IOWA ENERGY PLAN

APPENDIX G:
Iowa Energy Research and Development Core Competencies and Opportunities for Energy-Based Economic Development

Collaborate locally.
Grow sustainably.
Lead nationally.

IOWA ENERGY PLAN IS A JOINT INITIATIVE BETWEEN
IOWA economic development | IOWA DOT

Prepared by TEConomy Partners, LLC.

July 20, 2016

TECONOMY PARTNERS LLC
Innovating Tommorow's Economic Landscape

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I. INTRODUCTION

Like food and clean water, energy tends to be taken for granted in modern developed societies. We come home, flip a switch and our lights come on. If it is hot or cold outside our HVAC system cools or heats our home or workplace. We turn the ignition key in our car and a battery cranks the starter motor and fuel is injected to power combustion in our automobiles and trucks. We need to travel long distances, and jet engines make that a reality. We need to communicate locally and globally and our electronic devices operating over powered networks and the Internet provides the immediate means to do so. We want to be entertained, so we turn on the TV or our home entertainment system. And so it goes… for almost each and every one of us, at any given time in our lives we are consuming energy while giving little thought to where it comes from and how it gets to us.

It is probably fair to say that most of us give little consideration to energy until: we need to find a place to recharge our phone; a storm knocks our power out temporarily; we need to refill the tank in our car, or it is time to pay the electric or gas bill at the end of the month. What we seldom or ever pay attention to is the vast and hugely complex global and domestic web of infrastructure, networks and systems that surround us every day, moving liquid fuels, gases and electricity from one location to another to meet the needs of individuals, communities and industries. In Iowa, as in all of the U.S. and almost all of the world (outside of primitive societies) energy underpins the fabric of the economy and daily life. Its importance is hard to overstate.

While the use of natural gas, petroleum and electricity has been a ubiquitous part of society and modern economies for more than a century now, they are resources affected by current dynamic forces. Fossil fuel resources are not distributed evenly across the globe, and the geopolitical actions of the locations that produce these fuels very much influence the economies of those that do not. Renewable energy generation potentials are also unevenly distributed, dependent on geographic variations in wind, sunlight, water flow, or the biomass production capacity of the land. Global population growth and rising income levels are such that demand for energy are projected to rise substantially throughout the rest of this century. Worldwide population is projected to increase from 7 billion people in 2010 to 9.3 billion by 2030 (an increase of 2.3 billion, equivalent to doubling the entire current population of China and India). Competition for energy resources and demand for new energy technologies will present both threats and opportunities moving forward. In addition, widespread concern over atmospheric carbon levels and associated effects on climate represent a further dynamic that is having substantial effects on energy markets and the development of alternative technologies.

Energy has become, and will continue to be, a defining challenge for the World and the United States—economically, strategically and environmentally. Every state in the nation needs to be paying attention to its strengths, weaknesses, opportunities and threats in relation to the energy economy. The status quo for energy cannot be taken for granted. Change is upon us and those states and regions that understand, embrace and take advantage of the opportunities that come with change will be well positioned for economic advantage and growth.

Iowa is one of the U.S. states that has staked-out an early leadership role in the new energy economy. Iowa has a limited and low-quality fossil fuel resource base, and thus has historically been highly dependent on power generated from imported fossil fuels. Within the past decade, however, investment in renewable fuels, most notably in wind-power generation and biofuel production, has propelled Iowa to a leadership position in renewable energy production and know-how in these production technologies. The opportunity is for Iowa to further build on its renewable power deployment momentum AND to further its focus on technology-based economic development through innovation and early adoption of new, fast-growth energy technologies. Recognizing the opportunities ahead for Iowa, the State of Iowa, led by the Iowa Economic Development Authority [IEDA] and the Iowa Department of Transportation [DOT], initiated a formal planning process, the Iowa Energy Plan, to guide statewide energy development based on well-researched analysis of opportunities and the input of key stakeholders across the state.

What would an ideal Iowa Energy System and Energy Economy look like? Ideally it would follow these guiding principles:

- Foster long-term energy affordability and price stability for Iowa's residents and businesses.
- Increase the reliability, resiliency, safety and security of Iowa's energy systems and infrastructure.
- Stimulate research and development of new and emerging energy technologies and systems.
- Provide predictability by encouraging long-term actions, policies and initiatives.
- Expand opportunities for access to resources, technologies, fuels and programs throughout Iowa.
- Seek diversity in the resources that supply energy to and within Iowa.
- Support alternative energy resources, technology, and fuel commercialization in proven, cost-effective applications.
- Encourage sector-based workforce

Iowa is particularly well positioned to lead in the emerging new energy economy. Home to a major federally-funded national energy laboratory (Ames Lab) and research universities engaged in varied energy research there is significant energy R&D activity in the region. A substantial base of energy industry activity also exists in the state—with not only the activities of a diverse base of utilities (investor-owned, rural cooperatives and municipal-owned) but also an expanding base of companies engaged in the development and manufacturing of power generation systems, components and materials, and in products and services related to energy efficiency. Iowa's early leadership position in the production of biofuels and wind-power, provides a proven base of capability and achievement upon which to further build.

This report and additional TEConomy-produced Iowa Energy Plan white papers seek to:

- Identify trends likely to effect the impact of energy on the Iowa economy.
- Understand key assets across the energy value chain.
- Identify opportunities to generate technology-based economic development through R&D and commercialization of energy innovations.
- Identify opportunities to conserve energy and reduce any negative externalities associated with energy development, generation or use.
- Develop an integrated strategy to maximize energy-sector benefits for the Iowa economy.

Through the development of the Iowa Energy Plan it is anticipated that the State of Iowa will be able to realize substantial energy-based economic development benefits along multiple pathways (as illustrated on Figure 1).

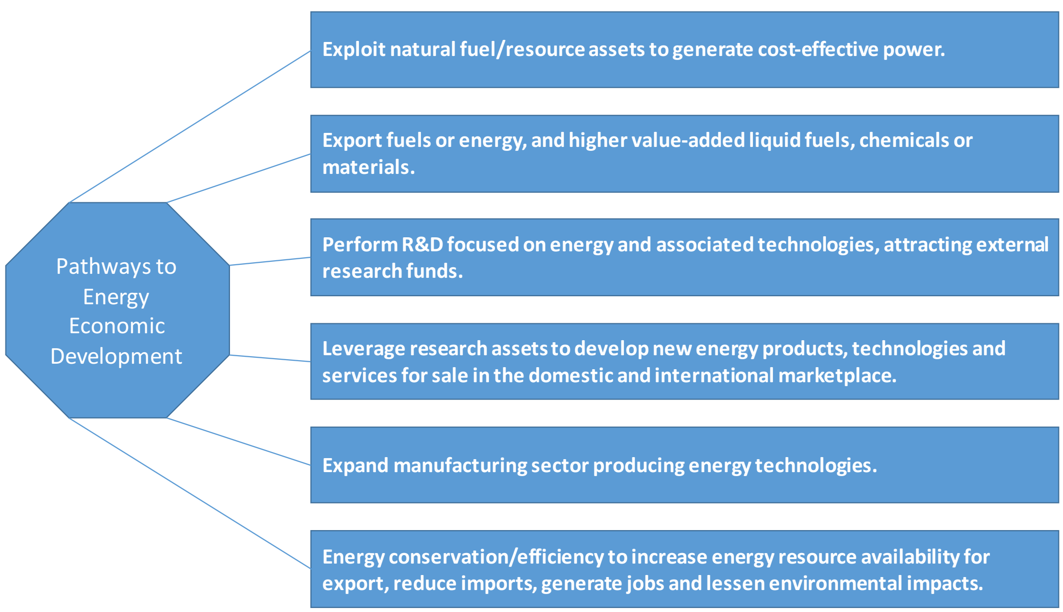


Figure 1. Pathways to Energy-based Economic Development in Iowa

About this Report

This report is part of a series of reports and analysis to inform the development of the full Iowa Energy Plan.

- The first report was titled "White Paper: Preliminary Assessment of Iowa's Energy Position" and provided statistics on energy supply and consumption trends in the state, and a review of key energy sectors in the state in terms of employment growth and associated economic factors.
- Additional analysis was received through stakeholder interviews to evaluate strengths, weaknesses, opportunities, and threats and organized around each working group classification during the course of the project.

This report incorporates information from the energy position report and SWOT interviews, together with an assessment of R&D competencies in Iowa in relation to energy, to provide a series of recommended "platforms" for Iowa energy-based economic development. A platform represents a major economic development thrust area containing near, mid-term and long-term development opportunities that ideally:

- Have an established or emerging cluster of Iowa businesses with interests in related areas of the energy sector.
- Provide opportunities for ongoing technology, product and service innovations to which Iowa's commercial, academic and government laboratory research capabilities can be applied.
- Present opportunities for collaborative public/private partnerships to promote shared interests and facilitate the development of a highly favorable operating environment for energy-based economic growth.
- Are associated with a significant potential market with an achievable line-of-sight for the sale of resources, new technologies, services and value-added products.
- Contribute to building and reinforcing key aspects of the "vision and guiding principles" as shown in the text box on page 2.

In examining options for energy-based economic development platforms in Iowa, opportunities across the full energy value chain (Figure 2) have been considered – with the goal being to identify development platforms that serve to reinforce the value-chain, build upon it, and provide ongoing large-scale opportunities for economic growth in Iowa.

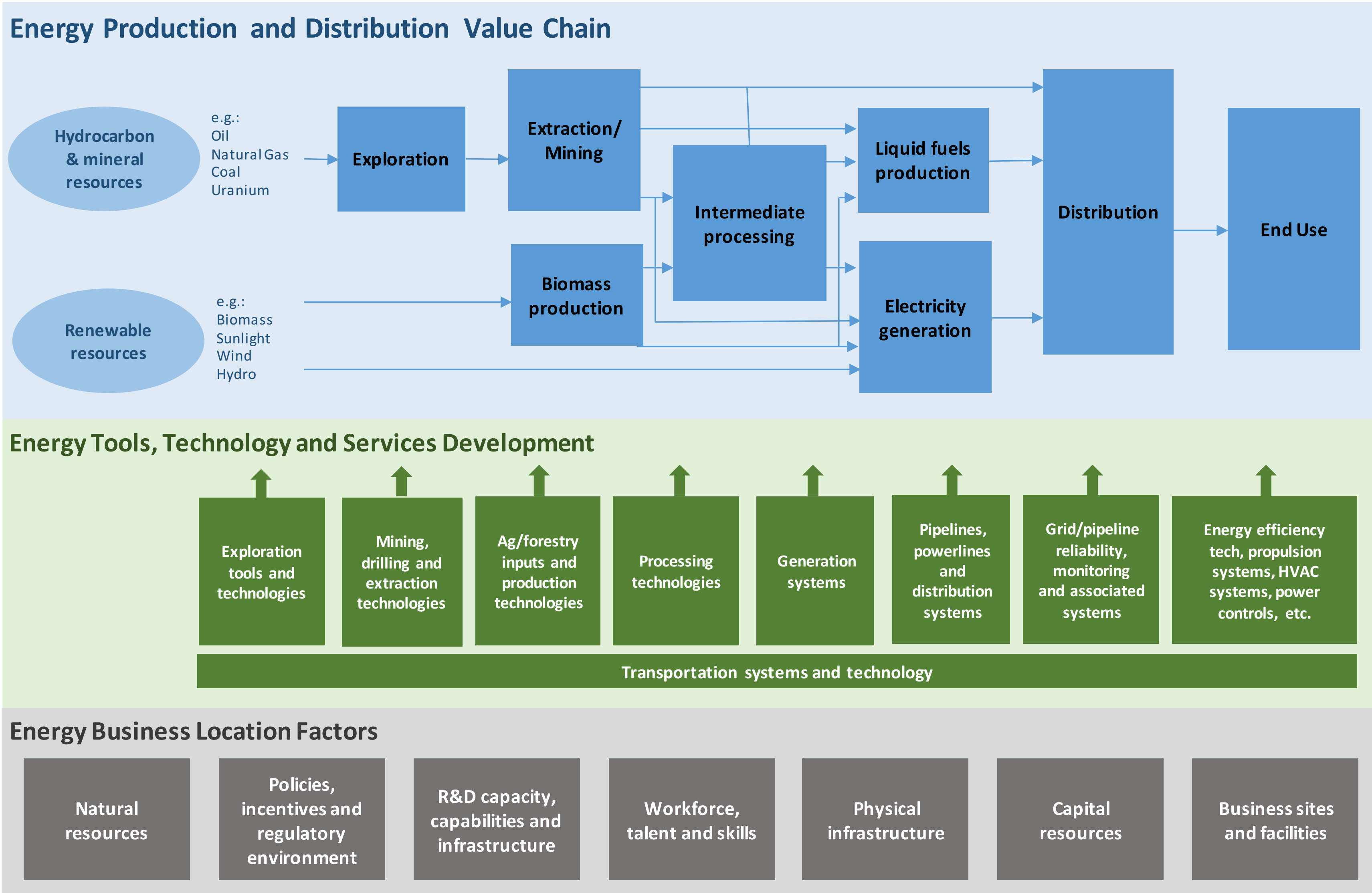


Figure 2. The Energy Value-Chain, Associated Technology Areas and Key Location Factors Impacting Value-Chain Development

II. RESEARCH & DEVELOPMENT (R&D) CORE COMPETENCIES

In today's global knowledge-based economy, competitive advantage is best achieved in an environment that proactively stimulates innovation, knowledge transfer and technology commercialization. Michael Best, a leading scholar of growth and development across regions notes in *The New Competitive Advantage*:[1]

> *Regions can be thought of as developing specialized and distinctive technology capabilities, which give them unique global market opportunities. The successful pursuit of these market opportunities in turn reinforces and advances their unique technological capabilities. Regional specialization results from cumulative technological capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization.*

One of the key elements for creating the potential for technology-based development (including energy-based economic development) is an analysis of the existing research and innovation competencies found within innovation clusters. Within Iowa, in the energy sector as broadly defined, there are multiple organizations and R&D entities with capabilities upon which future economic advances may be built. These include industry R&D groups, higher education, the Ames National Laboratory, and other parties.

Without a strong R&D foundation within universities and research institutions, it is difficult for any state, or nation to initiate or sustain major technology-based industrial development. In the energy technology space it is clear that research universities with engineering colleges, physical sciences research and (increasingly) bio-based product research, are particularly important contributors to basic and applied research in the field, as are, of course, U.S. Department of Energy National Laboratories, such as Ames Lab. Multinational and domestic energy and energy-technology companies also perform very important R&D activities. They are key collaborators for research with other organizations and critical to the commercialization of innovations

Because research is the driving force behind innovation and commercialization in a technology and engineering focused sphere such as energy, and because research core competencies have been shown to be the foundation of technology cluster development, it is imperative that the State of Iowa and key stakeholders in the development of the Iowa Energy Plan have a formal understanding of in-state energy research core competencies. To develop an independent analysis of core

[1] Michael Best. "The New Competitive Advantage: The Renewal of American Industry." Oxford University Press, 2001.

competencies, Iowa retained TEConomy Partners (TEConomy) to perform an independent assessment and evaluation of energy research core competencies and to identify robust energy-based economic development "platforms", with line-of-sight to commercialization and industry relationships.

A. Approach to Identifying Energy R&D Core Competencies

TEConomy identifies research core competencies using both quantitative and qualitative methods.

- Quantitative assessment uses statistical information on extramural grants, publications, and patent activities.
- Qualitative work includes interviews with key administrators, scientists, and researchers across the research drivers found in the R&D-performing institutions.

TEConomy focuses the core competency assessment on the following:

- In which fields of science and technology relevant to energy are the institutions receiving significant levels of funding, especially funding from "gold standard" external sources, such as federal agencies?
- In what energy and associated technology fields do the research institutions demonstrate a substantive and influential record of publication?
- In what energy and associated technology areas are patents and other intellectual property being generated?
- What areas of research are connected to, or have potential for, significant industry relationships?
- What areas of energy research and associated technologies do the subject institutions self-identify as being institutional core competencies and priorities?
- What energy-based economic development opportunities can be identified for Iowa?

Evaluating the answers to these questions, the TEConomy team is able to provide insights into the energy research base, and draw implications as to how these research strengths may best intersect with Iowa's energy industry, associated technological industries and economic base.

Underpinning the successful translation of research strengths into economic development opportunities requires the recognition of the importance of "market-driven" processes (Figure 4). The traditional model of commercialization assumes a "research-driven" pathway. This research-driven commercialization process spans a continuum from basic research leading to a major scientific breakthrough, to applied research leading to product development, and ending with industrial manufacturing and marketing. While that process can and does work in some instances, the shortcomings of the research-driven approach are that it is often divorced from commercialization and product development needs (the voice of the market) and has uncertain line-of-sight to true economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality and continuous market feedback."[2]

The components of a core competency can ideally bring together basic research, enabling technology, and applied research activities with a "line of sight" that moves seamlessly to address specific needs and market opportunities, and identifies robust technology platforms for generating economic development. Core competency areas that lack this linkage and connection to needs and market opportunities typically offer more limited economic development opportunities.

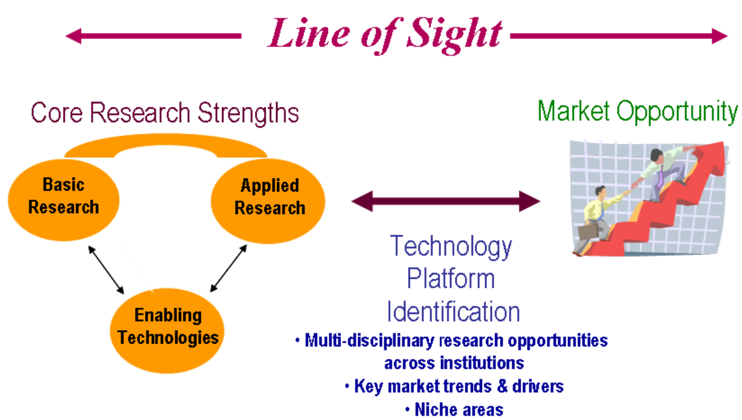


Figure 3. Market Opportunity, Technology Platforms and Core Competency Assessment

Defining Core Competencies

There is no one single source of information that serves to identify core research competencies and focus areas. Rather, a variety of integrated and complementary analyses are required to help identify a state's current position and areas of focus that may lead or contribute to future growth.

In identifying core energy-related research focus areas, TEConomy's objective is to identify those fields where there is a critical mass of activity along with some measure of excellence. This does not mean, however, that other fields of research excellence may not be present within the subject institutions. What it does mean is that these other research strengths are found in relatively limited pockets and so offer more limited opportunities upon which to build—but may still contribute in some manner.

[2] Council on Competitiveness, Picking Up the Pace: The Commercial Challenge to American Innovation (Washington, DC: Council on Competitiveness), pp. 9-10.

Several tests can be used to identify a core competency:

1. Is it a significant source of competitive differentiation? Does it provide the basis for a unique signature?
2. Does it comprise a critical mass of scientists and technologists?
3. Does it transcend a single business? Does it cover a range of businesses, both current and new?
4. Is it challenging for competitors to compete with and imitate?
5. Is there a line-of-sight to knowledge-transfer and commercialization of innovations arising from this R&D focus?

TEConomy's quantitative assessment starts with an in-depth examination of areas of critical mass in energy research and development. This quantitative review uses multiple data resources:

- Analysis of peer reviewed energy-related engineering and science publication statistics
- Analysis of patent/intellectual property generation statistics
- Assessment of SBIR funding and venture funding in associated technology fields in Iowa
- Identification of dedicated university centers or institutes designed to leverage institutionally identified areas of focus and excellence

> Core Competencies and State Technology-Based Economic Development
>
> In pursuing future activities, states are learning that research institutions must nurture the development of specialized areas of expertise, or "core competencies". According to Hamel and Prahalad in their widely acclaimed business strategy book, Competing for the Future, "Core competencies are the gateways to future opportunities. Leadership in a core competence represents a potentiality that is released when imaginative new ways of exploiting that core competence are envisioned."
>
> Core competencies are those focused areas where research institutions can bring a critical mass of activity—as measured by research, talent generation, and unique facilities & resources—along with an identified measure of excellence. Also, in the future, it is not just having deep strengths in single disciplines that will matter, but advancing inter-disciplinary fields that can apply technology convergence to addressing key research problems and applications development. As the Chronicle of Higher Education notes, "[interdisciplinary] partnerships are proliferating in academe—and slowly changing the face of science—because they offer the best hope for answering some of the thorniest research subjects."

In addition to the quantitative data, TEConomy Partners personnel also conducted interviews with multiple universities, Ames Lab and industry research leaders to gain additional insights regarding research strengths, opportunities, challenges and future directions. These interviews were supplemented with information from individual researcher and research team web pages and other accessible research resources to add further intelligence to the core competency considerations. TEConomy wishes to thank the participating universities, research institutions and individual researchers who met with the TEConomy analysis team over the course of the project. Institutions, including Iowa Regent Universities and Ames National Laboratory, were extremely helpful in facilitating meetings, hosting TEConomy staff on campus, and providing follow-on information in response to TEConomy inquiries. Similarly, Iowa Energy Plan working group members, together with a broad variety of key energy stakeholder organizations across Iowa contributed substantial information pertaining to research strengths and opportunities within the SWOT interview and worksheet completion process.

B. Core Competencies: Data Findings

1. Publications

Table 1 provides a review of publication data for Iowa institutions for the past five years. Data are provided in the totally energy-focused “Energy and Fuels” category, and for research disciplines that have energy topics contained within their research domain. TEConomy Partners used multiple key search terms to assist in identifying energy-related publishing activity in each of the disciplines – and the results for that search are shown in the column titled “IA Energy Specific Pubs – Key fields”. The column to the right, labeled “IA Energy-Related Key Fields, All Pubs” provides the full data for that discipline and it should be noted that many of these publications may not have an energy context. Reflecting this difference, the remaining columns use the “IA Energy Specific Pubs – Key Fields” data as the basis for their calculation.

In the “Energy & Fuels” category, Iowa institutions recorded 468 publications, representing 1.4% of all publications nationally in this field. This is higher than would be expected given that total R&D in Iowa is circa 0.8% of national R&D spending overall. An additional 1,069 publications are captured under other disciplines and flagged by key energy terms. Discipline areas in Iowa in which the publishing shows a high percentage of energy-related publications include “Electrochemistry” (73.6% flagged as energy-related) “Agricultural Engineering” (42.3%), “Chemical Engineering” (37.1%), “Thermodynamics” (37.1%) and “Biotechnology and Applied Microbiology” (19.3%). “Electrical and Electronic Engineering”, as would be expected, also has a considerable volume of energy-related publications, with the third highest count of 111 publications over the five-year time period.

Table 1. Iowa Key Energy-Related Research Fields and Comparative Context, 1/2011-3/2016

IA Energy - Key Research Fields	IA Energy Specific Pubs - Key Fields	IA Energy-Related Key Fields, All Pubs	IA Energy Specific Pubs Share of IA Energy Key Field	U.S. Energy-Related Key Fields, All Pubs	IA Energy Key Field Share of U.S. Energy Key Field
Energy & Fuels	468	468	100.0%	32,359	1.4%
Biotechnology & Applied Microbiology	161	833	19.3%	41,331	2.0%
Engineering, Electrical & Electronic	111	1,176	9.4%	129,477	0.9%
Engineering, Chemical	109	294	37.1%	21,270	1.4%
Materials Science, Multidisciplinary	92	972	9.5%	80,614	1.2%
Agricultural Engineering	91	215	42.3%	4,063	5.3%
Chemistry, Physical	80	808	9.9%	62,042	1.3%
Environmental Sciences	80	944	8.5%	56,261	1.7%
Physics, Applied	73	881	8.3%	10,397	8.5%
Chemistry, Multidisciplinary	67	1,555	4.3%	110,954	1.4%
Engineering, Mechanical	47	404	11.6%	33,170	1.2%
Nanoscience & Nanotechnology	43	429	10.0%	44,617	1.0%
Agronomy	40	449	8.9%	10,012	4.5%
Electrochemistry	39	53	73.6%	11,336	0.5%
Thermodynamics	36	97	37.1%	75,788	0.1%

Source: TEConomy Partners analysis of publication data from Thomson Reuters' Web of Science database. Note: Some individual publications can be captured under more than one key research field.

The intensive work of Iowa State University in biofuels and biorenewable processing technologies is evident in the significant number of publications evident in the "Biotechnology & Applied Microbiology", "Chemical Engineering", "Agricultural Engineering" and "Agronomy" fields.

There is also a significant "materials" context evident in these data – not only in terms of "Materials Science" with 92 publications, but also in clearly related areas such as "Nanoscience and Nanotechnology", "Electrochemistry", 'Thermodynamics", and "Applied Physics."

Table 2 shows how Iowa compares to the surrounding Midwest states in the specific "Energy & Fuels" publishing category. It is evident that Iowa performs quite competitively, on a par with Minnesota and Missouri (despite these states being twice the total state population size versus Iowa). Illinois has by far the highest level of publishing in this area, but that is not surprising given both the size of the state and it being home to two DoE national laboratories, the Fermi National Accelerator

Laboratory and Argonne National Laboratory, and multiple Tier 1 research universities. Wisconsin also has a considerably higher volume of publishing in energy and fuels areas than does Iowa.

Table 2. Iowa and Benchmark States Energy & Fuels Research Publications, 1/2011-3/2016

State	Number of Publications
Iowa	**468**
Illinois	1,804
Wisconsin	662
Minnesota	483
Missouri	435
Nebraska	232
South Dakota	206

Source: TEConomy Partners analysis of publication data from Thomson Reuters' Web of Science database.

Further insight as to the nature of important energy-related research taking place in Iowa is provided by reference to the most influential energy publications (as measured by citations) produced by one or more Iowa authors in the past five years. Table 3 lists those paper titles that have received 40 or more citations. Among these 15 high citation impact papers, the Iowa expertise in biorenewable at Iowa State University is evident, with 11 of the 15 papers focused on biorenewables subject matter.

Table 3. Most Cited (40+ Citations) Energy-Related Publications by Iowa Institutional Authors, 1/2011-3/2016

Publication Title	Journal Title	Author(s) Institution	Year	Times Cited	Fields of Research
Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis	GLOBAL CHANGE BIOLOGY BIOENERGY	Iowa State University	2013	122	Agronomy; Biotechnology & Applied Microbiology; Energy & Fuels
Thermopower enhancement in conducting polymer nanocomposites via carrier energy scattering at the organic-inorganic semiconductor interface	ENERGY & ENVIRONMENTAL SCIENCE	Iowa State University	2012	82	Chemistry, Multidisciplinary; Energy & Fuels; Engineering, Chemical; Environmental Sciences
Second generation biofuels: Economics and policies	ENERGY POLICY	Iowa State University	2011	77	Energy & Fuels; Environmental Sciences; Environmental Studies
Effects of torrefaction process parameters on biomass feedstock upgrading	FUEL	Iowa State University	2012	74	Energy & Fuels; Engineering, Chemical
The prediction and diagnosis of wind turbine faults	RENEWABLE ENERGY	University of Iowa	2011	70	Energy & Fuels
Distinguishing primary and secondary reactions of cellulose pyrolysis	BIORESOURCE TECHNOLOGY	Iowa State University	2011	66	Agricultural Engineering; Biotechnology & Applied Microbiology; Energy & Fuels
Criteria to Select Biochars for Field Studies based on Biochar Chemical Properties	BIOENERGY RESEARCH	Iowa State University	2011	62	Energy & Fuels; Environmental Sciences
All-conjugated poly(3-alkylthiophene) diblock copolymer-based bulk heterojunction solar cells with controlled molecular organization and nanoscale morphology	ENERGY & ENVIRONMENTAL SCIENCE	Iowa State University	2011	62	Chemistry, Multidisciplinary; Energy & Fuels; Engineering, Chemical; Environmental Sciences
A review of cellulosic biofuel commercial-scale projects in the United States	BIOFUELS BIOPRODUCTS & BIOREFINING	Iowa State University	2013	55	Biotechnology & Applied Microbiology; Energy & Fuels
Estimating profitability of two biochar production scenarios: slow pyrolysis vs fast pyrolysis	BIOFUELS BIOPRODUCTS & BIOREFINING	Iowa State University	2011	55	Biotechnology & Applied Microbiology; Energy & Fuels
A review of cleaning technologies for biomass-derived syngas	BIOMASS & BIOENERGY	Iowa State University	2013	50	Agricultural Engineering; Biotechnology & Applied Microbiology; Energy & Fuels

Publication Title	Journal Title	Author(s) Institution	Year	Times Cited	Fields of Research
Continuous culture of the microalgae Schizochytrium limacinum on biodiesel-derived crude glycerol for producing docosahexaenoic acid	BIORESOURCE TECHNOLOGY	Iowa State University	2011	48	Agricultural Engineering; Biotechnology & Applied Microbiology; Energy & Fuels
Seasonal dynamics of above- and below-ground biomass and nitrogen partitioning in Miscanthus x giganteus and Panicum virgatum across three growing seasons	GLOBAL CHANGE BIOLOGY BIOENERGY	Iowa State University	2012	46	Agronomy; Biotechnology & Applied Microbiology; Energy & Fuels
Modeling and simulation of compressed air storage in caverns: A case study of the Huntorf plant	APPLIED ENERGY	Iowa State University	2012	45	Energy & Fuels; Engineering, Chemical
Fast pyrolysis of microalgae remnants in a fluidized bed reactor for bio-oil and biochar production	BIORESOURCE TECHNOLOGY	Iowa State University	2013	40	Agricultural Engineering; Biotechnology & Applied Microbiology; Energy & Fuels

Source: TEConomy Partners analysis of publication data from Thomson Reuters' Web of Science database.

National Science Foundation (NSF) funding is one of the gold-standards for academic research and between 2011 and 2015 the NSF shows Iowa institutions receiving 53 awards totaling $36.8 million. 89.4% of the NSF funds were received by Iowa State University (Table 4).

Table 4. NSF Funded Energy-Related Research at Iowa Institutions, 2011-2015

Iowa Institution	Number of Energy-Related Awards	Total, NSF Energy-Related Funding
Coe College	1	$97,010
Eastern Iowa Community College	1	$1,237,526
Indian Hills Community College	2	$653,545
Iowa State University	42	$32,869,669
University of Iowa	6	$1,758,707
University of Northern Iowa	1	$160,015
Grand Total	**53**	**$36,776,472**

Source: TEConomy Partners analysis of NSF grant awards.

A key R&D asset for energy research in Iowa is the U.S. Department of Energy Ames National Laboratory (Ames Lab). At Ames Lab, which is located on the campus of ISU, there are approximately 745 people affiliated with the laboratory either as full- or part-time employees or as Laboratory associates. While one of the smaller national labs, Ames Lab is a specialized center in a number of critically important areas of energy research, including:

- Materials design, synthesis and processing
- Analytical instrumentation design and development
- Materials characterization
- Catalysis
- Computational chemistry
- Condensed matter theory
- Computational materials science
- Materials theory.

Materials for energy applications represent the core of Ames Lab research, and the Lab has world-class materials science research infrastructure and instrumentation for the study, characterization and production of advanced materials.

The Ames Lab also leads the Critical Materials Institute, a DOE Energy Innovation Hub funded at up to $120 million over five years. The Critical Materials Institute is designed to bring together leading researchers from other DOE national laboratories, academia and industry to "develop solutions to domestic shortages of rare-earth materials and other materials critical to U.S. energy security."

2. Interview-Identified R&D Focus Areas in Energy

To better understand the specific areas of institutional R&D focus around energy in Iowa, TEConomy Partners personnel held a series of on-site meetings and interviews at the largest energy R&D performing institutions – at Iowa State University, Ames National Laboratory (on the ISU campus) and the University of Iowa. These interviews highlighted a broad range of research foci at these institutions, with most of these foci being able to be classified in five primary areas:

- Materials for energy applications
- Grid systems and infrastructure
- Biorenewables
- Wind energy
- Energy efficiency.

Primary areas of specialized activity within each of these categories (identified through the interviews and subsequent reference to the institutional websites) are shown on Figure 5. An "other" category is also included for energy-associated research that does not fit into one of the five, or is a cross-cutting strength relevant to multiple themes.

It is evident from these primary areas that there is a significant focus of R&D activity taking place in areas of energy research that relate well to Iowa's energy economy. Work on wind energy and biorenewable energy is complementary to these as important growth sectors in the state. Similarly, R&D in grid systems is relevant in Iowa where the management of the electricity system is under the control of a wide variety of utility types and complicated by the integration of a growing portfolio of intermittent power generating renewable energy assets. Work on energy efficiency appears to focus more on industrial processes, and efficiencies in power systems and refrigeration systems – rather than the work of utilities and other energy efficiency promoters which focus more at the consumer end of the equation. The materials for energy applications research area holds promise for producing novel innovations that may be potentially commercialized in Iowa and for material improvements for important renewable systems (such as windmill blade and turbine components).

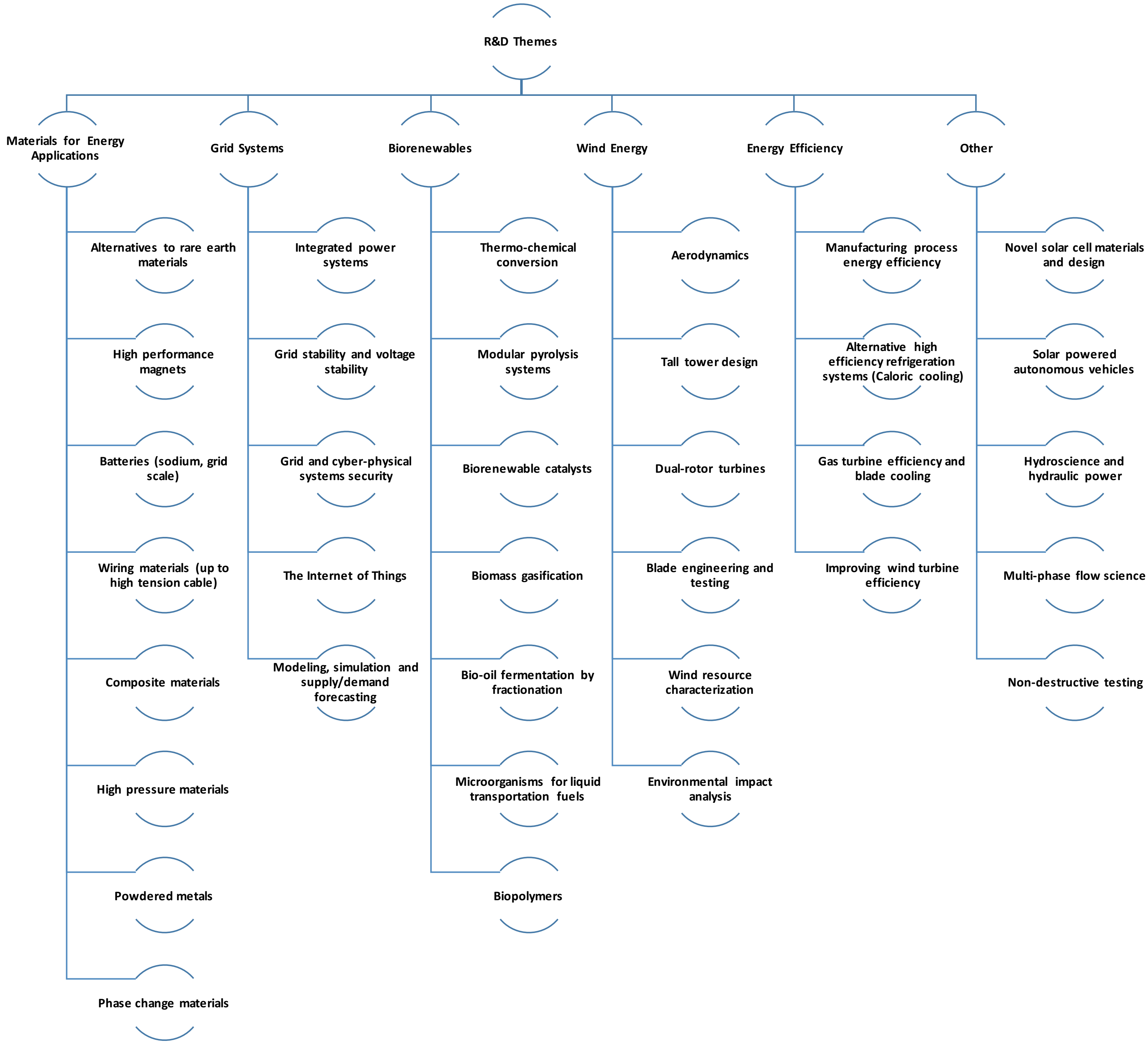


Figure 4. Interview Identified R&D Strength Areas at Ames National Laboratory and Major Energy R&D-performing universities in Iowa

3. Iowa Patent Generation in Energy and Energy-Related Innovations

While publications provide an important indicator of research activity, patents are similarly an excellent metric for understanding innovation output in a state. TEConomy subscribes to patent databases and performed a custom analysis of energy and energy-related patents for Iowa.

TEConomy used both Common Patent Classification (CPC) categories as well as keyword searches developed by World Intellectual Property Organization (WIPO) around energy technologies, to identify groupings of energy-related patents in Iowa. While there are potentially additional types of energy-related patents being generated in Iowa, it is not possible to build a completely comprehensive catalogue of patents due to the wide variety of applications and technologies encompassed. The patents here represent core energy generation, fuels, and climate change mitigation technologies. The technologies captured by the energy-related patent searches included:

- Power Generation, Distribution, & Storage
- Clean Transportation
- Energy Efficiency & Conservation Technologies
- Biofuels
- Wind Power
- Solar Power
- Hydropower
- Geothermal
- Carbon Capture
- Smart Grid
- Batteries
- Waste-to-Energy
- Fuel Cells
- Hydrogen Production & Storage
- Other Renewable Power and Climate Change Mitigation Technologies

Using the patent searches, Iowa energy-related patents from 2010-2015 were assessed for patents invented in state. The focus was on Iowa invented patents since they represent a more accurate measure of innovation that is generated within Iowa rather than intellectual property that companies "import" as assignees from other states or internationally. In other words, including "assigned" patents could lead to thinking there is more innovation taking place in Iowa than there is, since the actual innovation on the assigned patent occurred elsewhere. Concentrating on patents where the actual invention occurred in Iowa (or with Iowa resident inventors) provides a better understanding of Iowa innovation core competencies.

It should be noted that an Iowa invented patent does not mean that the innovation will necessarily be commercialized in the state – since patents can be licensed to out-of-state entities or bought by out-of-state entities. For energy-related patents, as shown on Table 5, there is an evident a mix between Iowa-invented IP being retained by local Iowa companies or being acquired by companies with out-of-state ownership.

Table 5. Iowa Energy and Energy-related Patents 2010-2015 – Count, Assignee and Number of Forward Citations

Assignee Location	Number of Energy Patents Invented	Number of Forward Citations
Iowa	110	218
Outside Iowa	194	519
Total	**304**	**737**

Source: TEConomy Partners analysis using Thomson Reuter's Thomson Innovation patent analysis database.

Table 6 and Figure 6 show the main energy categories in which Iowa invented patents are classified and shows quite a diverse mix of patent types.

Table 6. Iowa Energy and Energy-related Patents 2010-2015 by Category – Count and Forward Citations

Category	IA Invented Patents	Forward Citations
Power Generation/Distribution/Storage	113	360
Clean Transportation	75	103
Other Renewable Power	61	75
Energy Efficiency and Conservation Technologies	44	53
Biofuels	25	115
Wind	19	88
Smart Grid	7	19
Solar	3	9
Carbon Capture	2	0
Hydropower	2	13
Fuel Cells	1	0
Hydrogen Production	1	1

Source: TEConomy Partners analysis using Thomson Reuter's Thomson Innovation patent analysis database.

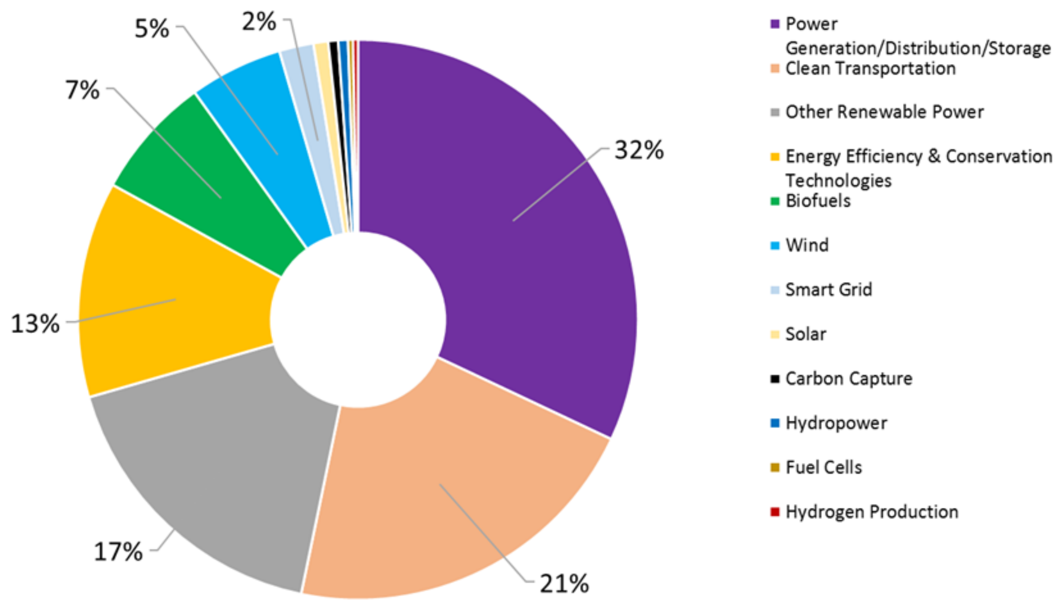


Figure 5. Iowa Energy and Energy-related Patents 2010-2015 by Category – Count and Forward Citations Source: TEConomy Partners analysis using Thomson Reuter's Thomson Innovation patent analysis database.

Table 7 shows the individual companies and institutions that are most active in the Iowa energy and energy-associated innovation space:

Table 7. Companies and Institutions with Largest Number of Energy-Associated Iowa Invented Patents (2010-15)

Assignee Name	Assignee State	Company Focus	Key Energy-Related Patenting Area in IA	Number of IA Invented Patents	Number of Forward Citations
Deere & Company	IL	Manufactures ag, construction, & forestry machinery	Clean Transportation	58	89
Schneider Electric USA Inc.	IL	Energy management & automation technologies	Power Gen/Dist/Storage	28	57
Rockwell Collins Inc.	IA	Avionics and IT systems	Power Gen/Dist/Storage, Energy Efficiency	24	55
ISU Research Foundation Inc.	IA	Public university	Biofuels, Other Renewables	18	95
Whirlpool Corporation	MI	Home appliance manufacturer	Energy Efficiency	11	3
Musco Corporation	IA	Large area & temporary lighting manufacturer	Energy Efficiency	9	17
GYCO Inc.	IA	Process & waste-to-energy engineering	Biofuels	9	17
RF Micro Devices Inc.	NC	Integrated communications circuits	Power Gen/Dist/Storage	8	14
Skyworks Solutions Inc.	MA	Communications semiconductor manufacturer	Power Gen/Dist/Storage	8	12
Broadcom Corporation	CA	Communications semiconductor manufacturer	Power Gen/Dist/Storage, Energy Efficiency	7	49
Cummins Inc.	IN	Engine, filtration, & power generation technologies	Clean Transportation	7	14
University of Missouri	MO	Public university	Carbon Capture, Other Renewables	6	0
Danisco US Inc.	CA	Food production, enzymes, & bioproducts	Other Renewables	5	3
Pioneer Hi Bred International	IA	Genetically modified agricultural products	Other Renewables	4	0
Avello Bioenergy Inc.	IA	Biomass pyrolysis technologies	Biofuels	4	10

Source: TEConomy Partners analysis using Thomson Reuter's Thomson Innovation patent analysis database.

In Figure 7 on the following page, TEConomy Partners provides a graphic summarizing the relative position of Iowa patents by general classification, positioning the patents in performance quadrants as noted in Figure 6:

- Areas of differentiated innovation for a state will ideally have both a high specialization in specific technology areas as demonstrated through experience in patenting as well as having high amounts of forward innovation activity in those areas. Figure 8 shows the relative position of detailed Iowa energy patenting areas in terms of their comparison to national trends on these attributes.
- ***Specialization index (x axis)*** shows how specialized an energy patenting category is in Iowa relative to proportions of US patenting in that area (>1 indicates more specialized relative to US, <1 indicates less specialized)
- ***Forward citation index (y axis)*** shows average rate of forward citations for Iowa patents relative to proportions of forward citations generated in energy areas across all US patents (>1 more forward citations than expected given US trends, <1 fewer forward citations than expected given US trends)
- ***Size of bubbles*** shows quantity of patents in the specific area for Iowa
- ***Color of bubbles*** shows aggregate energy category.

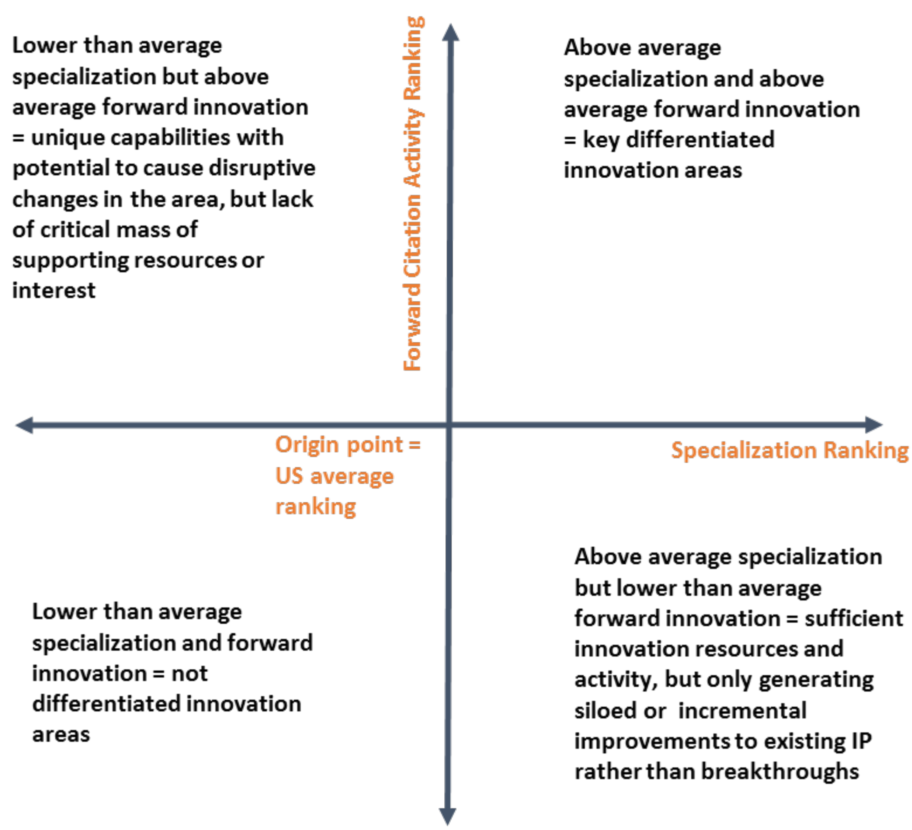


Figure 6. Patent Positioning Quadrant

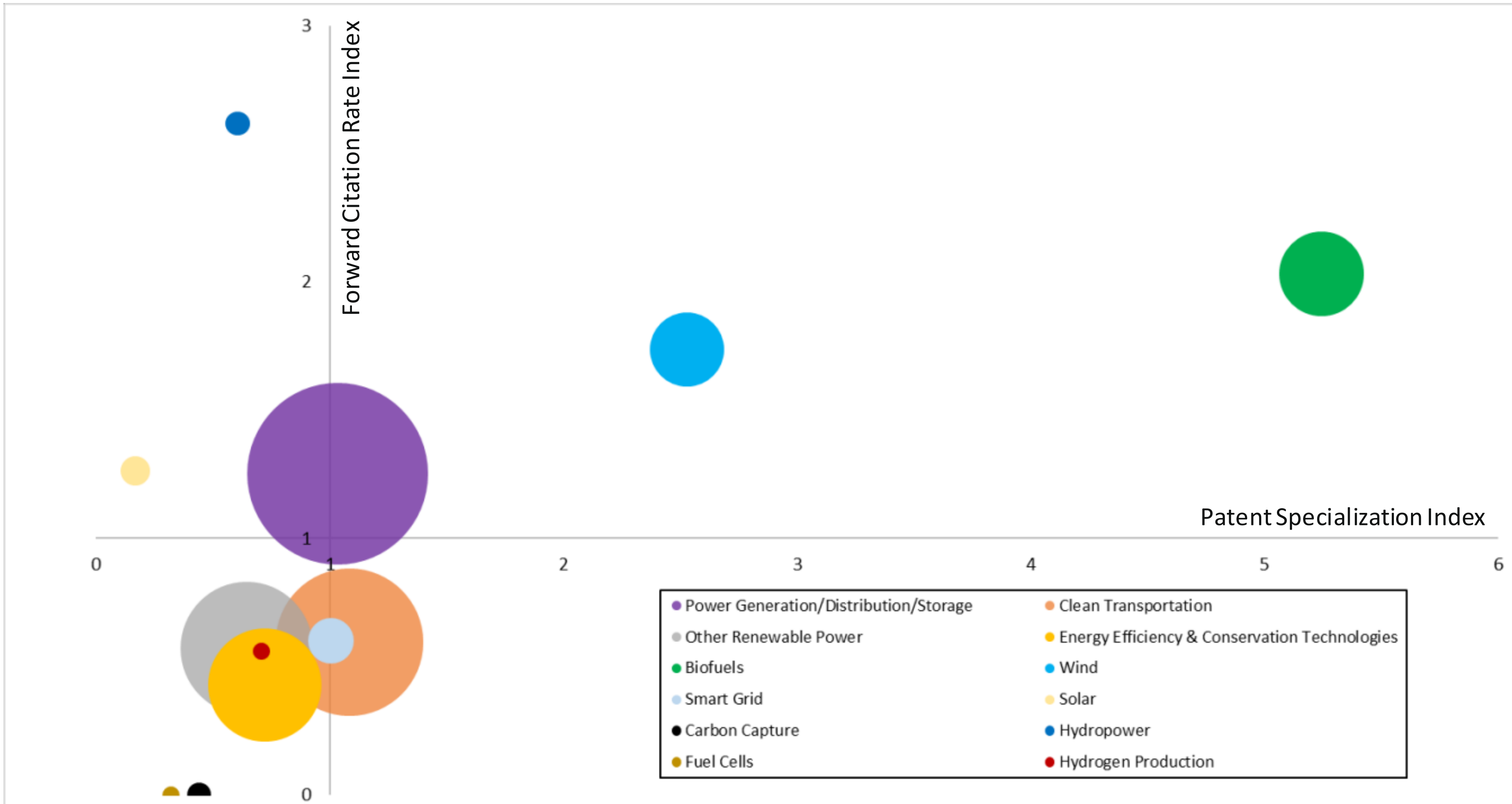


Figure 7. Iowa Patent Innovation Bubble Chart
Source: TEConomy Partners analysis using Thomson Reuter's Thomson Innovation patent analysis database.

Most large areas of Iowa patenting (reflected in the size of the bubble) are in the areas of infrastructure, energy efficiency, and clean transportation but they have low specialization and low forward citation impact relative to the rest of the U.S. – Iowa is not a specialized leader in these areas in terms of intellectual property (IP). This may be indicative of Iowa being a base of operations for these industries but not a hub for research, development and innovation.

Despite relatively low overall patenting numbers, both biofuels and wind power are highly specialized in terms of Iowa IP generation and have strong rates of forward citation. Biofuels is certainly the category that is most notable with a very high level of specialization indicating that Iowa is leading national trends – even though the actual patent number is not particularly large, indicative of this being an area that is not generating a large amount of patenting nationally either. Wind power also has some specialization based around turbine technologies generated by Iowa-based innovators.

4. Venture Investments in New and Expanding Energy Enterprise in Iowa

As research matures resulting in applied innovations, commercialization becomes the next logical step. TEConomy accessed corporate subscriptions to the Thomson Reuter's Thomson One venture capital database and government data to evaluate the level of activity in energy enterprise development in Iowa that has accessed venture funding or secured government SBIR or STTR awards.

Iowa has low levels of venture capital being invested in new energy ventures. Table 8 indicates that in the 16 years (2000 through 2015) only three Iowa energy-related companies received venture capital, with the majority ($22 million out of $26.25 million total) going to just one company Renewable Energy Group, Inc.

Table 8. Energy-Related Venture Capital Investments in Iowa, 2000-2015

Company Name	No. of Deals	Total Equity Invested ($ millions)	Current Status
Renewable Energy Group, Inc.	1	$22.00	Operational; HQ in Ames, IA
Catilin, Inc.	1	$3.00	Bought by Albermarle; IA operations closed
Renewable Fuel Products Inc.	3	$1.25	Operational; Located in Biomass Energy Conversion (BECON) Center
Total, Energy-Related VC Investment in IA Firms	5	$26.25	

Source: TEConomy Partners analysis of Thomson Reuter's Thomson One venture capital database.

It should be noted that generally the energy space has not been a hotbed of venture deals compared to other technology spaces such as IT or medical technology, but it does appear from the regional benchmarks shown in Table 9 that Iowa has not faired particularly well in comparison to surrounding states, especially in terms of the total equity invested.

Table 9. Iowa and Benchmark States Energy-Related Venture Capital Investments, 2000-2015

State	No. of Deals	No. of Companies	Total Equity Invested ($ millions)
Iowa	**5**	**3**	**$26.25**
Illinois	59	15	$449.84
South Dakota	3	1	$294.92
Missouri	15	9	$155.10
Minnesota	22	4	$114.44
Wisconsin	15	6	$97.78
Nebraska	3	3	$12.55

Source: TEConomy Partners analysis of Thomson Reuter's Thomson One venture capital database.

In terms of federal SBIR and STTR awards – which can go to both industry and R&D performing institutions such as universities - (Table 10) Iowa again shows a low level of performance versus other major Midwest states. Only South Dakota received less in SBIR/STTR funding in the 16-year period of 2000-2015, with Iowa having the second lowest number of awards (tied with Nebraska at just eight).

Table 10. Iowa and Benchmark States DOE SBIR and STTR Awards, 2000-2015

State	Number of Firms	Number of SBIR/STTR Awards	Total, SBIR/STTR Funding
Iowa	**6**	**8**	**$2,499,458**
Illinois	47	220	$69,771,238
Minnesota	12	59	$17,372,137
Wisconsin	21	43	$9,880,376
Missouri	11	26	$6,442,826
Nebraska	2	8	$3,699,994
South Dakota	3	4	$1,448,307

Source: TEConomy Partners analysis of data from SBIR.gov

Table 11 shows the individual companies that received the SBIR/STTR awards in Iowa.

Table 11. Iowa Energy-Related SBIR and STTR Awards, All Federal Agencies, 2000-2015

Company	Federal Agency	Phase I		Phase II		Totals	
		Awards	Funding Amount	Awards	Funding Amount	Awards	Funding Amount
Advanced Genome Technologies, LLC	DOE	1	$99,963			1	$99,963
Adv. Renewable Technology Int'l, Inc.	DOE	1	$149,868			1	$149,868
Amjet Turbine Systems, LLC	DOE	1	$149,627	1	$1,000,000	2	$1,149,627
Iowa Thin Film Technologies, Inc.	DOD	2	$219,229			2	$219,229
Molecular Express, Inc.	DOE	1	$100,000			1	$100,000
Northern Microdesign, Inc.	DOE	1	$100,000	1	$750,000	2	$850,000
Oren Consulting Services	USDA	1	$69,443			1	$69,443
Springboard Engineering, Inc.	DOE	1	$150,000			1	$150,000
Grand Total		**9**	**$1,038,130**	**2**	**$1,750,000**	**11**	**$2,788,130**

Source: TEConomy Partners analysis of data from SBIR.gov. Non-DOE awards determined through examination of individual Iowa SBIR/STTR awards.

C. Conclusions from the R&D Core Competencies Analysis

The evaluation of the core competencies by key criteria is summarized on Table 12, including:

- Publishing data
- Patenting data
- Presence of dedicated university research centers or stated as a strategic thrust of research by the institution
- SBIR/STTR and venture funding activity
- Notation regarding whether the competency was raised as such in interviews.

Table 12. Summary of Energy and Associated Discipline Strength Areas by Key Criteria

	Volume of Papers Published	Patents	Dedicated Research Centers or Stated Thrusts	SBIR/ STTR or VC Activity	Interviews Validated as an Area of R&D Strength or Concentration
Research Strength Area	Count by Field	Count by Classification	Yes or No (Comments)	Count	Yes or No (Comments)
Materials for Energy Applications	92 Materials Science 43 Nanotech 39 Electro-chemistry 36 Thermodynamics	Not identified individual category, but crosscutting in others	YES Main focus of Ames Lab: • Division of Materials Science and Engineering • Critical Materials Institute • Materials Preparation Center ISU: Lists "Advanced Materials" as a "signature research focus area" for the University: • Center for Catalysis • Center for Nondestructive Testing University of Iowa: • NSF IUCRC Photopolymerization Center • Nanoscience and Nanotechnology Institute	<=1	YES: 8 foci • Rare earth materials • High performance magnets • Batteries • Wiring/cable materials • Composite materials • High pressure materials • Powdered metals • Phase change materials
Grid Systems	111 Electrical and electronic engineering	113 Power generation, distribution and storage. 7 Smart grid	YES. ISU: Lists "Energy Sciences & Engineering" as a "signature research focus area" for the University: • Electric Power Research Center • Power Systems Engineering Research Center • Power Infrastructure Cyber Security Lab Ames Lab: Simulation, Modeling and Decision Science Program	<=1	YES: 5 foci • Integrated power systems • Grid and voltage stability • Grid & cyber-physical systems security • Internet of Things • Modeling/ simulation and forecasting

	Volume of Papers Published	Patents	Dedicated Research Centers or Stated Thrusts	SBIR/ STTR or VC Activity	Interviews Validated as an Area of R&D Strength or Concentration
Biorenewables	Most cited publications are in this area. 161 Biotechnology and Applied Microbiology 109 Chemical Engineering 91 Agricultural Engineering 40 Agronomy	25 Biofuels	YES ISU: Lists "Biorenewable Processes" as a "signature research focus area" for the University: • Bioeconomy Institute • Plant Sciences Institute • Center for Biorenewable Chemicals • Center for Carbon Capturing Crops Ames Lab: Division of Chemical and Biological Sciences University of Iowa: • Center for Biocatalysts and Bioprocessing	>1	YES: 7 foci • Thermo-chemical conversion • Modular pyrolysis systems • Biorenewable catalysts • Biomass gasification • Bio-oil fermentation by fractionation • Microorganisms for liquid transportation fuels • Biopolymers
Wind Energy	Crosscutting (incorporated in "Energy & Fuels" category	19 Wind	YES ISU: Wind Energy Initiative • Wind Energy Manufacturing Lab • Wind Energy Systems Lab • Wind Simulation Testing Lab • Structure Engineering Research Lab	<=1	YES: 6 foci • Aerodynamics • Tall tower design • Dual-rotor turbines • Blade engineering and testing • Wind resource characterization • Environment impact analysis
Energy Efficiency	Crosscutting (probably incorporated in multiple categories	44 Energy efficiency & conservation technologies	YES ISU: Wind Energy Initiative • Iowa Energy Center • Center for Building Energy Research • Institute for Transportation Ames Lab: Major program focus in Caloric Cooling for high efficiency refrigeration.	<=1	YES: 4 foci • Manufacturing process energy efficiency • Alternative high-efficiency cooling (refrigeration) systems • Gas turbine efficiency and blade cooling • Improving wind turbine efficiency

	Volume of Papers Published	Patents	Dedicated Research Centers or Stated Thrusts	SBIR/ STTR or VC Activity	Interviews Validated as an Area of R&D Strength or Concentration
Other…		75 Clean transportation 3 Solar	YES ISU: Computational Fluid Dynamics Center University of Iowa: Hydroscience and Engineering	>1	YES • Novel solar cells • Solar powered autonomous vehicles • Hydroscience and hydraulic power • Non-destructive testing

III. OPPORTUNITIES AND PLATFORMS FOR ENERGY-BASED ECONOMIC DEVELOPMENT IN IOWA

In addition to conducting interviews and databases searches for identification of core competencies, TEConomy Partners also integrated strengths, weaknesses, opportunities, and threats (SWOT) questions into the process. In this chapter, opportunities identified through the SWOT process are highlighted, and these opportunities are integrated with findings from the core competency analysis to suggest focused "platforms" for Iowa to advance to accomplish energy-based economic development.

A. Opportunities Based on Iowa Assets

Through triangulating the findings from existing reports, data and interviews, and the resulting SWOT analysis, multiple energy opportunity areas have been identified for Iowa. As would be expected, not all opportunities are equal—there is variability in the time horizon for potential realization of these opportunities, the scale of the opportunities, and their job and income generation potential for the state. The TEConomy team has identified 30 energy opportunity areas for Iowa, as shown on Table 13.

These 30 opportunity areas vary in potential time-frame for opportunity realization, and fall under six broad "energy group" themes of: transmission and distribution; renewable electric power; biofuels; energy efficiency; R&D-driven innovation and technology commercialization; and an "other" category.

Iowa, however, has multiple opportunities for energy-based economic development in the near-and mid-term time horizons.

Table 13. Listing of Identified Energy-Based Economic Development Opportunities for Iowa

ENERGY GROUP	ENERGY OPPORTUNITY AREA	
	NEAR-TERM (Present–3 years)	MID-TERM (3–8 years)
Transmission and Distribution	• Siting and development planning for strategic power transmission lines for selling power • Improved west to east connectivity for transmission inside Iowa • Siting and development planning for ethanol pipelines	• Development of power transmission lines and start of renewable electric power • Development of ethanol pipelines for more efficient distribution inside and outside Iowa

ENERGY GROUP	ENERGY OPPORTUNITY AREA	
	NEAR-TERM (Present–3 years)	MID-TERM (3–8 years)
Renewable Electric Power	• Increase solar installations (grid scale and distributed/rooftop) • Continue momentum in large-scale wind power development • Explore waste-to-energy project potentials	• Development of river-based hydro-power (if feasible)
Biofuels	• Promote market and infrastructure for higher blends of ethanol • Continue development of next-generation biofuels • Livestock waste-to-biogas projects	• Next-generation biofuels deployment • Development of modular biopower systems for distributed generation • Develop value-added chemicals industry from biofeedstocks
Energy Efficiency	• Increase awareness of existing programs • Enhance EE education activity by all Iowa utilities • Develop certification and training programs for installers and energy efficiency contractors	• Deploy proven smart-grid and advanced energy management technologies as become affordable.
R&D-Driven Innovation and Technology Commercialization	• Development of new components for wind-power • Develop an Advanced Energy Systems Integration Center to coordinate activities in next-generation grid and grid-management technologies • Ongoing development of advanced materials and domestic alternatives to critical materials • Grid-scale energy storage R&D	• Development of manufacturing industries for critical materials and advanced energy materials • Development of alternative biomass feedstocks for biofuels and bio-based products.
Other	• Ongoing attraction of inward investment by industry seeking reliable renewable power • Evaluation of agricultural systems to provide carbon capture/fixing	• Evaluation of next generation nuclear technologies for Iowa • Diversification of infrastructure to support alternatively fueled vehicles • Development of intermodal freight transport facilities.

In the **near-term** (defined as immediate to 3 years out) TEConomy finds there to be several areas of major energy opportunity that Iowa may pursue to enhance job generation and economic development in the state. TEConomy believes areas with the most promise in this time horizon include (Table 14):

Table 14. Summary of Main Opportunity Areas for Energy-Based Economic Development in Iowa

Near-Term Opportunity Area	Description of Opportunity	Job Generation Potential
Strategic power transmission line development	Iowa's ability to generate significant electric power from renewable resources presents opportunities for the state economy to benefit from selling high-demand renewable power. Doing so requires enhanced transmission line capacity.	Major short-term construction job potential. Followed by increasing employment in the production, installation and on-going operations of renewable power generation systems (primarily wind and solar).
Strategic ethanol pipelines	Iowa is the leading producer of ethanol in the nation and projects that serve to increase the efficiency of the industry are important. Currently ethanol is shipped from the site of production to petroleum refineries and blending operations for integration into the gasoline supply chain. Efficiencies can be gained through construction of a pipeline network in the state to link the production chain, and potentially for transporting ethanol to out-of-state locations more efficiently. As next-generation biofuels come online, the demand for the pipeline infrastructure will increase.	Major short-term construction job potential. Followed by increasing employment in the maintenance of pipeline infrastructure. Potential growth in ethanol production jobs through increased efficiency of supply chain.
Promote market and infrastructure for higher blends of ethanol	Auto makers, like Ford and Mercedes, have stated a desire to produce vehicles using highly efficient high-compression engines. These engines require high octane fuel, and the least expensive octane available is ethanol. The development of the market for high compression engines will require infrastructure to be deployed, including blender pumps, at gasoline distribution sites for E15-E85 fuels. It is in Iowa's interest to help promote the development of this market through incentivizing investment in the infrastructure.	Significantly higher ethanol blends have the potential to double or triple the size of the ethanol industry in Iowa.

Near-Term Opportunity Area	Description of Opportunity	Job Generation Potential
Increase solar power installations	Solar energy has seen limited penetration to-date into the Iowa energy mix. There is potential for enhancing renewable energy generation in Iowa through both utility solar projects and distributed/community generation. At current low energy price levels, however, this may become a longer-term play as the payback period for solar projects would likely be quite lengthy.	Significant in sales, installation and maintenance of solar systems – especially distributed solar, which has potential to generate jobs across the state.
Increase wind power installations	Iowa's wind resource is far from fully utilized. The major coming expansion of Mid Americans' wind generation capacity proves this point. In addition to siting more towers on new sites in Iowa there is also the potential to generate increased power from existing geographies using >100-meter-tall towers to access higher level wind, and adoption of novel systems such as dual rotor generators.	Major job potential in wind system manufacturing and construction/installation. Followed by increasing employment in on-going operations and maintenance of wind power systems, and the manufacturing of replacement components
Continue development of next generation biofuels	Iowa's leadership in starch-based ethanol is well-known. However, the long-term promise of ethanol fuel will be realized as processes are improved and commercialized for cellulosic biomass-to-ethanol production. Already Iowa leads in production of cellulosic ethanol, through the innovative process invented at Quad County Corn Processors that converts corn kernel fiber to ethanol and POET's Project Liberty facility in Emmetsburg, IA. Work in industry and at Iowa universities is intensive in this space both for fuels and downstream value-assed chemicals.	The growth of the ethanol industry in Iowa has been a success story, not only in terms of the jobs generated in the direct production and distribution of ethanol, but also in terms of the distributed economic benefits to farmers across the state. The realization of the promise of next generation ethanol will significantly increase the value of currently low-value cellulosic biomass and spur biofuel-based economic development to the next level.

Near-Term Opportunity Area	Description of Opportunity	Job Generation Potential
Waste-to-energy projects	Processes are already in-place and being used, in Iowa, in converting municipal waste to energy (for example in Ames). But penetration of this technology across the state is quite limited at the present time. There is significant opportunity to expand municipal waste-to-energy projects, and there is similarly opportunity for using agricultural waste and processing byproducts in energy generation applications.	Job potential in waste-to-energy system manufacturing and construction/installation. Followed by increasing employment in on-going operations and maintenance of waste-to-energy systems, and the manufacturing of replacement components.
Increase awareness of existing energy efficiency programs	Multiple stakeholders noted that while Iowa has a good leadership position in terms of utilities' programs to enhance energy efficiency there is still substantial room to raise awareness among energy consumers of their options in energy efficiency.	Increased awareness is likely to increase adoption of energy efficiency and conservation tools and technologies – increasing employment opportunities in the production of technologies and the installation of systems and products at homes and businesses.
Develop certification and training programs for installers and energy efficiency contractors	Education and certification programs for major categories of energy efficiency product installations will likely lead to better installations realizing enhanced cost savings and higher consumer confidence and demand for energy efficiency products.	As consumers gain trust in the quality of installation services and realize anticipated savings from properly sized and installed energy efficiency applications it is likely that demand for energy efficiency products will increase together with employment in the installation of energy efficiency products and solutions at consumer sites.
Development of new components for wind-power	Wind power is an important and rapidly growing component of Iowa's electric power generation. Manufacturers of wind energy systems, and R&D institutions, are developing new technologies to improve system performance and harness more power from the available wind resource. Technologies for modular concrete tall-towers, duel rotor systems, blade de-icing systems, early identification of blade stress, etc. are being investigated and developed in Iowa presenting opportunities for new manufactured wind system components and for increasing the efficiency of the wind power generation industry in Iowa	Potential for jobs in research and development, in manufacturing, and in sales, installation and ongoing maintenance of advanced wind power technologies. Potential for the economic advancement of Iowa through significant product exports.

Near-Term Opportunity Area	Description of Opportunity	Job Generation Potential
Develop an Advanced Energy Systems Integration Center to coordinate activities in next-generation grid and grid-management technologies	Iowa has an unusual energy production and distribution system – unusual in terms of the types and varieties of utility systems and in terms of the high penetration of renewable energy production. The management and optimization of such a diverse system presents an opportunity and demand for developing an Advanced Energy Systems Integration Center that would bring together the state, utilities, regional transmission organizations, and major R&D institutions (including Ames Lab and the Regent Universities) to jointly research, develop and pilot existing and new technologies for power management, grid stability, grid security, etc.	Potential for development of grid management and security products and services for commercialization in Iowa. R&D employment also.
Ongoing development of advanced materials and domestic alternatives to critical materials	Ames National Laboratory is the designated energy materials lab of the U.S. Department of Energy. Together with Iowa State University and the University of Iowa, Ames Lab's expertise in materials development, characterization, testing and production gives the state a unique signature capability. Strategic concerns over critical materials sources from overseas, together with the demand for specialized materials to improve energy production, storage and transmission makes this area of expertise a good opportunity area for Iowa. Work in alternative magnet materials, sodium grid scale batteries, high-performance conducting materials, phase-change materials, etc. each have the potential to yield innovations with substantial market potential.	Potentially significant with an opportunity for growing new business ventures to commercialize innovative materials. Examples might include a high-performance magnet production industry, battery production industry, alternative refrigeration industry (using caloric cooling), etc.

Near-Term Opportunity Area	Description of Opportunity	Job Generation Potential
Ongoing attraction of inward invest by industry seeking reliable renewable power	Iowa's existing base of renewable power has already proven important in attracting companies to the state who value clean power. Having power sources that are secure from global fossil fuel supply chain choke-points also carries value. Iowa's energy is low cost and reliable, and the integration of renewable power has been achieved while sustaining reliability and stability. It is an attractive sales point for the state.	The attraction of inward investment projects is highly competitive, but Iowa's renewable energy portfolio provides a relatively differentiated attractor for the state. Projects such as those seen from Facebook, Microsoft and Google show the competitiveness of Iowa in this regard.

B. From Opportunities and Core Competencies to Platforms: Identifying Robust and Scalable Platforms for Energy-Based Economic Development in Iowa

With Iowa having such a diverse variety of R&D core competencies and potential energy opportunities to pursue, it is beneficial to refine and simplify these opportunities into broader development "platforms" around which state and stakeholder partnerships can work to promote energy-based economic development. As noted previously, a "platform" represents a major economic development focus containing near- and mid-term development opportunities that ideally:

- Have an established or emerging cluster of Iowa businesses with interests in related areas of the energy sector.
- Provide opportunities for ongoing technology, product and service innovations to which Iowa's commercial, academic and government laboratory research capabilities can be applied.
- Present opportunities for collaborative public/private partnerships to promote shared interests and facilitate the development of a highly favorable operating environment for platform growth.
- Are associated with a significant potential market with an achievable line-of-sight for the sale of resources, new technologies, services and value-added products.
- Contribute to building and reinforcing key aspects of an "ideal Iowa energy economy" as shown in the text box on page 2.

Based on the above, TEConomy has identified five energy platforms for Iowa that can encompass the majority of the identified opportunity areas. These five platforms are shown on Figure 9 and include:

- **Renewable Electricity Platform:** Focused on the ongoing growth of wind power, and increased attention to be paid to solar PV installations, to generate substantial excess power capacity for export outside of the state of Iowa while meeting the needs and demands internal to the state. The platform also includes development of enhanced transmission line capacity to connect Iowa assets to out-of-state markets.

- **Biomass Conversion Platform:** Focused on the conversion of Iowa's abundant supply of biomass (especially cellulosic biomass) into liquid fuels and high value-added chemicals.
- **Grid Management & Resilience Platform:** Focused on leveraging the diverse characteristics of the Iowa energy grid in terms of utility types and sizes, renewable generation integration, distributed generation, etc. for the development and testing of grid management technologies and smart grid systems.
- **Energy Efficiency Platform:** Advancing best practices in proven energy efficiency strategies and technologies, in combination with the development of new energy efficiency innovations.
- **Energy Materials and Systems Manufacturing Platform:** Building upon Iowa's R&D core competencies in materials and the design and production of energy technologies to advance new manufacturing ventures and help existing companies expand and improve their product lines.

Each of these platforms provides opportunities to realize significant economic development within Iowa, build upon a base of existing assets and knowhow in the state, leverage Iowa resources, and present opportunities for exporting valuable products and services. It is also notable that there are connections between the platforms, whereby work on one will help advance the work of another.

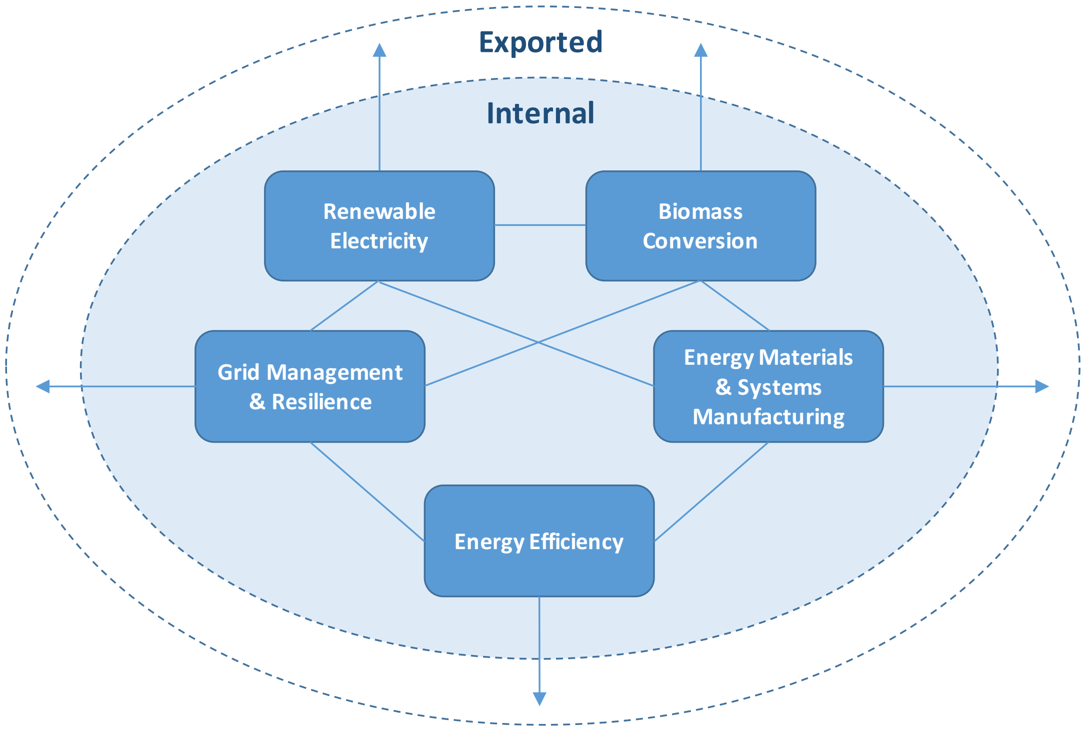


Figure 8. Suggested Platforms for Iowa Energy-Based Economic Development

The five recommended platforms perform well on contributing to the "ideal Iowa energy economy" characteristics noted previously. Table 15 shows TEConomy's qualitative scoring of these platforms against these criteria.

Table 15. Recommended Platform Performance on "Ideal" Iowa Energy Variables

	Renewable Electricity	Biomass Conversion	Grid Management and Resiliency	Energy Efficiency	Energy Materials and Systems Manufacturing
Foster long-term energy affordability and price stability for Iowa's businesses and residents	++	++	+++	+++	++
Increase reliability, resiliency, safety and security of Iowa's energy systems and infrastructure	++	++	+++	++	++

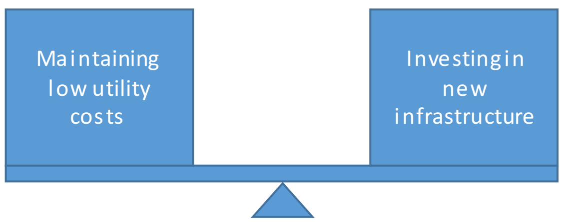
	Renewable Electricity	Biomass Conversion	Grid Management and Resiliency	Energy Efficiency	Energy Materials and Systems Manufacturing
Provide predictability by encouraging long-term actions, policies and initiatives	++	++	++	++	++
Expand opportunities for access to resources, technologies, fuels and programs throughout Iowa	+++	+++	+++	++	++
Seek diversity in the resources that supply energy to and within Iowa	+++	+++	+++	0	0
Support alternative energy resources, technology, and fuel commercialization in proven, cost-effective applications	+++	+++	+++	0	++
Encourage sector-based workforce development and educational activities that build clear pathways to rewarding energy careers	++	++	++	++	+++
Promote the protection of the environment and Iowa's natural resources	++	++	++	+++	++

+++ = Strong contributor to achieving this goal
++ = Contributor to achieving this goal
0 = Does not contribute to achieving this goal

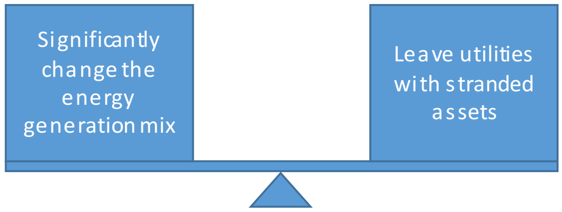
IV. BARRIERS AND CHALLENGES TO REALIZING IOWA'S ENERGY-BASED ECONOMIC DEVELOPMENT POTENTIAL

Changing something as complex and critically important as a state energy system does not come without challenges. A host of complex variables come into play in terms of considering pathways forward and developing an energy plan that optimizes opportunities while balancing potential conflicts and tensions between stakeholders. One way of summarizing challenges is to examine tensions that will need to be balanced in order for energy plan development, and more importantly, implementation of the plan to proceed. A series of graphics and brief narrative descriptions are provided below to highlight some of the key tensions observed.

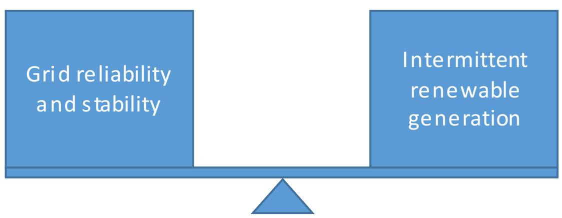
Primary Observed Tensions



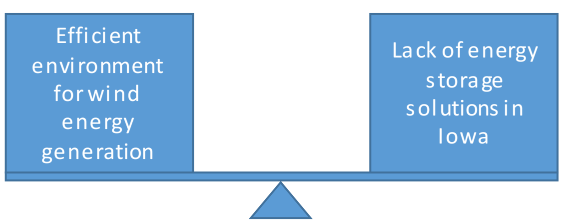
One of the obvious areas in which balance must be struck is in the need to build more transmission and distribution infrastructure for Iowa energy versus the desire to keep energy rates as low as possible for end users. Companies investing in major infrastructure projects need to recapture their investment – and rate increases would be the usual pathway.



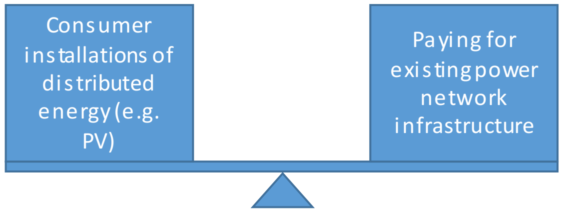
New technologies, federal Clean Power Plan (CPP) imperatives, and other factors make it desirable to change the mix of generating assets in Iowa – particularly away from coal-fired generation to alternative fuels. However, utilities invested in their existing assets (such as coal power plants) under assumptions of being able to recoup their investments over the useful life of the project, and a shifting generation portfolio leaves utilities with the risk of owning costly stranded assets.



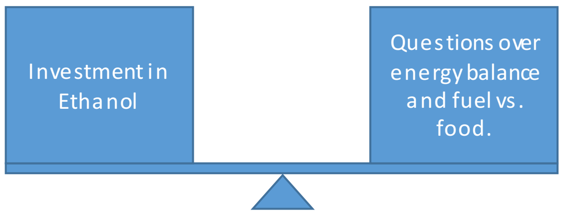
Grid stability and reliability is exceptionally important and it complicates the reliability and stability equation to mix in renewable power such as wind and solar that can experience significant generation variability.



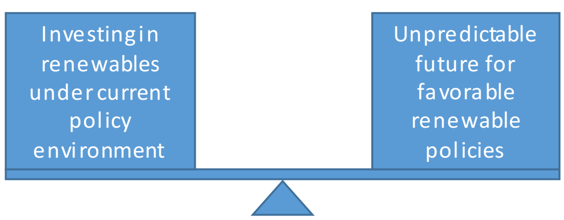
Related to the last tension there is not yet a clear path forward to affordable grid-scale energy storage for Iowa. So, while Iowa has a high performance environment for wind power generation, this performance is not balanced by having power storage solutions to flatten the generation curve.



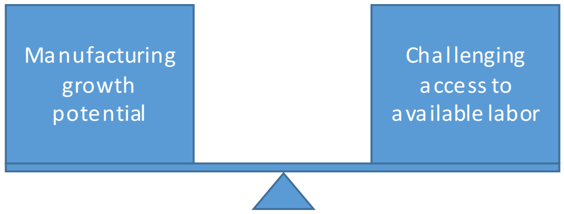
There are tensions inherent in the interest of consumers to install solar PV or other distributed generation technologies and the need for utilities to recoup cost for the connected grid infrastructure. There is also the issue of connecting distributed generation to the grid to sell excess power.



Iowa has benefitted economically from investing in ethanol production in the state – developing an industry that benefits farmers, ethanol producers and consumers. The industry is challenged, however, by questions over the energy balance of corn ethanol and the debate concerning food vs. fuel. Development of affordable commercial-scale cellulosic ethanol processes will significantly ameliorate concerns.



Another challenge affecting the ethanol industry (and other renewable power sectors) is a lack of assured ongoing political support for incentives and policies that help support and reward industry development. Investors have to balance the reward associated with incentives and the risk that an incentive may go away over time.



While there is potential for growing the renewable power industry and manufacturing of energy products, a number of leading manufacturers in Iowa are expressing frustration at being unable to access a job-ready workforce.

As the process advances in developing the Iowa Energy Plan, these tensions will need to be addressed and solutions and compromises found.