.[6] A 2016 review of 13 energy institutes found that 46% of them offered industry affiliate programs.[7] A 2017 survey of 18 sustainability institutes found that 72% of them gauge their performance based on student impact, such as student enrollment, the number of majors and minors, and alumni placement.[8]

Based on the notion that an organized network of energy institutes could benefit the academic and non-academic energy communities, this report explores commonalities and

[1] ASERTTI, "Members of ASERTTI," ASERTTI: Association of State Energy Research and Technology Transfer Institutions, 2019, http://www.asertti.org/about/members.aspx.
[2] David Conti, "Pitt, CMU, WVU, Case Western Unite in Pursuit of Energy Research Dollars," *Pittsburgh Tribune-Review*, April 3, 2016, https://archive.triblive.com/business/local-stories/pitt-cmu-wvu-case-western-unite-in-pursuit-of-energy-research-dollars/.
[3] Sarah Armitage, "University Energy Initiative Symposium," *MIT Center for Energy and Environmental Policy Research*, May 1, 2016, http://ceepr.mit.edu/news/77; Dartmouth College, "Dartmouth Energy Collaborative Co-Sponsors," The Arthur L. Irving Institute for Energy and Society, 2019, https://irving.dartmouth.edu/engagement/dartmouth-energy-collaborative-dec/dartmouth-energy-collaborative-co-sponsors.
[4] National Council for Science and the Environment, "Summit Reports," 3rd National Energy Education Summit, accessed October 26, 2019, https://energyedsummit.wordpress.com/2016-energy-education-summit-report/.
[5] Texas A&M Energy Institute, "TEES Gas and Fuels Research Center and Texas A&M Energy Institute Form Partnership for Qatar," *News and Events*, March 29, 2019, https://energy.tamu.edu/tees-gas-and-fuels-research-center-and-texas-am-energy-institute-form-partnership-for-qatar/.
[6] M.D. Bazilian, G. Clough, and M. Geuss, "The Evolving Roles and Structures of University-Affiliated Energy and Environment Institutes," 2019, https://www.cmu.edu/energy/news-multimedia/2019/images/energy-institute-review---colorado-school-of-mines.pdf.
[7] Ross Strategic, "Energy Institute Benchmarking Profiles," 2016.
[8] A. J. Hoffman and J. L. Axson, "Examining Interdisciplinary Sustainability Institutes at Major Research Universities," 2017, http://graham.umich.edu/media/pubs/Mitchell Report Final.pdf.

differences among institutes and the potential role that a network could play in advancing the collective interests of institutes and stakeholders. By way of this multi-part study, we offer an initial investigation into paths for and potential outcomes of forming a network. We present results from our (i) online review of institute websites, (ii) survey of 66 institute leaders who identified a network's potential benefits, challenges, and organizational structures, (iii) summit that convened leaders across 62 institutes to discuss research, funding, and educational opportunities that could be realized through networking, and (iv) survey of 48 stakeholders who shared their expectations of and willingness to interact with a network. Our findings suggest that a network could form and strengthen connections among institutes, improve educational and professional opportunities for students, staff, and faculty, and grow value and impact around synergies between academia, government, industry, and nonprofits.

What is an Energy Institute?

An energy institute is an organization that is anchored to a university and engages in energy research, development, deployment, or education. We recognize that energy institutes differ in strengths, specializations, and focuses. At our study outset, we reviewed institute websites and observed differences in naming—for example, "energy initiative" vs. "sustainability institute" vs. "environmental center"—and we noticed that institutes range in size, location, and resources. To help delineate our population, we describe below three characteristics found common among most institutes captured in this report. To illustrate these characteristics, we provide specific examples of institutes.

Research. Institutes conduct research to better understand and impact energy and environmental landscapes. Many institutes research and develop one or more aspects of energy technology. For example, institutes are working to advance renewables,[9] create sustainable biofuels and bioproducts,[10] develop efficient heating and cooling systems,[11] modernize the power grid,[12] and reduce carbon emissions from coal power plants.[13] Institutes range in their disciplinary approaches; in fact, many pursue interdisciplinary work, spanning branches of science and engineering and extending into law, economics, and politics.[14] Institutes also seek to understand and impact markets and public policy.[15]

Institutes affiliate with faculty. For example, the West Virginia University (WVU) Energy Institute offers database containing the names of over 100 energy WVU researchers spanning economics, efficiency, energy storage, renewables, and other areas.[16] To its affiliates, the WVU Energy Institute offers services such as proposal preparation and project management assistance.[17] Faculty at the Princeton University's Andlinger Center for Energy and the

[9] University of Colorado - Boulder, "Renewable and Sustainable Energy Institute," Conn Center for Renewable Energy Research, accessed December 6, 2019, https://www.colorado.edu/rasei/.
[10] University of Wisconsin - Madison, "Great Lakes Bioenergy," Great Lakes Bioenergy Research Center, 2019, https://www.glbrc.org/.
[11] University of California - Davis, "No Title," UC Davis Western Cooling Efficiency Center, accessed December 6, 2019, https://wcec.ucdavis.edu/.
[12] North Carolina State University, "About," FREEDM Systems Center, accessed December 6, 2019, https://www.freedm.ncsu.edu/about/.
[13] University of Kentucky, "Creating Technology to Meet Tomorrow's Energy Needs," Center for Applied Research, accessed January 11, 2019, https://caer.uky.edu/power-generation/.
[14] Stanford University, "Research," Stanford | Energy, accessed January 11, 2019, https://energy.stanford.edu/research/research-areas.
[15] University of Pennsylvania, "Kleinman Center for Energy Policy," Kleinman Center for Energy Policy, 2019, https://kleinmanenergy.upenn.edu/.
[16] West Virgnia University, "Energy Faculty Across Campus," West Virginia University Energy Institute, accessed March 3, 2020, https://energy.wvu.edu/partnering/energy-faculty-across-campus.
[17] West Virginia University, "WVU Faculty," West Virginia University: Energy Institute, accessed March 3, 2020, https://energy.wvu.edu/partnering/wvu-faculty.

Environment hold joint appointments in the center and another department. The Andlinger Center also supports visiting fellows from government, industry, and nonprofits.[18] Several institutes offer small grants to researchers in the form of seed funding. The Colorado School of Mines 2018 review of 36 energy institutes indicates that 19% of them offered seed funding for startup projects.[19]

Output. Institutes produce outcomes that contribute to scientific knowledge and inform public and private decision-making. Many energy institutes publish research reports and white papers,[20] including briefs and links to peer-reviewed articles,[21] on their websites. The University of Kentucky intellectual capital database lists over 60 patents belonging to researchers at the university's Center for Applied Energy Research.[22] Several institutes, including MIT's Energy Initiative,[23] Northwestern University's Institute for Sustainability and Energy,[24] and Illinois Institute of Technology's Wanger Institute for Sustainability Energy Research,[25] oversee smaller, more specialized centers that focus on specific technologies or research areas. For example, MIT's Energy Initiative administers nine low-carbon energy research centers, each focusing on a specific technology area (e.g., energy storage or mobility systems) and led by faculty co-directors, a Faculty Steering Committee, and an Advisory Committee.[26] Institutes offer students coursework and professional development opportunities. For example, University of California, Berkeley's Energy and Resources Group[27] and Tulane University's Energy Institute[28] offer energy-focused degrees and certificates. Appendix B, Tables B8–B11 list universities and institutes offering energy-focused education programs.

Engagement. Institutes engage stakeholders, who are individuals and organizations that share an energy institute's interests. Stakeholders are from academia, business, government, industry, law, nonprofits, media, philanthropy, private investment, and other organizations. Institutes interact with stakeholders through formal partnerships, such as research collaborations and industry consortia, and marketing and communications, such as social media and newsletters.[29] Institutes also engage stakeholders by hosting events, such as symposia, lectures, social activities, and, in some cases, day- or week-long workshops. For example, Columbia University's Women in Energy Program offers workshops, training, and networking opportunities to recruit, support, and

[18] Princeton University, "Faculty and Researchers," Andlinger Center for Energy and the Environment, accessed January 9, 2019, https://acee.princeton.edu/people/faculty-and-researchers/; Princeton University, "Gerhard R. Andlinger Visiting Fellows in Energy and the Environment," Andlinger Center for Energy and the Environment, accessed January 11, 2019, https://acee.princeton.edu/gerhard-r-andlinger-visiting-fellows-in-energy-and-the-environment/.
[19] M.D. Bazilian, G. Clough, and M. Geuss, "The Evolving Roles and Structures of University-Affiliated Energy and Environment Institutes," 2019, https://www.cmu.edu/energy/news-multimedia/2019/images/energy-institute-review---colorado-school-of-mines.pdf.
[20] University of Houston, "About the White Paper Series," UH Energy, accessed January 11, 2019, https://www.uh.edu/uh-energy/research/white-papers/.
[21] University of Hawaii, "Publications," Hawaii Natural Energy Institute, accessed January 11, 2020, https://www.hnei.hawaii.edu/publications.
[22] University of Kentucky, "Center for Applied Energy Research Faculty Patents," University of Kentucky: UKnowledge, accessed January 9, 2020, https://uknowledge.uky.edu/caer_patents/.
[23] Massachusetts Institute of Technology, "Low-Carbon Energy Centers," MITEI: MIT Energy Initiative, accessed September 13, 2020, http://energy.mit.edu/lcec/#overview.
[24] Northwestern University, "Centers," Northwestern: Institute for Sustainability and Energy, 2020, https://isen.northwestern.edu/centers.
[25] Illinois Institute of Technology, "Wanger Institute for Sustainable Energy Research (WISER) Illinois Institute of Technology," Illinois Institute of Technology, accessed March 3, 2020, https://web.iit.edu/wiser/research-centers-and-programs-cover.
[26] Massachusetts Institute of Technology, "Low-Carbon Energy Centers."
[27] University of California - Berkeley, "Programs," ERG: Energy and Resources Group | An Interdisciplinary Graduate Program at UC Berkeley, accessed March 3, 2020, https://erg.berkeley.edu/academics/program/.
[28] Tulane University, "Energy Certificate," University Catalog 2019-2020, accessed January 11, 2020, https://catalog.tulane.edu/business/energy/energy-specialization-major/#text.
[29] Ross Strategic, "Energy Institute Benchmarking Profiles," 2016.

develop women in energy fields.[30] Carnegie Mellon University's Wilton E. Scott Institute for Energy Innovation[31] and Duke University's Energy Initiative and Center for Energy, Development, and the Global Environment[32] host or facilitate annual "Energy Week" multi-day events that engage businesses, government leaders, faculty, and students. These events comprise networking, panel discussions, keynotes, and student competitions.

A 2016 review of 13 university energy institutes found that 46% of them offer industry membership programs.[33] These programs offer, in exchange for financial support, access to facilities, events, and research programs. For example, companies and energy utilities in the Leadership Sponsor Program at the University of California, Davis's Energy and Efficiency Institute pay an annual fee commensurate with their annual revenue to join the institute's Board of Advisors and for opportunities to speak at events, appear in promotional materials, partner with the university in research projects, and recruit employees.[34] Through its tiered membership program, Texas A&M University's Energy Institute invites affiliates to events, shares publications, offers affiliates a rotating position on the institute's advisory board, and collaborates with affiliates on research projects.[35]

Institutes engage policymakers by writing research papers and briefings and participating in outreach. The University of California, Berkeley's Energy Institute at Haas publishes white papers and blog posts online.[36] Institutes interact with policymakers by presenting expert testimony and briefings on Capitol Hill.[37] Several institutes include policymakers on their advisory boards.[38] Institutes also support local and regional projects. For example, North Carolina State University's Clean Energy Technology Center announced in 2019 a request for proposals to demonstrate and deploy technologies that reduce transportation-related emissions in North Carolina counties.[39] The University of Michigan Energy Institute assessed the feasibility of installing solar microgrids in Ann Arbor, Michigan.[40]

[30] Columbia University, "Columbia | SIPA: Center on Global Energy Policy," accessed January 9, 2020, https://energypolicy.columbia.edu/initiatives/women-energy.
[31] Carnegie Mellon University, "CMU Energy Week," CMU Energy Week, accessed January 1, 2019, https://www.cmu.edu/energy-week/.
[32] Duke University, "Energy Week at Duke University," Energy Week at Duke University, 2019, https://www.energyweekatduke.org/energy-week-at-duke.
[33] Ross Strategic, "Energy Institute Benchmarking Profiles," 2016.
[34] University of California - Davis, "Leadership Sponsor Program," UC Davis: Energy and Efficiency Institute, accessed April 1, 2020, https://energy.ucdavis.edu/leadership-sponsor-program/.
[35] Texas A&M University, "Four Tier Structure," Texas A&M University: Texas A&M Energy Institute, 2020, https://energy.tamu.edu/external-partnerships/four-tier-structure/.
[36] University of California - Berkeley, "Research," Energy Institute at Haas, accessed January 10, 2020, https://haas.berkeley.edu/energy-institute/research/.
[37] Columbia University, "No Title," Columbia SIPA Center on Global Energy Policy, accessed December 6, 2019, https://energypolicy.columbia.edu/; Carnegie Mellon University, "No Title," Wilton E. Scott Institute for Energy Innovation, 2019, https://www.cmu.edu/energy/.
[38] University of Michigan, "Advisory Board," Energy Institute: University of Michigan, accessed January 10, 2020, https://energy.umich.edu/about/leadership/advisory-board/; Stanford University, "Precourt Institute Energy Advisory Council," Stanford | Energy, accessed February 8, 2020, https://energy.stanford.edu/people/precourt-institute-energy-advisory-council.
[39] North Carolina State University, "Clean Fuel Advanced Technology (CFAT) Project," NC Clean Energy Technology Center, accessed March 3, 2020, https://nccleantech.ncsu.edu/our-work/center-projects/cfat-project-request-for-proposals-information/.
[40] University of Michigan, "Solar Microgrid Feasibility Study for City of Ann Arbor," Research Reports, accessed March 3, 2020, https://energy.umich.edu/research/publications/publication/solar-microgrid-feasibility-study-for-city-of-ann-arbor-2017/.

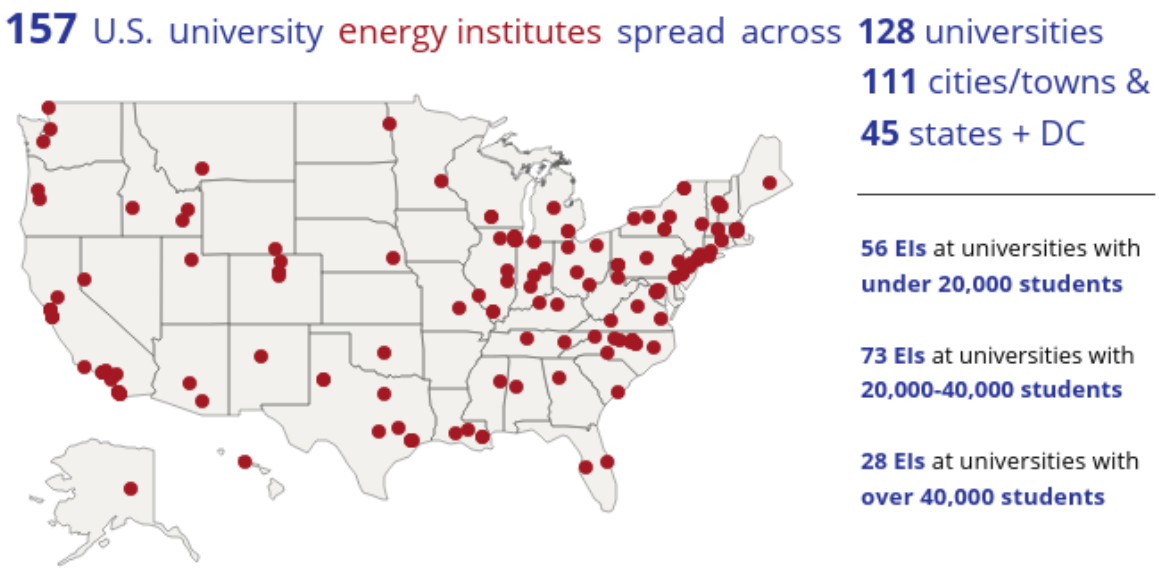

Figure 1. At least 157 U.S. university energy institutes are working to solve the world's energy and environmental challenges.

Each point on the map represents an energy institute's physical location or, if the physical location could not be determined, the university's main campus address. Enrollment includes undergraduate and graduate, distance learning, non-degree seeking, and full- and part-time students across all campuses of a university.

Institutes by the Numbers

The academic energy institute space has grown considerably in the past decade. As recently as 2009, the future of energy institute research was unclear.[41] Today, per our online review, at least 157 university institutes are working to solve the world's energy, environmental, and sustainability challenges. We present institute locations in Figure 1 and list institute names in Appendix A. Table A1. These institutes are spread across 128 universities, 111 cities and towns, 45 states, and Washington D.C. Thirty-nine institutes are in the Northeast, 27 are in the Midwest, 48 are in the South, and 43 in the West.[42] Fifty-six institutes are anchored to universities with fewer than 20,0000 students, 73 are anchored to universities with 20,000–40,000 students, and 28 are anchored to universities with more than 40,000 students.[43] One hundred two universities have one energy institute, 19 universities have two energy institutes, five universities have three energy institutes, and two universities—University of California, Berkeley and the University of California, San Diego—have four energy institutes.

Energy institutes cover a range of topics and disciplines. The most frequently used words in institute names are as follows:[44] One-hundred twenty-five institute names include "Energy," 41 include "Environment," 30 include "Sustainability," 21 include "Research," 15 include "Policy," eight include "Technology," and eight include "System." Several names suggest a

[41] Paul G. Falkowski and Robert M. Goodman, "Future Energy Institutes," *Science* 325, no. 5491 (2009).
[42] "References for Energy Institute Addresses," BOX Folder, accessed April 3, 2020, http://cmu.app.box.com/folder/105894073845.
[43] "University Student Enrollment," BOX Folder, created March 5, 2020, https://cmu.box.com/s/psgocbr6bg3ua2oe9tnu3m1acf4zgs4u.
[44] We excluded from our analysis Institute and Center. Also, we allowed variations of words, such as Sustainable/Sustainability and Environment/Environmental.

strongly cross-topical approach to their work. For example, 28 institute names include "Energy" and "Environment," 16 include "Energy" and "Sustainability," and 11 include "Environment" and "Sustainability." Six names include "Energy," "Environment," and "Sustainability." These institutes are the Center for Energy, Environment and Sustainability at Wake Forest University, the Center for Sustainable Energy and Environmental Engineering at East Carolina University, the Institute for the Study of the Environment, Sustainability and Energy at Northern Illinois University, the Institute for Sustainability, Energy, and Environment at University of Illinois, Urbana–Champaign, the Institute for Sustainable Energy and the Environment at Ohio University, and the International Center for Energy, Environment and Sustainability at Washington University, St. Louis.

Of the 98 institutes whose founding date we determined, one was founded before 1959, one was founded between 1960–1969, 11 were founded between 1970–1979, eight were founded between 1980–1989, six were founded between 1990–1999, 41 were founded between 2000–2009, and 30 were founded between 2010–2019.[45] The oldest institute—the Energy and Environmental Research Center at the University of North Dakota—was founded in 1951 under the U.S. Bureau of Mines.[46] The most recently founded institute—the Sustainability Institute at The Ohio State University—was founded in 2019.

Purpose of this Study

The purpose of this work is to explore opportunities for collaboration among U.S. university energy institutes. We seek to answer the following questions:

- Do institutes share common focuses and, if so, to what extent could these similarities and complementary strengths be leveraged to pursue common goals?
- What are the desired outcome(s) or product(s) of a network?
- What is the current and potential future role of institutes in higher education? What benefits and challenges would institutes encounter in joining a network?
- Would stakeholders be willing to interact with a hypothetical, future network and, if so, in what ways?
- How should a hypothetical, future network be governed and administered?
- How should a network function? How could it be funded sustainably?

We loosely define a network as a set of connected institutes. The type of network envisioned here is a social impact network, which thrives on reciprocal and complementary member-to-member connections. Through these connections, members share information and resources and, in so doing, mutually benefit.[47]

[45] "References for Energy Institute Founding Year," BOX Folder, accessed April 2, 2020, http://cmu.app.box.com/folder/105894073845.
[46] University of North Dakota, "Our History," EERC: Energy and Environmental Research Center, accessed January 13, 2020, https://undeerc.org/about/history.html.
[47] John Cleveland, "Using Social Impact Network to Achieve Large Scale Systems Change," Networks for Social Impact, accessed January 10, 2019, http://lifeaftercarbon.net/innovation-network-for-communities/networks-for-social-impact/.

Research Approach

Our study comprises an online review, institute leadership summit, and three surveys.

Web review. Our online review provides a broad albeit non-comprehensive compilation of U.S. academic energy institutes and their mission statements, educational programs, and founding dates. We began our review by searching the top 200 ranked U.S. universities as reported by U.S. News and World Report.[48] We later expanded our search to include institutes identified in the literature and through personal correspondence with universities.[49] To date, we identified 157 U.S. energy institutes. The locations of these institutes are displayed in Figure 1 and their names are listed in Appendix A, Table A1.

Leadership summit. We invited energy institute leaders to attend the University Energy Institute Leadership Summit in Pittsburgh, PA on September 25–26, 2019.[50] Seventy-eight institute leaders, spread across 62 institutes anchored to 57 universities and located in 54 cities and towns, 30 states, and Washington D.C., attended the summit. Figure 2 summarizes summit attendees and the types of activities in which they engaged. Over 75% of leaders worked as institute Directors, Faculty Directors, Executive Directors, Associate Directors, or Assistant Directors. Appendix C, Table C1 lists attending institutes and their host universities.

The summit comprised four roundtables discussions, two keynote talks, one panel discussion, one fireside chat, and social activities. The roundtable discussions addressed institute commonalities and differences, the role of institutes in higher education, benefits and challenges of forming a network, and potential organizational structures for a network. During these discussions, we invited leaders to record in a workbook their responses to discussion questions. Sixty-seven leaders, spread across 56 institutes anchored to 52 universities, completed and submitted their workbooks for inclusion in this study. We describe our materials and methods in Appendix D.

Using automated text analysis,[51] we gleaned keywords and themes from workbook responses. We performed topics extraction, text clustering, and sentiment analyses. Topics extraction identifies keywords and concepts in a text. Text clustering, or document grouping, groups similar texts and assigns a descriptive thematic name to each group. Sentiment analysis detects the overall attitude, or polarity (positive, negative, neutral), of a text.

[48] U.S. News and World Report, "U.S. News Best Colleges," 2019, https://www.usnews.com/best-colleges.
[49] A. J. Hoffman and J. L. Axson, "Examining Interdisciplinary Sustainability Institutes at Major Research Universities," 2017, http://graham.umich.edu/media/pubs/Mitchell Report Final.pdf.
[50] Carnegie Mellon University, "University Energy Institute Leadership Summit - 2019," Wilton E. Scott Institute for Energy Innovation, accessed January 13, 2019, https://www.cmu.edu/energy/events/2019/summit.html.
[51] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.

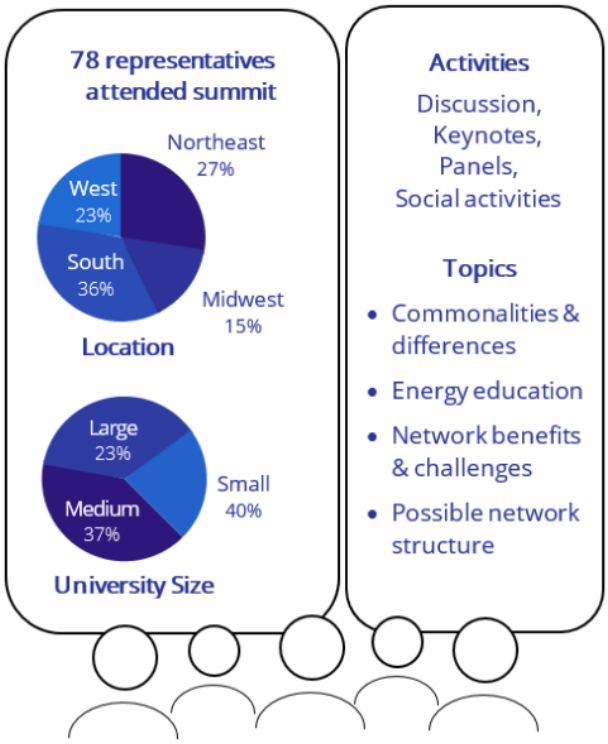

Figure 2. Seventy-eight energy institute leaders, spread across 62 institutes anchored to 57 universities, attended the 2019 University Energy Institute Leadership Summit. Forty-six of these leaders completed our post-summit survey about next steps, if any, toward forming a network.

During the summit, leaders discussed a potential network's mission and vision, role in higher education, possible funding paths, and possible organizational structures. The agenda comprised roundtable discussions, keynotes, panel discussions, and social activities.

Surveys. Prior to the summit, we surveyed university energy institute leaders about their expectations of a future, hypothetical network. Sixty-six leaders across 62 universities, 58 cities and towns, 30 states, and Washington, D.C., completed our pre-summit survey. Over 80% of leaders worked as Directors, Faculty Directors, Executive Directors, and Associate Directors. Figure 3 summarizes survey respondents, and Appendix C, Table C2 lists participating institutes and their host universities. Per our request, one and only one respondent per energy institute completed our survey, which asked leaders about their (i) institute organizational structures, (ii) institute research and strategic focuses, (iii) university educational and professional offerings, (iv) institute funding, (v) institute collaborations with industry, policymakers, and other universities, (vi) willingness to join a potential network, and (vii) opinions regarding a hypothetical network's structure. We describe our survey materials and methods in Appendix E.

Following the summit, we surveyed summit attendees for their feedback on the summit and opinions about next steps, if any, toward forming a network. We also asked attendees to share ideas or topics that were not raised during the summit but that they thought needed attention. Forty-six individuals completed our post-summit survey.

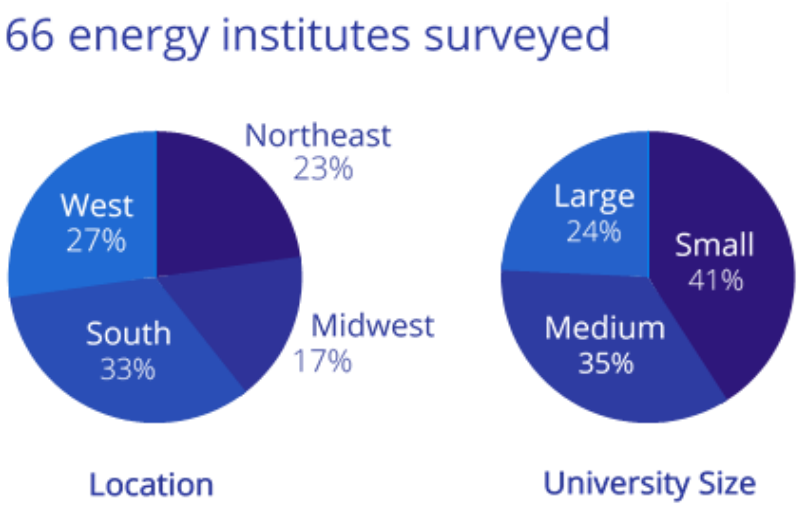

Figure 3. Sixty-six energy institutes, spread across 62 universities, participated in our pre-summit leadership survey.

Institute leaders shared information about their research and strategic focuses and opinions about the benefits and challenges of forming a network. Small universities are defined as those having under 20,000 students, medium universities are defined as having 20,000–40,000 students, and large universities are defined as having over 40,000 students.

We also surveyed stakeholders about their willingness to interact with a potential network. Forty-eight stakeholders, spread across business, nonprofits, government, philanthropy, policy, private investment, and academia, completed our survey. These stakeholders worked on average 18.1 years ($\sigma = 10.4$) in an energy-related field. Chairpersons, CEOs, directors, managers and other leaders, specialists, and senior professionals participated in our survey. Figure 4 summarizes survey respondents. Our survey asked stakeholders about their (i) current interactions, if any, with academic energy institutes, (ii) desire to interact with and benefit from a hypothetical network, (iii) concerns about forming a network, (v) opinions regarding possible organizational structures for a network, and (vi) willingness to contribute financially toward a network.

Outline

The remainder of our report presents findings from our online review, summit, and surveys. Our report is organized as follows:

Chapter 2: Commonalities and Differences

In this chapter, we present keywords extracted from institute mission statements collected online. We also present findings from our pre-summit leadership survey about current and potential future collaborations, research focuses, and organizational structures of a hypothetical network. Finally, we discuss institutes suggestions for topics that could be included in network mission and vision statements.

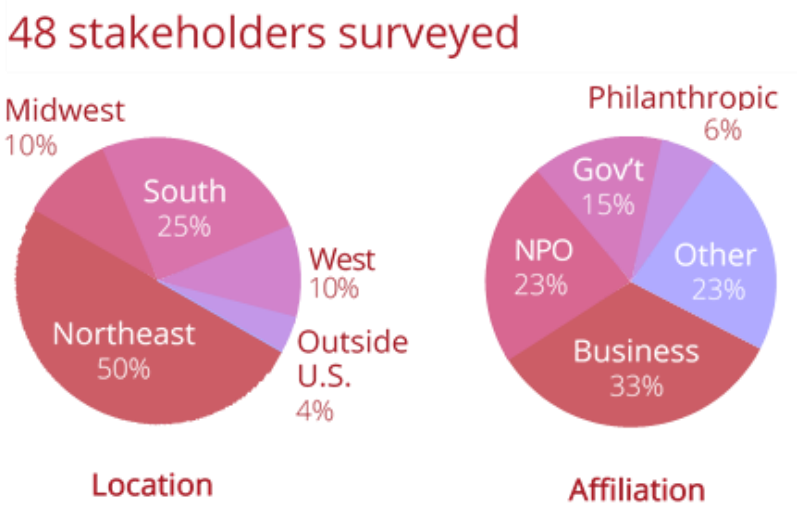

Figure 4. Forty-eight stakeholders, spread across the U.S., participated in our pre-summit stakeholder survey.

Stakeholders from business, nonprofit organizations, civil servants (government), and other affiliations shared their opinions about the benefits and challenges of forming a network. The "Other" affiliation includes elected government official(s), academia, industry, law, national laboratory, private investment, public policy, and research science.

Chapter 3: Energy Education

We review educational and professional development opportunities offered by institutes. Based on our summit finings, we discuss the potential role that an energy institute network could play in energy education and discuss topics and skills that could contribute to an energy-focused common core in higher education.

Chapter 4: Institute Expectations of a Network

We present findings from our pre-summit leadership survey indicating benefits that leaders most desire from a network. We also discuss challenges that leaders anticipated encountering if they to join a network. Finally, we discuss a network's potential organizational frameworks, including governance structures and possible sources of funding.

Chapter 5: Stakeholder Expectations of a Network

What expectations do stakeholders have of a network? This chapter presents findings from our pre-summit stakeholder survey indicating benefits that stakeholders most desired from a network and challenges that stakeholders anticipated encountering if they were to interact with a network.

Chapter 6: Steps toward Forming a Network

We present summit participants' overall evaluations of a future, hypothetical network and their suggestions for possible next steps toward forming a network, including possible topics for discussion at a future meeting.

Chapter 7: Summary and Recommendations

This chapter summarizes broad themes that emerged during our study. Institutes share common goals and leaders and stakeholders are willing to collaborate through a network. However, a network's vision, mission, and value proposition need clarification before a network can be formed. We recommend forming a steering committee to oversee a network's formation and holding an additional meeting among institutes to agree upon a network's purpose and objectives and identify potential funding paths.

Carnegie Mellon University's Institutional Review Board,[52] who protects the rights and welfare of humans in research, approved our study. We obtained the consent of participants before gathering their assessments. Throughout this report, we protect participant identities by excluding personal identifiers, such as participant names and organizations. All quotes are used with permission.

[52] Carnegie Mellon University, "Human Subjects Research," Office of Research Integrity and Compliance, accessed January 23, 2020, https://www.cmu.edu/research-compliance/human-subjects-research/index.html.

Chapter 2

Commonalities and Differences

Energy Institute Missions, Organizational Structures, and Focuses

Summary

This chapter examines energy institute mission statements, organizational structures, and research focuses. In their mission statements, institutes frequently mentioned research, environment, policy, and technology. Within each of these areas, institutes mentioned finer focuses such as climate, markets, and sustainability. Institutes ranged in size, and many employed specialized staff roles such as research, management, and communications positions. Institutes ranged in annual operations budgets from less than $500,000 to over $10 million. Most institutes indicated they engage in multidisciplinary or interdisciplinary research, education, and training. Institutes ranked infrastructure and grids, solar, and wind among their most important research areas. When asked to suggest elements for a network's mission and vision statements, institutes frequently mentioned "Energy," "Education," "Policy," and "Research."

Mission Statements

Of the 157 institutes we identified, 155 published mission statements online.[53] In length, these statements averaged 75 words and ranged between 9 and 325 words. Using text analysis,[54] we extracted keywords from institute mission statements. As displayed in Figure 5, institutes most frequently mentioned, in order of decreasing frequency, "Energy," "Research," "Environment," "Policy," "Technology," and "Science/Knowledge." We categorized institute mission statements by identifying all statements that mentioned a given keyword and, using text clustering, dividing these statements into categories. Appendix B, Table B1 presents category names resulting from this analysis. Below, we summarize our findings and provide several examples of mission statements.

Energy. Eighty-four percent of mission statements mentioned "Energy." The clustering algorithm grouped these statements into 56 categories. Eleven categories ("Alternative," "Climate," "Critical," "Industry," "Initiatives," "Institute," "National," "Problems," "Projects," "Public," and "Renewable") each contained four or more statements. For example, as part of its mission, categorized under "Climate," University of Massachusetts, Amherst's Center for Energy Efficiency and Renewable Energy "…provide[s] services at no cost to industrial, commercial and municipal clients, helping them to identify and implement cost-effective measures that reduce their operating costs, greenhouse gas emissions, and other environmental impacts."[55] University of Kentucky's Center for Applied Energy Research, whose mission was categorized under "Industry," "…investigate[s] energy technologies to improve the environment. Researchers contribute to technically-sound policies related to fossil and renewable energy."[56] North Carolina State University's Clean Energy Technology Center, whose mission was

[53] If an institute did not publish a formal mission statement but described their purpose online, we considered the purpose to be their mission statements.
[54] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.
[55] University of Massachusetts-Amherst, "Center for Energy Efficiency and Renewable Energy," UMassAmherst, accessed December 29, 2019, http://www.ceere.org/index.html.
[56] University of Kentucky, "Home," UK Center for Applied Research, accessed December 29, 2019, https://caer.uky.edu/.

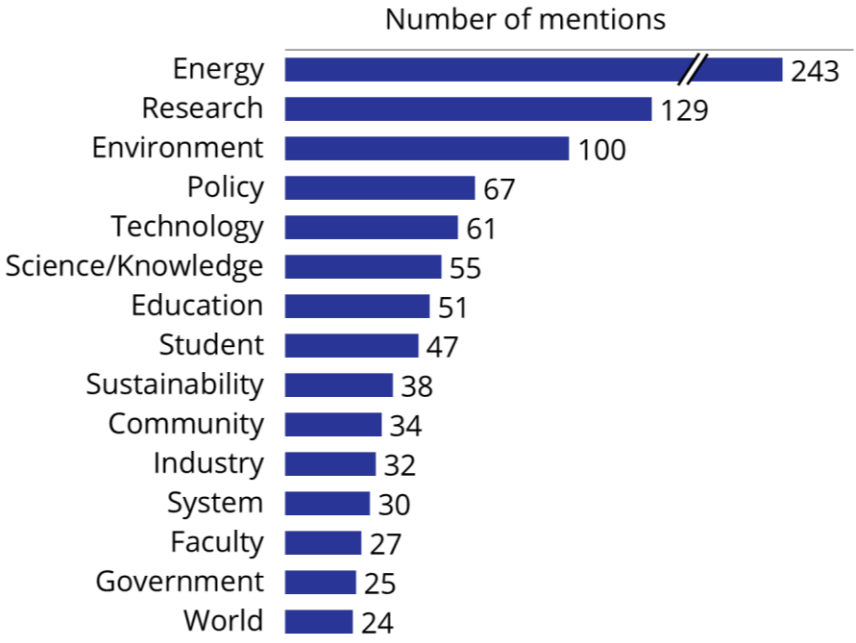

Figure 5. Keywords extracted from institute mission statements. Institutes most frequently mentioned "Energy," "Research," and "Environment." Often but less frequently, institutes mentioned "Technology," "Science/Knowledge," "Education," and "Policy."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than 26 mentions are not shown. Appendix B, Table B1 presents categories produced by our text clustering analysis.

categorized under "Initiatives," is "…a public service center seeking to advance a sustainable energy economy by educating, demonstrating, and providing support for clean energy technologies, practices, and policies."[57] Most categories, including "Business," "Education," "Future," "Implement," "Innovative," "Interdisciplinary," "Social," "Training," and "World," each contained three or fewer statements. For example, as part of its mission, categorized under "Future," University of Delaware's Energy Institute "…wed[s] experts across fields, industries, and the globe to advance efforts in energy discovery, development, and policy."[58] University of California, Santa Barbara's Institute for Energy Efficiency, whose mission statement was categorized under "Innovative," is "…dedicated to the development of cutting-edge science and technologies that support an efficient and sustainable energy future."[59] Northwestern University's Institute for Sustainability and Energy, whose mission was categorized under "Social," "…advances global energy and sustainability solutions through transformational research, interdisciplinary education, and public engagement."[60]

Research. Seventy-four percent of mission statements mentioned "Research." The clustering algorithm grouped these statements into 56 categories. Ten categories ("Academic,"

[57] North Carolina State University, "NC Clean Energy Technology Center," Mission and Funding, 2019, https://nccleantech.ncsu.edu/about-us/mission-funding/.
[58] University of Delaware, "About Us," Delaware Energy Institute, accessed December 29, 2019, https://dei.udel.edu/about-us/.
[59] University of California-Santa Barbara, "About," The Institute for Energy Efficiency, accessed December 28, 2019, https://iee.ucsb.edu/about.
[60] Northwestern University, "Mission and History," Northwestern Institute for Sustainability and Energy, accessed December 27, 2019, https://isen.northwestern.edu/mission-history.

"Alternative," "Decision," "Environmental," "Mission," "Power," "Related," "Strategic," "Sustainable," and "Understanding") each contained three or more statements. For example, College of William and Mary's Commonwealth Center for Energy and the Environment, whose mission was categorized under "Decision," is "…in one sense, a think-tank dedicated to the development and support of interdisciplinary work …and also supports a unique environment for interdisciplinary teaching and research…"[61] University of California, Irvine's Advanced Power and Energy Program, categorized under "Power," "..conducts research in the following five elements of the energy domain for generating electricity and power in the transportation sector: Energy systems integration and impacts, renewable fuels, energy storage, fuel cell science and technology, [and] combustion science and technology." University of California, Los Angeles' Institute of the Environment and Sustainability, whose mission was categorized under "Sustainable," "…embrace[s] communications and interactive public events as both a responsibility and an opportunity to be a change agent in the service of a sustainable environment."[62] Most categories, including "Campus," "Collaborative," "Commercialization," "Economic," "Management," "Public," "Resilient," and "Transition," each contained two or fewer statements. For example, University of Notre Dame's Center for Sustainable Energy's mission, categorized under "Campus," is to "…foster and grow energy-related research, support education and community outreach, and influence the national and global discussions of the most pressing energy policy issues and questions of our time."[63] Vanderbilt University's Institute for Energy and Environment, whose mission was categorized under "Resilient," conducts research that "…elucidates the relationships among individual, institutional, and societal choices for energy production and use, and the impacts and benefits of these choices on the environment and health through links with climate, water quality, economics, social psychology, and natural resources."[64] The University of Tennessee, Knoxville's Bredesen Center for Interdisciplinary Research and Graduate Education, whose mission was categorized under "Transition," "…unites resources and capabilities from the University of Tennessee and Oak Ridge National Laboratory to promote advanced research and to provide innovative solutions to global challenges in energy, engineering, and computation."[65]

Environment. Forty-seven percent of mission statements mentioned "Environment." The clustering algorithm grouped these statements into 48 categories. Three categories ("Resources," "Louisiana," and "Studies") each contained three or more statements. For example, Eastern Illinois University's Center for Clean Energy Research and Education's mission, categorized under "Resources," is in part "…to facilitate collaborative research in renewable energy by faculty across the entire university…[and] to enable students to study clean energy in order to be knowledgeable in environmental protection, natural resource preservation, and social responsibilities and solutions."[66] University at Buffalo's Research and Education in Energy, Environment and Water Institute, whose mission was categorized under "Studies," "…aims to establish University at Buffalo as a global leader in research and education in select areas in energy, environment, and water. It is enabling and promoting interdisciplinary, innovative

[61] Clemson University, "About," Clemson in Charleston, accessed December 21, 2019, https://www.clemson.edu/cecas/departments/charleston/about/index.html.
[62] University of California-Los Angeles, "No Title," UCLA: Institute of the Environment and Sustainability, accessed December 28, 2019, https://www.ioes.ucla.edu/mission/.
[63] University of Notre Dame, "About," ND Energy, accessed December 30, 2019, https://energy.nd.edu/about/.
[64] Vanderbilt University, "Energy and Environment – A Critical Area for the 21st Century," Vanderbilt Institute for Energy and Environment, accessed December 30, 2019, https://www.vanderbilt.edu/viee/.
[65] The University of Tennessee-Knoxville, "The Bredesen Center," The University of Tennessee, Knoxville, accessed December 28, 2019, https://bredesencenter.utk.edu/.
[66] Eastern Illinois University, "Eastern Illinois University Center for Clean Energy Research and Education," Eastern Illinois University, accessed December 21, 2019, http://castle.eiu.edu/energy/.

research and education in addition to offering outreach programs to the broader community."[67] Most categories, including "Advanced," "Business," "Cost," "Dynamic," "Experts," "Law," "Scientists," and "Solving," each contained two or fewer statements. For example, as part of its mission, categorized under "Cost," Tulane University's Energy Institute "…provides educational opportunities that improve understanding of the integration of energy markets, policies, technology, and the environment. These initiatives include programming in energy accounting, analytics, economics, finance, operations and supply chain management, strategy, and trading, as well as applied and basic research in business, engineering, and sciences."[68] Rice University's Center for Energy Studies mission, categorized under "Solving," is in part "…to provide policymakers, corporate leaders, and the public with quality, data-driven analysis of issues that influence energy markets…"[69] Yale University's Energy Sciences Institute, whose mission was categorized under "Advanced," "…is developing new ways to generate and store energy from renewable sources such as the wind and sun. Its work builds upon the groundbreaking research by Yale scientists who are studying alternative energy solutions…"[70]

In addition to the keywords identified above, 32% of mission statements mentioned "Policy," 21% mentioned "Technology," 33% mentioned "Science/Knowledge," and 38% mentioned "Education." Statements that mentioned "Policy" were grouped into 35 categories, including "Adaption," "Emissions," "Foster," "Ideas," "National," and "State." Statements that mentioned "Technology" were grouped into 27 categories, including "Electrochemical," "Fuels," "Heating," "Inform," "Protection," and "Systems." Statements that mentioned "Science/Knowledge" were grouped into 35 categories, including "Community," "Endeavor," "Learning, Service," "Officials," "Skills," and "Wind." Finally, statements that mentioned "Education" were grouped into 37 categories, including "Catalyze," "Clean," "Demand," "Ideas," "Production," "and "Team." Appendix B, Table B1 lists all category names.

Organizational Structure and Budget

In our pre-summit leadership survey, we provided respondents with a list of staff roles and asked respondents to select all roles employed by their energy institute. We also provided space for respondents to write staff roles. Figure 6 presents staff roles selected from the given list. We found that nearly all institutes employed an overall leader, such as a director or executive director. Ninety-five percent of institutes whom we surveyed employed a director, executive director, or associate director. However, only 5% of institutes indicated filling all three roles. Seventy-four percent of institutes employed a director, 56% employed one or more associate directors, 44% employed an executive director, and 18% employed a co-director. Thirty-six percent of institutes had an external advisory board, 18% had an internal advisory board, and 29% had both internal and external advisory boards. Seventeen percent of institutes had no advisory board. Ninety-seven percent of institutes had affiliated faculty. Ninety-one percent of institutes reported having dedicated physical space.

Institutes differed in their number and type of staff. Appendix B, Figure B1 presents the number of full-time equivalent (FTE) staff employed by institutes. Sixty-four percent of institutes had fewer than 10 FTE staff, 28% between 10 and 30 FTE staff, and 6% greater than

[67] University at Buffalo, "Our Focus," University at Buffalo: Research and Education in Energy, Environment and Water, accessed December 28, 2019, http://www.buffalo.edu/renew/about-us/our-focus.html.
[68] Tulane University, "About the Institute," Tulane University: Freeman School of Business, accessed December 28, 2019, https://freeman.tulane.edu/energy-institute/about.
[69] Rice University, "About the Center for Energy Studies," Rice University's Baker Institute for Public Policy, accessed December 27, 2019, https://www.bakerinstitute.org/center-for-energy-studies/about-energy-studies/.
[70] Yale University, "No Title," Yale University: Energy Sciences Institute, accessed December 30, 2019, https://energysciencesinstitute.yale.edu/.

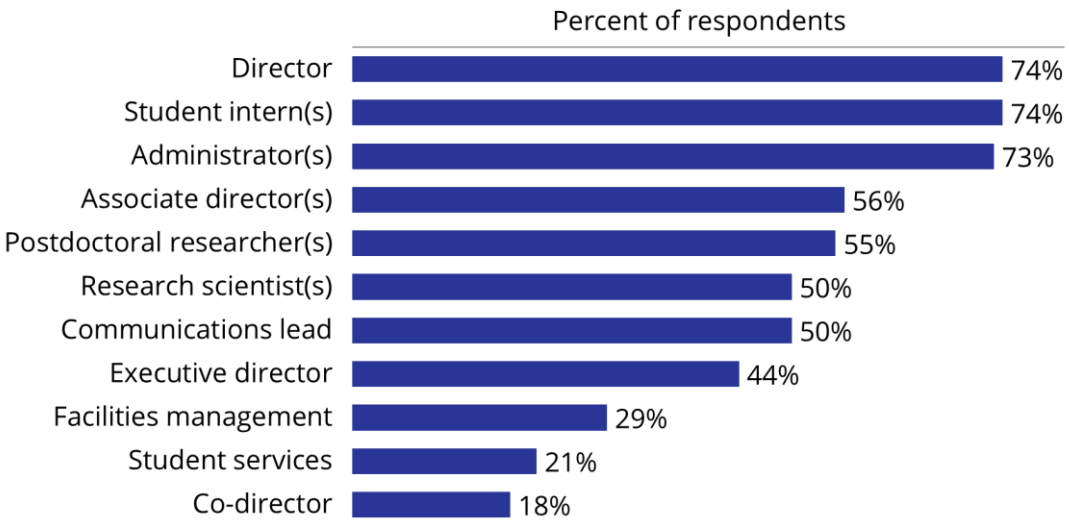

Figure 6. Staff roles employed by energy institutes. Most institutes employed a director, and slightly over half employed one or more associate directors. Most institutes indicated they had at least one administrator, and half indicated they had one or more research scientists.

Staff role is displayed along the vertical axis, and the percentage of survey respondents is displayed along the horizontal axis. Student intern includes student researcher. In the survey, we stated "Executive or administrative director," although we intended "Executive or operating director." All funding sources shown were selected from the list given in the question. Appendix B, Table B2 presents staff roles written by respondents.

30 FTE staff. Seventy-four percent of institutes employed at least one student intern, and 73% employed at least one administrator. Half of institutes employed a communications lead. Fifty-five percent of institutes employed at least one postdoctoral researcher, and 50% employed at least one research scientist. Twenty-nine percent of institutes hired facilities management, and 29% employed at least one student services employee. In the space provided below the question, respondents wrote, in total, 30 staff roles not included in the given list. Appendix B, Table B2 lists these staff roles. Four respondents wrote a program manager, two wrote an attorney, two wrote a development director, and two wrote a laboratory director. Respondents also wrote, in alphabetical order and among other staff roles, an extension specialist, industry liaison, outreach and events coordinator, partnerships director, proposal manager, and several research staff roles, including a research and communications director, a research coordination and sponsorships director, research development staff, a research operations lead, and research, education, and innovation specialists.

In our pre-summit leadership survey, we asked respondents to approximate their institute's annual operations budget. Figure 7 presents institute budgets, which ranged from less than $500,000 to over $10 million. Twenty-three percent of institutes operated on budgets less than $500,000, 20% between $0.5–$1 million, 39% between $1–$3 million, 8% between $3–$5 million, and 16% greater than $3 million. We also asked respondents to rank their institute funding sources in order of annual contribution amount. We provided respondents with a list of funding sources and asked respondents to rank all applicable sources, and we provided space for

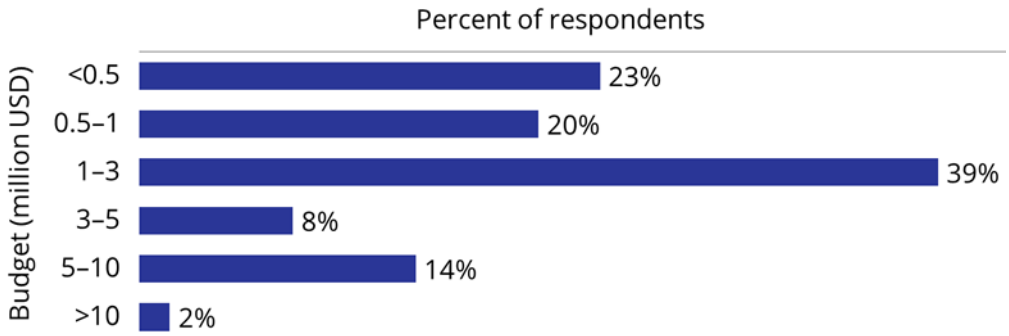

Figure 7. Annual operations budget of energy institutes. Thirty-nine percent of institutes indicated they operate on budgets between $1–$3 million, and forty-three percent indicated they operate on budgets less than $1 million.

Annual operations budget is displayed along the vertical axis, and the percentage of survey respondents is displayed along the horizontal axis.

respondents to write funding sources. Appendix B, Figure B2 presents funding sources selected from the given list. Seventy-one percent of institutes ranked university appropriations among their funding sources, and 70% ranked government funding among their funding sources. Respondents also ranked, in order of decreasing frequency of selection, industry support, philanthropic donations, nonprofit organizations, "founding" or named gifts, and tuition and fees. Five respondents wrote funding sources not provided in the given list. Of these respondents, one wrote alumni gifts; another wrote foundations; another wrote grants; another wrote state appropriations; and another wrote law firm sponsorships.

Strategic Focuses

In our pre-summit leadership survey, we asked respondents to rank their institute's five most important strategic focuses. In the question, we defined strategic focus as a goal, objective, or outcome that supports an energy institute's overall mission. We provided respondents with a list of strategic focuses. We also provided space for respondents to write focuses. Figure 8 presents strategic focuses selected from the given list. Eighty-nine percent of institutes ranked multidisciplinary or interdisciplinary research among their five most important strategic focuses, and 86% ranked educating and training students among their five most important strategic focuses. Institutes also ranked, among their five most important strategic focuses and in order of decreasing frequency of selection, collaboration with industry, collaboration with government, informing policymakers, collaboration with other universities, engaging the general public, facilitating technology-to-market, offering seed grants, and fostering entrepreneurship.

Respondents wrote strategic focuses not provided in the given list and related to collaboration and research (Appendix B, Table B3). Seven respondents wrote strategic focuses related to collaboration. Of these respondents, one wrote collaboration with government, industry, and other universities; another wrote collaboration with government and other universities; another wrote collaboration with non-governmental organizations; another wrote collaboration with other on-campus units to meet energy and sustainability goals; another wrote interactions with attorneys and law firms; another wrote research collaborations and strategic hires; and another wrote partnership with industry. Two respondents wrote strategic focuses related to research. One of these respondents, one wrote research (the respondent did not specify

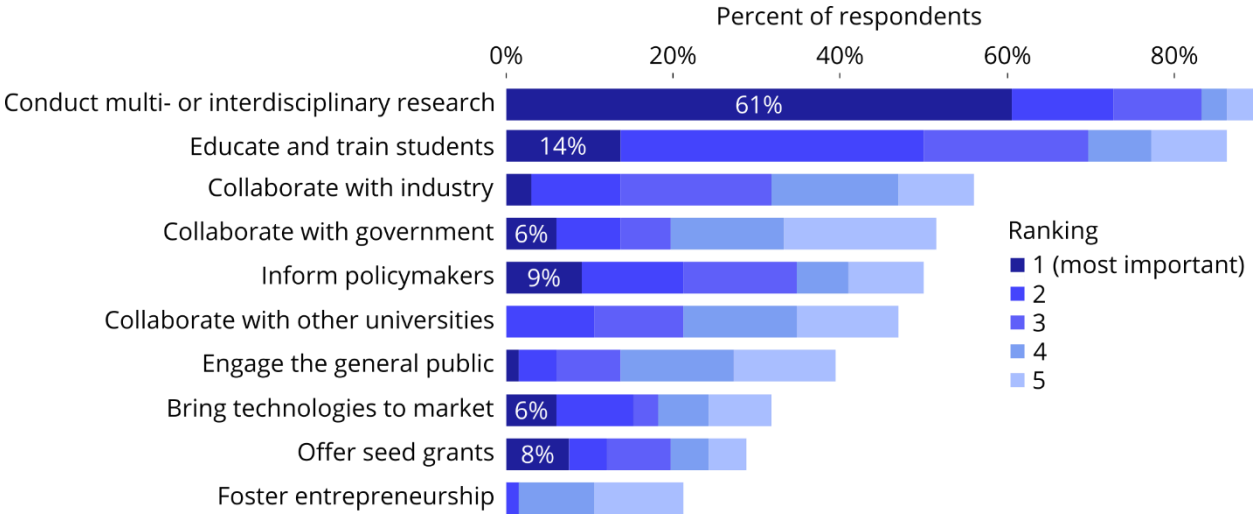

Figure 8. Strategic focuses of energy institutes. Sixty-one percent of Institutes ranked multidisciplinary or interdisciplinary research as their most important strategic focus.

Strategic focus is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. Each shade represents the percent of participants who ranked a strategic focus as first, second, third, fourth, or fifth most important (a darker shade indicates greater importance). We labeled all percentages corresponding to the first ranking and that were selected by at least 5% of respondents. All strategic focuses shown were selected from the list given in the question. Appendix B, Table B3 presents strategic focuses written by respondents.

the type of research), and the other wrote discovery research and translational research. This respondent defined mention that discover research involves interdisciplinary research, and translation research focuses on bringing technologies to market.

Research Focuses

In our pre-summit leadership survey, we asked respondents to rank their institutes' most important research focuses.

Applications. We presented respondents with a list of research applications and provided space for respondents to write research applications. Figure 9 presents research applications selected from the given list. Fifty-nine percent of institutes ranked infrastructure and grids among their three most important research applications, and 36% ranked climate change among their three most important research applications.

Respondents wrote research applications not provided in the given list and related to policies, markets, economics, grids, systems, renewables, and environmental impact reduction (Appendix B, Table B4). Twelve respondents wrote applications related to policies, markets, and economics. Of these respondents, six wrote applications related to policy, including energy and environmental policies, rate design, state and local polices, and utility programs. Four respondents wrote applications related to markets, including electricity markets and policies, and energy and environmental markets, and two respondents wrote applications related to economics,

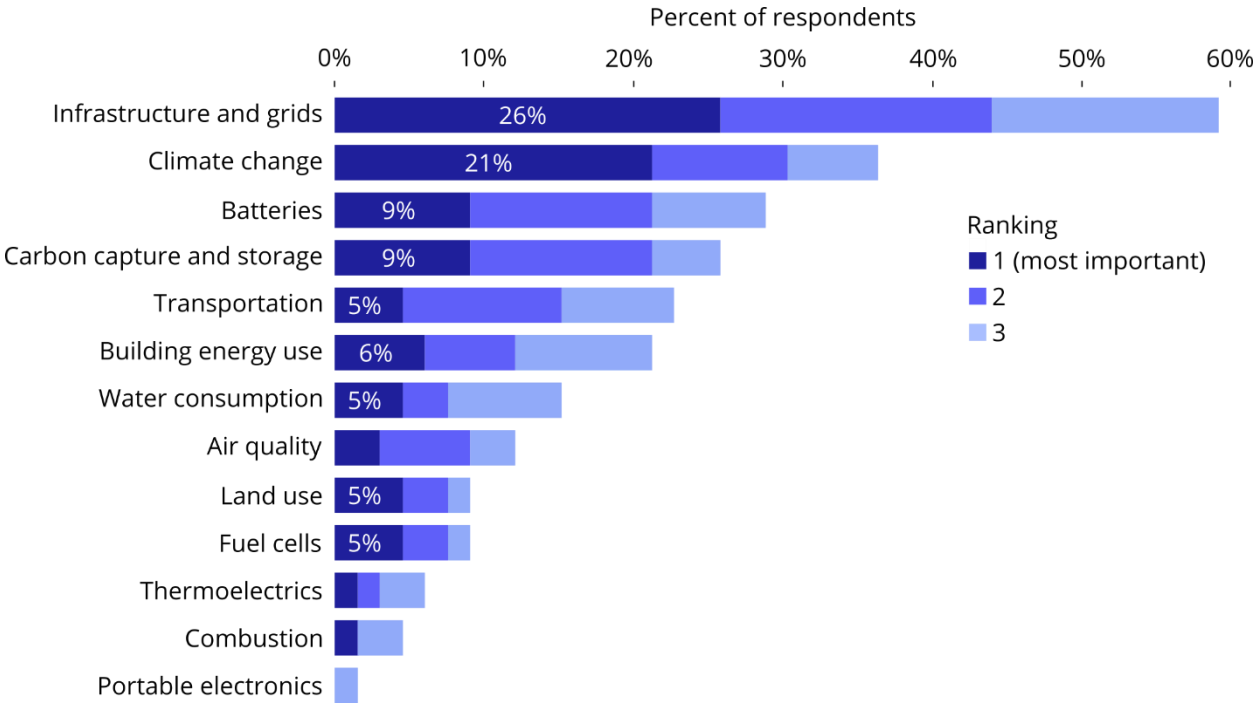

Figure 9. Applications researched by energy institutes. Twenty-six percent of institutes ranked infrastructure and grids as their most important research application, and 21% ranked climate change as their most important research application.

Research application is displayed along the vertical axis, and the percent of survey participants who selected each research application is displayed along the horizontal axis. All research applications shown were selected from the list given in the question. Appendix B, Table B4 presents research applications written by respondents.

including green growth.[71] When indicating their research applications, ten respondents wrote applications related to energy systems and the grid. These applications included distributed energy integration and valuation, energy systems integration and engineering, future energy systems, grid improvement, infrastructure and grids, and sustainable urban systems (e.g., waste, transportation, housing, and communication). Eight respondents wrote applications related to renewables, including artificial photosynthesis, bioenergy, the integration of renewables with the grid, renewable electricity, renewable fuels, solar, and wind. Four respondents wrote applications related to environmental impact reduction. Of these respondents, two wrote carbon capture and storage, one wrote greenhouse gas management, and one wrote reduction in environmental impact.

Energy sources. We presented respondents with a list of energy sources and provided space for institutes to write energy sources. Figure 10 presents energy sources selected from the given list. Sixty-seven percent of institutes ranked solar among their three most important energy sources, and 48% of institutes ranked wind among their three most important energy sources. Institutes

[71] Organisation for Economic Co-operation and Development, "What Is Green Growth and How Can It Help Deliver Sustainable Development?," OECD: Better Policies for Better Lives, accessed January 20, 2020, http://www.oecd.org/greengrowth/whatisgreengrowthandhowcanithelpdeliversustainabledevelopment.htm.

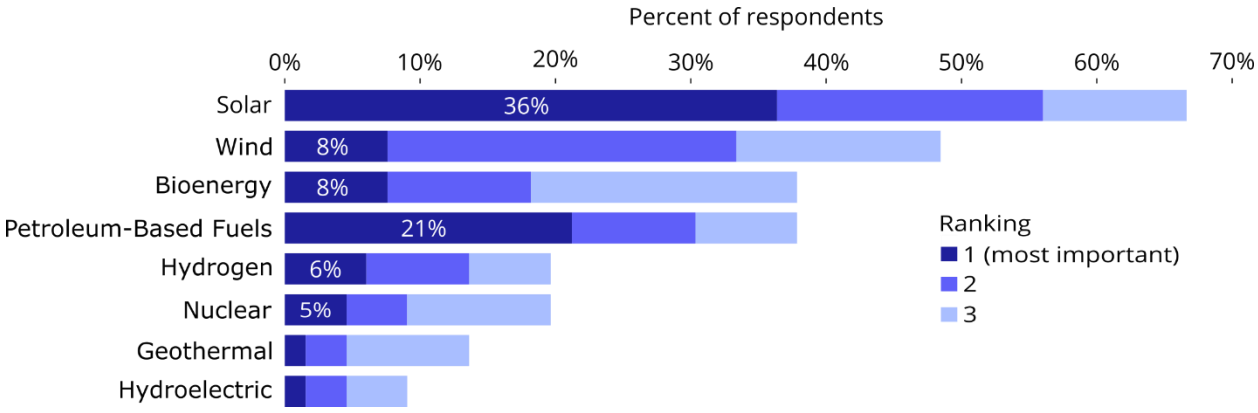

Figure 10. Energy sources researched by energy institutes. Thirty-six percent of institutes ranked solar energy as their most important energy source, and 21% percent ranked petroleum-based fuels as their most important energy source.

Energy source is displayed along the vertical axis, and the percent of survey participants who selected each energy source is displayed along the horizontal axis. All energy sources shown were selected from the list given in the question. Appendix B, Table B5 presents energy sources written by respondents.

also ranked, among their three most important energy sources and in order of decreasing frequency of selection, bioenergy, petroleum-based fuels, hydrogen, nuclear, geothermal, and hydroelectric energy.

Respondents wrote energy sources not provided in the given list and related to infrastructure, fossil fuels, solar, bioenergy, energy efficiency, and wind energy (Appendix B, Table B5). Five respondents wrote energy sources related to infrastructure. Of these respondents, one wrote energy efficient infrastructure; another wrote integration of renewables with the grid; another wrote grid integration, control, and protection; another wrote grid-scale storage; and another wrote infrastructure. Four respondents wrote sources related to natural gas and fossil fuels. Of these respondents, one wrote fossil and renewable natural gas; another wrote resource development for oil and gas production; another wrote fossil energy; and another wrote natural gas. Two respondents wrote bioenergy sources. One of these respondents wrote bioenergy and bioproducts, and the other wrote biofuels. Two respondents wrote energy efficiency, and two respondents wrote wind energy.

Research techniques. We presented respondents with a list of research techniques and provided space for institutes to write research techniques. Figure 11 presents research techniques selected from the given list. Sixty-seven percent of institutes ranked modeling and simulation among their three most important research techniques, and 55% ranked laboratory experiments among their three most important energy techniques. Institutes also identified, among their three most important research techniques and in order of decreasing frequency of selection, markets and economics, public policy, field experiments, cybersecurity, decision science, law, artificial intelligence, internet of things, and politics.

Respondents wrote research techniques not provided in the given list and related to social science and humanities, experimentation, and computation (Appendix B, Table B6). Four respondents wrote techniques related to humanities, law, policy, and social science. Of these respondents, one wrote human behavior; another wrote social sciences, policy, law, and humanities; another wrote energy policy, and the same respondent wrote human behavior. In

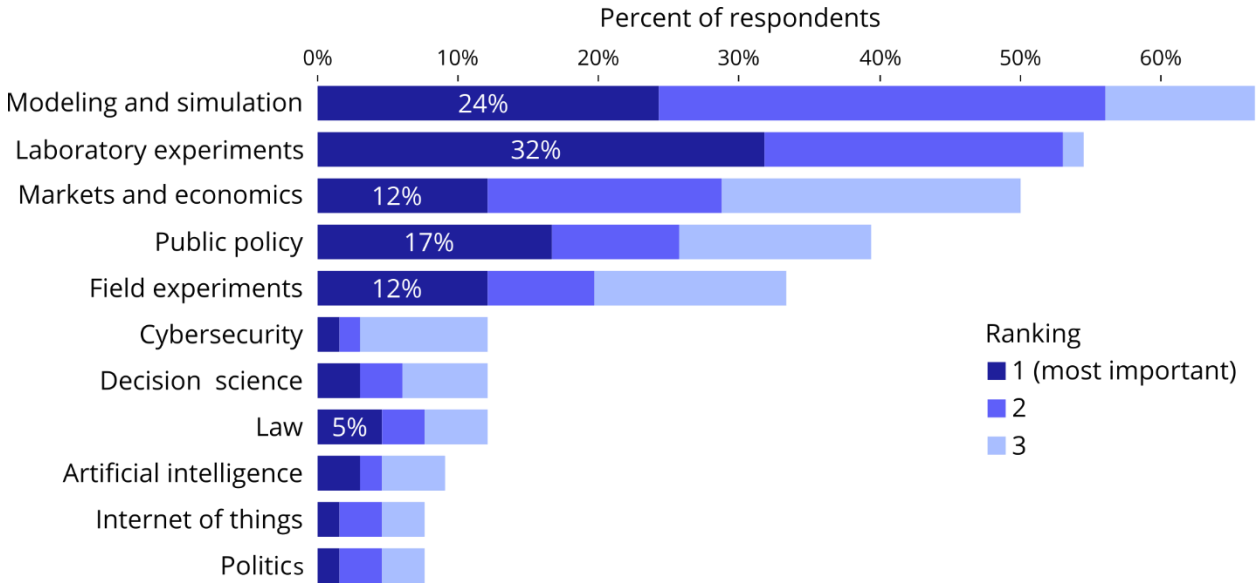

Figure 11. Research techniques used by energy institutes. Thirty-two percent of institutes ranked laboratory experiments as their most important research technique, and 24% ranked modeling and simulation as their most important energy source.

Research technique is displayed along the vertical axis, and the percent of survey participants who selected each research technique is displayed along the horizontal axis. All research techniques shown were selected from the list given in the question. Appendix B, Table B10 presents research techniques written by respondents.

addition, three respondents wrote laboratory experiments, three respondents wrote modeling or simulation, two respondents wrote artificial intelligence or machine learning, and two respondents wrote field experiments.

Interactions with Stakeholders and Energy Institutes

Of the institutes we surveyed, 94% indicated they interact with industry, 89% indicated they interact with policymakers, and 71% indicated they interact with one or more other U.S. university energy institutes.

Industry. Figure 12 presents institute interactions with industry. Fifty-eight percent of institutes ranked receiving financial support from industry among their three most frequent interactions, and half of institutes ranked communicating informally among their three most frequent interactions. Institutes also identified, among their three most frequent interactions and in order of decreasing frequency of selection, including an industry representative on their advisory board, sharing knowledge, hosting events, offering an industry membership or consortium program, sharing resources (equipment, tools, or facilities), and co-authoring papers. Four respondents wrote interactions not provided in the given list and related to formal collaborations and resource sharing. Of these respondents, one wrote collaboration on government-funded projects with industry; another wrote inviting industry professionals to attend or present at conferences and workshops; another wrote leasing laboratory and office space; and another wrote offering an industry partnership program.

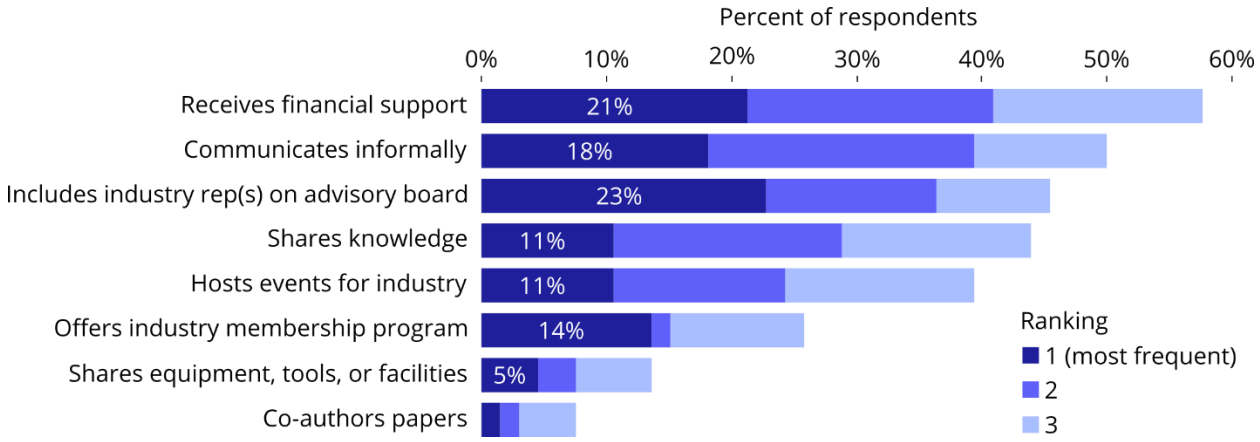

Figure 12. Energy institute interactions with industry. Twenty-three percent of institutes ranked including an industry representative on their advisory board as their most frequent interaction, and twenty-one percent ranked receiving financial support as their most frequent interaction, and

Interaction is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. In the survey, "Industry membership program" appeared as "Industry membership or consortium program." All interactions shown were selected from the list given in the question.

Policymakers. Figure 13 presents institute interactions with policymakers. Sixty-one percent of institutes ranked communicating informally with policymakers among their three most frequent interactions, and fifty-two percent of institutes ranked advising policymakers among their three most frequent interactions. Institutes also ranked, among their three most frequent interactions and in order of decreasing frequency of selection, hosting events, publishing policy-oriented literature, partnering with policy-oriented institutes at their university, including one or more policymakers on their advisory board, testifying at congressional hearings, co-authoring papers, and supporting an associate director of policy outreach. Six respondents wrote interactions not provided in the given list and related to formal collaboration, funding, and events. Of these respondents, one wrote hosting legislative briefings; another wrote participating in formal rulemakings; another wrote partnering with a specific university's policy center; another wrote performing research, writing reports, and participating in government program planning; another wrote receiving funding from policymakers; and another wrote scientifically supporting policy and engaging international policy.

Institutes. Figure 14 presents institute interactions with other U.S. university energy institutes. Forty-two percent of institutes ranked communicating informally among their three most frequent interactions, and 36% ranked co-writing funding proposals among their three most frequent interactions. Institutes also identified, among their three most frequent interactions and in order of decreasing frequency of selection, co-writing funding proposals, co-sponsoring events, participating in a regional alliance, sharing knowledge, receiving funding for co-written proposals, co-authoring papers, hosting faculty or visiting scholars, working with government through an energy institute collaboration, sharing resources (equipment, tools, or facilities), and working with industry through an energy institute collaboration. One respondent wrote an interaction not provided in the given list. This respondent indicated that their institute sits on the advisory boards of other institutes.

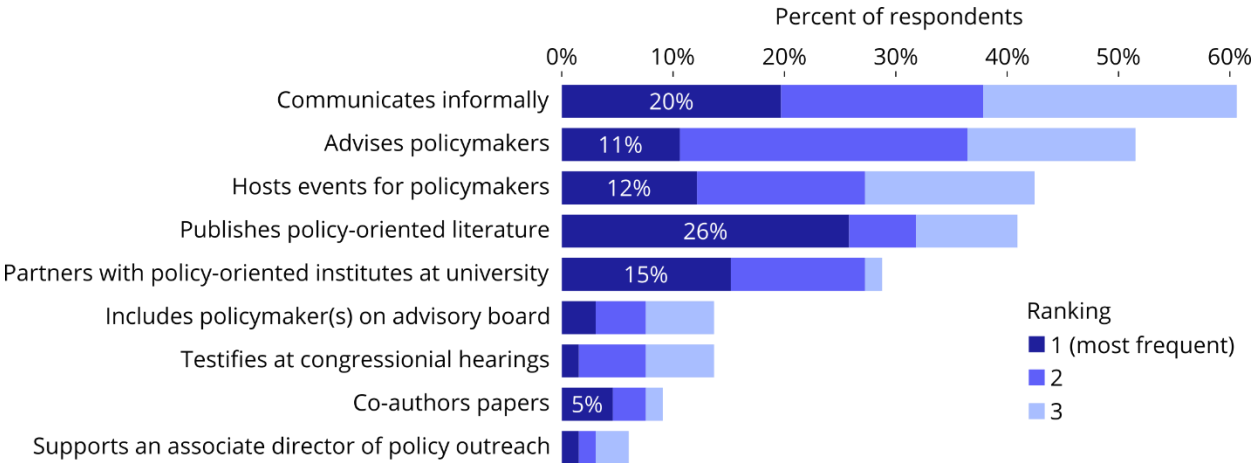

Figure 13. Energy institute interactions with policymakers. Twenty-six percent of institutes ranked publishing policy-oriented literature as their most frequent interaction, and 20% of institutes ranked communicating informally as their most frequent interaction.

Interaction is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. All interactions shown were selected from the list given in the question. EI stands for energy institute.

Potential Elements of a Network's Mission and Vision

All institutes who completed our pre-summit leadership survey indicated they would consider joining today a new network of U.S. university energy institutes in some form, such as a collaboration or partnership. At the 2019 University Energy Institute Leadership Summit,

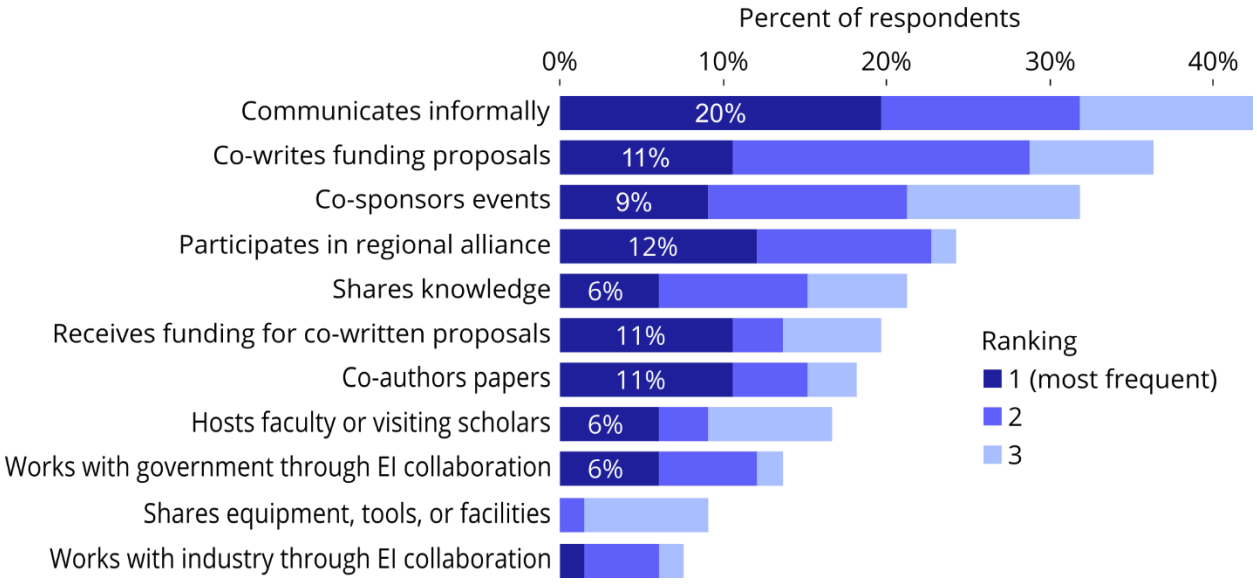

Figure 14. Energy institute interactions with other energy institutes. Twenty percent of institutes ranked communicating informally as their most frequent interaction.

Interaction is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. All interactions shown were selected from a list.

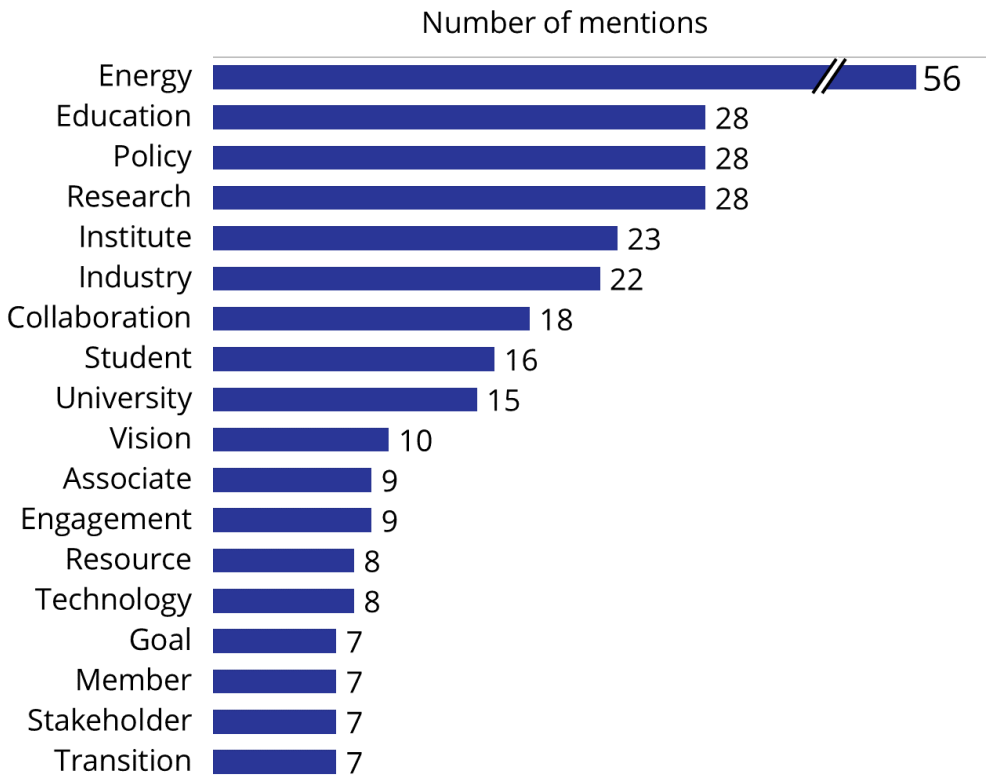

Figure 15. ***What would the mission and vision statements of a university energy institute network say? What elements, such as research focuses, policy impact, industry collaboration, technology advancement, and education, would be included?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently mentioned "energy," "education," "Policy," and "Research," Often but less frequently, participants mentioned "Institute," "Industry" "Collaboration," "Student," and "University."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than seven mentions are not shown. Appendix B, Table B7 presents categories produced by our text clustering analysis.

attendees participated in a roundtable discussion about the vision and mission statements of a potential network. We asked attendees: What would the mission and vision statements of a university energy institute network say? What elements, such as research focuses, policy impact, industry collaboration, technology advancement, and education, would be included? Using text analysis,[72] we extracted keywords from workbook responses.

As displayed in Figure 15, participants most frequently mentioned, in order of decreasing frequency, "Energy," "Education," "Policy," "Research," "Institute," and "Industry." We categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B7

[72] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.

presents category names resulting from this analysis. Below, we summarize our findings and provide several examples of responses.

Energy. In their responses, 52% of participants mentioned "Energy." The clustering algorithm grouped these responses into 10 categories. Six categories ("Advancing," "Age, Case, Scholar, Sources," "Carbon, Exists, Net-Zero," "Pillars," "Represent," and "Technology, Continue") each contained four responses, and all other responses each contained two or three responses. For example, one response, categorized under "Advancing," stated "A forum to advance energy in [an] economically positive, humanely compassionate, and environmentally responsible manner to improve life on earth and well into future." Another response, categorized under "Carbon, Exists, Net-Zero," stated in part "Provide technical support to the energy/power industry on how to transition to a net-zero carbon future. Develop knowledge, know-how on the 'energy of the future,' disseminate, educate next generation of energy students/leaders. Provide and work with external stakeholders and government entities to develop policies and programs for a net-zero carbon future." Another response categorized under "Pillars," stated in part "Interdisciplinary—Three pillars: Education-Research-Engagement—Recognizing differences/emphasis…" Another response, categorized under "Represent," stated in part "Vision: Building better conversations for better research, unlocking more funding. Mission: A non-competitive collaborative network to facilitate advancement of energy-related research and scholarship…" Yet another response, categorized under, "Technology, Continue," stated "…Connect engineering and technology research with policy and continual research…bring together strengths and focuses, influence funders, increase money for research and education…"

Education. In their responses, 38% of participants mentioned "Education." The clustering algorithm grouped these responses into eight categories: "Advocacy," "Exists," "Pillars," "Serve," "Stakeholders," "Support," "Transition, visibility," and "Versus." One of these categories, "Support," contained four responses, and all other categories each contained three responses. For example, one response, categorized under "Support," stated "Website with database: Expertise, resources/instrumentation/facilities, teaching materials, job searches—resources for other energy institutes/public/media. Education should be a priority." Another response, categorized under "Advocacy," stated in part "Education and research should be mission…industry collaboration, policy, and advancement are all secondary—advocate education and outreach, and research to enhance funding…" Another response, categorized under "Serve," stated in part "…(1) Serve as a clearinghouse for energy related institutes and education programs; (2) Advocate for increased local, regional, national, and international funding to support energy research at universities; (3) Facilitate platform for identifying research collaboration opportunities or initiatives; (4) Serving as a resource for students; (5) Talent clearinghouse for hiring future faculty; (6) Share best practices." Yet another response, categorized under "Transition, Visibility" stated in part "…Advancing efforts to renovate and improve the capacity of energy education and research, its organization in universities, and its impact in the world. Advancing the visibility and importance of energy work at universities."

Policy. In their responses, 38% of participants mentioned "Policy." The clustering algorithm grouped these responses into eight categories: "Average, Reach," "Case," "Focus," "Network," "Outreach," "Represent," "Serve, Sources," and "Versus." One of these categories, "Network," contained four responses, and all other categories each contained three responses. For example, one response, categorized under "Network," stated "Mission: A network of university-based interdisciplinary energy scholars; network will collectively advance energy research, education, and engagement for government leaders, policymakers, industry, students, and the general public in the age of energy transition. Vision: The energy institute network will assemble a network of energy scholar networks to address the challenges of the age of energy transition." Another

response, categorized under "Case," stated "Universities have education and research as a core. These seem to be important things to include. Industry collaboration, technology advancement, and policy are more of a case-by-case basis, depending on the nature of the institute. Perhaps there would be an umbrella network but then a few more policy focused [networks] around energy institute areas within that." Yet another response, categorized under "Serve, Sources," stated "Collaboration with industry [is] important; collaboration among energy institutes; lead transition from previous set of energy sources and policies to the new set of sources and policies."

Research. In their responses, 42% of participants mentioned "Research" in their responses. The clustering algorithm grouped these responses into eight categories. Four categories ("Case, Group," "Faculty," "Serve, Influence," and "Transition") each contained four responses, and four categories ("Federal," "Represent," "Table," and "Versus") each contained three responses. For example, one response, categorized under "Faculty," stated in part "Mission: Connect, collaborate among members, disseminate information/research…" Another response, categorized under "Transition," stated "[The mission and vision statements] would contain (not in any order): (1) Education—informal (i.e., student training on projects), (2) Outreach/engagement, (3) Research." Yet another response, categorized under "Versus," stated "Can [a] network speak with singular voice? Or, is it just an interface with broadest expertise, versus approach by 'information with an agenda?'"

In addition to the keywords described above, 32% of responses mentioned "Institute," and 30% mentioned "Industry." Responses that mentioned "Institute" were categorized into eight categories, which were "Age, Building, Capacity, Scholar," "Case," "Global," "Resources," "Serve," "Set, Sources," "Stakeholders," and "Versus." Finally, responses that mentioned "Industry" were categorized into eight categories, which were "Age, Benefit, Scholar," "Broad, Come, Community, Connect, Governmental, High, Participation, Place, Science, Vehicle," "Future," "Individual," "Influence," "Serve," "Students," and "Visibility." Appendix B, Table B7 lists all category names.

Conclusions

Energy institutes share similar goals and strategic focuses. In their mission statements, institutes frequently mentioned environment, policy, technology, and science. Institutes whom we surveyed indicated identified among their most important strategic focuses interdisciplinary or multidisciplinary research, especially on infrastructure, grids, solar energy, and wind energy, and educating and training students. Nearly all institutes indicated they interact with stakeholders, including industry, policymakers, and other institutes.

Institutes differed in their specific goals, staff roles, and types of collaboration. Within energy, research, and environment, institute mission statements mentioned climate, resilience, cost, law, power, sustainability, and resources, among other areas. Many institutes employed specialized staff roles, such as a research operations and industry outreach staff. In terms of research areas, institutes focused on climate change, hydroelectric energy, hydrogen, infrastructure and grids, geothermal energy, renewables, petroleum-based fuels, and nuclear energy. Institutes interacted with stakeholders through many means, including advising policymakers, co-writing funding proposals, hosting events, publishing literature, and sharing knowledge.

The mission and vision statements of a hypothetical network could capture a range of interests while maintaining clear and concise objectives. Summit attendees suggested mission

and vision statements focus on education, policy, and research. Attendees also suggested a network focus on advancing technology, collaborating with industry, developing an energy talent clearinghouse, increasing energy research funding, transitioning to a net-zero carbon energy system, and sharing best practices among institutes.

Chapter 3

Energy Education

The Role of Energy Institutes in Higher Education

Summary

This chapter describes energy-focused educational opportunities offered by universities and explores a potential network's role in higher education. Universities indicated they offer energy educational programs spanning a range of disciplines and topics, including science, engineering, law, policy, renewables, resources, systems, and technology. When asked how professional mentoring and internships could be blended and supported in energy education initiatives, summit attendees suggested internships, mentoring, student exchanges, and student organizations. Attendees also suggested an energy-related, educational "common core" could include economics, business, policy, and law courses and that institutes could share course materials through a repository.

Energy Education Programs

In our pre-summit leadership survey, we asked respondents: What energy-focused education programs does your university offer? To supplement the responses we received, we reviewed the websites of the 62 universities whose energy institutes participated in our survey. Figure 16 presents the proportion of universities who, according to our survey and online review, offered energy-focused degree or certificate programs. Sixty-nine percent of universities offered one or more energy-focused master's degrees. Appendix B, Table B8 lists these degrees. We identified 78 energy-focused master's degrees spread across 43 universities. Five degrees were offered by energy institutes; all other degrees were offered by schools or departments. The institutes who offered degrees are: Northwestern University's Institute for Sustainability and Energy,[73] Texas A&M University's Energy Institute,[74] University of California, Berkeley's Energy and Resources Group,[75] and University of California, Davis' Energy and Efficiency Institute.[76]

As indicated by their names, the master's degrees spanned a range of topics and disciplines. The most frequently used words in degree names are as follows: Fifty-one percent of degree names included "Science," 38% included "Engineering," 33% included "Environment," 19% included "Systems," 13% included "Management," 10% included "Business," 10% included "Law" or "Legal," and 10% included "Sustainability."[77]

[73] Northwestern University, "MSES – Program Overview," Northwestern: Institute for Sustainability and Energy, accessed January 1, 2020, https://isen.northwestern.edu/mses-program-overview.
[74] Texas A&M University, "Master of Science in Energy," Texas A&M University: Texas A&M Energy Institute, accessed December 30, 2019, https://energy.tamu.edu/education/master-of-science-in-energy/.
[75] University of California - Berkeley, "Programs."
[76] University of California - Davis, "Apply to the Energy Graduate Group," UC Davis: Energy and Efficiency Institute, accessed January 1, 2020, https://energy.ucdavis.edu/education/energy-graduate-group/apply-to-the-energy-graduate-group/.
[77] In our analysis of degree, major, minor, and certificate names, we allowed variations of words, such as Sustainable/Sustainability and Environment/Environmental. We excluded Energy.

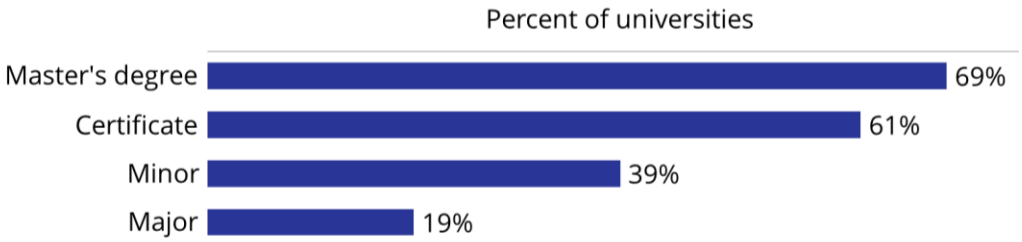

Figure 16. Energy-focused degree programs offered by energy institutes. Sixty-nine percent of institutes indicated that their university offers a master's degree program, and 61% indicated that their university offers a certificate program.

Program type (Master's degree, certificate, undergraduate minor, or undergraduate major) is displayed along the vertical axis, and the percent of universities is displayed along horizontal axis. In our compilation of energy-focused education programs, we considered only the 62 universities whose institutes participated in our pre-summit leadership survey. Appendix B, Tables B8, B9, B10, and B11 lists the names of energy-focused master's degrees, certificates, minors, and majors, respectively.

Sixty-one percent of universities offered one or more energy-focused certificates (Figure 16). We identified 53 energy-focused certificates spread across 35 universities. Appendix B, Table B9 lists these certificates. Thirteen certificates were offered by energy institutes; all other certificates were offed by schools or departments. Fifty-seven percent of certificates were offered at the graduate level, 26% offered at the undergraduate level, 15% offered professionally, and 1% did not specify a level. The most frequently used words in certificate names are as follows: Seventeen percent of certificate names included "Sustainability," 15% included "Renewable," 11% included "Engineering," 9% included "Management," 9% included "Policy," 9% included "Technology," 8% included "Environment," 8% included "Law," 6% included "Clean," 6% included "Assessment," and 6% included "Systems."

Thirty-nine percent of universities offered one or more energy-focused minors (Figure 16). We identified 32 energy-focused minors spread across 23 universities. Appendix B, Table B10 lists these minors. Seven minors were offered by energy institutes; all other minors were offed by schools or departments. The most frequently used words in minor names are as follows: Twenty-eight percent of minor names included "Sustainability," 25% included "Engineering," 13% included "Environment," 9% included "Studies," 6% included "Policy," 6% included "Science," 6% included "Technology," 6% included "Resource," 6% included "Systems," and 6% included "Water."

Nineteen percent of universities offered one or more energy-focused majors (Figure 16). We identified 18 energy-focused majors spread across 12 universities. Appendix B, Table B11 lists these majors. All majors were offed by schools or departments; no majors were offered by energy institutes. The most frequently used words in major names are as follows: Thirty-nine percent included "Engineering," 22% included "Management," 22% included "Resource" or "Resources," 17% included "Environment," 11% included "Policy," 11% included "Systems," and 6% included "Land."

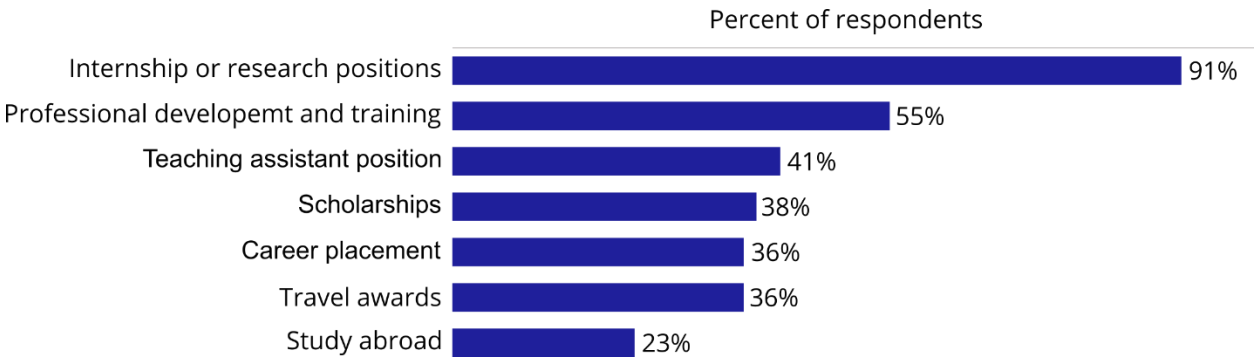

Figure 17. Professional development opportunities offered by energy institutes and for students. Nearly all institutes offered internship or research positions. Slightly over half of institutes provided professional development and training opportunities.

Professional development opportunity is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. The opportunities shown were selected from the list given in the question. Appendix B, Table B12 presents professional development opportunities written by respondents.

Professional Development Opportunities

In our pre-summit leadership survey, we asked respondents: What professional opportunities does your energy institute offer students? We provided respondents with a list of opportunities and asked respondents to select all opportunities offered by their institute. We also provided space for respondents to write professional development opportunities. Figure 17 presents professional development opportunities selected from the given list. Ninety-one percent of institutes offered internship or research positions. Institutes also offered, in order of decreasing frequency of selection, professional development and training opportunities, teaching assistant positions, scholarships, career placement, travel awards, and study abroad opportunities.

Institutes wrote professional development opportunities not provided in the given list and related to research, extracurricular activities, leadership, and grants (Appendix B, Table B12). Four respondents wrote opportunities related to research. Of these respondents, one wrote being a top-tier research university; another wrote research fellowships; another wrote research support for energy business faculty; and another wrote support for research projects. Two respondents wrote opportunities related to competitions. One of these respondents wrote business-related, hackathon, and poster competitions, and the other wrote energy competitions. Two respondents wrote leadership opportunities. Both respondents specified leadership opportunities offered during their university's Energy Week. Two respondents wrote opportunities related to seed or small grants. One of these respondents wrote seed grants, and the other wrote mini grants.

Blending Professional Development with Education

At the 2019 University Energy Institute Summit, we asked attendees: How should professional mentoring and internships be blended and supported in energy education initiatives? Using text analysis software,[78] we extracted keywords from participants' responses. As displayed

[78] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.

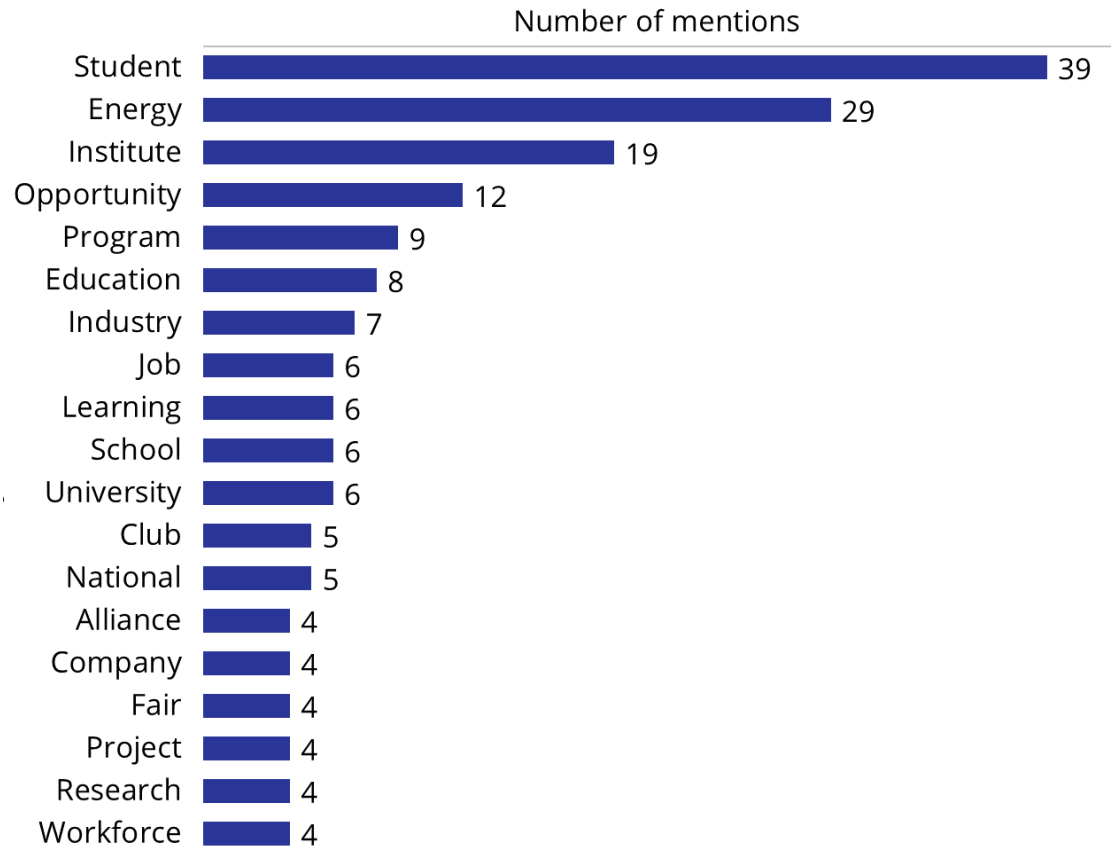

Figure 18. ***How should professional mentoring and internships be blended and supported in energy education initiatives?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently "Student," "Energy," and "Institute." Often but less frequently, participants mentioned "Opportunity," "Program," "Education," and "Industry."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than four mentions are not shown. Appendix B, Table B13 presents categories produced by our text clustering analysis.

in Figure 18, participants most frequently mentioned, in order of decreasing frequency, "Student," "Energy," "Institute," "Opportunity," "Program," "Education," and "Industry." We categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B13 presents category names resulting from this analysis. Below, we summarize our findings and provide several examples of responses.

Student. In their responses, 50% of participants mentioned "Student." The clustering algorithm grouped these responses into 10 categories. Five of these categories ("Advising, Match, Partnerships, Recruiting, Studies," "Events," "Facilitate, Renewable," "Offer," and "Share") each contained four responses, and the other five categories ("College, Community, Dicey, Path," "Exchanges," "Industry," "Award," and "PostDoc") each contained three or fewer responses. For example, one response, categorized under "Advising, Match, Partnerships,

Recruiting, Studies," stated in part "A capstone project is a good part of an energy studies program and this can build on an internship. There needs to be advising/mentoring to identify and match up students with internships." Another response, categorized under "Events," stated in part "…Solutions are very specific to each school. Perhaps regional events. Larger events with students from different schools. Develop best practice guidance." Another response, categorized under "Facilitate, Renewable," stated "The network could play a really important role in facilitating mentoring and internships for students. As the network matures and can bring in funding, then perhaps a program run by the network offering fellowships to facilitate getting students broader experience would be attractive." Another response, categorized under "Offer," stated "Would be nice to offer more cross-pollinating between institutes, offer opportunities for summer research 'sabbaticals'—same for student internships at a different institute, especially for graduate students. The opportunity for exchanges could really help spur more collaborative research." Yet another response, categorized under "Share," stated "Would make sense to have the institute serve as a clearinghouse for internships and co-ops: A network of organizations that have problems they would like solved and can be tackled by students at different stages of education."

Energy. In their responses, 38% of participants mentioned "Energy." The clustering algorithm grouped these responses into eight categories. Two of these categories ("Industry" and "Institute") each contained four responses, five categories ("Area," "Award," "Exchange, Shared," "Experiential," and "Incorporate, Possible") each contained three responses, and one category ("Job") contained two responses. For example, one response, categorized under "Industry," stated in part "Within our institute, we run a capstone (project-based) course…We team student groups directly with corporations that are navigating a changing energy sector and that are looking to solve a core challenge with their business model. The student projects are thus real, have tangible effect, are grounded, and provide industry connections for students." Another response, categorized under "Institute," stated "Institutes should pay attention to their university's energy club(s). These groups are critical for connecting students to each other across disciplines and to alumni. The institute can serve as an informal home and support structure for the club, reduce volatility from student turnover by hosting resources and providing continuity." Another response, categorized under "Award," stated in part "…Another idea discussed was having an energy leadership award. Students would apply, winners would be rotated through various internships/field trips. These students get extra exposure to the complexity and interconnect nature of energy, as well as prestige from the award. This better prepares our future leaders." Another response, categorized under "Experiential," stated "Experiential learning in energy a must. Internships/alliance with technical schools." Yet another response, categorized under "Incorporate, Possible" stated in part "…Co-ops and internships at energy-related companies. Visiting positions at energy institutes when possible. This will be highly institution dependent. Some institutions can incorporate internships into graduate education, some cannot."

Institute. In their responses, 18% of participants mentioned "Institute." The clustering algorithm grouped these responses into four categories. Three of these categories ("Education," "Incorporate, Part, Possible, Research," "Job," and "Directly") each contained three responses, and one of these categories ("Directly") contained two responses. For example, one response, categorized under "Education," stated "A breadth of opportunities—co-ops, student exchange, and faculty and staff exchanges between institutes would be a very welcome approach." Another response, categorized under "Incorporate, Part, Possible, Research," stated in part "Internship[s] [are a] very important part of education, and hence, it should be part of education of some students and energy institute network to build the bridge with industry and even national labs…" Another response, categorized under "Job," stated "…Advertise jobs/internships in newsletters.

Share job sites across institutes in this network. Collaboration with student exchanges and sabbatical opportunities for faculty—engage all alumni in energy." Yet another response, categorized under "Directly," stated "This is very important. Depending on how the institute is structured, the institute could offer internships or conduit for internships. The industrial advisory board of the institute could be engaged to provide internships and mentoring. A summer institute offered in energy for students. The network could be a clearinghouse for programs."

In addition to the keywords described above, 12% of responses mentioned "Opportunity," 18% mentioned "Program," 11% mentioned "Education," and 8% mentioned "Industry." Responses that mentioned "Opportunity" were grouped into two categories, which were "Campus, Job, Offer, Research" and "Certificate, Major, Minor." Responses that mentioned "Program" were grouped into four categories, which were "Facilitate," "Institute," "National," and "School, Support." Responses that mentioned "Education" were grouped into two categories, which were "Area, College, Community, Dicey, Mentor, Part, Path, Professional," and "Incorporate, Possible." Finally, responses that mentioned "Industry" were grouped into two categories, which were "Career, Education, Fair, Part, Renewable," and "Directly, Projects, Reality." Appendix B, Table B13 lists all category names.

Should a Network offer its own Courses?

At the summit, we asked attendees: Should a network offer its own courses? If so, what would be the course format (online, in-person, other)? Who should teach the courses? How could teaching be shared among energy institutes? Using text analysis software,[79] we performed a sentiment analysis, which gauged respondents' attitudes. The software tagged 60% of participants' responses as positive or strongly positive, 10% as negative or strongly negative, 16% as without sentiment, and 4% as neutral (nine percent of participants did not respond to this question). We note, however, that many positive or strongly positive responses do not explicitly support the notion of a network but instead suggest alternative roles that a network could play in higher education.

Positive or strongly positive responses. We manually categorized responses tagged as positive or strongly positive under the following headings: (i) Yes, a network should offer courses (ii) No, a network shouldn't offer courses but could still play a role in higher education, (iii) Individual energy institutes (not necessarily a network) could play a role in education, (iv) No response as to whether a network should offer courses; network could assist in course development, and (v) It depends. Appendix B, Table B14 presents these headings and the responses falling thereunder. We categorized eleven responses under (i) Yes, a network should offer courses. The individuals who wrote these responses suggested offering access to courses at other universities, continuing education courses, a joint certificate, an introductory energy course, massive open online courses, a repository of course resources, technoeconomic and life cycle analysis courses, and workshop courses on, for example, business models and proposal writing.

Eleven respondents indicated (ii) No, a network shouldn't offer courses but could still play a role in higher education. These respondents specified a network's possible roles, including creating a repository of course materials, developing curricula, hosting visiting lecturers. offering continuing and professional education courses, offering courses to the public, offering online lectures and webinars, and supporting faculty, including faculty visits.

[79] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.

Eight respondents indicated (iii) Individual energy institutes (not necessarily a network) could play a role in education. Respondents suggested that energy institutes could develop curricula, facilitate courses taught through colleges, help universities recruit students, organize field trips, share course resources, and teach a course that has a common core component.

Seven respondents indicated (iv) No response as to whether a network should offer courses; network could assist in course development. These respondents suggested that a network could create a repository of course resources and energy topics, develop energy curricula, facilitate the sharing of course resources, offer a free online introductory course for the general public, offer webinars, and provide access to available online courses.

We categorized two participants' responses under (v) It depends. One of these respondents explained that whether a network should offer courses depends on the course content, and the other explained that whether a network should offer courses depends on the extent to which institute focuses coincide.

Negative or strongly negative responses. Seven responses were tagged as negative or strongly negative (Appendix B, Table B15). One of these respondents suggested that a network offer webinars and graduate courses but recommended that a network not try to reinvent the wheel. Another respondent suggested that a network not offer courses because funding models (e.g., student credit hours) differ across universities. Another respondent suggested that a network not offer courses because universities are different. This respondent did not elaborate further. Finally another respondent suggested that a network not offer courses, stating in part "…For that matter, even institutes don't necessarily offer energy courses. That's in the sphere of departments and schools, typically. There could be some role, but the gap/needs will need to be carefully identified."

Possible Common Core for Energy

At the summit, we asked attendees: What energy-related skills should be covered by higher education? Should there be a "common core" of energy-related courses, topics, and skills? If so, what should be the common core? We extracted keywords from participants' responses. As displayed in Figure 19, participants most frequently mentioned, in order of decreasing frequency, "Energy," "Course," "Student," "Policy," "System," "Environment," "Science," and "Technology." We categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B16 presents category name resulting from this analysis. Below, we summarize our findings and provide several examples of responses.

Energy. In their responses, 82% of participants mentioned "Energy." The clustering algorithm grouped these responses into 16 categories. Six of these categories ("C1," "Depth," "Future," "Knowledge," "Law," and "Training") each contained four responses, and all other responses each contained three responses. For example, one response, categorized under "Depth," stated in part "…Basic energy footprint—energy systems, energy supply chain, and society required infrastructure—how it works." Another response, categorized under "Future," stated "Energy transition management for society: Different cores for future professionals, future engineers, future citizens, [and] different pathways in and through. Engage first-year students in climate solutions! Business-as-usual is not enough in energy education. Skills in being an agent of change: Soft skills, project management." Another response, categorized under "Knowledge," stated "The business of energy and hardcore energy sources are important. Economics: Understanding how energy is traded; social justice/ethics." Another response, categorized under "Law," stated "Energy: Technical, policy, business, law, social science—Freshman 101— Soft

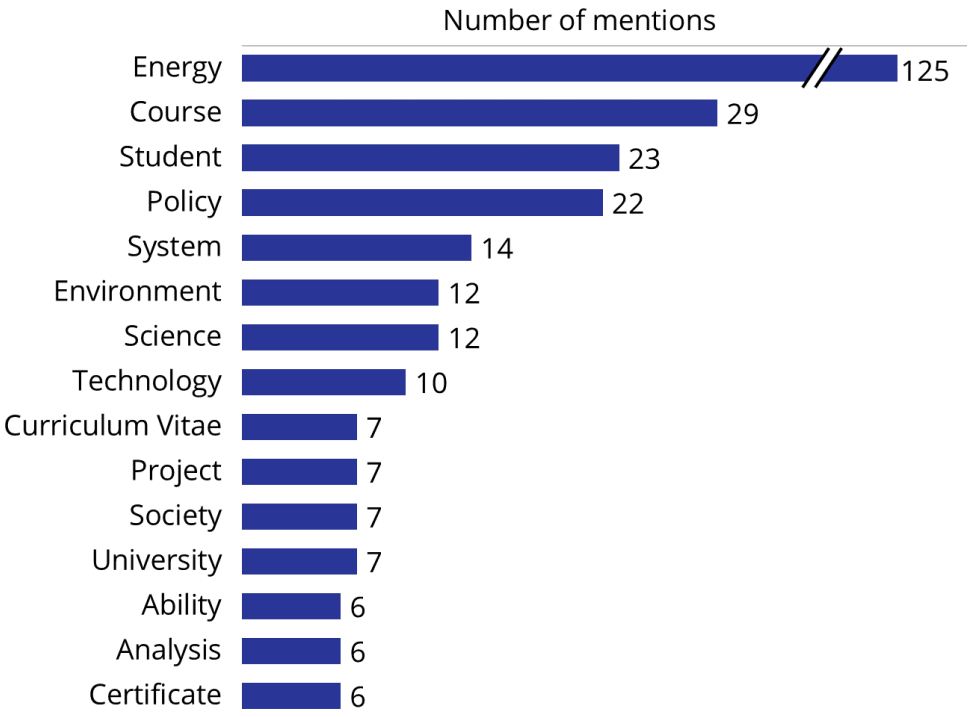

Figure 19. ***What energy-related skills should be covered by higher education? Should there be a "common core" of energy-related courses, topics, and skills? If so, what should be the common core?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently mentioned "Energy," "Course," "Student," and "Policy." Often but less frequently, participants mentioned "System," "Environment, "Science," and "Technology."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than six mentions are not shown. Appendix B, Table B16 presents categories produced by our text clustering analysis.

skills: Communication, collaboration, project management." Yet another response, categorized under "Training," stated "Energy economics training should have a formal introduction to electrical engineering. Energy engineering should include a formal introduction to energy/policy. 'Energy cross training!'"

Course(s). In their responses, 44% of participants mentioned "Course." The clustering algorithm grouped these responses into eight categories. Five of these categories ("Classes," "Context," "Coursework, Study," "Engineering" and "Universities,") each contained four responses, and the other three categories ("Analysis," "Climate," and "Create, Innovation, Team") each contained three responses. For example, one response, categorized under "Classes," stated in part "The core wouldn't need to state specific classes, but rather, types of classes that capture the interdisciplinary nature of energy. For example, a number of energy technology classes, a number of energy policy classes, etc. The core should have at least one course that handles the interaction of some of the broad categories related to energy. For example, water-energy course or energy-health course. The core should include experiential learning (internship, co-op,

etc.)…" Another response, categorized under "Context," stated "(1) Techno, policy, politics, social, economics. (2) Menu of options: Minors or certificate programs. (3) Energy literacy: Apply to common understanding—current system of energy. (4) What's the value of energy (economics, markets) and information scope." Another response, categorized under "Coursework, Study," stated "Energy studies should include quantitative study and science as well as policy, economics, and sustainability coursework. (1) Gateway course: Energy and climate, (2) Capstone project, (3) Coursework across all aspects of energy." Another response, categorized under "Engineering," stated "Energy literacy: BTUs, Barrels, etc. Speak the units. Energy 101 seminars. Energy system approach. Energy content in existing courses." Yet another response, categorized under "Universities," stated "Undergraduate: Common core course, yes. Graduate: Not relevant at expert level."

Student. In their responses, 23% of participants mentioned "Student." The clustering algorithm grouped these responses into four categories. Three categories ("Colleges, Community, Content, Context, Incorporate, Offer, Single, Work," "Diagram, Different," and "Principles") each contained four responses, and one category ("Leaders") contained one response. Here, we provide several examples. For example, one response, categorized under "Colleges, Community, Content, Context, Incorporate, Offer, Single, Work," stated "Should ensure all students have access, including junior college and community colleges, and it's not just for engineering or STEM students. One possible implementation is to have energy as a general education requirement for all students. Broad enough to be interesting and accessible by all. Should have an international view. Maybe required freshman class. Topics to include: Teamwork, societal, and community impacts, projects and management, economics and business, policy, maybe part of a summer reading program?" Another response, categorized under "Diagram, Different," stated "Understanding the energy flow 'survey diagram' is very important and basic for energy literacy, and students should understand how the survey diagram has changed over the past 50 years and how it must look in 2050. [It's] also important for students to understand the scale and longevity of energy projects (e.g., power plants, transmission lines, etc.). There is an infrastructure aspect to energy that students should know." Another response, categorized under "Principles," stated "Common core is right idea (more than one): (1) For energy engineering students, (2) For broader student population (awareness, citizens)." Yet another response, categorized under "Leaders," stated "Experiential learning course that will give students an exposure to [a] wide array of energy sector issues (e.g., fields trips to power plants). Energy core components: Technology courses, policy courses."

Policy. In their responses, 32% of participants mentioned "Policy." The clustering algorithm grouped these responses into eight categories. Five of these categories ("Basic," "Classes," "Colleges, Community, Single," "Depth," and "Training") each contained three responses, and three categories ("Coursework, Create, Study," "Environment," and "Universities") each contained two responses. Here, we provide several examples. For example, one response, categorized under "Basic," stated in part "Yes to a common core program, one that provides the basics of energy and challenges in the different fields: Engineering, science, policy, environmental, and law. This would allow for a common language and an awareness early on about challenges in adjacent spaces…" Another response, categorized under "Classes," stated "Difficult to define to get broad acceptance. Some specific topics discussed: Lifecycle assessment, technoeconomic skills, energy systems, possibly policy side." Another respondent, categorized under "Colleges, Community, Single" stated in part "…Energy literacy: Diversity of background, upper level undergraduate, types/resources of energy, living standards versus energy, technology and social (economics, policy)." Another response, categorized under "Depth," stated in part "Value of energy—innovation, economics, markets, advancement of

society, policy (international), sustainable energy. General Education requirement." Yet another response, categorized under "Training," stated "Energy fuels and resources; energy conversion and technologies; energy and environment; energy policy, law, and regulation; energy consumption and demand; modeling and prediction; energy communications; society, energy, justice; geopolitics."

In addition to the keywords described above, 20% of responses mentioned "System," 17% mentioned "Environment," 14% mentioned "Science," and 14% mentioned "Technology." Responses that mentioned "System" were grouped into four categories, which were "Decision, Topics," "Innovation, Team," "Policy," and "Work." Responses that mentioned "Environment," were grouped into four categories, which were "Analysis, Areas," "C1," "Degree," and "Knowledge." Responses that mentioned "Science" were grouped into three categories, which were "Advanced," "Areas, Coursework, Focus, Issues, Offer, Single, Specific, Study," and "Challenges, Common, Environment, Law." Finally, responses that mentioned "Technology" were grouped into three categories, which were "Analysis, Areas," "Classes," and "Degree." Appendix B, Table B16 lists all category names.

Conclusions

To address the world's energy-related challenges, energy-focused education and training programs are evolving. Most universities whom we surveyed offered energy-focused degrees or certificates. These programs spanned business, engineering, management, science, systems, law, and sustainability. In addition, most institutes offered professional opportunities for student growth and development. Institutes offered student internship and research positions, career placement, grant writing workshops, professional development and training, teaching assistant positions, and scholarships.

A common core in higher energy education could comprise a range of topics, including business, economics, engineering, law, policy, and the social sciences, as well as a range of skills, including collaboration, communication, and project management. Summit attendees suggested a network could help develop energy courses by creating a repository of course notes, syllabi, and slides. Also, summit attendees suggested that professional mentoring and internships could be blended and supported in energy education initiatives by facilitating capstone courses, granting student awards, supporting student energy organizations, and offering fellowships, student exchanges, and a repository of job and internship openings. Attendees also suggested that advisors and mentors could help match students with job and research opportunities.

Chapter 4

Institute Expectations of a Network

Benefits, Challenges, and Possible Organizational Structures for Collaboration

Summary

What should collaboration look like among energy institutes? This chapter presents institute expectations of a future, hypothetical network. Institutes desired that a network, if formed, facilitate communication and collaboration among institutes, grow energy research funding nation-wide, and engage stakeholders, especially policymakers. Most institutes identified more research funding and bigger impact on national policy as the most important benefits they would want to receive from a network but identified differing interests and goals and lack of funding as potential challenges that their institute could encounter in joining a network. Institutes recommended funding a network through membership dues, foundations, government support, and industry support. In terms of governance and administrative structures for a potential network, institutes recommended initially appointing an advisory board and hiring one or two staff members.

Products of a Network

At the 2019 University Energy Institute Leadership Summit, we asked attendees: What is the intended joint product of a network? How would responsibilities be assigned and shared among energy institutes? Or, is the network a facilitator without a role in a specific project? As displayed in Figure 20, participants most frequently mentioned "Institute," "Research," "Energy," "Member," "Product, "Industry," and "Policy." Using text analysis software,[80] we categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B17 presents category names resulting from this analysis. Below, we summarize our findings and provide several examples of responses.

Institute. In their responses, 33% of participants mentioned "Institute." The clustering algorithm grouped these responses into eight categories. Six of these categories ("Curriculum," "Energy," "Identity, Public," "Impact," "Year," and "1st, AAU, Activities, CHARACTERISTICS, Constellations, DATA-SHARING, Happen, Industry-institutes, Internships, Link, Magic, MAKERS, Solutions, Sustainability, Syllabi, Talent, Technical, Transparent, White") each contained three responses, and the other two categories ("Small" and "Think") each contained two responses. For example, one response, categorized under "Curriculum," stated "Website with clearinghouse information on research and education capacities of respective institutes, including potential shared resources, such as curricula. Conferences with student presentations on research, opportunities for job and career fair, and graduate group recruiting." Another response, categorized under "Energy," stated in part "Federal: Grow overall energy research funding. Local/regional: Help energy institutes in advocating for importance of energy

[80] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.

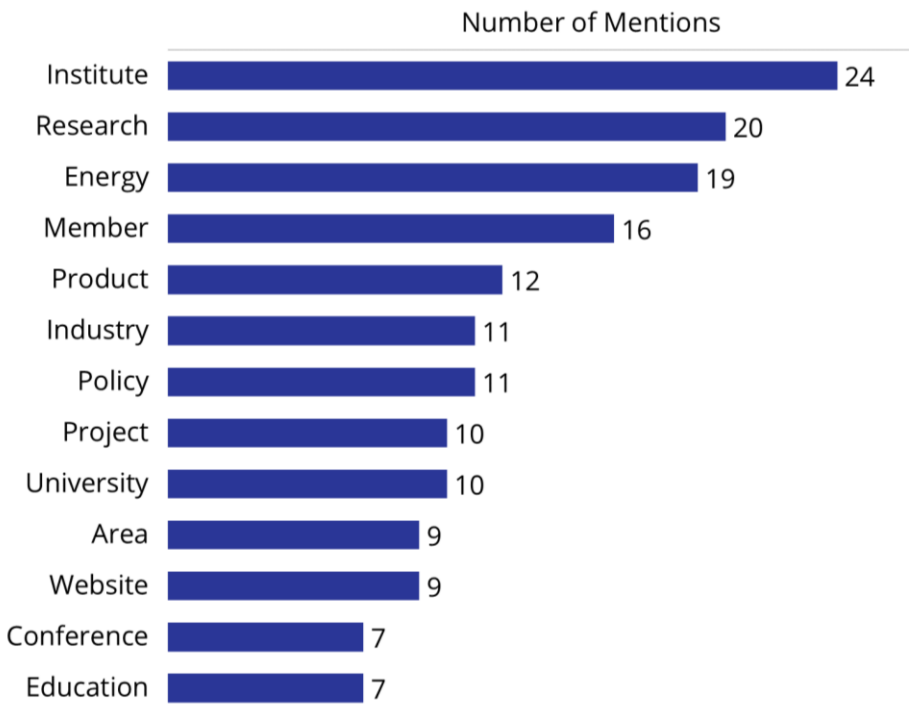

Figure 20. ***What is the intended joint product of a network? How would responsibilities be assigned and shared among institutes? Or, is the network a facilitator without a role in a specific project?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently mentioned "Institute," "Research," "Energy," and "Member." Often but less frequently, participants mentioned "Product," "Industry," and "Policy."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than seven mentions are not shown. Appendix B, Table B16 presents categories produced by our text clustering analysis.

challenges. Industry: Workforce development; certified professional. Members: Share the information—best practices, webinars, educational content. Investors: Due diligence on IP/technology-to-market? Or, translational R&D facilitating teams for them…" Another response, categorized under "Identity, Public" stated in part "…Documentation of identified needs (updated annually or bi-annually) could be a useful product from the network. Establish rigorous, vetting process for products." Another response, categorized under "Impact," stated "(1) Tools to increase collective impact: Common impact criteria, gaps analysis, data on institute areas of expertise to enable communication. (2) Sharing to enable increased individual impact: Best practices in institutes, collaborating on projects, voice to policy members, funders, etc. Moonshot: Combine discretionary funds to common major project." Another response, categorized under "Year," stated in part "…Tackle big energy challenges—joint initiative once we have priority areas and more network tools (database?)—more than one meeting per year (rotate locations among member institutes)." Yet another response, categorized under "1st, AAU, Activities, CHARACTERISTICS, Constellations, DATA-SHARING, Happen, Industry-institutes, Internships, Link, Magic, MAKERS, Solutions, Sustainability, Syllabi, Talent,

Technical, Transparent, White," stated in part "Need steering committee first. First is database/website—community building—link to all institutes' websites—make our activities more transparent—and annual meeting? Share data, information, expertise areas, internships, clearinghouse (?), best practices, jobs, white papers, syllabi…conference."

Research. In their responses, 24% of participants mentioned "Research." The clustering algorithm grouped these responses into four categories ("Human, Infrastructure," "Impactful," "Limited," and "Study"), each of which contained four responses. For example, one response, categorized under "Human, Infrastructure," stated in part "Internal: Information-sharing, best practices. Get good stories out. Website clearinghouse. External: Create human energy infrastructure. Data sharing. Policy documents, like National Academies of Engineering report. Best practices. Increased funding. Connecting with industry and stakeholder[s], facilitate human infrastructure for evolving energy landscape. Need one to two full-time persons…" Another response, categorized under "Impactful," stated in part "(1) Create useful, impactful collaborations: In research and education, in various industry sectors and application areas, with government, industry organizations, and other entities that perform service and public education. (2) Establish standards and practices for operating successful, impactful institutes (e.g., best practice impacts). (3) Identify needs for research and education programs, based on input from broad constituency (e.g., rather than needs identified by DOE, NSF, etc. program directors), through workshops, web meetings, surveys, involving industry, investors, academic, government, foundations (potential funders), etc.…" Another response, categorized under "Limited," stated "Responsibilities should be assigned as part of the membership. Members will do x, y, and z and get access to [ellipses]. Yes, the network should serve as a facilitator without a role in a specific project. It should serve as a way to connect universities to others with expertise they don't have in order to pursue funding opportunities." Yet another response, categorized under "Study," stated "(1) Grow the pie (available research funding), (2) Lessons learned and success stories (sharing platform), (3) Policy papers/support to help inform policymakers, (4) Intellectual property information for interested industry/investors, (5) Help with technology-to-market (?), (6) Connect lab/industry to students."

Energy. In their responses, 21% of participants mentioned "Energy" The clustering algorithm grouped these responses into four categories. Two of these categories ("Human, Infrastructure," and "National") each contained four responses, and the other two categories ("Share" and "Technology-to-Market") each contained three responses. For example, one response, categorized under "Human, Infrastructure," stated "Expand the pie, advocate on behalf of the energy community. Influence in grant area decisions. Be able to develop teams. Clearinghouse." Another response, categorized under "National," stated "A national report, based on the work of a task force, detailing what the nation needs from universities in energy over the next few decades and how universities need to respond to those needs. Another work group to prepare the data/needs for a national energy security education act (modeled on the National Defense Education Act of 1958). A working group on how to expand the reach of energy at universities into parts of the university beyond engineering. Standing up interesting collaborations on important issues." Another response, categorized under "Share," stated "Website, social network, conferences, workshops, clearinghouse, catalogue of successful inter-university research generated through the network. Real success: Joint projects across two or more universities. Lesser benefits: Best practices by energy institutes and energy education." Yet another response, categorized under "Technology-to-Market," stated "Joint product—technical solutions and

student talent—energy to industry, responsibilities—networks would form constellations of industry-institutes and then let the magic happen."

Member. In their responses, 17% of participants mentioned "Member." The clustering algorithm grouped these responses into four categories. Three of these categories ("Easier," "Human, Infrastructure, Workshops" and "Impact") each contained three responses, and the other category ("Voice") contained two responses. For example, one response, categorized under "Easier," stated "Convening like this. Rich information (e.g., website) on institution-specific expertise—create collaborative opportunities across members but not 'engineer' collaboration. Not serving as institutional lead in a collaborative proposal with select universities as Co-PIs. Not efficient." Another response, categorized under "Human, Infrastructure, Workshops" stated "The network should not be perceived as favoring some members over others. I think the ease of communication between members and flow of relevant knowledge to members…is the product, reducing transaction costs for the activities of the members as a whole." Another response, categorized under "Impact," stated "Possibilities: Workforce aggregation (students, Ph.D.'s, post-docs, non-tenured research associates), helps grow the pie of energy-related research, members (shared information, best practices, potentially shared content), help reform terms to transition technology (partnering skills)." Yet another response, categorized under "Voice," stated in part "Position papers on pathways to the future. The power is the collective voices of all members. Need to also include voices/institutes from key places around the world…"

In addition to the keywords described above, 20% of responses mentioned "Product," 11% mentioned "Industry," and 15% mentioned "Policy." Responses that mentioned "Product" were grouped into four categories, which were "Members," "Impactful," "Participant," and "Small." Responses that mentioned "Industry" were grouped into two categories, which were grouped into "Energy, Information" and "Human, Identified, Impactful, Infrastructure." Finally, responses that mentioned "Policy" were grouped into four categories, which were "Help, Industry," "Human, Infrastructure," "Research," and "Small." Appendix B, Table B17 lists all category names.

Desired Benefits and Intended Interactions with a Network

In our pre-summit leadership survey, we asked respondents: How would you want your energy institute to benefit from joining today a new network of U.S. university energy institutes? We provided respondents with a list of benefits and asked respondents to rank the five most important benefits that their institute would desire. We also provided space for respondents to write benefits. Figure 21 presents benefits selected from the given list. Seventy-six percent of institutes ranked increased research funding among their five most important benefits, and 68% percent of institutes ranked bigger impact on national policy among their five most important benefits. Institutes also ranked, among their five most important benefits and in order of decreasing frequency of selection, more opportunities for students, more collaborations with academia, more collaborations with industry, more collaborations with government, better ability to engage the general public, reduced time to bring technologies to market, more media attention, bigger impact on state policy, more publications, bigger impact on local policy, and more patents.

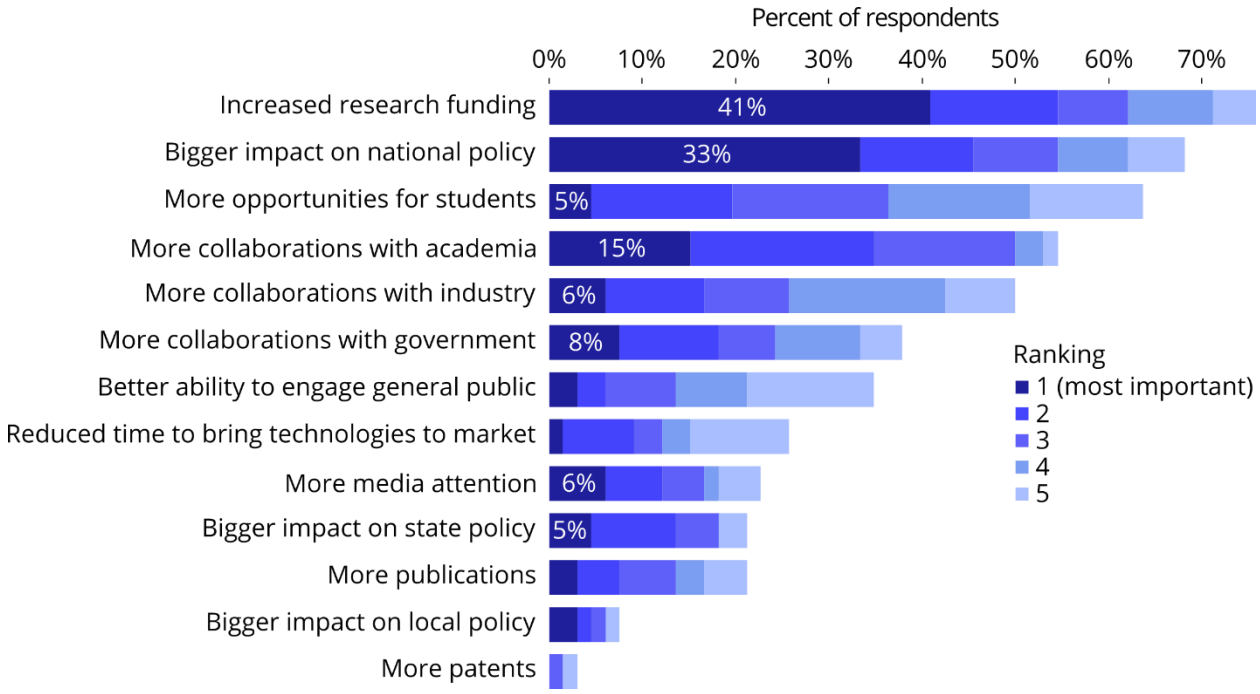

Figure 21. Benefits that energy institutes would desire from a network. Forty-one percent of institutes ranked increased research funding as their most important benefit, and 33% of institutes ranked bigger impact on national policy as their most important benefit.

Benefit is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. All benefits shown were selected from the list given in the question.

Four respondents wrote benefits not provided in the given list and related to students, collaborations, and sustainability initiatives. Of these respondents, one wrote better ability to recruit graduate students (this same respondent mentioned they would like to better understand how they can contribute to a network given their institute's limited resources); another wrote more collaborations with national and early-stage investors; another wrote coordination and development of transformative sustainability initiatives; and another respondent wrote they desire all benefits provided in the given list.

In our pre-summit leadership survey, we asked respondents: How would your energy institute interact today with a new network of U.S. university energy institutes? We provided respondents with a list of interactions and asked respondents to rank their institute's five most likely interactions. We also provided space for respondents to write interactions. Figure 22 presents interactions selected from the given list. Sixty-one percent of institutes ranked co-writing funding proposals among their three most likely interactions, and 44% ranked informal communication among their three most likely interactions. Institutes also ranked, among their three most likely interactions and in order of decreasing frequency of selection, co-sponsoring events, sharing knowledge, working with government through a network, working with industry through a network, co-authoring papers, hosting faculty or visiting scholars, and sharing resources (equipment, tools, or facilities).

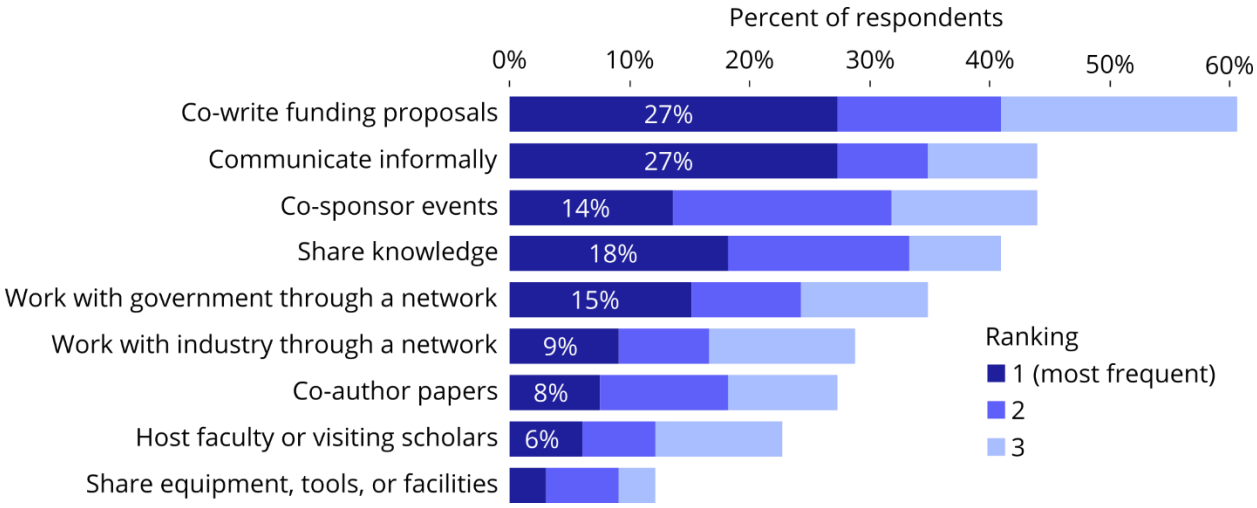

Figure 22. Institutes' intended interactions with a network. Twenty-seven percent of institutes ranked co-writing funding proposals as their most frequent interaction, and twenty-seven percent of institutes ranked communicating informally as their most frequent interaction.

Intended interaction is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. All interactions shown were selected from the list given in the question.

Five respondents wrote interactions not provided in the given list. Of these respondents, four indicated they would pursue all interactions listed in the question, and one wrote that their institute would, through a network, co-author papers and work with the government.

Anticipated Challenges to Interacting with a Network

In our pre-summit leadership survey, we asked respondents: What challenges do you think your energy institute would encounter if it were to join today a new network of U.S. university energy institutes? We provided respondents with a list of challenges and asked institutes to rank their institute's five most considerable challenges. We also provided space for respondents to write challenges. Figure 23 presents challenges selected from the given list. Eighty percent of institutes ranked differing interests or goals among their five most considerable challenges, and 77% identified lack of funding among their five most considerable challenges. Institutes also ranked, among their five most considerable challenges and in order of decreasing frequency of selection, lack of central management in a network, competition for funding, risk of developing an agenda or partiality, logistical difficulty, intellectual property issues, risk of excluding universities from opportunities, and general lack of collaboration with other universities, among their five most considerable challenges.

Five respondents wrote challenges not provided in the given list and related to the time and resources required to form and develop a network. Of these respondents, two wrote the time required to participate in a network; another wrote lack of commitment and purpose; another wrote risk of exhausting its energy institute's current resources; and another wrote opportunity cost, stating "Any time spent on this endeavor will be less time spent doing something else. So, the real question is whether time allocated to this activity will really help us to be more effective and increase the value of our products."

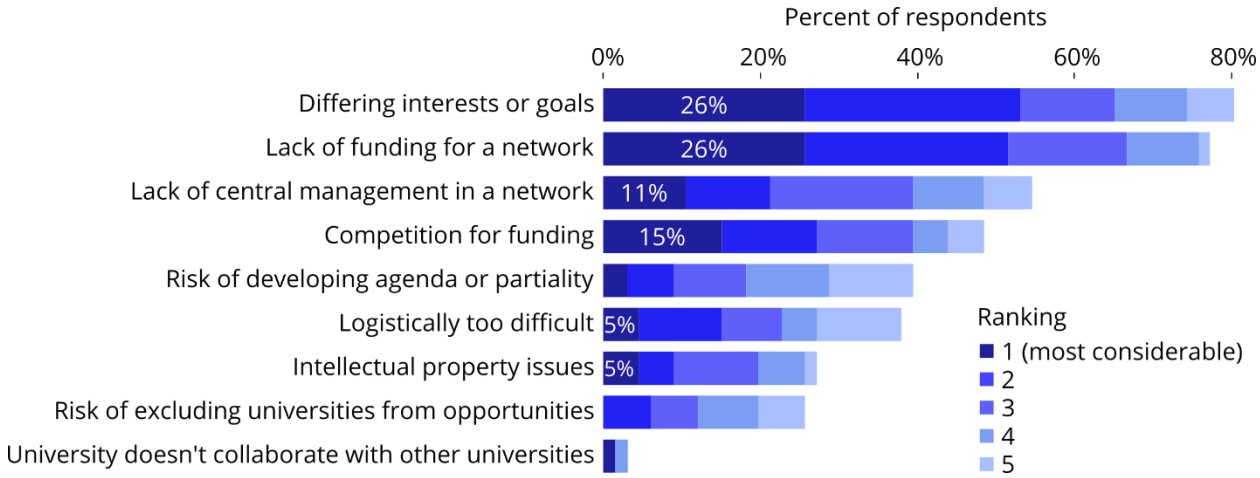

Figure 23. Challenges that institutes anticipate encountering if they were to join a network. Twenty-six percent of institutes ranked differing interests or goals as the most considerable challenge, and 26% of institutes ranked lack of funding for a network as the most considerable challenge.

Anticipated challenge is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. All anticipated challenges shown were selected from the list given in the question.

Funding a Network

At the summit, we asked attendees: How should a network be funded? What are potential funding sources? How could a network be used to create funding opportunities? We extracted keywords from participants' responses. As displayed in Figure 24, participants most frequently mentioned, in order of decreasing frequency, "Member/Partner," "Foundation," "Industry," "Institute," "Fee," "University," and "Organization." We categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B18 presents category names resulting from this analysis. Below, we summarize our findings and provide several examples of responses.

Member/Partner. In their responses, 50% of participants mentioned "Member/Partner." The clustering algorithm grouped these responses into nine categories. Six of these categories ("Conference," "Grants," "Multiplied," "Participate," "Specific, Opportunities," and "Support") each contained four responses, and the other three categories ("Create," "Educational," "Money") each contained three responses. For example, one response, categorized under "Conference," stated "DOE funding and membership fees. Conference income. Advocate for increased federal funding in energy foundations." Another response, categorized under "Grants," stated in part "An initial 'free' membership period, say one year, could be supported through grants from foundations. Some diversity in sources…" Another response, categorized under "Multiplied," stated in part "Individual institute contributions could be used at the start, but there has to be value for each institute and may not be sustainable. Federal funding is not likely. Private sector funding may be more feasible…" Another response, categorized under "Specific, Opportunities," stated "Depends on what opportunities exist. Could we internally fund? Or, perhaps members make in-kind contributions of time and resources?" Yet another response,

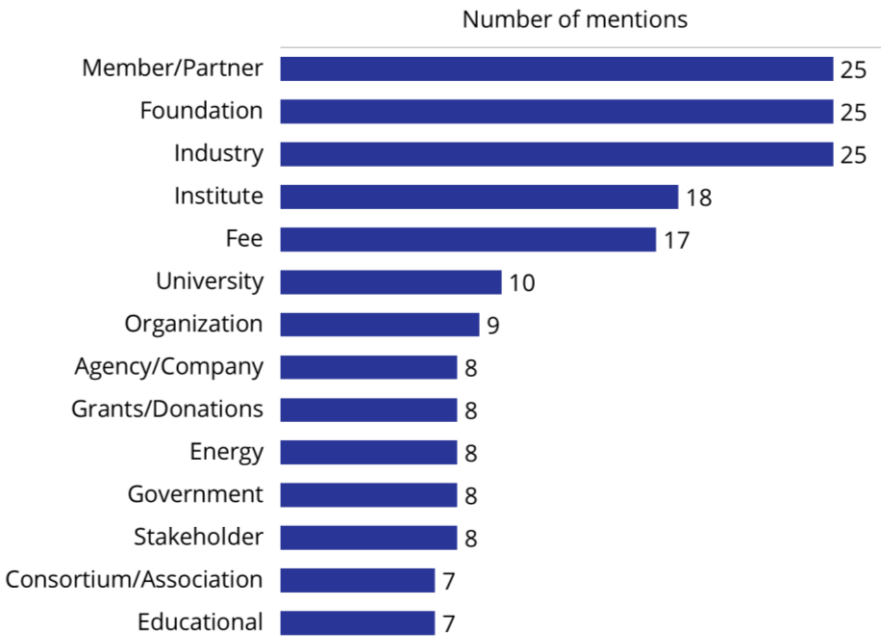

Figure 24. ***How should an energy institute network be funded? What are potential funding sources? How could a network be used to create funding opportunities?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently mentioned "Member/Partner," "Foundation," and "Industry," Often but less frequently, participants mentioned "Institute," "Fee," "University," and "Organization."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than seven mentions are not shown. Appendix B, Table B18 presents categories produced by our text clustering analysis.

categorized under "Support," stated "Three part model: (1) Foundation to launch, (2) To sustain: Government agency (DOE, NSF), (3) To sustain: membership dues (maybe a tiered payment schedule)."

Foundation. In their responses, 36% of participants mentioned "Foundation." The clustering algorithm grouped these responses into eight categories, which were "Grants," "Institutes," "Money," "Money, Think, Sloan," "Multiplied," "Research," "Sharing," and "Support. Each of these categories contained three responses. For example, one response, categorized under "Institutes," stated in part "…While member institutes are one source, we must be careful not to price out smaller institution[s] (e.g., institutes that are not university-wide and have small budgets); it certainly seems that an organization like DOE, for example, could fund us since there would be synergy benefits to U.S. energy policy to do so. Perhaps start-up funding from a foundation until we figure this out." Another response, categorized under "Money," stated "A donor or foundation would be an ideal funder, at least for an initial 3–5 year period. Perhaps an industrial partnership could be used. A network could also advocate for funding from federal and other government agencies. Membership may also work." Another response, categorized under "Research," stated "This all depends on mission, vision, and strategic priorities for 3, 5, 20 years. Could include: Philanthropic, campus, industry, regional. Probably not federal since conflict of

interest, and probably not industry or industrial foundation due to skeptics." Yet another response, categorized under "Sharing," stated "Funding: Foundation funds to launch (seed funding); Membership dues to sustain; Should members self-fund the network? Hire dedicated coordinator."

Industry. In their responses, 24% of participants mentioned "Industry." The clustering algorithm grouped these responses into four categories: "Campus, COI, Consortium, Individuals, Industry-funded, NMMI, Priorities, Running, Self-funded, Size, Skeptics, Strategic," "Energy," "Grants," and "Support." Each of these categories contained four responses. For example, one response, categorized under "Campus, COI, Consortium, Individuals, Industry-funded, NMMI, Priorities, Running, Self-funded, Size, Skeptics, Strategic," stated "(1) Initially energy institute funded—can be scaled per size—to get up and running, (2) Sustained funding: Industry, government, foundations, individuals." Another response, categorized under "Energy," stated "Network: Connect industry 5–10 year roadmaps with university experts [who] can address the needs of the roadmaps. Then, go after federal funding in a win-win-win (agency-industry-university). Have industries define their needs. Network connect appropriate researchers to those industries. Product after federal funding: Technology solutions and students in industry." Another response, categorized under "Grants," stated "Industrial membership and annual support for meetings and networking from government. Additional resources from industry and government should fund small scale seed grants when three or more institutes join each other. Make directory of expertise of all institutes and make them into subcategories." Yet another response, categorized under "Support," stated "There are tradeoffs with both member support and stakeholder support. Members are unlikely to pay enough to support large-scale activities. Stakeholders will want to see demonstration of value before buying in. For growing the network, I propose three stages, each contingent on success of the last: (1) Proof of concept (two to three years), charitable support, one full-time equivalent, focus on value to members, (2) Small scale (three to five years), member support, expand focus to stakeholder engagement, (3) Sustainable scale, members, foundations, industry associations, etc. all buy-in."

In addition to the keywords described above, 24% of participants mentioned "Institute," and 22% mentioned "Fee." Responses that mentioned "Institute" were grouped into four categories, which were "Better, Center, Journal, Nationally, President," "Dues," "Money," and "Multiplied, Product." Responses that mentioned "Fee" were grouped into five categories: "Closer, Government, Income, Increased, Offering, Sustainable," "Educational," "Grant," "Small," and "Think." Appendix B, Table B18 lists all category names.

Anticipated Financial Contributions to a Network

In our pre-summit leadership survey, we asked respondents: How much financial support would your energy institute be willing to contribute annually to participate today in a new network of U.S. university energy institutes? We asked energy institute to select one choice form the following list: No financial support, less than $2,000, $2,000–$4,000, $4,000–$6,000, $6,000–$8,000, $8,000–$10,000, and greater than $10,000. Figure 25 presents institutes' intended annual financial contributions. Seventy-four percent of institutes indicated they would financially contribute some amount to a network, and 21% indicated they would not financially contribute to a network (14% did not respond to this question). Twenty-three percent of institutes

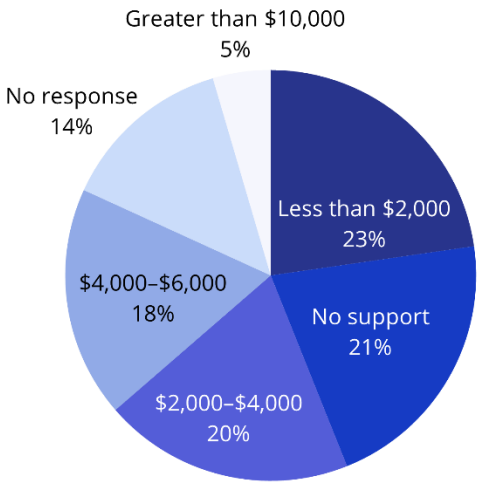

Figure 25. Institutes' anticipated annual financial contributions, if any, to a network. Seventy-four percent of institutes indicated they would financially contribute to a network, and 21% indicated they would not financially contribute to a network.

The percent of survey participants who selected each funding range is indicated. All ranges were selected from the list given in the question.

indicated they would contribute $2,000 per year, 20% between $2,000–$4,000, 18% between $4,000–$6,000, and 5% greater than $10,000. In total, institutes suggested they would contribute $104,000–$184,000 per year.[81]

Geographical Scope and Shared Assets of a Network

In our pre-summit leadership survey, we asked respondents: In your opinion, what should be the geographical scope of a new network of U.S. university energy institutes, if one were formed today? We provided respondents with a list of geographical scopes and asked

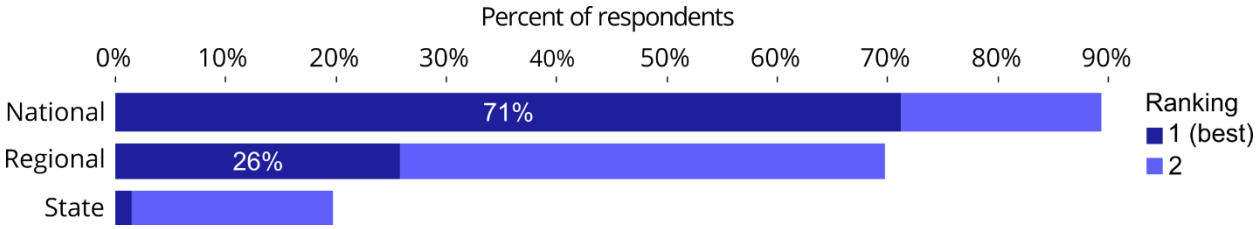

Figure 26. Institutes' preferred geographical scopes of a network. Seventy-one percent of survey participants ranked a national scope as the best scope, and 26% of survey participants ranked a regional scope as the best scope.

Geographical scope is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. All geographical scopes shown were selected from the list given in the question.

[81] The lower bound ($104,000) equals the sum of respondents' lower bounds, and the upper bound ($184,000) equals the sum of respondents' upper bounds. In the case of respondents who indicated greater than $10,000, we treated $10,000 as both a lower and upper bound.

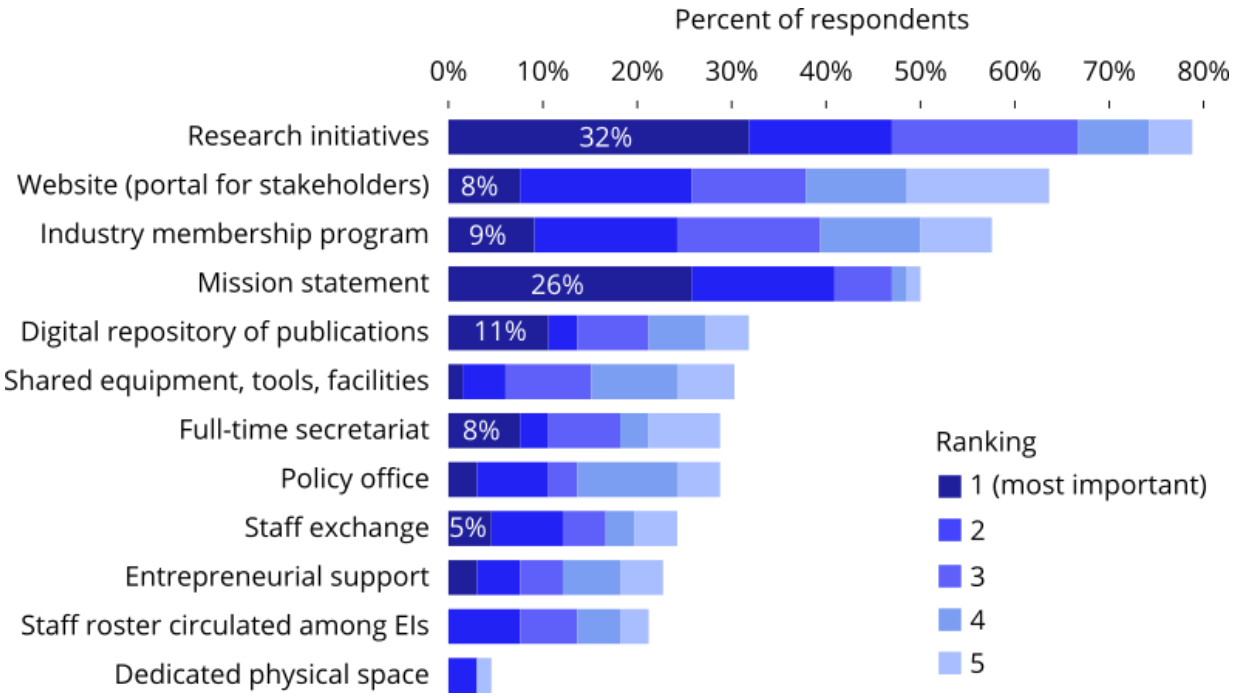

Figure 27. Institutes' rankings of a potential network's shared assets. Thirty-two percent of institutes ranked research initiatives as the most important asset, and 26% of institutes ranked a mission statement as the most important asset.

Shared asset is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. In the survey, "Industry membership program" appeared as "Industry membership or consortium program." All shared assets shown were selected from the list given in the question. EI stands for energy institute.

respondents to rank the two best geographical scopes. We also provided space for institutes to write geographical scopes. Figure 26 presents geographical scopes selected from the given list. Eighty-nine percent of institutes ranked a national scope among the two best geographical scopes, and 70% ranked a regional scope among the two best geographical scopes. Two respondents wrote geographical scopes not provided in the given list. Both respondents wrote international scope.

In our survey, we asked respondents: In your opinion, what shared assets should belong to a new network of U.S. university energy institutes, if one were formed today? We provided respondents with a list of assets and asked respondents to rank the five most important assets. We also provided space for institutes to write assets. Figure 27 presents assets selected from the given list. Seventy-seven percent of institutes ranked research initiatives among the five most important assets. Institutes also ranked, among the five most important assets and in order of decreasing frequency of selection, a website (portal for stakeholders), industry membership or consortium program, mission statement, digital repository of publications, shared resources (equipment, tools, or facilities), full-time secretariat, policy office, staff exchange, entrepreneurial support, staff roster circulated among institutes, and dedicated physical space.

Five respondents wrote assets not provided in the given list and related to a network's purpose, activities, and outreach. Of these respondents, one wrote annual meetings to share knowledge, findings, and new ideas; another wrote educational opportunities for the public and students; another wrote grant writers; another wrote a strategic partner office focused on technology development, deal flow, and engagement of corporations and private investors (this respondent explained that such an office could facilitate a range of activities, including joint technology development agreements and start-up investment); and another respondent commented on the importance of identifying a network's role in the research community, stating "Perhaps the most important shared asset is a sense of community, and a better understanding of how we can best contribute to overall community success. How can we fit into the ecosystem of researchers in a way that minimizes unnecessary redundancy and maximizes utility of the results of our efforts?"

Governance and Administrative Structures

At the summit, we asked attendees: What kind of governance or administrative structure, and evolution thereof, would most benefit members of an energy institute network? We extracted keywords from participants' responses. As displayed in Figure 28, participants most frequently mentioned, in order of decreasing frequency, "Board/Leadership," "Member," "Institute," "Governance," "People," and "Vision." We categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B19 presents category names resulting from this analysis. Below, we summarize our findings and provide several examples of responses.

Board/Leadership. In their responses, 17% of participants mentioned "Board/Leadership." The clustering algorithm grouped these responses into four categories. Three of these categories ("Act, Change, People," "Objectives, Repository," and "Secretariat, CMU, Rice") each contained three responses, and the other category ("Region") contained one response. Here, we provide several examples. One response, categorized under "Act, Change, People," stated "Depends: (1) Decentralized and based on shared interests that change, or (2) Strong, central, core leadership if there is a more defined set of goals that don't change. I like (1) better..." Another response, categorized under "Objectives, Repository," stated "Only needed if [a] network does a lot, more than just a repository. Maybe members could vote on board members who would serve for a set time period. If [a network] is only a repository, only IT staff would be needed to maintain it. Initially, one to two good students could be hired to create the automation of populating and updating the repository." Another response, categorized under "Secretariat, CMU, RICE," stated "Secretariat hosted at one institution, responding to a Board. Board now appointed—Carnegie Mellon University, Colorado School of Mines, Rice University. Eventually voted in by members." Yet another response, categorized under "Region," stated "How about having regional representatives to start? We are probably more familiar with the programs in our region and that could be a good way to enhance early communication/collaboration. Elected board members eventually."

Member. In their responses, 15% of participants mentioned "Member." The clustering algorithm grouped these responses into four categories. Two of these categories ("Fund" and "Region") each contained three responses, and the other two categories ("Institute" and "Repository") each contained two responses. Here, we provide several examples. One response, categorized under "Fund," stated "Start small. Identify a few, key, commonly valued items by the members of the

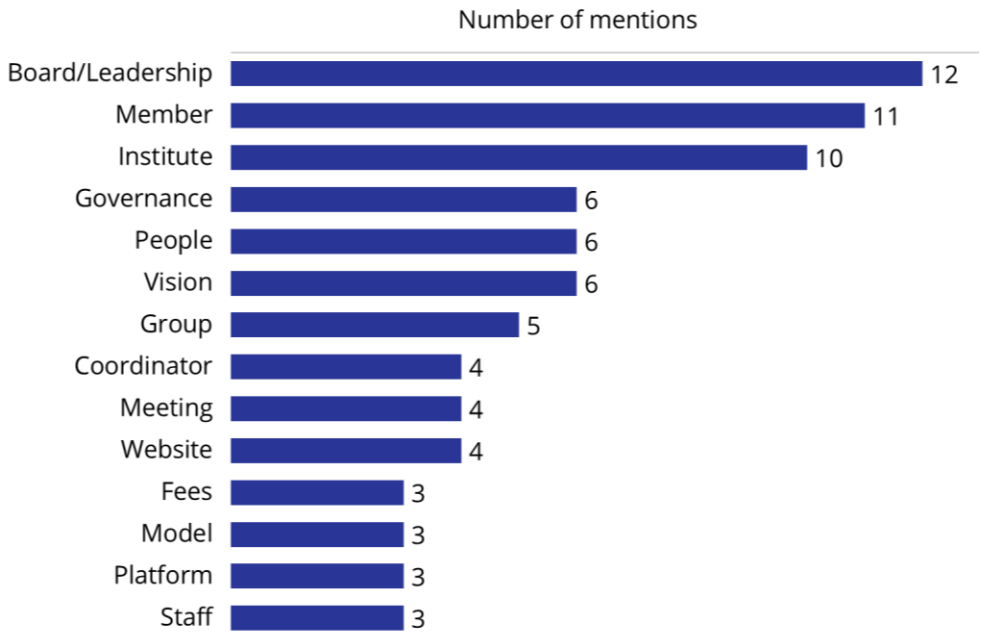

Figure 28. ***What kind of governance or administrative structure, and evolution thereof, would most benefit members of an energy institute network?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently mentioned "Board/Leadership," "Member," and "Institute." Often but less frequently, participants mentioned "Governance," "People," and "Vision."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than three mentions are not shown. Appendix B, Table B19 presents categories produced by our text clustering analysis.

network. Focus hard on driving strong value—even if it is a small set of values. For the first two to three years: One to two full time staff and one to two graduate students—could be housed at one or two institutes, based on interest and resources. Will be very important for the hosting institutes to strive hard to be genuinely inclusive and representative." Another response, categorized under "Region," stated in part "…Some staff for coordination. Two tier membership: Primes = University; Seconds = Industry, non-governmental organization, etc." Another response, categorized under "Institute" stated "Small, simple structure. Needs to be nimble. Tiered membership with different voices/votes and different fees: Full member, Associate Member, Participant. A secretariat plus part time staff." Yet another response, categorized under "Repository," stated "Start with a network based on the platform of members attending. A small group should volunteer to manage online platform and others to plan next meeting."

Institute. In their responses, 14% of participants mentioned "Institute." The clustering algorithm grouped these responses into three categories. One of these categories ("Board") contained four responses, one category ("Support") contained three responses, and one category ("Objectives") contained two responses. Here, we provide several examples. One response, categorized under "Board," stated "There needs to be an employee somewhere who gets paid to keep this network growing and thriving. Ideally, they are seen as not strongly/permanently tied to one institution,

so maybe founding an independent non-profit is the way to go." Another response, categorized under "Support," stated "Start with Carnegie Mellon University/[Colorado school of Mines]/Rice University as secretariat and two hired program staff (volunteers from amongst institute leadership)." Yet another response, categorized under "Objectives," stated "The structure should be defined by the objectives. If an initial objective involves a few institutes, then those should be the initial leaders of the network. Perhaps then as other objectives are defined, then rotating leadership among institutes may work."

In addition to the keywords described above, 9% of responses mentioned "Governance," 6% mentioned "People," and 8% mentioned "Vision." Responses that mentioned "Governance" were grouped into two categories, which were "Impact, Regional" and "Vision." Responses that mentioned "People" were grouped into two categories, which were "Act, Coordinator" and "Agreed, Beginning, Broad, Clearinghouse, Clients, Creating, Database, Dedicated, Depends, Greater, Ideas, Ideal, Informal, Internet, Kind, Loose, Million, Money, Network, Nimble, Right, Supported, Transparent, Trusted, Versus, Widely." Finally, responses that mentioned "Vision" were grouped into two categories, which were "Act, Coordinator, People, Shared" and "Governance, Impact." Appendix B, Table B19 lists all categories.

Conclusions

Members of a network could work together to increase research funding, enhance education, and impact public and private decision-making. Institute leaders whom we surveyed suggested that a network could forge and strengthen research partnerships while also serving as a collective voice to inform policy. Summit participants suggested that a network facilitate communication among institutes, who through a network could share best practices, course material, data, intellectual property, job opportunities, papers, and together host conferences, events, and meetings.

Furthermore, a network could engage stakeholders across a range of affiliations. Institutes whom we surveyed indicated that they would most desire through a network more research funding, bigger impact on national policy, more opportunities for students, and more collaborations with academia, industry, and government. Institutes expressed willingness to co-write funding proposals, communicate informally, co-sponsor events, share knowledge, and work with government and industry through a network. Institutes recommended that a hypothetical network share, among other assets, research initiatives, an online portal for stakeholders, an industry membership program, and a mission statement.

Potential challenges to forming a network include differing interests or goals and lack of funding. Summit participants recommended that to lead and coordinate a network a core group of universities appoint an advisory board and hire one or two staff members. As a network matures, institutes could rotate leadership and elect an advisory board. Summit participants suggested that seed funding from foundations or member contributions initially support a network. As a network matures, it could be sustained by membership dues and government and industry funding.

Chapter 5

Stakeholder Expectations of a Network

Stakeholder Opinions about Forming a Network

Summary

This chapter presents stakeholder expectations of a future, hypothetical network. Most stakeholders whom we surveyed indicated they currently interact with and participate in events hosted by energy institutes. Nearly all stakeholders indicated they would consider interacting with a network, if one were formed. Stakeholders indicated they would most desire through a network more collaborations with academia and bigger impact on national policy. However, stakeholders identified differing interests or goals, lack of funding, and logistical difficulty as the most considerable challenges to engaging a network. Less than half of stakeholders indicated they would financially contribute to a network.

Interactions with Institutes

Of the stakeholders whom we surveyed, 85% reported interacting with one or more U.S. university energy institutes. We presented stakeholders with a list of interactions and asked stakeholders to select all form(s) of interaction in which they currently engage with one or more energy institutes. We also provided space for stakeholders to write interactions. Figure 29 presents interactions selected form the given list. Sixty-seven percent of stakeholders indicated that the participate in events hosted by institutes, 63% indicated they donate to institutes, and 60% indicated they communicate informally with institutes. Stakeholders also indicated, in order of decreasing frequency of selection, sharing knowledge with institutes, collaborating through contracts or grants, sharing resources (equipment, tools, or facilities), participating in an industry membership or consortium program, co-authoring papers, and receiving policy advice from institutes. Five stakeholders wrote interactions not provided in the given list. One stakeholder wrote hiring interns from energy institutes; another wrote interacting with an energy institute through a fellowship; another wrote judging pitch competitions; another wrote organizing collaborations between energy institutes, higher education programs, and colleagues; and another wrote sourcing investment opportunities through energy institutes.

In our survey, we asked stakeholders: Would you, in your professional capacity, consider interacting today with a new network of U.S. university energy institutes in some form, such as a collaboration or partnership? Ninety-four percent of stakeholders indicated they would consider interacting with such a network. We provided stakeholders with a list of interactions and asked stakeholders to rank their five most likely interactions with a network. Figure 30 presents interactions selected from the given list. Eighty-eight percent of stakeholders ranked participating in events hosted by a network among their five most likely interactions. Stakeholders also ranked, among their five most likely interactions and in order of decreasing frequency of selection, sharing knowledge, communicating informally, collaborating through contracts or grants, reading literature affiliated with a network, serving on a network's or institute's advisory board, participating in an industry membership or consortium program, co-authoring papers, giving donations, gifts, or sponsorships, receiving policy advice from a network, and sharing resources (equipment, tools, or facilities). Two respondents wrote

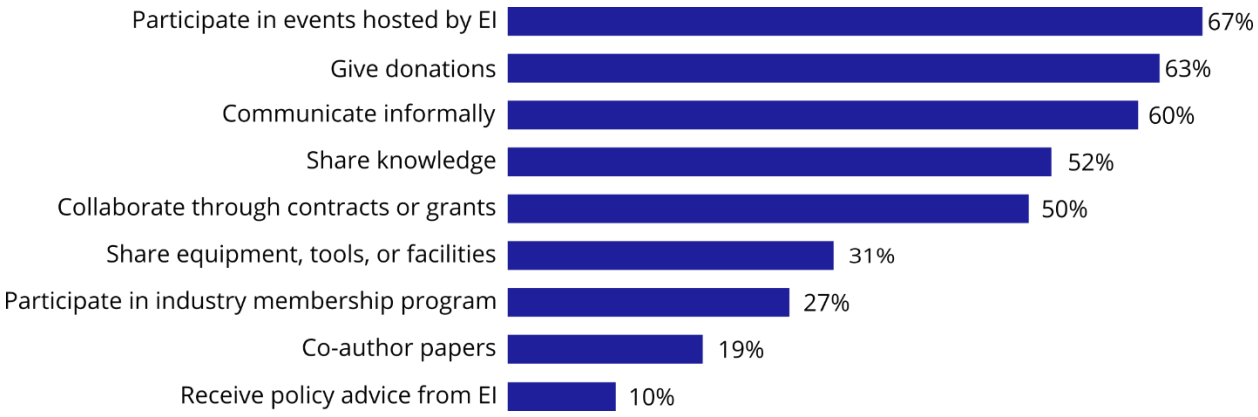

Figure 29. Stakeholders' current interactions with energy institutes. Sixty-seven percent of stakeholders indicated they participate in events hosted by an energy institute, and 63% indicated they communicate informally with one or more energy institutes.

Interaction is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. All interactions shown were selected from the list given in the question. EI stands for energy institute.

interactions not provided in the given list. One of these respondents wrote that they would leverage the network to communicate with and market to energy innovators, and the other wrote that they would develop a program or write a publication involving multiple institutes.

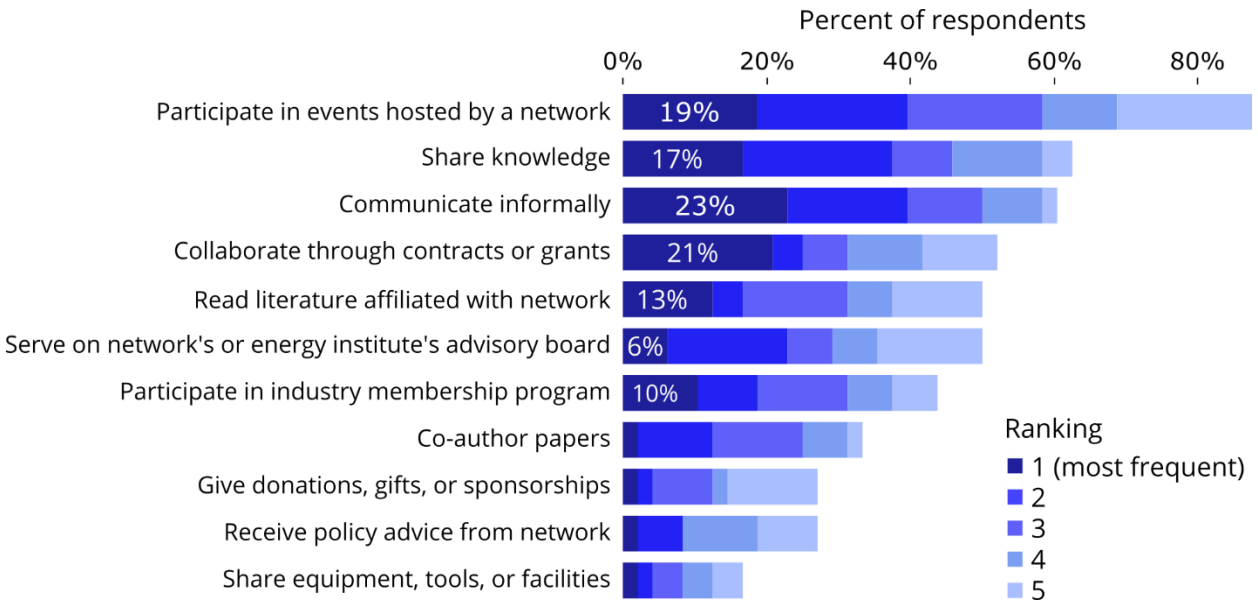

Figure 30. Stakeholders' intended interactions with a network. Twenty-three percent of stakeholders ranked communicating informally as the most frequent interaction, and 21% ranked collaborating through contracts or grants as the most frequent interaction.

Intended interaction is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. In the survey, "Industry membership program" appeared as "Industry membership or consortium program." All interactions shown were selected from the list given in the question.

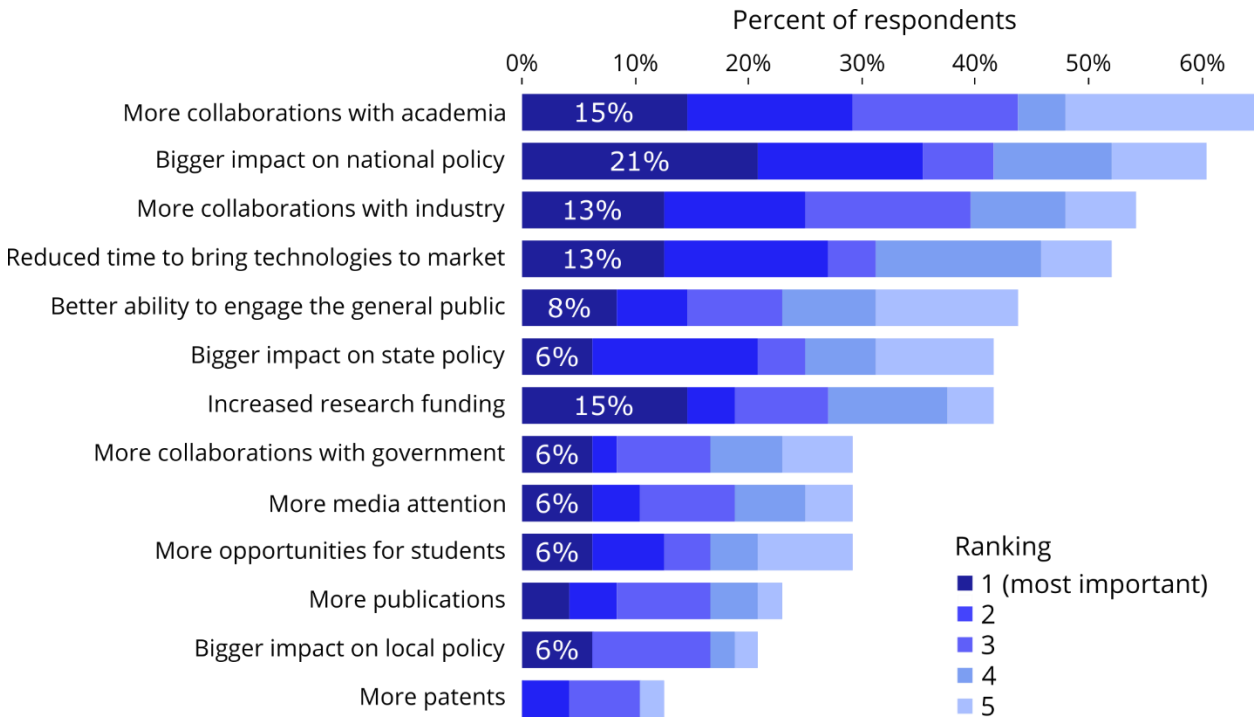

Figure 31. Benefits that stakeholders would desire from a network. Fifteen percent of stakeholders ranked more collaborations with academia as their most important benefit, and twenty-one percent of stakeholders ranked bigger impact on national policy as their most important benefit.

Desired benefit is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. All benefits shown were selected from the list given in the question.

Desired Benefits and Anticipated Challenges of a Network

In our survey, we asked stakeholders: How would you, in your professional capacity, want to benefit from interacting today with a new network of U.S. university energy institutes? We provided stakeholders with a list of benefits and asked stakeholders to rank the five most important benefits they desire from a network. We also provided space for stakeholders to write benefits. Figure 31 presents benefits selected from the given list. Sixty-five percent of stakeholders ranked more collaborations with academia among their five most important benefits, and 60% of stakeholders ranked bigger impact on national policy among their five most important benefits. Stakeholders also ranked, among their five most important benefits and in order of decreasing frequency of selection, more collaborations with industry, reduced time to bring technologies to market, better ability to engage the general public, bigger impact on state policy, increased research funding, more collaborations with government, more media attention, more opportunities for students, more publications, bigger impact on local policy, more patents. Three respondents wrote benefits not provided in the given list. One respondent, who ranked from the list more collaborations with academia as their most important benefit, clarified that they desire greater impact in (but not more) interactions with academia; another wrote a bigger

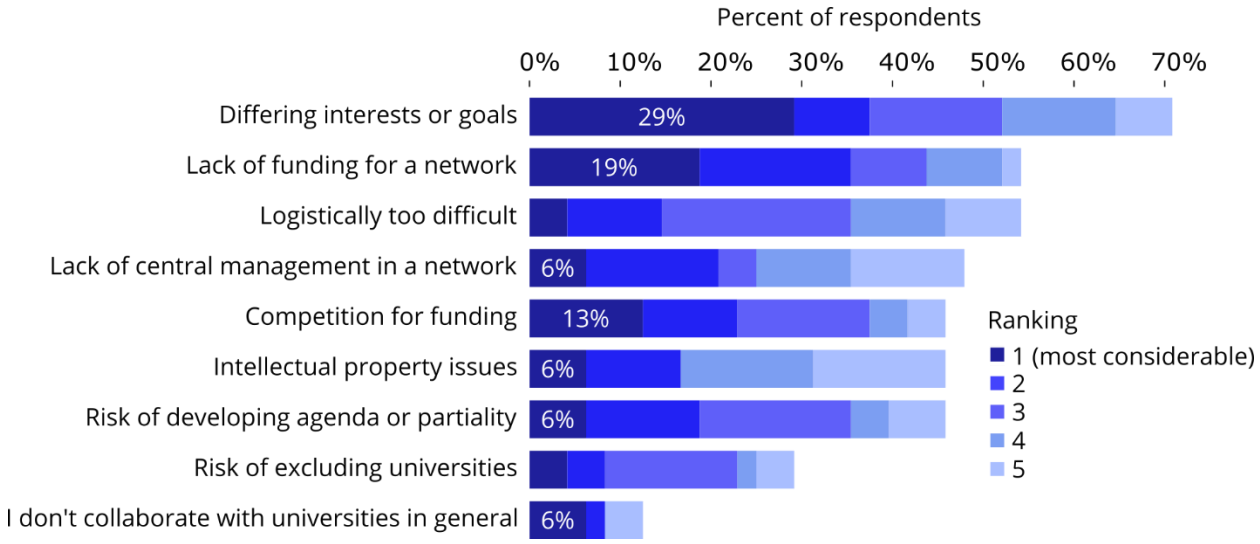

Figure 32. Challenges that stakeholders anticipate encountering if they were to join a network. Twenty-nine percent of stakeholders ranked differing interests or goals as the most considerable benefit, and 19% ranked lack of funding for a network as the most considerable benefit.

Anticipated challenge is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. All challenges shown were selected from the list given in the question.

and more coherent approach to energy-focused higher education; and another wrote broader access to leading researchers.

In our survey, we asked stakeholders: What challenges do you, in your professional capacity, think you would encounter while interacting today with a new network of U.S. university energy institutes? We provided stakeholders with a list of challenges and asked stakeholders to rank the five most considerable challenges. We also provided space for stakeholders to write challenges. Figure 32 presents challenges selected from the given list. Seventy-one percent of stakeholders ranked differing interests or goals among the five most considerable challenges. Fifty-four percent of stakeholders ranked lack of funding for a network among the five most considerable challenges, and 54% ranked logistical difficulty among the five most considerable challenges. Stakeholders also ranked, in order of decreasing frequency of selection, lack of central management in a network, competition for funding, intellectual property issues, risk of a network developing an agenda or partiality, risk of excluding universities from opportunities, and general lack of collaboration with universities. Four respondents wrote challenges not provided in the given list. Of these respondents, two wrote lack of time; another wrote lack of a network's clear value proposition; and another wrote that individuals may not share goals and interests and are busy.

Geographical Scope and Shared Assets

In our survey, we asked stakeholders: In your opinion, what should be the geographical scope of a new network of U.S. university energy institutes, if one were formed today? We provided stakeholders with a list of geographical scopes and asked stakeholders to rank the two best scopes. We also provided space for stakeholders to write geographical scopes. Figure 33

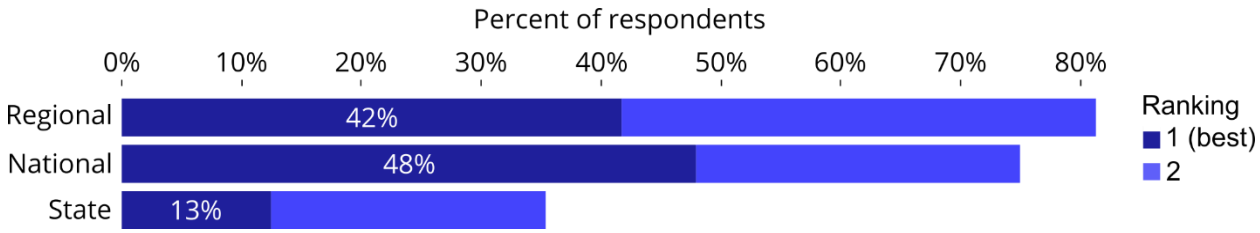

Figure 33. Stakeholders' preferred geographical scopes of a network. Forty-eight percent of stakeholders ranked a national scope as the best scope, and 42% of stakeholders ranked a regional scope as the best scope.

Geographical scope is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. All geographical scopes shown were selected from the list given in the question.

presents geographical scopes selected from the given list. Eighty-two percent of stakeholders ranked a regional scope among the two best scopes, and 74% of stakeholders ranked a national scope among the two best scopes. Two respondents wrote geographical scopes not provided in the given list. Both respondents wrote an international scope. One of these respondents clarified that a U.S. scope is well-suited to achieving policy and funding goals, and an international scope is well-suited to energy data and research goals. The other respondent did not elaborate further.

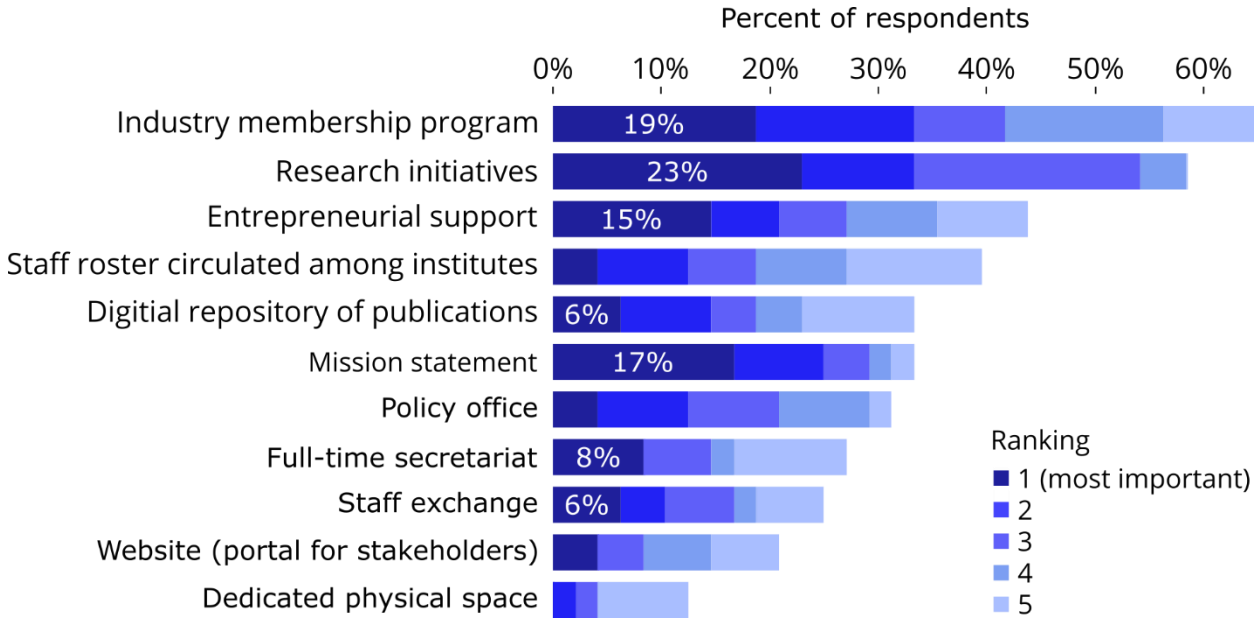

Figure 34. Stakeholders' rankings of a potential network's shared assets. Stakeholders ranked an industry membership program and research initiatives among the most important shared assets.

Shared asset is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. In the survey, "Industry membership program" appeared as "Industry membership or consortium program." All shared assets shown were selected from the list given in the question.

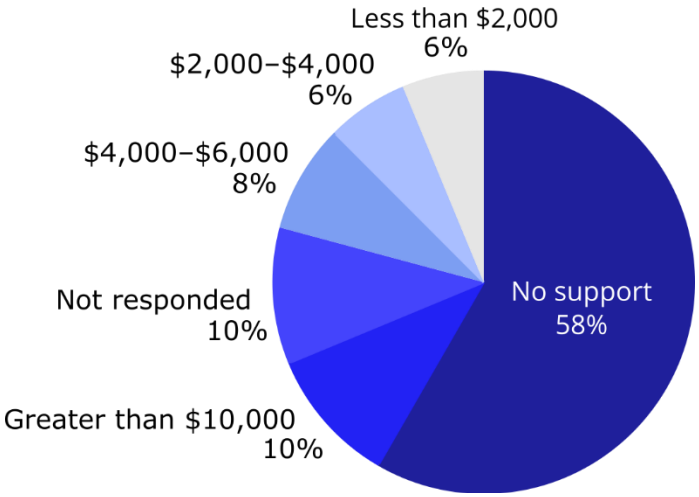

Figure 35. Stakeholders' anticipated annual financial contributions, if any, to a network. Thirty-two percent of stakeholders indicated they would financially contribute to a network, and 58% indicated they would not financially contribute to a network.

The percent of survey participants who selected each funding range is indicated. All ranges were selected from the given list.

We asked stakeholders: In your opinion, what shared assets should belong to a new network of U.S. university energy institutes, if one were formed today? We provided stakeholders with a list of assets and asked stakeholders to rank the five most important assets. We also provided space for stakeholders to write assets. Figure 34 presents assets selected from the given list. Sixty-five percent of stakeholders ranked an industry membership or consortium program among the five most important assets, and 58% of stakeholders ranked research initiatives among the five most important assets. Stakeholders also ranked, among the five most important shared assets and in order of decreasing frequency of selection, entrepreneurial support, a staff roster circulated among institutes, a digital repository of publications, a mission statement, a policy office, a full-time secretariat, a staff exchange, a website (portal for stakeholders), and dedicated physical space. Three respondents wrote assets not provided in the given list. One respondent wrote intellectual property visibility and complementary technology matching; another wrote that the network must focus on only one issue in order to be helpful to academic energy groups; and another wrote a common agenda and referenced the Collective Impact Model.[82]

Anticipated Financial Contributions to a Network

In our survey, we asked stakeholders: How much financial support would you, in your professional capacity, be willing to contribute annually to work today with a new network of U.S. university energy institutes? We asked stakeholders to select one choice from the following list: No financial support, less than $2,000, $2,000–$4,000, $4,000–$6,000, $6,000–$8,000, $8,000–$10,000, and greater than $10,000. Figure 35 presents stakeholders' anticipated financial contributions. Fifty-eight percent of stakeholders indicated they would not financially contribute

[82] John Kania and Mark Kramer, "Collective Impact," Stanford Social Innovation Review, accessed January 27, 2020, https://ssir.org/articles/entry/collective_impact.

to a network, and 32% indicated they would financially contribute some amount to a network (10% did not respond to this question). Six percent of stakeholders indicated they would contribute less than $2,000 per year, 6% between $2,000–$4,000 per year, 8% between $4,000–$6,000 per year, and 10% greater than $10,000 per year. In total, stakeholders suggested they would contribute $52,0000–$72,000 per year.[83]

Conclusions

A network could foster communication and collaboration among stakeholders and university energy institutes. Stakeholders suggested that, if a network were formed, they would participate in events hosted by, share knowledge with, communicate informally with, and collaborate with a network. Stakeholders recommended that a network include an industry membership or consortium program, research initiatives, entrepreneurial support, and a staff roster circulated among institutes. Many stakeholders preferred that a network be regional or national in scope.

Stakeholders ranked differing interests or goals, lack of funding for a network, and logistical difficulty among the most considerable challenges that could be encountered in joining a new network. Less than half of stakeholders indicated they would financially support a network, although the vast majority of stakeholders indicated they would interact with a network.

[83] The lower bound ($52,000) equals the sum of respondents' lower bounds, and the upper bound ($72,000) equals the sum of respondents' upper bounds. In the case of respondents who indicated greater than $10,000, we treated $10,000 as both a lower bound and upper bound.

Chapter 6

Steps Toward Forming a Network

Energy Institute Opinions about Next Steps

Summary

This chapter presents institute recommendations for next steps toward forming a network. Most leaders evaluated a network as an excellent or good idea. However, after attending the summit, participants commented on the need to better define a network's mission, vision, and funding path. Summit attendees suggested holding an additional meeting to build among institutes consensus regarding practical steps toward structuring, launching, and operating a network. To secure stakeholder buy-in, attendees suggested creating a directory of energy experts, engaging stakeholders through partnerships and publications, and obtaining additional stakeholder input through electronic and virtual communication.

Overall Assessment of a Network

In our post-summit survey, we asked summit attendees: With the information that you gathered at the summit, how would you evaluate the idea of forming a network of U.S. university energy institutes in some form, if the opportunity arose today? We asked attendees to select one option from the following list: Excellent Idea, good idea, fair idea, poor idea, and terrible idea. Figure 36 presents attendees' evaluations. Forty-four percent of attendees evaluated the network as an excellent idea, 42% as a good idea, 6% as a fair idea, and 2% as a poor idea.

We asked respondents to explain their evaluation. Appendix B, Table B20 presents explanations provided by respondents who evaluated the network as an excellent idea. Four respondents provided explanations related to collaborations. Of these respondents, two mentioned a network's potential to improve collaborations in general, one mentioned a network's potential to facilitate collaborations in interdisciplinary areas, such as technology development, social justice, innovation, and sustainability, and finally, another mentioned a network's potential to match academic researchers and coordinate joint research proposals. Two respondents provided explanations related to a network's ability to facilitate information sharing. One of these respondents explained that a network could facilitate the sharing of best practices among institutes, and the other explained that information sharing would reduce redundancy in energy-related work. Two respondents explained that a network could influence energy-related funding. One of these respondents explained that a network could help DOE identify problems to solve (this same attendee recommended that a network include diverse institutes), and the other explained that a network could serve as a collective voice to inform DOE policy and funding. In addition, two respondents explained that a network could impact national policy, and two respondents explained that a network could be useful in general.

Appendix B, Table B21 presents explanations provided by respondents who evaluated a network as a good idea. These respondents explained that a network's focuses and value need clarification. Four respondents expressed uncertainty about a network's focuses. Of these respondents, one explained that a network needs to determine if it's inwardly or outwardly focused, another explained that a network needs clear objectives, especially during its early stages of formation, another explained that a network's vision and agenda need clarification, and

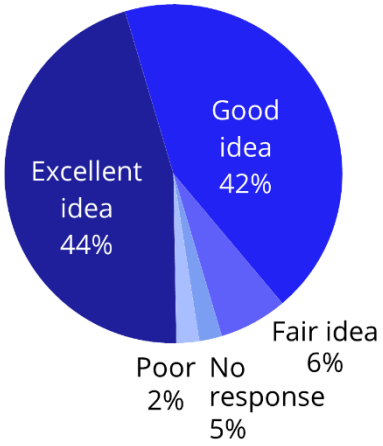

Figure 36. Summit attendees' evaluations of the overall idea of forming a network. Forty-four percent of survey participants evaluated a network as an excellent idea, and 42% of respondents evaluated a network as a good idea.

The percent of leaders who selected each option is indicated. All evaluations shown were selected from the list given in the question. Appendix B, Tables B20 and B21 present explanations provided by respondents who evaluated a network as an excellent or good idea, respectively.

finally, another stated that a network's objectives need clarification in general. Four attendees expressed uncertainty about a network's value. Of these attendees, one explained that a network's value proposition needs to be identified and communicated, another explained that a network's value proposition depends on a network's objectives, another explained that a network needs to bring value to all member energy institutes, and finally, another expressed uncertainty about a network's value proposition in general.

Three respondents evaluated a network as a fair idea. These respondents explained that a network's value proposition needs clarification. One respondent explained they support networking in general but do not understand a network's return on investment, another recommended holding additional annual meetings to determine a network's value, and finally, the other did not provide an explanation.

One respondent evaluated a network as a poor idea. This respondent explained that they support networking but recommended identifying a network's value before forming an organization requiring membership dues and staff.

Steps toward Forming a Network

In our post-summit survey, we asked attendees: In your opinion, what should be the next steps toward forming a network of U.S. university energy institutes? We provided respondents with a list of next steps and asked attendees to rank the five most important steps. We also provided space for attendees to write steps. Figure 37 presents steps selected from the given list. Seventy-five percent of respondents ranked meeting again among the five most important next steps, and 60% ranked creating a network's vision statement among the five most important next steps. Respondents also ranked, among the five most important steps and in order of decreasing frequency of selection, creating a network's mission statement, hosting an additional meeting for

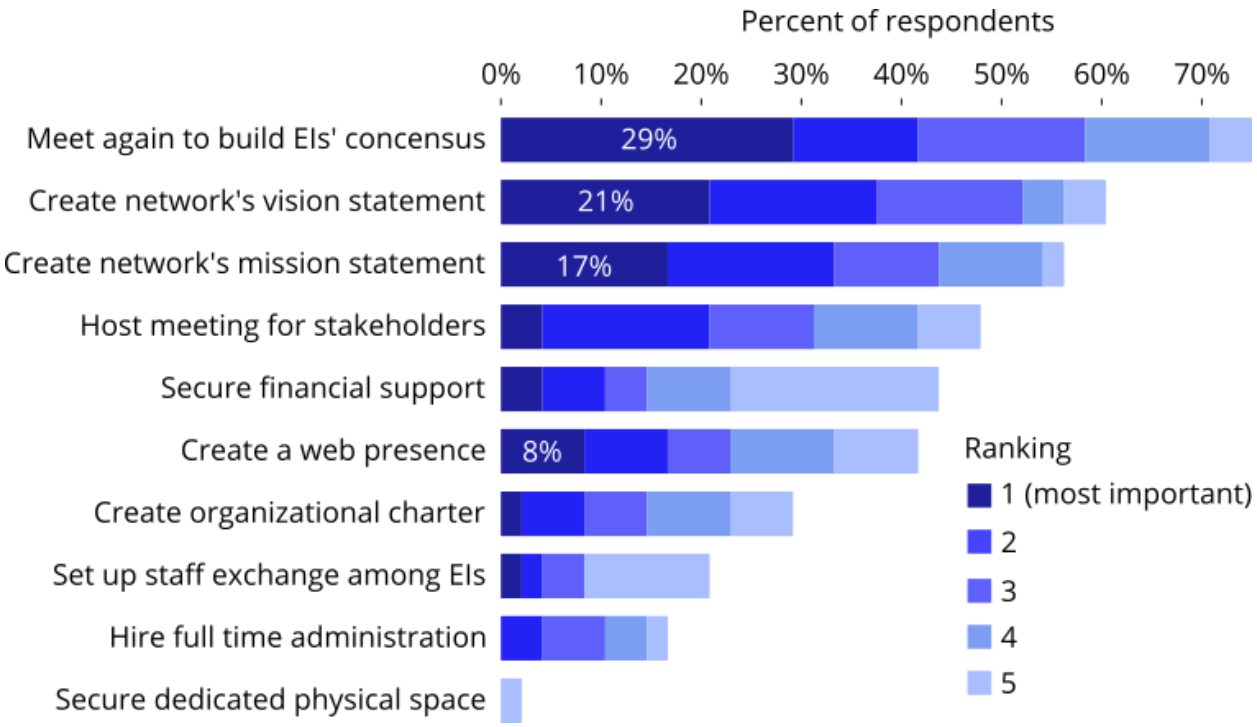

Figure 37. Summit attendees' recommended next steps toward forming a network. Twenty-nine percent of survey participants ranked holding an additional meting as the most important step, and 21% of survey participants ranked creating a network's vision statement as the most important steps.

Next step is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. All next steps shown were selected from the list given in the question. Appendix B, Table B22 presents next steps written by respondents.

stakeholders, securing financial support, creating a web presence, creating an organizational charter, setting up a staff exchange among institutes, hiring a full-time administration, and securing dedicated physical space.

Several attendees wrote next steps not provided in the given list and related to forming a steering committee, obtaining input from stakeholders, defining a network's vision, and fostering communication (Appendix B, Table B22). Two respondents wrote forming a steering committee to oversee the planning and formation of a network. One of these respondents clarified that an interim steering committee should have broad representation from the energy institute community to ensure that the network works for and is supported by many institutes, and the other stated that a steering committee should have decision-making authority. Two respondents wrote obtaining input from stakeholders electronically. One of these respondents recommended using email, phone, or Skype to obtain stakeholder input, and the other recommended using webinars to obtain stakeholder input.

We asked respondents: If additional meetings among U.S. university energy institutes were held to discuss and plan forming a network, with what frequency do you think these meetings should be held? We asked respondents to select one frequency from the following list:

Twice per year, once per year, and once every two years.[84] We also provided space for respondents to write frequencies. Fifty-seven percent of respondents recommended meeting once per year, 26% recommended meeting twice per year, and nine percent recommended meeting once every two years. Respondents wrote frequencies not included in the given list. We present these frequencies in Appendix B, Table B23. Two respondents wrote that, in general, meetings should occur relatively frequently during a network's early stages of formation, and two respondents wrote that meetings should occur twice per year during a network's early stages of formation. Respondents also recommended alternative years for smaller leadership meetings, more frequent meetings for network subcommittees and less frequent meetings for the entire network, once per two to three months for online discussions, and holding separate meetings for directors and staff—once per year for directors and once per year for staff.

Securing Stakeholder Buy-In

At the 2019 University Energy Institute Leadership Summit, we asked attendees: How could a network secure stakeholder buy-in? What are avenues for forming and growing collaborations with industry, policymakers, and other stakeholders? Using text clustering,[85] we extracted keywords from participants' responses. As displayed in Figure 38, participants most frequently mentioned, in order of decreasing frequency, "Stakeholder," "Energy," "Member/Partner," "Institute," "National," "Research," and "Industry." We categorized participants' responses by identifying all responses that mentioned a given keyword and, using text clustering, dividing these responses into categories. Appendix B, Table B24 presents the category names. Below, we summarize our findings and provide examples of responses.

Stakeholder. In their responses, 30% of participants mentioned "Stakeholder." The clustering algorithm grouped these responses into eight categories. Four of these categories ("Accessible, Accurate, Bit, Build, Businesses, Comments, Faculty, Gateway, Goals, Government, Heard, Horizon, Ideology, Industry, Longer, Matching, Portal, Proposition, Resources, Shopping, Skills, Stop, Suited, Tell, Universities," "Achieve," "Influenced," and "Members") each contained three responses, and four of these categories ("Buy-In, Energy, Institute's," "National," "Setup, Student," and "Technology") each contained two responses. For example, one response, categorized under "Accessible, Accurate, Bit, Build, Businesses, Comments, Faculty, Gateway, Goals, Government, Heard, Horizon, Ideology, Industry, Longer, Matching, Portal, Proposition, Resources, Shopping, Skills, Stop, Suited, Tell, Universities," stated "I've heard many comments on who our stakeholders are—faculty, industry, etc. Again, by having a bit of an accessible directory of skills and resources, stakeholders might have a portal or gateway to matching their needs with institutions best suited to meeting those goals." Another response, categorized under "Achieve," stated "Achieve bigger objectives that can't be achieved individually; internal versus external stakeholders; recognize all stakeholders, those who can pay and who cannot." Another response, categorized under "Influenced," stated in part "Questions on conflicts of interest must be addressed…Including other interests for people who don't have money to pay to play (energy justice)." Yet another response, categorized under "Members," stated "The network administrator(s) can set up a directory of member institutes for stakeholders to get the big picture

[84] In this question, we intended to ask participants to select one option from the following list: Once per two years, once annually, or twice per year. Instructions were accidentally omitted and the question instead provided spaces for participants to rank each option. Here, we present all "1" rankings.
[85] "Extract Valuable Information from Any Text Source (Version 3.4.1.0)," MeaningCloud, 2019, https://www.meaningcloud.com/; MonkeyLearn, "Text Analysis," accessed January 13, 2019, https://monkeylearn.com/text-analysis/.

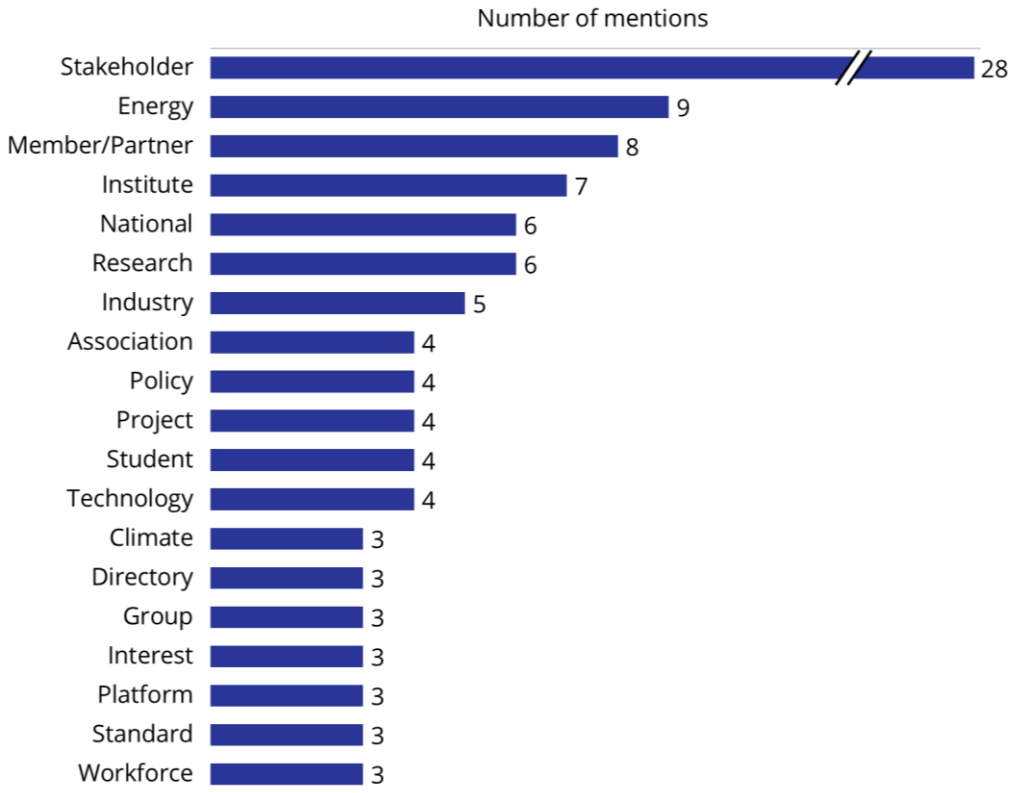

Figure 38. ***How could a network secure stakeholder buy-in? What are avenues for forming and growing collaborations with industry, policymakers, and other stakeholders?***

Keywords extracted from summit participants' responses to the question above. Participants most frequently mentioned "Stakeholder," "Energy," "Member/Partner," and "Institute." Often but less frequently, participants mentioned "National," "Research," and "Industry."

Keyword is displayed along the vertical axis, and the number of mentions is displayed along the horizontal axis. Keywords with fewer than three mentions are not shown. Appendix B, Table B24 presents categories produced by our text clustering analysis.

and choose a partner with the best alignment. They can also convene meetings of members with stakeholders invited to speak and network."

Energy. In their responses, 14% of participants mentioned "Energy." The clustering algorithm grouped these responses into three categories. One of these categories ("Institute's") contained four responses, one category ("Influenced, Money, Professional, Society") contained three responses, and one category ("National") contained two responses. For example, one response, categorized under "Institute's," stated in part "…Need to get all energy institutes (that participate) to buy-in first. Then, that could be leveraged to get stakeholder[s]. Diverse stakeholder base, even those who don't have money…" Another response, categorized under "Institute's," stated "Demonstrated expertise (past evidence) and small successes (multi-institution current projects). Serve as a think-tank/sound board for a national policy and similar

to requests for information (RFIs) that DOE puts out." Another response, categorized under "Influenced, Money, Professional, Society," stated "Energy professional society. Annual energy conference." Yet another response, categorized under "National," stated "National policy impact, informing national energy research, local-regional-national, best practices, stakeholder engagement."

Member/Partner. In their responses, 12% of participants mentioned "Member/Partner." The clustering algorithm grouped these responses into two categories, which were "Organizations" and "Work." Each of these categories contained four responses. For example, one response, categorized under "Organizations," stated "As stated by speakers, [a network] has to provide shared benefits. Find a funding source (philanthropy, dues) to help form initial partnerships that can demonstrate success." Another response, categorized under "Organizations," stated "By demonstrating that the whole is more important than the sum. Helping to share [in] an open source way what we know so members don't waste time on small problems but on big issues…Use the network to identify the most promising ideas." Another response, categorized under "Work," stated "Can they be members of the network if they have significant R&D efforts? For example, Exxon, EPRI. Establishing the 'voice' of the network as authoritative will be crucial to gaining purchase with stakeholders. If we're too vanilla or too internal in our approach, we won't attract attention." Yet another response, categorized under "Work," stated "Working with national labs. University partnerships are important."

Institute. In their responses, 9% of participants mentioned "Institute." The clustering algorithm grouped these responses into two categories, which were "Buy-In, Value" and "Member, Standard." Each of these categories contained three responses. For example, one response, categorized under "Buy-In, Value" stated "By demonstrating some value. For example, joint policy publications from multiple institutes may demonstrate more significant impact on decision-makers and therefore demonstrate value." Yet another response, categorized under "Member," stated "Idea: Establish some standards or metrics that institutes/universities could adopt as industry standards—beyond publications, grant money. Find collaborators—directory—make products."

In addition to the keywords described above, 6% of participants mentioned "National," 12% mentioned "Research," and 8% mentioned "Industry." Responses that mentioned "National" were grouped into two categories, which were "Available, Communications, Engagement, Help, Impact, Influence, Level, Local, Network, Practices, Purchase, Regional, Research, Stakeholder, State, Tools" and "Board, Collaboration, Current, CWS, Demonstrated, Department, DOE, Ecus, Evidence, Expertise, EXXON, Important, Labs, Multi-institution, NETL, NREL, Oven, Partnerships, Past, Possible, Projects, Puts, Requests, RFIs, Serve, Similar, Small, Sounding, Successes, Think-tank, University, Working." Responses that mentioned "Research" were grouped into two categories, which were "Development, DOE, Groups, Organize" and "National." Finally, responses that mentioned "Industry" were grouped into two categories, which were "Bread, DOE, Groups, Organize" and "Stakeholder, Standard."

Topics and Ideas for Further Discussion

In our post-summit survey, we asked summit attendees: Were there ideas or topics not raised during the summit that you think need attention? Respondents wrote 38 different topics, which we list in Appendix B, Table B25. Below, we present broad themes that emerged across leaders' responses.

Benefits and costs of a network. Respondents wrote topics related to a network's benefits, costs, and funding. For example, one respondent wanted to learn more about a hypothetical network's strategy to increase the total amount of research funding given to institutes. Another respondent mentioned that it would have been useful at the summit to differentiate between and discuss different types of benefits offered by a network, particularly benefits to its members versus benefits to society. Another respondent suggested listing tasks that a network might accomplish and assessing the benefits and costs of each task at varying levels of engagement. Three respondents mentioned funding. Of these respondents, one commented on the tightness of institute budgets, and another mentioned funding models. Two respondents mentioned the need to consider why, in the first place, an energy institute network is needed. One of these respondents mentioned that it may be too early to form an organization requiring membership dues.

Forming and operating a network. Respondents suggested addressing the logistics of forming a network. For example, one respondent mentioned the need to discuss a network's legal framework, and another respondent suggested discussing how a network might leverage laboratory and equipment already available at institutes. Respondents also commented on a network's role in the research community. One respondent mentioned the need to discuss DOE's role in formalizing a network, and yet another respondent mentioned the need to consider a network's role within existing communities, such as national laboratories and economic development groups. Yet another respondent mentioned diversity and inclusion. This respondent explained that collective action among energy institutes can help the energy institute community address energy challenges.

Individual institutes. Respondents wanted to learn more about energy institute operation, funding, and other logistics. One respondent wanted to learn more about how universities support their energy institutes and about other energy institutes that exist on campus. Another respondent suggested discussing how to serve competing constitutes within a university. Respondents also suggested discussing directors' roles in institutes, negotiating cost share within universities, and the placement of energy institutes within the university.

Conclusions

Network mission and objectives need clarification before further steps can be taken to structure and launch a network. Leaders who evaluated a network as a good or fair idea expressed uncertainty about network focuses and the value proposed by a network. To build consensus around purpose and goals, leaders recommended planning additional meetings among institutes, drafting mission and vision statements, and gathering additional input from stakeholders. Institutes could meet annually or biannually during a network's early stages and less frequently as the network develops. Leaders also recommended forming a steering committee to oversee a network's formation

Summit attendees recommended engaging a range of stakeholders, including those could and those who could not financially contribute to a network, and obtaining stakeholder input using email, phone, Skype, or webinars. To engage stakeholders, a network could create a web portal or directory through which stakeholders learn about and engage with academic energy experts. Institutes could further engage stakeholders by collectively hosting events and conferences.

Chapter 7

Summary and Recommendations

Reflections and Paths Forward

Summary

In this chapter, we identify broad themes that emerged during this study and recommend next steps toward forming a new network of U.S. university energy institutes. Our study revealed that institutes overlap in their missions and visions but differ in their finer interests, goals, and organizational structures. To better define a hypothetical network's purpose and plant the seed for network growth, we recommend forming a steering committee, hiring a small secretariat, holding additional meetings, creating a web presence, and gathering additional input from stakeholders. Installing or electing an advisory board composed of member institutes and prominent leaders in the U.S. energy community is also recommended.

Broad Themes

The following themes emerged during our study:

Institutes overlapped in their aims and strategic focuses but differed in their specific strengths and specializations. All leaders whom we surveyed indicated they would consider joining a new network of U.S. university energy institutes. Institutes overlapped in their missions to advance energy-related research, educate and train students, and impact scientific, technological, and policy landscapes. However, institute leaders and stakeholders anticipated that differing interests and goals could be a considerable challenge in engaging a network. Institutes vary in size, operating budget, governance structure, and their finer focuses and initiatives.

Institute leaders and stakeholders recommended that a network be national in scope, initiate opportunities for collaboration in research and education, and facilitate information sharing. Leaders suggested that institutes through a network host conferences and meetings, initiate joint projects, produce reports, and share best practices, data, papers, and student opportunities. Institutes leaders and stakeholders suggested a network could engage industry, policymakers, and nonprofits. In addition, summit participants suggested that a common core in higher education could comprise a range of topics, including business, economics, engineering, law, policy, and social science. Institutes could create a repository through which resources for these courses are shared.

A network could be financially supported by start-up and sustained funding from member contributions and/or external institutions. Institutes, foundations, government agencies, companies, and other stakeholders could support a small organization with a light dedicated staff. Our findings suggest that if a network were formed, institutes and stakeholders would contribute $299,000–$510,000 annually to a network.[86] Assuming an average staff employee salary of $75,000 (2019 USD), which amounts to $100,000 after taxes, benefits, and other

[86] The 66 institutes whom we surveyed indicated they would contribute $104,0000–$184,000 (Figure 25) per year. Assuming the entire pool of 157 institutes contributes the same amount per institute as our sample, we multiply the lower and upper financial contributions by 157/66 = 2.4. As a result, the anticipated contribution of all 157 institutes would equal $247,000–$438,000. Stakeholders indicated they would contribute $52,0000–$72,000 per year (Figure 35). Summing institute and stakeholder annual contributions, the total contribution from institutes and stakeholders would equal $299,000–$510,000.

costs,[87] and start-up costs of $35,000 (2019 USD),[88] institutes and stakeholders could support a consortium with 2–4 staff given minimal support from each institute. Receiving support from external entities is possible, but the funding source must be carefully considered, and the possibility of external influence tied to these funds must be avoided. *The organized network should not be influenced by outside agendas.*

Funding approaches need further discussion. Institutes and stakeholders identified lack of funding as one of the most considerable challenges to joining a network. Summit attendees suggested that a network could be funded by foundations, membership dues, government agencies, and industry. A foundation could provide seed funding for a network and, as a network develops, it could be sustained by membership fees, government, and industry contributions. After the summit, attendees still identified funding as a topic needing further discussion.

Before a network can be further developed, its value proposition, objectives, and vision need to be agreed upon. Summit attendees and survey respondents commented on the need to better define network vision, goals, and focuses. Summit attendees recommended, among the most important next steps toward forming a network, holding an additional meeting, which could be the first of several meetings to build consensus among institutes about next steps. Attendees also recommended creating vision and mission statements and determining the specific tasks and activities in which a network would engage.

A network should be jointly advised and centrally administered. To lead and coordinate a network, institute leaders recommended appointing and, eventually, electing an advisory board, which could comprise member institutes and outside leaders. A dedicated staff could be hired to facilitate daily communication and collaboration among institutes. Summit attendees also suggested a steering committee oversee the network's formation and early development.

Additional input should be obtained from stakeholders. Eighty-five percent of stakeholders whom we surveyed indicated they would interact with a network, but only 32% of stakeholders indicated they would financially contribute to a network. Institutes suggested that additional input be obtained from stakeholders through meetings, email, phone, Skype, or webinars. To secure stakeholder buy-in, summit attendees recommended creating a portal or directory through which stakeholders could learn about and engage academic experts.

Recommended Next Steps

To leverage complementary institute strengths, we suggest the following steps toward forming a network:

A steering committee should be formed to oversee the planning and formation of a network. The proposed steering committee would help structure, launch, and develop the network. The committee should be diverse and include participants from institutes ranging in size, location, and specialization. To ensure balanced representation, we recommend limiting the number of representatives per university. The steering committee should oversee the following tasks:

[87] Barbara Weltman, "How Much Does an Employee Cost You?," U.S. Small Business Administration, 2019, https://www.sba.gov/blog/how-much-does-employee-cost-you.
[88] Robert H. Scott, "The Use of Credit Card Debt by New Firms," 2009, https://www.kauffman.org/-/media/kauffman_org/research-reports-and-covers/2009/08/kfs_credit_card_debt_report.pdf; U.S. Department of Labor, "Producer Price Indexes (Annual Averages for Total Manufacturing Industries) [Data File]," 2020, http://www.bls.gov/ppi/.

- *Plan next meeting* (currently targeting January or February 2021): Decide on agenda and meeting format. Ask institutes to suggest discussion topics and action items.
- *Review energy institute list:* Determine if energy institutes are missing from the list presented in Appendix A and develop a rubric to identify and classify institutes henceforth.
- *Draft vision and mission statements:* Draft core statements and send to institutes and stakeholders for feedback. Present and discuss revised statements at Winter 2021 meeting.
- *Obtain additional stakeholder input:* Through a survey or virtual meeting, learn more about stakeholder expectations of a network and ways to engage stakeholders.
- *Create industry membership program:* Beginning with a simple web portal or director, launch a program that allows stakeholders to interact with institutes.
- *Form advisory board:* Initially appoint an advisory board. As a network matures, institutes could rotate leadership or elect an advisory board.
- *Create funding model:* Develop a strategy for early outreach to potential funders.

Create initial light secretariat function with at least one dedicated employee. To maintain momentum beyond a nascent network, hiring a dedicated small staff focused on regular communication is critical. A secretariat would facilitate the network's day-to-day operations, including administration of joint projects, event planning, internal and external communications, and website updates. Finding the right balance between connectivity and associated complexity will be key to ensuring a network's effectiveness.

Create website for institutes to communicate and share information with one another. As a first step toward forming a network, institutes could share, by way of a discussion board, BOX folder, networking page, or database/repository, the following information:

- *Best practices:* Strategies for enhancing education and student professional growth, growing collaborations, impacting policy, and strengthening research programs.
- *Course materials:* Lectures slides, videos, notes, and syllabi.
- *Funding opportunity announcements:* Regional, state, and national funding opportunities.
- *Student opportunities:* Fellowships, job openings, research awards, and scholarships.
- *Literature:* Briefs, peer-reviewed publications, white papers.
- *News:* Regional, state, and national news. Business, policy, and science updates.
- *Preliminary research findings:* Ideas, initial data, and seeds for new projects.

As a network develops, these forms of communication could evolve into joint projects, such as reports and research proposals, and exchange of faculty, staff, and students among institutes.

Create web portal for stakeholders to interact with a network. If a web portal can be created soon, it would allow stakeholders to quickly learn about a network and form partnerships with academic experts. A portal could be a directory or archive that summarizes expertise areas, funding and partnership opportunities, and institute resources (e.g., laboratories). As a network evolves, the portal could become a landing site and registration page for a network affiliate program.

Hold additional meetings (beyond the proposed Winter 2021 meeting) among institutes to build consensus around a network's vision and objectives. In the early stages, there could be several annual or biannual meetings among institutes to discuss and converge on a network's

mission, vision, specialties, and funding path. These meetings could comprise smaller breakout sessions to focus on energy-related topics and organizational issues. Between meetings, it would be useful to identify the potential tasks and activities of a network and continue soliciting input from institutes and stakeholders about the costs, benefits, and overall value of completing these tasks.

Obtain additional input from stakeholders about their needs and goals. To better understand stakeholder interests and expectations of a network, we recommend engaging a large and diverse stakeholder sample including foundations, government, industry, law, and nonprofit organizations. Stakeholders input could be obtained through surveys or virtual meetings.

Final Thoughts

This report has explored commonalities, differences, and potential collaborations among the many institutes that are conducting energy-related work at universities in the U.S. This investigation has taken the form of a multi-tiered study, the results of which have been presented, analyzed, and discussed in this report.

Many institutes already collaborate with industry, policymakers, and other universities. A clear opportunity exists: Finding a nation-wide organization of energy institutes could lead to bigger research impact, greater policy influence, and more collaborative funding. In addition, a network could help smaller or newer energy institutes learn and grow more rapidly as they interact with larger, more established institutes. Because institutes differ in strengths and specializations, network mission and vision would need to be inclusive, clearly communicate objectives and organizational values, and engage stakeholders from a range of disciplines.

Once first steps are taken, it is hoped that the network would grow in scope and influence and elevate the U.S. academic energy institute movement to a level at which all such institutes could work together to most effectively address the nation’s and world’s most pressing energy-related challenges. Institute leaders and stakeholders are interested in working together, perhaps initially by sharing resource and best practices. As a network develops, institutes could co-sponsor national events, engage policymakers, form industry partnerships, publish reports, pursue education initiatives, and write joint funding proposals.

As hubs for energy research, education, and outreach, energy institutes are uniquely positioned to shape environmental, policy, and technological landscapes. A network could grow collaborations in the academic and non-academic energy communities, establish a diverse and accessible body of experts to inform decision-making, and advance research toward achieving sustainability goals.

Appendix A

Energy Institute List

Number of Energy Institutes

As of April 2, 2020, we identified 157 U.S. university energy institutes, which are listed in Table A1. To report an energy institute missing from this list, please email the institute's name, university name, and contact information to the Wilton E. Scott Institute for Energy Innovation, Carnegie Mellon University at scottinstitute@andrew.cmu.edu.

Defining Energy Institute

This study includes only institutes that indicated, in their mission statements, on their websites, or by personal correspondence, a focus on energy research, development, deployment, or education. Energy here refers to the production, process, or storage of energy. We excluded energy institutes or centers administered by or part of other energy institutes.

Institutes Affiliated with Multiple Universities

Three institutes—Carnegie Energy Innovation, the Center for Advanced Energy Studies, and the Center for Information Technology Research in the Interest of Society (CITRIS) and the Banatao Institute—are affiliated with multiple universities or organizations. CITRIS and the Banatao Institute facilitates collaboration among the University of California campuses at Berkeley, Davis, Merced, and Santa Cruz [1]. Carnegie Energy Innovation is an independent project of the Carnegie Institution for Science [2]. The Center for Advanced Energy Studies (CAES) is a consortium between Boise State University, Idaho National Laboratory, Idaho State University, the University of Idaho, and the University of Wyoming [3]. For consistency, throughout this study, we affiliated Carnegie Energy Innovation with Stanford University, on which campus Carnegie Energy Innovation is housed [2].

Table A1. University energy institutes in the U.S. This table is alphabetized by university. References are presented at the end of this appendix. List updated April 2, 2020.

University	Energy institute	Ref.
American University	Center for Environmental Policy	[4]
Appalachian State University	Appalachian Energy Center	[5]
Arizona State University	Julie Ann Wrigley Global Institute of Sustainability	[6]
Ball State University	Center for Energy Research/Education/Service	[7]
Boise State University	The Energy Policy Institute	[8]
Boise State University, Idaho State University, Idaho National Laboratory, University of Idaho, University of Wyoming	Center for Advanced Energy Studies	[9]
Boston University	BU Institute for Sustainable Energy	[10]
Bowling Green State University	Center of Excellence for Sustainability and the Environment	[11]
California Institute of Technology	Resnick Sustainability Institute	[12]

Continued on next page

Table A1 continued

Carnegie Mellon University	Wilton E. Scott Institute for Energy Innovation	[13]
Case Western Reserve University	Great Lakes Energy Institute	[14]
Central Michigan University	Great Lakes Institute for Sustainable Systems	[15]
Clarkson University	Center for Sustainable Energy Systems	[16]
Clarkson University	Institute for a Sustainable Environment	[17]
Clemson University	Clemson University Restoration Institute	[18]
College of William and Mary	Commonwealth Center for Energy and the Environment	[19]
Colorado School of Mines	The Payne Institute for Public Policy	[20]
Colorado State University	Colorado State University Energy Institute	[21]
Columbia University	Center on Global Energy Policy	[22]
Columbia University	Columbia Electrochemical Energy Center	[23]
Columbia University	The Earth Institute	[24]
Cornell University	Cornell Atkinson Center for Sustainability	[25]
Cornell University	Cornell Energy Systems Institute	[26]
Dartmouth College	Arthur L. Irving Institute for Energy and Society	[27]
Dartmouth College	Revers Center for Energy	[28]
Drexel University	A.J. Drexel Institute for Energy and the Environment	[29]
Duke University	Center for Energy, Development, and the Global Environment	[30]
Duke University	Duke University Energy Initiative	[31]
Duke University	Nicholas Institute for Environmental Policy Solutions	[32]
East Carolina University	Center for Sustainable Energy and Environmental	[33]
Eastern Illinois University	Center for Clean Energy Research and Education	[34]
George Mason University	Center for Energy Science and Policy	[35]
Georgetown University	Georgetown Climate Center	[36]
Georgia Institute of Technology	Georgia Tech Strategic Energy Institute	[37]
Harvard University	Harvard University Center for the Environment	[38]
Howard University	Center for Energy Systems and Control	[39]
Idaho State University	Energy Systems Technology and Education Center	[40]
Illinois Institute of Technology	Wanger Institute for Sustainable Energy Research	[41]
Indiana University	Center for Research in Energy and the Environment	[42]
Indiana University-Purdue University	Richard G. Lugar Center for Renewable Energy	[43]
Johns Hopkins University	Initiative for Sustainable Energy Policy	[44]
Lehigh University	Institute for Cyber Physical Infrastructure and Energy	[45]
Louisiana State University	Center for Energy Studies	[46]
Loyola University Chicago	Institute of Environmental Sustainability	[47]
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Pace University	Pace Energy and Climate Center	[62]
Princeton University	Andlinger Center for Energy and the Environment	[63]
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Stanford University	Carnegie Energy Innovation	[72]
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University of Colorado, Boulder	Renewable and Sustainable Energy Institute	[116]
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Appendix B

Supplementary Data

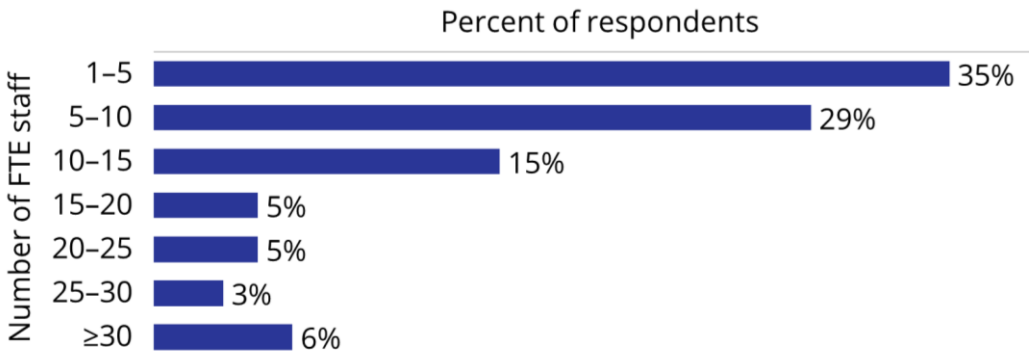

Figure B1. Full-time equivalent (FTE) staff at energy institutes. Most energy institutes employ fewer than 10 FTE staff, 15% employ between 10 and 15 staff, and 19% employ more than 15 FTE staff.

The number of FTE staff is displayed along the vertical axis, and the percent of survey participants is displayed along the horizontal axis. The bin width equals five FTE staff. Within each bin, the lower bound is inclusive, and the upper bound is exclusive.

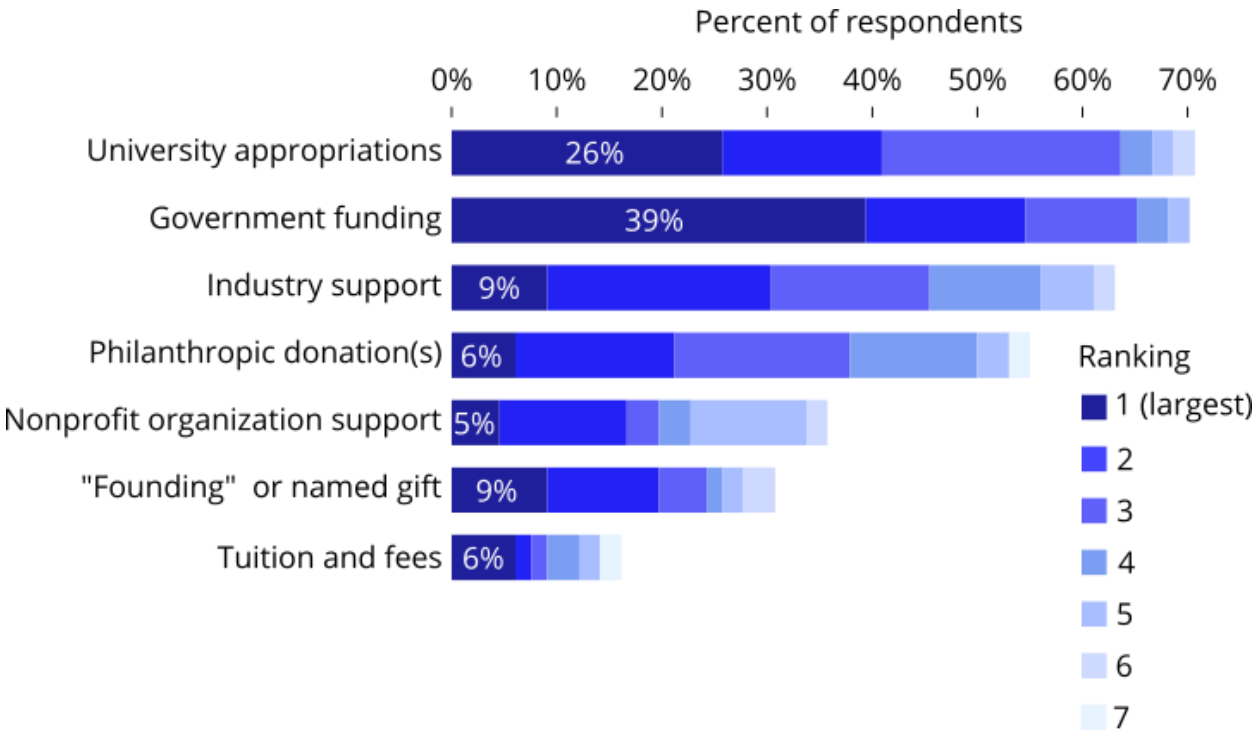

Figure B2. Institutes' funding sources ranked in order of annual contribution amount. Thirty-nine percent of Institutes ranked government funding as their largest funding source, and 26% of institutes ranked university appropriations as their largest funding source.

Funding source is displayed along the vertical axis, and the percent of survey respondents is displayed along the horizontal axis. Industry support include contracts, grants, gifts, and sponsorships. Tuition and fees are paid directly to the institute. All funding sources shown were selected from the list given in the question.

Table B1. Text clustering analysis of energy institutes' mission statements. We first identified all mission statements that mentioned a given keyword, as specified in Figure 5 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these mission statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of mission statements that a category contains.

Keyword	Category name (size)			
Energy	Climate (8)	Innovative (3)	Promote (2)	Education (1)
	Public (8)	Mission (3)	Resources (2)	Efficiency (1)
	Initiatives (5)	Social (3)	Science (2)	Environmental (1)
	Renewable (5)	Address (2)	Students (2)	Faculty (1)
	Alternative (4)	Facilitate (2)	Transition (2)	Fuels (1)
	Critical (4)	Federal (2)	University (2)	Generation (1)
	Industry (4)	Future (2)	World (2)	Integration (1)
	Institute (4)	Government (2)	Advanced (1)	Issues (1)
	National (4)	Grid (2)	Approaches (1)	Law (1)
	Problems (4)	Group (2)	Business (1)	Other Topics (1)
	Projects (4)	Help (2)	Climate, Change (1)	State (1)
	Environment (3)	Interdisciplinary (2)	Commercialization (1)	Storage (1)
	Focus (3)	Leaders (2)	Conduct (1)	Support (1)
	Implement (3)	Leading (2)	Create (1)	Training (1)
Research	Mission (6)	Critical (2)	Resources (2)	Fuels (1)
	Power (6)	Economic (2)	Science (2)	Help (1)
	Sustainable (5)	Efficiency (2)	Scientists (2)	Human (1)
	Academic (3)	Energy-related (2)	Sector (2)	Information (1)
	Alternative (3)	Environment (2)	SEEPAC (2)	Leading (1)
	Decision (3)	Expand (2)	Storage (2)	Management (1)
	Environmental (3)	Grid (2)	Transition (2)	Policy (1)
	Related (3)	Initiatives (2)	Wind (2)	Problems (1)
	Strategic (3)	Institute (2)	Build (1)	Promote (1)
	Understanding (3)	Interdisciplinary (2)	CEEL (1)	Public (1)
	Bring (2)	International (2)	Collaborative (1)	Quality (1)
	Business (2)	Issues (2)	Commercialization (1)	Sources (1)
	Campus (2)	Projects (2)	Dedicated (1)	Support (1)
	Clean, Leaders (2)	Resilient (2)	Focus (1)	Training (1)
Environment	Resources (4)	Require (2)	Consulting, Highly (1)	Projects (1)
	Louisiana (3)	Scientists (2)	Cost (1)	Protection (1)
	Studies (3)	Solving (2)	Dynamic (1)	Related (1)
	Advanced (2)	Sources (2)	Faculty (1)	Team (1)
	Approaches (2)	Understanding (2)	Goal (1)	Technologies (1)
	Efficiency (2)	Vermont (2)	Integrated (1)	Transition (1)
	Environment (2)	Affordable,	Investigating (1)	Unique, Diverse (1)
	Experts (2)	Approaches (1)	Issues (1)	Visiting (1)
	Florida (2)	Business (1)	Law (1)	
	Foster (2)	Climate, Impacts (1)	Management (1)	
	Help (2)	Commercial (1)	MIT (1)	
	Industry (2)	Connect (1)	National (1)	
	Initiatives (2)	Consequences,	Ottinger (1)	
	Mission (2)	Investigating (1)	Policy (1)	

Continued on next page

Table B1 continued

Policy	Adaptation (3) IEXE (3) State (3) Arizona (2) Business (2) CEES (2) Education (2) Foster (2) National (2) Sustainable (2)	Vermont (2) York (2) Alternative (1) Approaches, Partnerships (1) Arizona, Create (1) Berkeley (1) CEEL (1) CEEPR (1) CES (1)	Choices (1) Conduct (1) Current, Design, Fossil (1) Emissions (1) Ensure, Viable (1) ERC (1) Ideas (1) ISE (1) Law, Resources (1)	Levels (1) Market (1) Resources (1) SEEPAC (1) Sound (1) Studies (1) Visiting (1)
Technology	Foster (3) Electrochemical (2) ESE (2) Protection (2) Achieve, Colorado (1) Alternative (1) Andlinger (1) Banking, Dimension, Employ, Employee, Financial, Firms, Incorporates (1)	CEES, MSU (1) CERT, Seriously (1) Characteristics, Encountered, Essential (1) Climate (1) Florida (1) Fuels (1) Growing (1) Heating (1) Inform (1) Knowledge (1)	Officials (1) Power (1) Problems (1) Related (1) Shape (1) Sources (1) Systems (1) Team (1) University (1)	
Science/Knowledge	Capital, Communications (2) Center (2) Choices, VIEE (2) Collaboration (2) Community (2) Electrochemical (2) Endeavor (2) Established, Tradition (2)	IEXE (2) Issues (2) Learning, Service (2) NUCRET (2) Problems (2) Sources (2) Supports (2) Wind (2) Approaches (1)	Better (1) Carbon, Emissions (1) CEEL (1) CEES (1) CES (1) CES, Baker, Capital, Comparative (1) Chemistry, Yale (1) Contribute, Operations (1)	DEI (1) Environmental (1) ESE (1) Foster (1) Grant, Level (1) Implications (1) Initiatives (1) Law (1) Officials (1) Skills (1)
Education	Center (3) Collaborative (3) Agencies, Customers, Federal, Manufacturing, Path, Visit (2) Analytics, Art, Conservation, Corporations, Federal, Life, Reliable (2) Arizona (2) Basic (2) Campus (2) Catalyze (2)	CEAGE (2) CEES (2) CERT, Houston (2) Environment (2) Ideas (2) IIT (2) ISE (2) Production (2) Protection (2) Sectors (2) VIEE (2) Affecting, Consulting, Deliver, Highly, Planet, Skill, Success (1)	Campus-wide, Continue, Growth (1) CEEL (1) CER, Continue, Distributed, Original (1) Clean (1) Demand (1) Discussion, Pressing, Questions (1) ERC (1) ERC, Analysts, Economist, Highly, Multi-disciplinary, Scientists (1)	ESE (1) Health, Response (1) Illinois, Scientists (1) Innovative (1) Law (1) Learning (1) MIT (1) Team (1) Wind (1)

Table B2. ***Which of the following staff roles does your energy institute have?***

The staff roles below were written by pre-summit leadership survey respondents. We grouped similar staff roles together, and we indicate below the number of respondents who mentioned each staff role. Each response belongs to one and only one category. Figure 6 in the main text presents respondents' selections from the list given in the question.

Staff role	Number of respondents
Program manager	4
Attorney	2
Development director	2
Laboratory director	2
Administrative assistant	1
Analysts	1
Assistant director	1
Business development manager	1
Chief operating officer	1
Deputy director	1
Doctoral fellows	1
Extension specialist	1
Faculty	1
Finance team who administers sponsor funding	1
Human resources	1
Industry liaison	1
Information services	1
Manager	1
Outreach and events coordinator	1
Partnerships director	1
Project manager	1
Proposal manager	1
Research and communications director	1
Research coordination and sponsorships director	1
Research development	1
Research director	1
Research operations lead	1
Research staff	1
Research, education, and innovation specialists	1
Sustainability director	1
Visiting scholars	1

Table B3. ***What are your energy institute's strategic focuses?***

The focuses below were written by pre-summit leadership survey respondents. We grouped similar strategic focuses together, and we indicate below the number of respondents who mentioned each strategic focus. Each response belongs to one and only one category. In addition to the focuses below, one respondent mentioned that their energy institute pursues all the focuses in the given list, and another respondent stated that they were unable to rank the listed focuses. Figure 8 in the main text presents respondents' selections from the list given in the question.

Strategic focus	Number of respondents
Collaboration	7
Research	2
Develop solutions to international challenges	1
Education	1
Engage alumni	1
Facilities investment	1
Implement solutions at scale using entrepreneurial models	1
Lead initiatives that help solve state and regional challenges	1
Technology-to-market	1

Table B4. ***What applications does your energy institute research?***

The applications below were written by pre-summit leadership survey respondents. We grouped similar applications together, and we indicate below the number of respondents who mentioned each application. Each response belongs to one and only one category. In addition to the applications below, three respondents mentioned data science or modeling, which we considered techniques and thus did not include in this table, and two respondents mentioned education, which we considered a strategic focus and thus did not include in this table. Figure 9 in the main text presents respondents' selections from the list given in the question.

Research application	Number of respondents
Policies, markets, economics	12
Grids, energy systems	10
Renewables	8
Environmental impact reduction	4
Water	3
Water-Energy-Food nexus	3
Advanced materials, advanced manufacturing	2
Catalysis	2
Efficiency	2
Energy and society	2
Energy in developing countries	2
Advanced digital technologies for oil and gas operations	1
Batteries	1
Business models and supply chain efficiency	1
Chemical reaction engineering	1
Cyberphysical security for energy operations	1
Demand side management	1
Electricity	1
Emerging energy technologies	1
Energy geoscience	1
Energy in cold climates	1
Energy in healthcare	1
Environmental threats to communities	1
Federal lands	1
Fuel cells	1
Materials and chemistry in energy	1
Non-battery storage	1
Politics associated with sustainability transitions	1
Power electronics	1
Transportation	1

Table B5. ***What energy sources does your energy institute research?***

The energy sources below were written by pre-summit leadership survey respondents. We grouped similar energy sources together, and we indicate below the number of respondents who mentioned each energy source. Each response belongs to one and only one category. In addition to the sources below, one respondent mentioned that their institute researches all sources in the given list. Figure 10 in the main text presents respondents' selections from the list given in the question.

Energy source	Number of respondents
Infrastructure	5
Natural gas, fossil fuels	4
Solar	4
Bioenergy	2
Energy efficiency	2
Wind	2
Electricity from all sources	1
Electricity from grid	1
Fusion	1
Geothermal	1
Hydrokinetic	1
Rare earth minerals and critical materials	1
Renewable implications (e.g., intermittency)	1
Transportation fuels	1
Waste-to-energy	1

Table B6. ***What research techniques does your energy institute use?***

The research techniques below were written by pre-summit leadership survey respondents. We grouped similar research techniques together, and we indicate below the number of respondents who mentioned each research technique. Each response belongs to one and only one category. Figure 11 presents respondents' selections from the list given in the question.

Research technique	Number of respondents
Humanities, law, policy, social science	4
Laboratory experiments	3
Modeling or simulation	3
Artificial intelligence or machine learning	2
Field experiments, piloting	2
Big data	1
Case studies	1
Commercial scaleup	1
Statistics	1
Statistical and econometric analysis	1
Testbeds and pilot lines	1

Table B7. ***What would the mission and vision statements of a university energy institute network say? What elements, such as research focuses, policy impact, industry collaboration, technology advancement, and education, would be included?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 15 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size is indicated and represents the number of responses that a category contains.

Keyword	Category name (size)	
Energy	• Advancing (4) • Age, Case, Scholar, Sources (4) • Bridge (3) • Carbon, Exists, Net-Zero (4) • Help (3)	• Network (2) • Pillars (4) • Represent (4) • Technology, Continue (4) • Versus (2)
Education	• Advocacy (3) • Exists (3) • Pillars (3) • Serve (3)	• Stakeholders (3) • Support (4) • Transition, Visibility (3) • Versus (3)
Policy	• Average, Reach (3) • Case (3) • Focus (3) • Network (4)	• Outreach (3) • Represent (3) • Serve, Sources (3) • Versus (3)
Research	• Case, Group (4) • Faculty (4) • Federal (3) • Represent (3)	• Serve, Influence (4) • Table (3) • Transition (4) • Versus (3)
Institute	• Age, Building, Capacity, Scholar (3) • Case (3) • Global (2) • Resources (2)	• Serve (2) • Set, Sources (3) • Stakeholders (3) • Versus (3)
Industry	• Age, Benefit, Scholar (2) • Broad, Come, Community, Connect, Governmental, High, Participation, Place, Science, Vehicle (2) • Future (3) • Individual (3)	• Influence (2) • Serve (2) • Students (3) • Visibility (3)

Table B8. Master's degrees focused on energy, as reported by participants in our pre-summit leadership survey and information we gathered online. We considered only the 62 universities whose energy institutes participated in our pre-summit leadership survey. These universities are listed in Appendix C, Table C2. The degree name needed to include the word "Energy" to be included in this table. We included specializations, concentrations, tracks, and focuses. If a degree name included the word "Energy," then we did not look further into the degree's specializations and concentrations. We excluded individual courses, as these were too granular. An asterisk indicates that the degree was offered by an energy institute; all other degrees were offered through colleges or schools. Figure 16 in the main text presents the percent of universities who offered energy-focused education programs.

University	Master's degree	Reference
Appalachian State University	Master of Science in Technology; Concentration: Renewable Energy Engineering	[2]
Arizona State University	Master of Science in Architecture; Concentration: Energy Performance and Climate-Responsive Architecture	[3]
	Professional Science Master's in Solar Energy Engineering and Commercialization	[4]
Boise State University	Master of Public Administration; Track: Environmental, Natural Resource, and Energy Policy and Administration	[5]
Boston University	Master of Arts in Energy and Environment	[6]
	Master of Business Administration; Concentration: Energy and Environmental Sustainability	[7]
Carnegie Mellon University	Master of Business Administration; Track: Energy Business	[8]
	Master of Science in Civil and Environmental Engineering; Concentration in Energy Infrastructure Systems	[9]
	Master of Science in Energy Science, Technology and Policy	[10]
Clarkson University	Master of Science in Energy Systems	[11]
Colorado School of Mines	Master of Science in Advanced Energy Systems	[12]
	Master of Science in Mineral and Energy Economics	[13]
	Master of Science in Natural Resources and Energy Policy	[14]
Duke University	Master of Business Administration; Concentration: Energy and Environment	[15]
	Master of Business Administration; Concentration: Energy Finance	[15]
	Master of Environmental Management; Specialization: Energy and Environment	[16]
	Master of Public Policy; Concentration in Environment and Energy	[17]

Continued on next page

Table B8 continued

Illinois Institute of Technology	Master of Engineering in Environmental Engineering; Specialization: Energy/Environment/Economics	[18]
	Master of Engineering in Materials Science and Engineering; Specialization: Energy/Environment/Economics	[18]
	Master of Engineering in Mechanical and Aerospace Engineering; Specialization: Energy/Environment/Economics	[18]
	Master of Engineering; Track: Energy Systems, Energy Conservation, and Buildings	[18]
	Master of Engineering; Track: Energy Systems, Energy Generation, and Markets	[18]
	Master of Engineering; Track: Energy Systems, Energy Generation, and Sustainability	[18]
	Master of Science in Materials Science and Engineering; Specialization: Energy/Environment/Economics	[18]
Indiana University–Purdue University Indianapolis	Master of Science in Environmental Science; Concentration: Energy	[19]
Johns Hopkins University	Master of Science in Energy Policy and Climate	[20]
Lehigh University	Master of Engineering in Chemical Energy Engineering	[21]
	Professional Master of Engineering in Energy Systems Engineering	[22]
New York University	Master of Laws in Environmental and Energy Law	[23]
	Master of Science in Global Affairs; Concentration: Environment and Energy Policy	[24]
Northwestern University	Master of Science in Energy and Sustainability*	[25]
	Master of Science in Mechanical Engineering; Specialization: Energy and Sustainability	[26]
Rice University	Master of Energy Economics	[27]
Rutgers University	Master of Engineering in Energy Systems Engineering	[28]
Southern Methodist University	Master of Business Administration; Concentration in Energy Finance	[29]
Stanford University	Master of Science in Civil and Environmental Engineering; Concentration: Atmosphere/Energy	[30]
	Master of Science in Energy Resources Engineering	[31]
Texas A&M University	Master of Science in Energy*	[32]
The George Washington University	Master of Science in Engineering Management; Focus: Environmental and Energy Management	[33]

Continued on next page

Table B8 continued

The Pennsylvania State University	Master of Professional Studies in Renewable Energy and Sustainability Systems	[34]
	Master of Science in Energy and Mineral Engineering	[35]
	Master of Science in Energy, Environment, and Food Economics	[36]
The University of North Carolina, Charlotte	Master of Business Administration; Concentration: Energy	[37]
	Master of Science in Applied Energy and Electromechanical Systems	[38]
	Master of Science in Engineering Management; Concentration: Energy Analytics	[39]
The University of Oklahoma	Executive Master of Business Administration in Energy	[40]
	Master of Legal Studies in Oil, Gas, and Energy Law	[41]
The University of Texas, Austin	Master of Science in Energy and Earth Resources	[42]
	Master of Science in Energy Management	[43]
Tufts University	Master of Science in Offshore Wind Energy Engineering	[44]
Tulane University	Master of Management in Energy	[45]
University of California, Santa Barbara	Master of Environmental Science and Management; Specialization: Energy and Climate	[46]
University of California, Berkeley	Master of Arts in Energy and Resources*,†	[47]
	Master of Science in Energy and Resources*,†	[47]
University of California, Davis	Master of Science in Energy Systems*	[48]
University of Colorado, Boulder	Master of Engineering in Electrical, Computer and Energy Engineering	[49]
	Master of Science in Electrical, Computer and Energy Engineering	[49]
	Master of the Environment; Specialization: Renewable and Sustainable Energy	[50]
	Professional Master of Science in Electrical, Computer and Energy Engineering	[51]
University of Connecticut	Master of Energy and Environmental Management	[52]
	Master of Laws in Energy and Environmental Law	[53]
	Master of Science and Master of Engineering in Advanced Manufacturing for Energy Systems	[54]
University of Delaware	Master of Energy and Environmental Policy	[55]
University of Houston	Master of Science in Global Energy Management	[56]

Continued on next page

Table B8 continued

University of Illinois, Urbana–Champaign	Master of Engineering in Energy Systems	[57]
	Master of Science in Civil Engineering or Environmental Engineering (Energy-Water-Environment Sustainability)	[58]
University of Maryland	Master of Engineering in Energy Systems Engineering	[59]
University of Minnesota	Master of Laws; Concentration in Environmental and Energy Law	[60]
University of Southern California	Master of Science in Mechanical Engineering; Concentration: Energy Conversion	[61]
University of Washington	Master of Science in Civil Engineering: Energy Infrastructure	[62]
University of Wisconsin, Madison	Master of Science in Resource and Energy Demand Analysis	[63]
University of Wyoming	Master of Business Administration in Energy Management	[64]
Vermont Law School	Master of Energy Regulation and Law	[65]
	Master of Laws in Energy Law	[66]
West Virginia University	Master of Laws in Energy and Sustainable Development Law	[67]
	Master of Science in Energy Environments	[68]
	Master of Science in Energy Systems Engineering	[69]
Yale University	Master of Environmental Management; Specialization: Energy and the Environment	[70]

† The Energy and Resources Master's Degree (MA or MS) is offered independently or jointly with a Master of Public Policy or Juris Doctor Law Degree.

Table B9. Certificates focused on energy, as reported by participants in our pre-summit leadership survey and based on information we gathered online. We only considered the 62 universities whose energy institutes participated in our pre-summit leadership survey. These universities are listed in Appendix C, Table C2. The certificate name needed to include the word "Energy" to be included in this table. We excluded concentrations, tracks, and emphases. An asterisk indicates that the certificate was offered by an energy institute; all other certificates were offered through a college or school. Figure 16 in the main text presents the percent of universities who offered energy-focused education programs.

University	Certificate	Level	Reference
Arizona State University	Energy and Sustainability	Undergraduate	[71]
Boston University	Energy and Sustainability	Graduate	[72]
Clarkson University	Business of Energy	Graduate	[73]
Clemson University	Renewable Energy	Undergraduate	[74]
Colorado School of Mines	Natural Resources and Energy Policy	Graduate	[75]
Colorado State University	Power and Energy	Graduate	[76]
Duke University	Energy and Environment	Undergraduate	[77]
Idaho State University	Energy Systems Technology	Undergraduate	[78]
	Applied Nuclear Energy	Graduate	[79]
Illinois Institute of Technology	Current Energy Issues	Graduate	[80]
Indiana University-Purdue University Indianapolis	Energy Management and Assessment	Graduate	[81]
New York University	Certificate in Clean Energy	Professional	[82]
North Carolina State University	Renewable Energy Assessment	Undergraduate	[83]
	Renewable Energy Assessment and Development	Graduate	[84]
Northwestern University	Institute for Sustainability and Energy Certificate*	Undergraduate	[85]
Rice University	Energy Data Management	Professional	[86]
Rutgers University	Master's certificate in energy*	Graduate	[87]
Southern Methodist University	Financial Skills for the Energy Industry	Professional	[88]

Continued on next page

Table B9 continued

Stanford University	Energy Engineering and Technologies	Graduate	[89]
	Energy Innovation and Emerging Technologies	Professional	[90]
Texas A&M University	Energy*	Graduate	[91]
The Ohio State University	Bioenergy	Undergraduate	[92]
	Energy	Professional	[93]
The Pennsylvania State University	Bioenergy	Open education	[94]
	Energy Management and Policy*	Graduate	[95]
	Solar Energy	Graduate	[96]
	Wind Energy	Graduate	[97]
The University of Oklahoma	Energy	Graduate	[98]
	Oil and Gas, Natural Resources, and Energy Law	Graduate	[99]
The University of Texas, Austin	Graduate Portfolio in Energy Studies*	Graduate	[100]
	Energy	Professional	[101]
	Energy Management	Undergraduate	[102]
Tulane University	Energy*	Undergraduate	[103]
	Energy and Environment	Graduate	[104]
University of Alaska, Fairbanks	Sustainable Energy	Undergraduate	[105]
University of California, Berkeley	Energy and Clean Technology Law	Graduate	[106]
University of Colorado, Boulder	Renewable and Sustainable Energy*	Professional	[107]
	Renewable and Sustainable Energy*	Graduate	[107]
	Renewable and Sustainable Energy*	Undergraduate	[107]
University of Connecticut	Energy and Environmental Law*	Graduate	[108]
University of Delaware	Renewable Energy Engineering and Policy	Graduate	[109]
University of Houston	Global Climate, Energy and Environment	Graduate	[110]
	Power Electronics and Renewable Energy Technologies	Graduate	[111]
	Upstream Energy Safety	Graduate	[112]

Continued on next page

Table B9 continued

University of Illinois, Urbana–Champaign	Energy and Sustainability Engineering	Graduate	[113]
University of Maryland	Energy Systems Engineering	Graduate	[114]
University of Pennsylvania	Energy Management and Policy*	Graduate	[115]
University of Wisconsin, Madison	Energy Analysis and Policy*	Graduate	[116]
	Engineering for Energy Sustainability*	Undergraduate	[117]
	Engineering Thermal Energy Systems	Undergraduate	[118]
Vermont Law School	Energy Law	Graduate	[119]
Yale University	Energy Studies	Undergraduate	[120]
	Financing and Deploying Clean Energy	Professional	[121]

Table B10. Minors focused on energy, as reported by participants in our pre-summit leadership survey and based on information we gathered online. We considered only the 62 universities whose energy institutes participated in our pre-summit leadership survey. These universities are listed in Appendix C, Table C2. The minor name needed to include the word "Energy" to be included in this table. We excluded concentrations, tracks, and emphases. An asterisk indicates that the minor was offered by an energy institute; all other minors were offered through a college or school. Figure 16 in the main text presents the percent of universities who offered energy-focused education programs.

University	Minor	Reference
Boston University	Sustainable Energy	[122]
Clarkson University	Sustainable Energy Systems Engineering	[123]
Colorado School of Mines	Energy*	[124]
Colorado State University	Energy Engineering	[125]
	Sustainable Energy	[126]
Duke University	Energy Engineering	[127]
Illinois Institute of Technology	Energy/Environment/Economics	[128]
Lehigh University	Energy Engineering	[129]
Massachusetts Institute of Technology	Energy Studies*	[130]
North Carolina State University	Renewable Energy Assessment	[131]
	Sustainable Energy	[132]
Rice University	Energy and Water Sustainability	[133]
San Diego State University	Energy Studies*	[134]
Texas A&M University	Analysis, Design and Management of Energy Conversion Systems	[135]
The Pennsylvania State University	Energy Business and Finance	[136]
	Energy Engineering	[137]
The University of Oklahoma	Global Energy, Environment, and Resources	[138]
University of California, Berkeley	Energy and Resources*	[139]
	Energy Engineering	[140]

Continued on next page

Table B10 continued

University of California, Davis	Energy Efficiency	[141]
	Energy Policy	[141]
	Energy Sciences and Technology	[141]
University of Colorado, Boulder	Energy Engineering	[142]
University of Delaware	Energy and Environmental Policy	[143]
	Sustainable Energy Technology	[144]
University of Houston	Energy and Sustainability*	[145]
University of Illinois, Urbana–Champaign	Sustainability, Energy, and Environment Fellows Program*	[146]
University of Nebraska-Lincoln	Energy Science	[147]
	Food, Energy and Water in Society	[148]
University of Notre Dame	Energy Engineering	[149]
	Energy Studies*	[150]
University of Pennsylvania	Energy and Sustainability	[151]

Table B11. Majors focused on energy, as reported by participants in our pre-summit leadership survey and based on information we gathered online. We considered only the 62 universities whose energy institutes participated in our pre-summit leadership survey. These universities are listed in Appendix C, Table C2. The major name needed to include the word "Energy" to be included in this table. We excluded concentrations, tracks, and emphases. An asterisk indicates that the major was offered by an energy institute; all other majors were offered through a college or school. Figure 16 in the main text presents the percent of universities who offered energy-focused education programs.

University	Major	Reference
Idaho State University	Energy Systems (multiple programs)	[152]
Indiana University–Purdue University Indianapolis	Energy Engineering	[153]
Ohio University	Energy Engineering	[154]
Stanford University	Atmosphere/Energy	[155]
	Energy Resources Engineering	[156]
The Pennsylvania State University	Energy and Sustainability Policy	[157]
	Energy Business and Finance	[158]
	Energy Engineering	[159]
The University of Oklahoma	Energy Management	[160]
	Global Energy, Environment and Resources	[161]
University of California, Berkeley	Energy Engineering	[162]
University of Colorado, Boulder	Electrical, Computer and Energy Engineering	[163]
University of Delaware	Energy and Environmental Policy	[164]
University of Wyoming	Energy Resource Management and Development	[165]
	Energy Systems Engineering	[166]
West Virginia University	Energy Land Management	[167]
	Environmental and Energy Resources Management	[168]
Yale University	Energy Studies	[169]

Table B12. ***What professional development opportunities does your energy institute offer students?***

The professional development opportunities below were written by pre-summit leadership survey respondents. We grouped similar opportunities together, and we indicate below the number of respondents who mentioned each opportunity. Each response belongs to one and only one category. One respondent mentioned a faculty fellows program, which we did not consider a student opportunity and thus did not include in this table. Figure 17 in the main text presents respondents' selections from the list given in the question.

Professional development opportunity	Number of respondents
Research support and opportunities	4
Competitions	2
Leadership opportunities	2
Seed or small grants	2
Attendance at energy conferences and events	1
Energy seminars and forums	1
Field trips	1
Grant writing workshops	1
Guest lectures	1
Industry and entrepreneurship fellows program	1
Networking events	1
Research awards	1
Student ambassadors program	1
Student organization support	1
Tuition waivers	1
Undergraduate degree completion program	1

Table B13. ***How should professional mentoring and internships be blended and supported in energy education initiatives?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 18 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of responses that a category contains.

Keyword	Category name (size)	
Student	• Advising, Match, Partnerships, Recruiting, Studies (4) • Award (2) • College, Community, Dicey, Path (3) • Events (4) • Exchanges (3)	• Facilitate, Renewable (4) • Industry (3) • Offer (4) • PostDoc (2) • Share (4)
Energy	• Area (3) • Award (3) • Exchange, Shared (3) • Experiential (3)	• Incorporate, Possible (3) • Industry (4) • Institute (4) • Job (2)
Institute	• Directly (2) • Education (3)	• Incorporate, Part, Possible, Research (3) • Job (3)
Opportunity	• Campus, Job, Offer, Research (4) • Certificate, Major, Minor (4)	
Program	• Facilitate (4) • Institute (3)	• National (3) • School, Support (2)
Education	• Area, College, Community, Dicey, Mentor, Part, Path, Professional (3) • Incorporate, Possible (4)	
Industry	• Career, Education, Fair, Part, Renewable (3) • Directly, Projects, Reality (2)	

Table B14. ***Should an energy institute network offer its own courses? If so, what would be the course format (online, in-person, other)? Who should teach the courses? How could teaching be shared among energy institutes?***

Responses tagged as positive or strongly positive [1]. We grouped similar responses together under the headings shown. Each response is categorized under one and only one heading.

Responses tagged as positive or strongly positive
Yes, network should offer courses
Accessing already available courses would be helpful; each network member could save room for other members
Offering courses through a network could be beneficial; network could offer workshop courses on various topics (e.g., business models, proposal writing, how to direct and market your energy institute)
Network could offer continuing education classes and repository of course resources
Network could offer Energy 101 course
Network could offer joint certificate
Network could offer joint certificate involving instructors from different schools
Network could offer massive open online courses; also, network could facilitate sharing of slides
Network could offer shared, specialized online course and continuing education
Network could offer technoeconomic analysis and life cycle analysis courses
Yes, network should offer courses; network could offer and facilitate sharing of modules, syllabi, course resources
Yes, network should offer courses; seminars, online shared courses; credit? Share course materials?
No, network shouldn't offer courses but could still play role in higher education
No, network probably shouldn't offer courses; instead, network could create catalog of online asynchronous courses and serve as clearinghouse of course syllabi
No, network shouldn't offer courses; instead, energy institutes could develop course content (e.g., textbooks, notes)
No, network shouldn't offer courses; instead, network could support faculty visits
No, network shouldn't offer courses; instead, network could offer lectures and online courses
No, network shouldn't offer courses; instead, network could offer online or in-person guest lecturers
No, network shouldn't offer courses; instead, network could offer repository of course materials, slides, etc.
No, network shouldn't offer courses for students; instead, network could offer courses for public or to recruit students into energy fields; network could also provide course materials
No, network shouldn't offer traditional courses; instead, network could develop curricula and offer high-level leadership courses, faculty support, sharing of curriculum ideas, non-traditional courses, continuing and professional education
Offering courses through a network could be difficult; instead, network could create inventory of course content and provide access to experts

Table B14 continued

Offering courses through a network could be difficult; instead, network could offer topical webinars
Offering courses through a network would be difficult; instead, jointly develop course materials and perhaps host visiting lecturers
Individual energy institutes (not necessarily a network) could play a role in education
Institutes are developing new energy degree programs (e.g., sustainability), which could facilitate conversation
Institutes could develop and share curricula and keep inventory of energy courses
Institutes could facilitate courses but they would need to be taught through colleges
Institutes could help universities recruit students and educate multiple audiences, including future leaders, professional, and non-energy audiences
Institutes could offer courses that are, perhaps, cross-listed with schools and colleges
Institutes could offer general education energy literacy course; network could facilitate sharing of course resources
Institutes could organize field trips
Institutes could teach a course that has a common core component
No response as to whether a network should offer courses; network could assist in course development
Network could facilitate sharing of syllabi, course materials, lecture slides, and notes
Network could offer free online course for general public and that introduces the basics of energy and systems
Network could offer repository of course resources
Network could offer repository of materials about different energy topics
Network could offer resources related to education and curricula
Network could offer webinars and assist in developing energy curricula
Network could provide access to available online courses
It depends
Whether network should offer courses depends on the goal; could be difficult for energy institutes to agree on content; perhaps offer courses on energy business or regulation
Whether network should offer courses depends on extent to which institute focuses coincide
No opinion
Whether or not a network offers courses is inconsequential

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Table B15. ***Should an energy institute network offer its own courses? If so, what would be the course format (online, in-person, other)? Who should teach the courses? How could teaching be shared among energy institutes?***

Responses tagged as negative or strongly negative [1]. We grouped similar responses together under the headings shown. Each response is categorized under one and only one heading.

Responses tagged as negative or strongly negative
Network could offer webinars and graduate courses; reference existing online programs; don't reinvent wheel
No, network shouldn't offer courses; instead, network could share courses
No, network shouldn't offer courses; instead, network could offer course materials
No, network shouldn't offer courses; many energy institutes don't offer their own courses, which are typically offered by schools and departments; a network's role in education depends on the gaps and needs
No, network shouldn't offer courses; funding models, which are based on student credit hours, differ across universities
No, network shouldn't offer courses; too much variation among universities
Offering courses through a network would be very difficult; teaching (vs. research) is not well-rewarded at energy institutes

Table B16. ***What energy-related skills should be covered by higher education? Should there be a "common core" of energy-related courses, topics, and skills? If so, what should be the common core?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 19 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of responses that a category contains.

Keyword	Category name (size)	
Energy	• Adaptable, Appreciate, Batteries, Broach, Computer, Faith, Hard, Magnitudes, Mandated, Non-disciplinary, Pose, Steam, Talks, Thermal (3) • Approach (3) • Areas, Focus, Curricula (3) • C1 (4) • Classes (3) • Colleges, Community (3) • Coursework, Diagram, Study (3)	• Create (3) • Curriculum (3) • Depth (4) • E.g. (3) • Future (4) • Knowledge (4) • Law (4) • Principles (3) • Training (4)
Course	• ANALYSIS (3) • Classes (4) • Climate (3) • Context (4)	• Coursework, Study (4) • Create, Innovation, Team (3) • Engineering (4) Universities (4)
Student	• Colleges, Community, Content, Context, Incorporate, Offer, Single, Work (4) • Diagram, Different (4)	• Leaders (3) • Principles (4)
Policy	• BASIC (3) • Classes (3) • Colleges, Community, Single (3) • Coursework, Create, Study (2)	• Depth (3) • Environment (2) • Training (3) • Universities (2)
System	• Decision, Topics (3) • Innovation, Team (3)	• Policy (4) • Work (3)
Environment	• Analysis, Areas (3) • C1 (2)	• Degree (3) • Knowledge (3)
Science	• Advanced (2) • Areas, Coursework, Focus, Issues, Offer, Single, Specific, Study (4)	• Challenges, Common, Environment, Law (3)

Continued on next page

Table B16 continued

Technology	• Analysis, Areas (3) • Classes (4) • Degree (2)

Table B17. ***What is the intended joint product of a network? How would responsibilities be assigned and shared among institutes? Or, is the network a facilitator without a role in a specific project?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 20 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of responses that a category contains.

Keyword	Category name (size)	
Institute	• Curriculum (3) • Energy (3) • Identify, Public (3) • Impact (3) • Year (3)	• 1st, AAU, Activities, CHARACTERISTICS, Constellations, DATA-SHARING, Happen, Industry-institutes, Internships, Link, Magic, MAKERS, Solutions, Sustainability, Syllabi, Talent, Technical, Transparent, White (3) • Small (2) • Think (2)
Research	• Human, Infrastructure (4) • Impactful (4)	• Limited (4) • Study (4)
Energy	• Human, Infrastructure (4) • National (4)	• Share (3) • Technology-to-Market (3)
Member	• Easier (3) • Human, Infrastructure, Workshops (3)	• Impact (3) • Voice (2)
Product	• Members (4) • Impactful (3)	• Participant (3) • Small (3)
Industry	• Energy, Information (4) • Human, Identified, Impactful, Infrastructure (3)	
Policy	• Help, Industry (3) • Human, Infrastructure (3)	• Research (2) • Small (2)

Table B18. ***How should an energy institute network be funded? What are potential funding sources? How could a network be used to create funding opportunities?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 24 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of responses that a category contains.

Keyword	Category name (size)	
Member/Partner	• Conference (4) • Create (3) • Educational (3) • Grants (4) • Money (3)	• Multiplied (4) • Participate (4) • Specific, Opportunities (4) • Support (4)
Foundation	• Grants (3) • Institutes (3) • Money (3) • Money, Think, Sloan (3)	• Multiplied (3) • Research (3) • Sharing (3) Support (3)
Industry	• Campus, COI, Consortium, Individuals, Industry-funded, NMMI, Priorities, Running, Self-funded, Size, Skeptics, Strategic (4) • Energy (4)	• Grants (4) • Support (4)
Institute	• Better, Center, Journal, Nationally, President (4) • Dues (4)	• Money (4) • Multiplied, Product (4)
Fee	• Closer, Government, Income, Increased, Offering, Sustainable (3) • Educational (4) • Grant (3)	• Small (2) • Think (3)

Table B19. ***What kind of governance or administrative structure, and evolution thereof, would most benefit members of an energy institute network?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 28 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of responses that a category contains.

Keyword	Category name (size)	
Board/Leadership	• Act, Change, People (3) • Objectives, Repository (3)	• Region (2) Secretariat, CMU, Rice (3)
Member	• FUND (3) • Institute (2)	• Region (3) Repository (2)
Institute	• Board (4) • Objectives (2) • Support (3)	
Governance	• Impact, Regional (3) • Vision (3)	
People	• Act, Coordinator (2) • Agreed, Beginning, Broad, Clearinghouse, Clients, Creating, Database, Dedicated, Depends, Greater, Ideas, Ideal, Informal, Internet, Kind, Loose, Million, Money, Network, Nimble, Right, Supported, Transparent, Trusted, Versus, Widely (2)	
Vision	• Act, Coordinator, People, Shared (3) • Governance, Impact (2)	

Table B20. ***With the information you gathered at the summit, how would you evaluate the idea of forming a network of U.S. university energy institutes in some form, if the opportunity arose today?***

Explanations provided by attendees who evaluated a network as an excellent idea. We grouped similar responses together, and we indicate below the number of respondents who provided each explanation. Each response belongs to one and only one category. Figure 36 in the main text presents attendees' evaluations of the overall idea of forming a network.

Explanation	Number of respondents
Network could improve collaborations among institutions	4
Network could facilitate sharing of information among energy institutes	2
Network could provide collective voice that impacts funding	2
Network could provide collective voice that impacts national policy	2
Network would be useful	2
Energy institutes currently work on mutual goals	1
Energy institutes need to provide technical assistant and leadership to society during energy transition	1
Universities are educating future leaders	1

Table B21. ***With the information you gathered at the summit, how would you evaluate the idea of forming a network of U.S. university energy institutes in some form, if the opportunity arose today?***

Explanations provided by attendees who evaluated a network as a good idea. We grouped similar responses together, and we indicate below the number of respondents who provided each explanation. Each response belongs to one and only one category. Figure 36 in the main text presents attendees' evaluations of the overall idea of forming a network.

Explanation	Number of respondents
Focuses of a network need clarification	4
Value proposition of network needs clarification	4
Annual meetings, hosted by different universities and allowing for collaborations and sharing of information, should precede the formation of a formal network	1
Focus of network should be on community building, benchmarking, information sharing, and regular meetings	1
Interests and funding range widely across EIs	1
Summit attendees' input should be considered in creating the network's structure and mission	1
Many EIs are focused on state and regional, opposed to national advocacy, issues	1
Network offers many benefits at low cost	1
Previous research institute consortia should be researched before proceeding further; what wren the success and failure modes?	1
Structure of network needs clarification	1
Time commitment to form a network needs clarification	1

Table B22. ***In your opinion, what should be the next steps toward forming a network of U.S. university energy institutes?***

The steps below were written by post-summit survey respondents. We grouped similar steps together, and we indicate the number of respondents who mentioned each step. Each response belongs to one and only one category. Figure 37 in the main text presents respondents' selections from the list given in the question.

Next step	Number of respondents
Form steering committee to lead planning of network	2
Obtain input from stakeholders electronically	2
Develop clear action items and vision before meeting	1
Gather more data (other than websites)	1
Hire part-time coordinator to work through logistics of forming a network	1
Invoke help of experienced energy experts to craft vision statement (recognizing that a network can't meet everyone's expectations)	1
Maintain communication	1
Produce report of findings from the summit and distribute the report to wide and relevant audience (summit attendees and non-attendees)	1

Table B23. ***If additional meetings among U.S. university energy institutes were held to discuss and plan forming a network, with what frequency do you think these meetings should be held?***

The meeting frequencies below were written by post-summit survey respondents. We grouped similar frequencies together, and we indicate the number of respondents below who mentioned each frequency. Each response belongs to one and only one category.

Meeting frequency	Number of respondents
Relatively frequently at beginning	2
Twice per year at beginning	2
Alternate years for smaller, network leadership meetings	1
More frequent meetings for network subcommittees than for entire network	1
Once per two to three months (for now) for online discussions	1
Once per year at beginning, then perhaps less frequently	1
Once per year at beginning, then twice per year	1
Once per year for directors and once per year for staff (two separate meetings)	1
Once to twice per year at beginning, then once every two years	1
Twice per year at beginning, then once per year	1
Twice per year at least at beginning	1

Table B24. ***How could a network secure stakeholder buy-in? What are avenues for forming and growing collaborations with industry, policymakers, and other stakeholders?***

Text clustering analysis of summit participants' responses to the question above. We first identified all responses that mentioned a given keyword, as specified in Figure 38 of the main text and repeated in the left column of this table. We then used text analysis software [1] to group (categorize) these statements and assign each category a descriptive name, as specified in the right column of this table. Each category's size represents the number of responses that a category contains.

Keyword	Category name (size)	
Stakeholder	• Accessible, Accurate, Bit, Build, Businesses, Comments, Faculty, Gateway, Goals, Government, Heard, Horizon, Ideology, Industry, Longer, Matching, Portal, Proposition, Resources, Shopping, Skills, Stop, Suited, Tell, Universities (3) • Achieve (3)	• Buy-in, Energy, Institute's (2) • Influenced (3) • Members (3) • National (2) • Setup, Student (2) • Technology (2)
Energy	• Influenced, Money, Professional, Society (3) • Institute's (4) • National (2)	
Member/Partner	• Organizations (4) • Work (4)	
Institute	• Buy-in, Value (3) • Member, Standard (3)	
National	• Available, Communications, Engagement, Help, Impact, Influence, Level, Local, Network, Practices, Purchase, Regional, Research, Stakeholder, State, Tools (2) • Board, Collaboration, Current, CWS, Demonstrated, Department, DOE, Ecus, Evidence, Expertise, EXXON, Important, Labs, Multi-institution, NETL, NREL, Oven, Partnerships, Past, Possible, Projects, Puts, Requests, RFIs, Serve, Similar, Small, Sounding, Successes, Think-tank, University, Working (2)	

Continued on next page

Table B24 continued

Research	• Development, DOE, Groups, Organize (4) • National (4)
Industry	• Broad, DOE, Groups, Organize (3) • Stakeholder, Standard (2)

Table B25. ***Were there ideas or topics not raised during the summit that you think need attention?***

The topics below were written by post-summit survey respondents. All topics were mentioned by one and only one respondent, except "benchmarks and metrics," "regional issues," and "revisiting the premise that a central organization is needed," each of which was mentioned by two respondents, and "funding," which was mentioned by three participants. Each line begins a new topic. This list is alphabetized.

Topics and ideas not raised during summit that need attention, as reported by post-summit survey respondents
Affiliated faculty
Balancing renewables and non-renewables
Benchmarks and metrics
Benefits of a network and differences between benefits to members vs. benefits to society
Bridging gap between universities and practitioners
Cost share within universities, how to negotiate
Cost-benefit analysis of tasks that a network might accomplish (list tasks and consider costs/benefits of each)
Directors' roles in institutes
Diversity and inclusion
Donor stewardship
Education and workforce training offerings
Experiences collaborating with other energy institutes (host panel of institutes who've successfully collaborated)
Experiences from speakers at other campuses (different voices)
Faculty engagement
Funding
Increasing the "size of the pie" (how to do this)
Indirect costs, overhead, facilities and administrative costs
Institutional sustainability
Integrating hard and soft sciences
Intellectual property
Laboratory and equipment at institutes (how to leverage these capabilities)
Leadership development
Legal framework of network
Planning a network-wide, national event in which energy institutes participate within their home states
Non-traditional models
Organizational structure
Place/role of network within existing communities (e.g., national laboratories, economic development groups)
Placement of energy institute within university
Proposal services
Regional issues
Revisit purpose of more and more research funding
Revisiting the premise that a network is needed; is it too early to form a dues-paying membership organization?
Seed grants (what are best practices?)
Serving competing constituencies within a university (how to navigate)
Student organizations
Subject matter issues
U.S. Department of Energy's role in formalizing a network
University support: How do universities support energy institutes? Also, what other institutes exist on-campus?

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Appendix C

Summit Attendees and Survey Respondents

Tables C1 and C2 list energy institutes who attended the 2019 University Energy Institute Leadership Summit and completed the pre-summit leadership survey, respectively. Seventy-eight institutes attended the 2019 University Energy Institute Leadership Summit, and 67 of these institutes submitted their workbook responses for inclusion in this study. Sixty-six institutes participated in the pre-summit leadership survey.

Table C1. Energy institutes who attended the 2019 University Energy Institute Leadership Summit. Seventy-eight leaders, spread across 62 institutes anchored to 57 universities, attended the summit. Sixty-seven leaders, spread across 56 institutes anchored to 52 universities, submitted their workbooks. This table is alphabetized by university.

University	Energy institute
Appalachian State University	Appalachian Energy Center
Arizona State University	ASU LightWorks (a unit of the Julie Ann Wrigley Global Institute of Sustainability)[1]
Boise State University, Idaho State University, Idaho National Laboratory, University of Idaho, University of Wyoming	Center for Advanced Energy Studies
Boston University	BU Institute for Sustainable Energy
Carnegie Mellon University	Wilton E. Scott Institute for Energy Innovation
Case Western Reserve University	Great Lakes Energy Institute
Clemson University	Clemson University Restoration Institute
Colorado School of Mines	The Payne Institute for Public Policy
Colorado State University	Colorado State University Energy Institute
Dartmouth College	Arthur L. Irving Institute for Energy and Society
Duke University	Duke University Energy Initiative
Illinois Institute of Technology	Wanger Institute for Sustainable Energy Research
Johns Hopkins University	Initiative for Sustainable Energy Policy
Lehigh University	Energy Research Center
Lehigh University	Institute for Cyber Physical Infrastructure and Energy
Massachusetts Institute of Technology	Center for Energy and Environmental
Massachusetts Institute of Technology	MIT Energy Initiative
New York University	Institute for Policy Integrity
North Carolina A&T State University	Center for Energy Research and Technology
North Carolina State University	NC Clean Energy Technology Center
North Carolina State University	NC State Future Renewable Electric Energy Delivery and
Northwestern University	Institute for Sustainability and Energy at Northwestern
Ohio University	Institute for Sustainable Energy and the Environment
Rice University	Center for Energy Studies
Rutgers, The State University of New Jersey	Rutgers Energy Institute

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Table C1 continued

Southern Methodist University	Maguire Energy Institute
Stanford University	Carnegie Energy Innovation
Stanford University	Precourt Institute for Energy
Texas A&M University	Texas A&M Energy Institute
Texas Tech University	In Planning
The Ohio State University	The Sustainability Institute
The Pennsylvania State University	Penn State Institutes of Energy and the Environment
The University of Texas, Austin	UT Austin Energy Institute
Tufts University	Center for International Environment and Resource Policy
Tulane University	Tulane Energy Institute
University at Buffalo	Research and Education in Energy, Environment and Water Institute
University of Alabama	Institute for Sustainable Energy
University of Alaska, Fairbanks	Alaska Center for Energy and Power
University of California, Berkeley	Energy and Resources Group
University of California, Davis	Energy and Efficiency Institute
University of California, San Diego	Deep Decarbonization Initiative
University of California, Santa Barbara	The Institute for Energy Efficiency
University of Colorado, Boulder	Renewable and Sustainable Energy Institute
University of Connecticut	Center for Clean Energy Engineering
University of Delaware	Delaware Energy Institute
University of Hawaii, Manoa	Hawaii Natural Energy Institute
University of Houston	The Environment, Energy, and
University of Kentucky	Center for Applied Energy Research
University of Louisville	Conn Center for Renewable Energy Research
University of Maryland	Maryland Energy Innovation Accelerator
University of Maryland	Maryland Energy Innovation Institute
University of Michigan	University of Michigan Energy Institute
University of Minnesota	Institute on the Environment
University of Notre Dame	ND Energy - Center for Sustainable Energy
University of Pennsylvania	Kleinman Center for Energy Policy
University of Pittsburgh	Center for Energy
University of Virginia	UVA Environmental Resilience Institute
University of Wisconsin, Madison	Great Lakes Bioenergy Research Center
University of Wyoming	Center for Energy Regulation and Policy
Vermont Law School	Institute for Energy and the Environment
West Virginia University	West Virginia University Energy Institute
Yale University	Energy Sciences Institute

[1] "About ASU Lightworks," Global Sustainability | Lightworks, Arizona State University, accessed April 7, 2020, https://sustainability.asu.edu/lightworks/about/.

Table C2. Energy institutes who participated in the pre-summit leadership survey. Sixty-six leaders, spread across 66 institutes anchored 62 universities, participated in the survey. Per our request, one person per institute participated. This table is alphabetized by university.

University	Energy institute
American University	Center for Environmental Policy
Appalachian State University	Appalachian Energy Center
Arizona State University	ASU LightWorks (a unit of the Julie Ann Wrigley Global Institute of Sustainability)[1]
Boise State University	Energy Policy Institute
Boise State University, Idaho State University, Idaho National Laboratory, University of Idaho, University of Wyoming	Center for Advanced Energy Studies
Boston University	BU Institute for Sustainable Energy
California Institute of Technology	Resnick Sustainability Institute
Carnegie Mellon University	Wilton E. Scott Institute for Energy Innovation
Case Western Reserve University	Great Lakes Energy Institute
Clarkson University	Institute for a Sustainable Environment
Clemson University	Clemson University Restoration Institute
Colorado School of Mines	The Payne Institute for Public Policy
Colorado State University	Colorado State University Energy Institute
Dartmouth College	Arthur L. Irving Institute for Energy and Society
Duke University	Duke University Energy Initiative
Illinois Institute of Technology	Wanger Institute for Sustainable Energy Research
Indiana University–Purdue University Indianapolis	Richard G. Lugar Center for Renewable Energy
Johns Hopkins University	Initiative for Sustainable Energy Policy
Lehigh University	Energy Research Center
Massachusetts Institute of Technology	Center for Energy and Environmental
Massachusetts Institute of Technology	MIT Energy Initiative
New York University	Institute for Policy Integrity
North Carolina A&T State University	Center for Energy Research and Technology
North Carolina State University	NC Clean Energy Technology Center
North Carolina State University	NC State Future Renewable Electric Energy Delivery and
Northwestern University	Institute for Sustainability and Energy at Northwestern
Ohio University	Institute for Sustainable Energy and the Environment
Rice University	Center for Energy Studies
Rutgers, The State University of New Jersey	Rutgers Energy Institute
San Diego State University	Sustainable Energy Center
Southern Methodist University	Maguire Energy Institute
Stanford University	Carnegie Energy Innovation
Stanford University	Precourt Institute for Energy
Texas A&M University	Texas A&M Energy Institute
The George Washington University	Environmental and Energy Management Institute
The Ohio State University	The Sustainability Institute

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Table C2 continued

The Pennsylvania State University	Penn State Institutes of Energy and the Environment
The University of North Carolina, Charlotte	Energy Production and Infrastructure Center
The University of Oklahoma	Energy Institute
The University of Texas, Austin	UT Austin Energy Institute
Tufts University	Center for International Environment and Resource Policy
Tulane University	Tulane Energy Institute
University of Alaska, Fairbanks	Alaska Center for Energy and Power
University of California, Berkeley	Energy and Resources Group
University of California, Berkeley	Energy Institute at Haas
University of California, Davis	Energy and Efficiency Institute
University of California, Santa Barbara	The Institute for Energy Efficiency
University of Colorado, Boulder	Renewable and Sustainable Energy Institute
University of Connecticut	Center for Clean Energy Engineering
University of Delaware	Delaware Energy Institute
University of Houston	The Environment, Energy, and
University of Illinois, Urbana–Champaign	Institute for Sustainability, Energy, and Environment
University of Maryland	Maryland Energy Innovation Institute
University of Minnesota	Institute on the Environment
University of Nebraska–Lincoln	Nebraska Center for Energy Sciences Research
University of Notre Dame	ND Energy - Center for Sustainable Energy
University of Pennsylvania	Kleinman Center for Energy Policy
University of Southern California	USC Energy Institute
University of Virginia	UVA Environmental Resilience Institute
University of Washington	Clean Energy Institute
University of Wisconsin, Madison	Wisconsin Energy Institute
University of Wyoming	Center for Energy Regulation and Policy
Vanderbilt University	Vanderbilt Institute for Energy and Environment
Vermont Law School	Institute for Energy and the Environment
West Virginia University	West Virginia University Energy Institute
Yale University	Energy Sciences Institute

[1] "About ASU Lightworks," Global Sustainability | Lightworks, Arizona State University, accessed April 7, 2020, https://sustainability.asu.edu/lightworks/about/.

Appendix D

Summit Materials and Methods

Organization of Summit

The 2019 University Energy Institute Leadership convened on September 25–26 in Pittsburgh, PA [1]. The summit comprised four roundtable discussions, two keynotes, one panel discussion, one fireside chat, two welcome sessions, two recap sessions, and social activities. Each roundtable discussion lasted approximately 45 min–1 hr, 15 min, keynotes lasted 1 hr, the fireside chat lasted 1 hr, and the panel lasted 45 mins. The social activities comprised two networking receptions, one at the summit's beginning and one on the evening of the first day, two networking meals, and three networking breaks between sessions.

At the summit's beginning, each leader received a workbook. We invited all leaders to participate in our research study by signing a consent form. Participants submitted their workbooks at the end of the summit. We shared with leaders that if they consented to participate we would incorporate their workbook response into our report.

During roundtable discussions, we invited leaders to record, in their workbooks, responses to discussion questions. These questions asked leaders about the focuses and organizational frameworks of a potential network. At the beginning of each roundtable discussion, a presenter briefly introduced the session and then posed three to four discussion questions to the group. Leaders discussed these questions at their tables for about 30 mins and were then invited to record responses in their workbooks. Toward the end of each roundtable discussion session, tables shared with the larger group key points from their discussions [2-4].

All leaders, including those who did not consent to participate in the research, were given a workbook at the summit's beginning and invited to participate in roundtable discussions. After the summit, we collected the workbooks of attendees who agreed to submit their feedback for inclusion in this report. Carnegie Mellon University's Institutional Review Board approved our study.

Attendee Background

We invited 236 energy institute leaders across 145 institutes anchored to 123 universities to attend our summit. Seventy-eight leaders across 62 institutes anchored to 57 universities attended the summit. Sixty-seven leaders across 56 institutes anchored to 52 universities completed and submitted their workbooks for inclusion in this study. One of these leaders was informally affiliated with an energy institute.

In addition to energy institute leaders, 11 energy experts from academia, nonprofit organizations, and government attended the summit. Eight of these experts spoke at the summit, and none of these experts submitted a workbook for this study. In addition, a team of nine Carnegie Mellon University support staff attended the summit and did not submit a workbook.

Workbook Preparation

The workbook is available online [5]. The workbook allowed leaders to respond to roundtable discussion questions and provide feedback to sessions. We intended for our discussion questions to build upon but not replicate our pre-summit survey questions. Whereas

our pre-summit questions focused on energy institute and stakeholder interests and goals, our summit discussion questions focused on the vision and mission statements, potential funding sources, educational offerings, and possible governance structures of a network.

Analysis of Workbook Responses

Following the summit, we transcribed participants' workbook responses into Microsoft Excel. We followed up with 11 participants to clarify their statements. Eight of these participants provided clarification. During transcription, we cleaned participants' response by spelling out non-proper noun abbreviations (e.g., we changed govt to government, and univ to university). We also spelled out symbols. For example, we changed "&" to "and" and "$" to "money." Finally, we standardized proper noun spellings. For example, we changed "Dept. of Energy" to "DOE" and "CM" to "CMU" (short for Carnegie Mellon University).

We used MeaningCloud's Excel Add-In [6] to analyze participants' workbook responses. We conducted topics extraction, text clustering, and sentiment analysis. We used MeaningCloud's API [7] to analyze institute mission statements because they combined exceeded Excel's cell character limit.

Topics extraction. For each question, we combined responses into a single text in Excel. We performed text extraction on the combined text. We extracted keywords and their corresponding frequency.

Text clustering. We identified responses that mentioned a given keyword. We allowed variants of keywords, such as policies/policy and sustainable/sustainability. Using Excel, we conducted text clustering (document grouping), which divided these responses into categories and assigned each category a descriptive thematic name.

Sentiment analysis. To gauge participant attitudes, we conducted sentiment analysis on responses. The sentiment analysis tagged each response as positive or strongly positive, negative or strongly negative, neutral, or no sentiment.

References

Appendix D References

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Appendix E

Survey Materials and Methods

Survey Development

We conducted two pre-summit surveys, one of which we administered to energy institute leaders, and the other of which we administered to stakeholders. In addition, we conducted a post-summit survey administered to attendees of the 2019 University Energy Institute Leadership Summit. Our surveys are available online [1–3].

Prior work informed the survey content. Bazilian, Clough, and Geuss [4] investigated energy institute governance structures, funding sources, and productive output. Ross Strategic [5] explored institute strategic and research focuses, including events and industry affiliate programs. Hoffman and Axson [6] examined sustainability institutes, including educational offerings, sources of revenue, and performance metrics.

To ease the cognitive burden of completing our surveys, we included more closed ended than open ended questions [7]. Most ranking questions listed 10 or more items but asked respondents to rank only three to five of these items. We also provided space for respondents to write responses.

In pre-summit surveys, we asked respondents about their current interests and goals before asking for their opinions about a network. We chose this order of questions to minimize the possibility of peer pressure [8]. Likewise, in our post-summit survey, we first asked respondents for their feedback about the summit before asking for their opinions regarding next steps, if any, toward forming a network.

Testing and Preparation

We conducted trial runs of our pre-summit leadership and stakeholder surveys [9]. Below, we describe tester feedback and subsequent changes to our survey drafts.

Leadership survey. Two students, two university administrators, and one postdoctoral researcher tested our leadership survey. In our initial draft, we asked respondents to identify their research focuses from a list comprising applications, energy sources, and techniques. One tester recommended that research focuses be divided into separate lists. In response to this feedback, we separated research focuses into lists of research applications, energy sources, and research techniques and asked participants to identify their focuses in each list. Another tester asked if energy source referred to an energy source consumed by an institute building or researched by the institute. We changed the wording of this question to clarify that energy sources referred to sources researched (not consumed) by the institute. Another tester mentioned that a network's choice of shared assets depended on geographical scope. In response, we changed the order of questions to ask about network scope before asking about its shared assets.

Stakeholder survey. Two industry professionals, one consultant, one doctoral student, and one postdoctoral researcher tested our stakeholder survey. When asked which shared assets should belong to a future network, one tester wrote facilities for analysis and fabrication. In response to this feedback, we added "Shared equipment, tools, or facilities" to the list given in the question. When asked whether they would consider interacting with a network, another tester asked for clarification about when—today or in the future—these interactions would occur. In response, we clarified that stakeholders would interact today with a network. Another tester recommended

that the survey cover page describe the intended audience. In response, we added a statement to the survey cover page describing the intended audience as individuals interested in U.S. university energy institute research.

Administration of Surveys

All surveys were administered online using Qualtrics. Invitees received a link that allowed them to save their responses and complete the survey in multiple sittings.

We administered our pre-summit leadership survey between July 17–November 1, 2019. We invited 265 leaders across 162 energy institutes anchored to 125 universities to complete the survey. Sixty-six leaders across 66 institutes anchored to 62 universities completed the survey. Per our request, only one individual per institute participated. Fifty-nine leaders completed the survey before the summit, and seven leaders completed the survey after the summit. The pre-summit leadership survey asked respondents to provide their first and last names, email address, energy institute name, and university name.

We administered our pre-summit stakeholder survey from July 17–September 16, 2019. We invited 214 stakeholders, including chairpersons, CEOs, directors, managers, presidents, senior professionals, specialists, support staff, vice presidents, and other leaders, who collectively were spread across 188 organizations, including businesses, nonprofits, government, and other organizations, to complete the survey. We obtained recommendations for stakeholder participants from energy institute leaders and other stakeholders. The survey did not require respondents to identify themselves.

We invited 89 individuals to complete our post-summit survey, 46 of whom participated. We conducted the survey from September 30–November 1, 2019. We invited all summit attendees except support staff to complete the survey. The survey did not require respondents to identify themselves.

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