
Pennsylvania's
CLEAN ENERGY PROJECTS
Universities
Innovation Centers
Economic Dev. Centers
Non-Profits
Businesses
Environ. Orgs.
Colleges
Incubators
SAINT FRANCIS UNIVERSITY
INSTITUTE FOR ENERGY
2018

# Survey Report Prepared for and Made Possible by the Met Ed/Penelec Sustainable Energy Fund

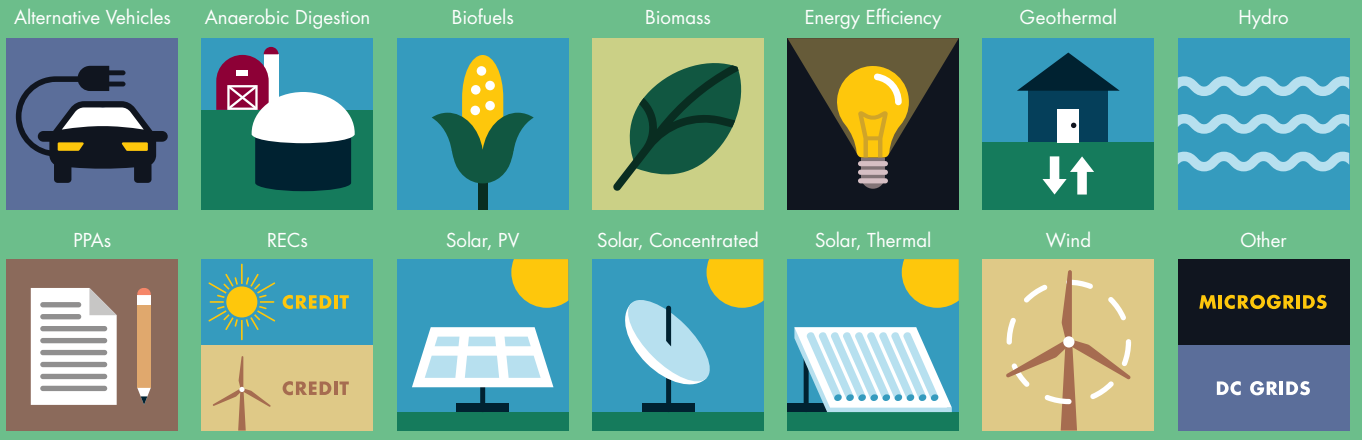
## Prepared by the Saint Francis University Institute for Energy

## 2018

**Acknowledgements:**
The Saint Francis University Institute for Energy would like to thank everyone who supported this project, particularly the interviewees who willingly took the time to provide the Institute with the data necessary to prepare the report.

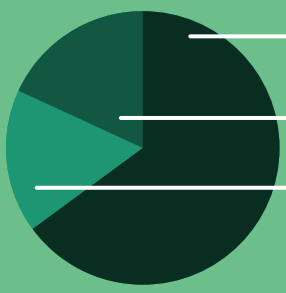
# Renewable & Clean Energy Projects

SAINT FRANCIS UNIVERSITY FOUNDED 1847 — INSTITUTE FOR ENERGY




**at Pennsylvania Institutions, Incubators, Economic Development Centers, and Organizations**

## Stakeholders Surveyed:



**30** Institutions of Higher Ed.

**7** Innovation and Economic Development Centers

**9** Other Organizations

& **61** Total Individual Survey Participants

### Most Typical Clean Energy Strategies Deployed:

- Energy Efficiency Upgrades
- Solar Projects
- Purchase of RECs or PPAs with Renewable Generators

The most researched renewable technology is **solar**.

The most invested-in clean energy companies are: **biofuels/biomass**, **energy efficiency**, and **smart grids**.

**Biggest obstacles for deploying new clean energy technologies:** Up front capital investment costs, slow return on investments, low and declining electricity costs, building ownership, and permitting.

**Biggest motivations for deploying new clean energy technologies:** Educational/teaching tool, organizational sustainability goals, and cost savings.

## NEXT BIG CLEAN ENERGY GAME CHANGER/BREAKTHROUGH:

1. Energy storage technology
2. Reductions in solar PV costs
3. Use of electric vehicles
4. Smart grids
5. Federal/State renewable incentives & policies
6. Building automation, sensors, & efficiency tech.
7. More wind farm construction
8. Use of existing dams for hydro-electric power
9. Fuel cell technology

# EXECUTIVE SUMMARY

The Commonwealth of Pennsylvania has been, and continues to be, home to an abundant array of energy resources. The state has traditionally been known for its fossil resources. Today, renewable energy technologies are emerging as viable alternatives for Pennsylvanians. To better understand the changing energy landscape, the Saint Francis University Institute for Energy conducted a survey of Pennsylvania organizations (and/or individuals working in sustainable energy fields) to understand the status of sustainable energy in the state and identify potential 'game-changing' technologies. Over 60 stakeholders from institutions of higher education, business development centers, and other organizations were interviewed from November 2017 to Jan 2018 and were asked a series of questions to provide a snapshot of the current market and provide a hint of what may occur in the future.

Respondents cited energy storage technology as having the most potential to become a "game-changer" in the clean energy industry. Solar photovoltaics (PV) and the use of electric vehicles were the second and third most likely breakthroughs mentioned, respectively. The development of storage technologies, such as lithium ion batteries, offers the opportunity for advanced deployment of intermittent sources of power, such as wind and solar). Energy storage also enables advances in the development of alternative vehicles.

These clean energy technologies and many others are being researched by institutions around the state to find new, cheaper and more efficient technologies. The survey indicated that solar energy research was the most common clean energy topic being studied, followed by energy storage and energy efficiency.

While sustainable energy has seen significant growth over the past 15 years and is growing rapidly, respondents noted a number of potential barriers to additional deployment in the state, including up front capital investment costs, slow return on investments, and low and declining electricity costs. Besides financial considerations, building ownership and permitting were cited as some of the biggest obstacles to deploying projects.

The following report compiles data from sampled Pennsylvania institutions of higher education, incubators, innovation centers, economic development centers and other stakeholders to examine what renewable energy and energy efficiency technologies are currently being deployed and researched to better understand the obstacles and opportunities for future development.

# OBJECTIVES

**The primary objectives of this report were to:**

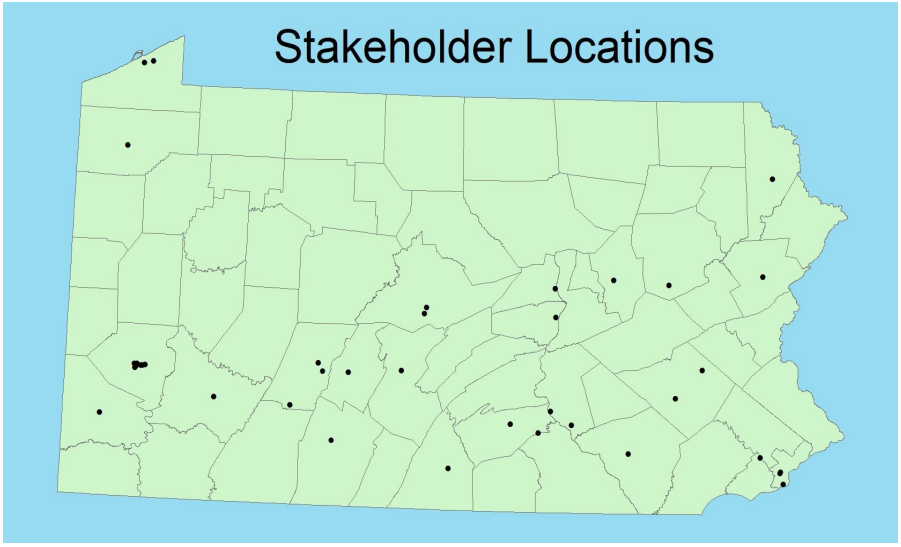
1.) Discover and demonstrate stakeholders' biggest needs and obstacles pertaining to development of clean or renewable energy projects
2.) Identify the most up-to-date and relevant renewable energy projects currently being deployed in the state
3.) Identify sustainable energy technologies that may be "game-changing" in the next 5 years

# METHODOLOGY

The Saint Francis University Institute for Energy (Institute) worked with the MetEd/Penelec Sustainable Energy Fund (SEF) to develop a list of survey questions to administer to the stakeholders (see Appendix B). Specific stakeholders included Pennsylvania institutions of higher education, economic development centers, innovation centers, incubators, and others performing work in the renewable and clean energy sectors. Approximately 146 individual stakeholders were contacted, of which 61 provided feedback between mid-November 2017 and mid-January 2018. Phone interviews were the primary method of obtaining data, followed by email correspondence, online surveys, and in-person interviews. Supplementary data was also obtained through the web.

Participating stakeholders represent voices from across the Commonwealth. They were classified into three different groups:

| Colleges/Universities | Innovation Centers and Economic Development Centers | Other |
|---|---|---|
| 30 organizations | 7 organizations | 9 organizations |
| 45 individual respondents | 7 individual respondents | 9 individual respondents |




Multiple interviews were conducted for some organizations. For example, the Institute contacted the physical operational plants of many of the organizations to best understand the renewable energy projects that were currently deployed and under development on campus, and the Institute also spoke to faculty about research projects and up and coming renewable energy technologies. Although attempts were made to provide a complete picture of activities occurring at each organization, many of them have hundreds or thousands of employees, so this report should be viewed as a snapshot of activities occurring at the given organizations and not necessarily representative of *all* activities/projects. In addition, the information in this report came from individuals and may or may not be representative of the views held by the organizations for which these individuals work.

# SURVEYED ORGANIZATIONS

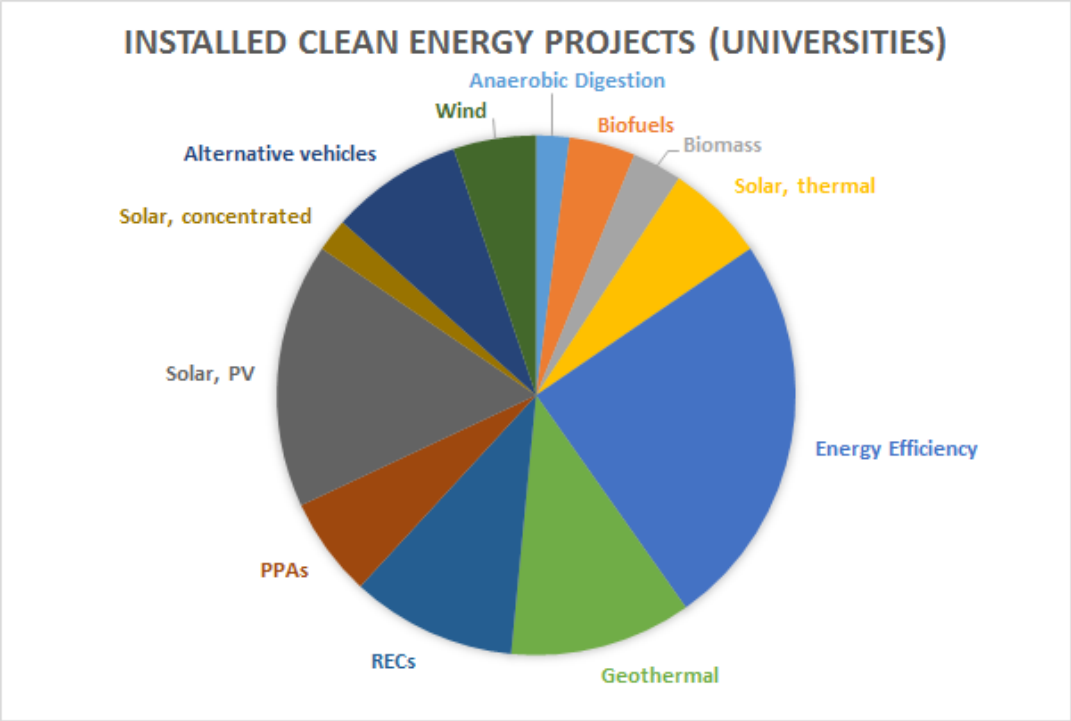
| Colleges and Universities | University Energy Research Centers |
|---|---|
| Allegheny College | A.J. Drexel Institute for Energy and the Environment |
| Bloomsburg University | A.J. Drexel Nanomaterials Institute |
| Bucknell University | Carnegie Mellon, Wilton E. Scott Institute for Energy Innovation |
| Carnegie Mellon University | Penn State, Battery & Energy Storage Technology Center |
| Chatham University | Saint Francis University, Institute for Energy |
| Community College of Allegheny County | University of Pittsburgh, Energy Center |
| Dickinson College | |
| Drexel University | **Economic Development Centers** |
| Duquesne University | Bedford County Development Association |
| Franklin & Marshall College | Huntingdon County Business and Industry, Inc. |
| Mercyhurst University | Saint Francis University Small Business Development Center |
| Messiah College | Southern Alleghenies Planning & Development Commission |
| Mount Aloysius College | |
| Northampton Community College | **Innovation Centers** |
| Pennsylvania Environmental Resource Consortium | Ben Franklin Technology Partner, Central and Northern PA |
| Pennsylvania State University, Berks | Innovation Works, Ben Franklin Institute |
| Pennsylvania State University, Erie | University of Pittsburgh, Innovation Institute |
| Pennsylvania State University, Harrisburg | |
| Pennsylvania State University, Hazelton | **Other** |
| Pennsylvania State University, Navy Yard | Clean Energy Co-op |
| Pennsylvania State University, University Park | FirstEnergy |
| Saint Francis University | Green Building Alliance |
| Saint Vincent College | Hot Earth Collaborative |
| Susquehanna University | Mid-Atlantic Renewable Energy Association |
| University of Pennsylvania | The Nature Conservancy |
| University of Pittsburgh | Pennsylvania Environmental Council |
| University of Pittsburgh, Johnstown | Penn State Extension |
| Villanova University | Sustainable Energy Education and Development Support |
| Washington & Jefferson College | |
| Wilson College | |

# COLLEGES AND UNIVERSITIES

## Summary of Colleges and Universities

Representatives from a total of 30 colleges and universities provided feedback for this report. When applicable, corresponding university energy research organizations were contacted to obtain information about current renewable energy research on campus. Individual faculty members were contacted to discuss research as well. University operations/physical plant representatives were contacted to better quantify the renewable projects that were already in operation at the university. Campus sustainability coordinators often provided information, too. The answers provided represent the views of the individuals who responded, and may not necessarily reflect the whole university community.

**Summary of university/college installed clean energy technologies:**
The most common clean energy technology deployed across PA college and university campuses was in the form of energy efficiency upgrades. The second most deployed technology was solar photovoltaics followed by the purchase of renewable energy credits or power purchase agreements with renewable energy generators to supply campus power. Geothermal and alternative vehicle charging stations were also popular at higher education institutions. There were no hydro projects on campuses, however there were organizations purchasing power through a PPA with hydro electric generation companies.




Nearly every university and college in the state reported performing energy efficiency upgrades. Projects typically fell into two categories: upgrades to infrastructure or attempts to change energy use behavior. Energy efficiency projects were typically noted as having the quickest

return on investment (ROI) of all the clean energy projects institutions of higher education explored.

A total of approximately five megawatts (MW) of solar PV had been installed within this stakeholder group. Solar PV systems surveyed ranged in size from 1 kilowatt to 3 megawatts. Smaller systems were typically owned by the institutions, but these organizations often signed a power purchase agreement for larger systems. In those situations, the institution purchased the power from the solar farm and did not own the panels. Power purchase agreements have become more popular amongst universities and other non-profits because the for-profit installers are eligible for federal tax incentives (that nonprofits are not) and are able to pass those savings down to the consumer.

Many colleges noted purchasing Renewable Energy Credits (RECs), specifically, Green-e certified renewable energy credits. Others noted power purchase agreements with solar farms, wind farms, and in-state hydro dams.

Geothermal systems were popular as well, with eleven universities citing using this technology in one or more systems across campus.

Alternative vehicle charging stations were prevalent amongst colleges and universities. One university was using their electric car charging stations to leverage more renewable projects with an internal policy that requires additional demand for electricity created by the use of the charging stations come from on-site renewable power.

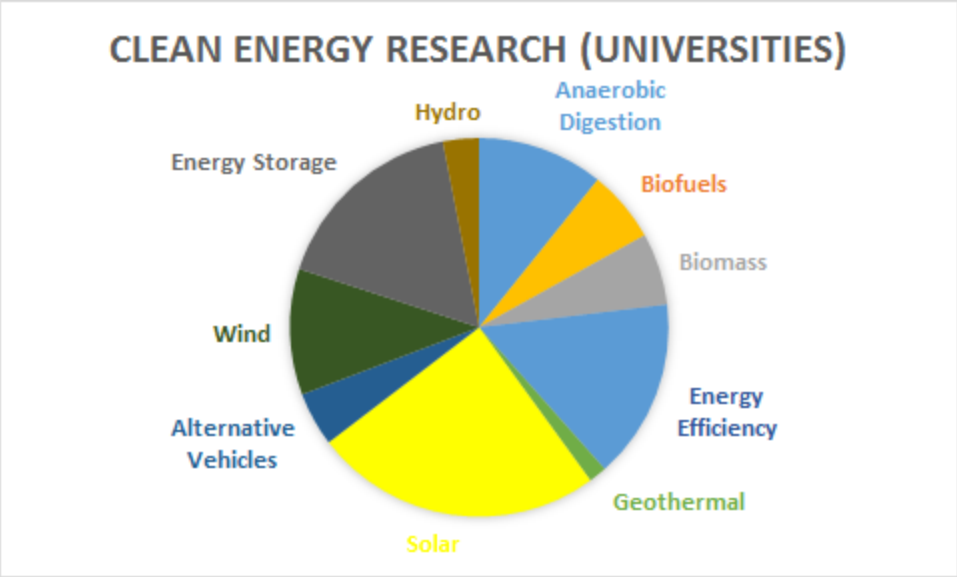
Some universities used biofuels in their fleet vehicles and other applications, like hydraulic fluids in elevators. Three universities were using biomass for heating applications. Anaerobic digestion was typically only used for demonstration, but did contribute to a handful of organization's overall energy mixes.

The most typical solar thermal application was for solar hot water heating used in dorms and other campus buildings. Solar hot water systems were noted by multiple universities; however, some stated that they experienced a lengthy return on investment. Several concentrated solar applications have also been installed in the state.

Many universities cited power purchase agreements with wind farms as a method of reaching their sustainability goals. A few small wind turbines have been deployed at PA institutions of higher education, although small-scale wind power was often noted to have mechanical issues and problems requiring qualified maintenance workers to fix broken turbines.

**Summary of University Research**

The most researched renewable energy technology in the state was in the field of solar power, followed by energy storage and energy efficiency.




In the field of solar, researchers reported studying new materials and finding ways to increase efficiencies. Some projects focused on deploying solar in locations that have lost grid power from a natural disaster or another reason.

The second biggest clean energy research focus was in the field of battery storage. Battery storage was also noted as the biggest potential "game-changer" amongst all stakeholders interviewed for this report. Pennsylvania laboratories have been conducting research on nearly every aspect of the battery storage sector, ranging from the manufacturing process, to the materials used, to the end application and to the pairing of renewable technologies.

Energy efficiency was the third most researched clean energy topic at universities. Examples of research in this field included how to effectively use renewable and non-renewable energy resources for sustainable global development and creating new sensing systems for construction companies to develop more sustainable, efficient, and economical buildings. The majority of energy efficiency research being conducted at universities was in the field of building sensing and automation as well as behavior studies of energy use and conservation.

**Summary of Motivations**

The number one motivation for implementing a clean or renewable energy technology on campus, according to the stakeholders the Institute interviewed, was the use of the technology as an educational tool. Almost all the universities with on-site solar or wind projects incorporated data collection from that system into coursework or student research projects. The second biggest motivation for installing clean energy projects was to reach campus sustainability goals. Some schools have documented clear sustainability goals, such as committing to a zero carbon footprint. Many universities and colleges also have "climate action plans." Such plans set energy conservation goals that are spurring the use of renewable energy through onsite renewable projects or the purchase of RECs as well as through energy

conservation efforts. Lastly, the third biggest motivator for universities was overall cost savings, typically seen with the implementation of energy efficiency projects.

**Summary of Major Obstacles**
Access to the upfront capital funding and lengthy return on investments of renewable projects was the number one barrier for institutions interested in installing clean and renewable energy projects. Many universities cited cheap and declining electricity prices as primary barriers as well. Typical installed costs of solar may be 10-15 cents/kWh, which can be more than double the current electric rate at some institutions. With ROIs of 20-30 years, many universities are not willing to invest in onsite technology. Energy efficiency upgrades, however, typically have much shorter returns, which is why so many institutions are implementing these first.

Recent federal Department of Energy funding freezes were also noted by many researchers in the field of renewable energy as a major current obstacle. Space constraints, permitting, access to operations and maintenance support and institutional pushback were also cited as being major obstacles in deploying new projects.

**Summary of "Game-Changers"**
The number one game-changing technology in the field of clean energy cited by members of academia was the anticipated breakthroughs in the field of energy storage. Energy storage plays a significant role in the success of renewable energy because it allows intermittent renewables to become more reliable and dispatchable.

Stakeholders also cited the continuously declining costs of solar technology as the second biggest breakthrough expected in the next five years. They cited the use of electric vehicles as well as smart grid technologies as likely game-changers as well.

Other commonly cited game-changers among universities included energy efficiency technologies like automation and integration of buildings, vehicles, and other sensors interacting; new federal and state renewable energy incentives and policies; more wind installations; use of existing PA hydro dams for hydroelectric; and fuel cell technology.

# INNOVATION AND ECONOMIC DEVELOPMENT CENTERS

## Summary of Innovation and Economic Development Centers

Of the 28 business development organizations and innovation centers contacted for this study, seven provided information incorporated into this report.

The percentage of business related organizations responding to the survey was significantly lower than that of the higher education and other categories. In general, it appears that when sustainable energy projects/opportunities present themselves, these business-oriented organizations will act on them, but it is not a primary focus of their work. Some organizations offered energy development/improvement assistance at one time, but no longer do, due to

funding limitations. Others organizations noted that they did not find a great demand for energy related services.

None of the economic development centers or innovation centers were currently using any clean energy technologies on-site. They cited cost savings as the number one motivation for those they worked with to install a clean energy project. They cited building ownership as the biggest obstacle for installing a project at their organization, as many of these organizations lease their commercial space.

Two of the organizations that participated in the survey were involved with investments in new clean energy startup companies. The most invested in technologies were biofuels/biomass, followed by energy efficiency and smart grids.

# OTHER ORGANIZATIONS

## Summary of "Other" Organizations

During the course of this research, 15 additional organizations that were not directly related to higher education or economic development were contacted for this study, with nine providing information incorporated into this report.

Some of the organizations in this category featured sustainable building practices and/or renewable energy deployment at their operations.

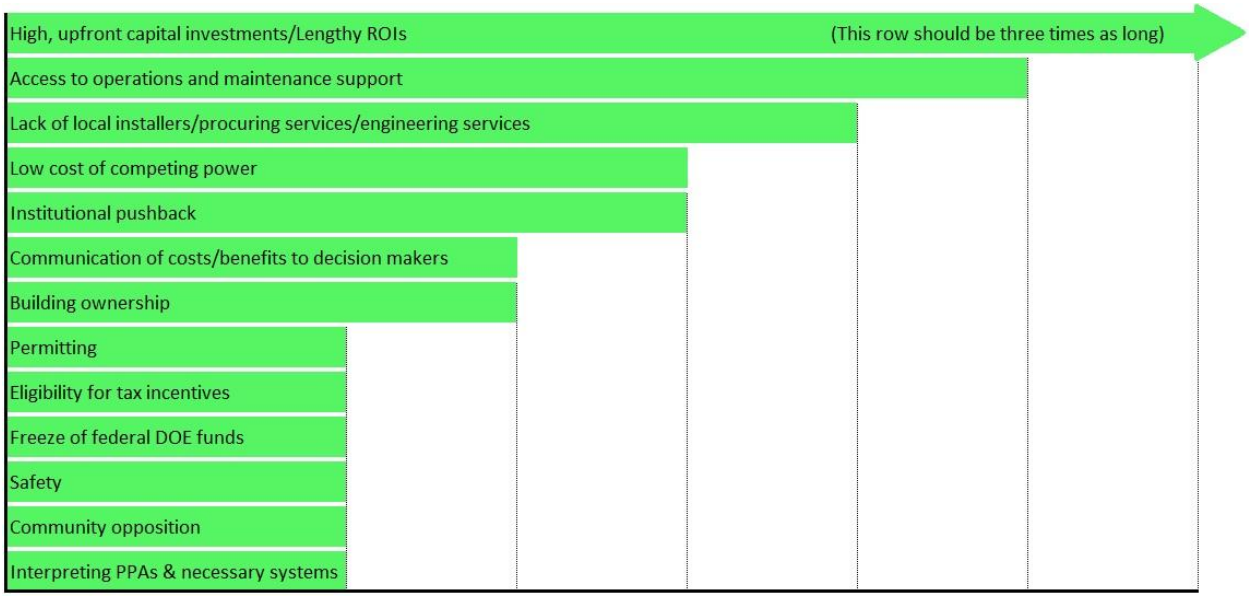
Cost savings, environmental benefits, sustainability goals, and regulatory compliance were all cited as motivations for installing new projects.

These stakeholders cited building ownership, access to capital for new projects, long returns on investments, ineligibility for tax incentives (non-profits), permitting, issues with supply chain, and zoning/municipal laws as major obstacles when developing a new renewable project.

# CONCLUSION

## Common Clean Energy Barriers

The number one barrier for developing new clean energy projects, across all types of stakeholders surveyed, came down to economics. Access to capital coupled with lengthy return on investments were the top reasons projects did not go into development. Many interviewees cited low competing electricity prices as primary factors for lengthy ROIs. Organizations commonly cited building ownership as a major reason, too.




**Addressing the Obstacles**

This report was intended to identify barriers to developing new clean energy projects in the Commonwealth as well as identify new funding opportunities and mechanisms to address the acknowledged obstacles. Below we have addressed some of the barriers and obstacles of developing renewable and energy efficiency projects in Pennsylvania.

*Access to Capital*

With access to upfront capital cited as a major obstacle for the majority of stakeholders, determining new methods for access is essential to the development of new clean energy projects in the Commonwealth.

The work completed at the Clean Energy Co-op in Honesdale is a success story in the field of renewable financing. This northeast Pennsylvania community investment organization installed solar panels on a community building using funds raised by co-op investors. The organization then sells the power from the solar panels to nonprofits at a better rate than the non-profits could construct the project themselves, due to tax incentives. The Co-op also has recently experimented with another funding structure—acting like a green bank to provide low interest funding for a renewable energy project. The organization offered a low interest loan to a farm to

purchase and install solar panels. The long-term loan payments are *less than* the farm's annual cost for electricity, making the construction of the solar system an easy economic decision.

Another funding mechanism, the use of "revolving funds" was mentioned by a handful of stakeholders. "Revolving funds" are where returns on investments in green technology are reinvested in more renewable projects.

The Pennsylvania Nature Conservancy has been researching these "green" financing tools and Energy Investment Partnerships (EIPs). Their "Pennsylvania Energy Investment Partnership Report" from July 2017 highlighted the need for more green financing opportunities in the Commonwealth.

*Access to Operations and Maintenance Support and Local Suppliers/Installers*
There is a clear and demonstrated need for more technical support in the field of renewables. Penn State has begun offering new training programs dealing with high voltage energy storage systems and microgrids, but trained small wind, geothermal, solar (panel and power system) technicians appear to be lacking. The Institute discovered multiple instances where such programs existed, but were no longer offered or are currently offered but at limited capacity. Government statistics have cited solar and wind technicians as the fastest growing careers in the next 10 years, yet there seems to be minimal student interest in these opportunities.[1] There needs to be future work in education sparking more passion for renewable energy topics at a younger age and more discussions about possible careers in the clean energy fields at all levels of education, if the industry is to grow.

*Low and Declining Cost of Electricity*
The low cost of competing electricity was cited often by stakeholders. Even with power purchase agreements, many organizations and nonprofits have been reluctant to make any increases to operational costs. Instead of funding complete renewable systems, one option would be for another party to provide "gap" funding for renewable projects. For example, if a university was paying 5 cents/kWh, but a private solar installer was willing to install a solar system on campus and sell the power back to the university for 13 cents/kWh, another organization would could provide the 8 cents/kWh cost gap. This idea was cited by three different interviewees. Expanding such a project in a way that surrounding community members had an opportunity to buy into the project may further decrease overall costs as well.

*Building Ownership*
Many businesses and organizations cited building ownership as a major barrier for on-site renewable energy deployment or energy efficiency upgrades. Because electricity costs are often passed to the renter, there is very little incentive for the building owner to make upgrades or install a renewable system. One option is to explore more business platforms like "Solar Power Rocks," a company that rents roof space, puts solar on it, and pays dividends to the building owner. Exploring more solutions like this would provide valuable opportunities and

[1] "Fastest Growing Occupations," U.S. Bureau of Labor Statistics, April 13, 2018, https://www.bls.gov/ooh/fastest-growing.htm.

guidance for the millions of renters who want to go solar. Encouraging community energy projects, such as the Keystone Solar Farm, could also be a way for organizations who may not have space available to join in on a project, even if power is not generated on-site.

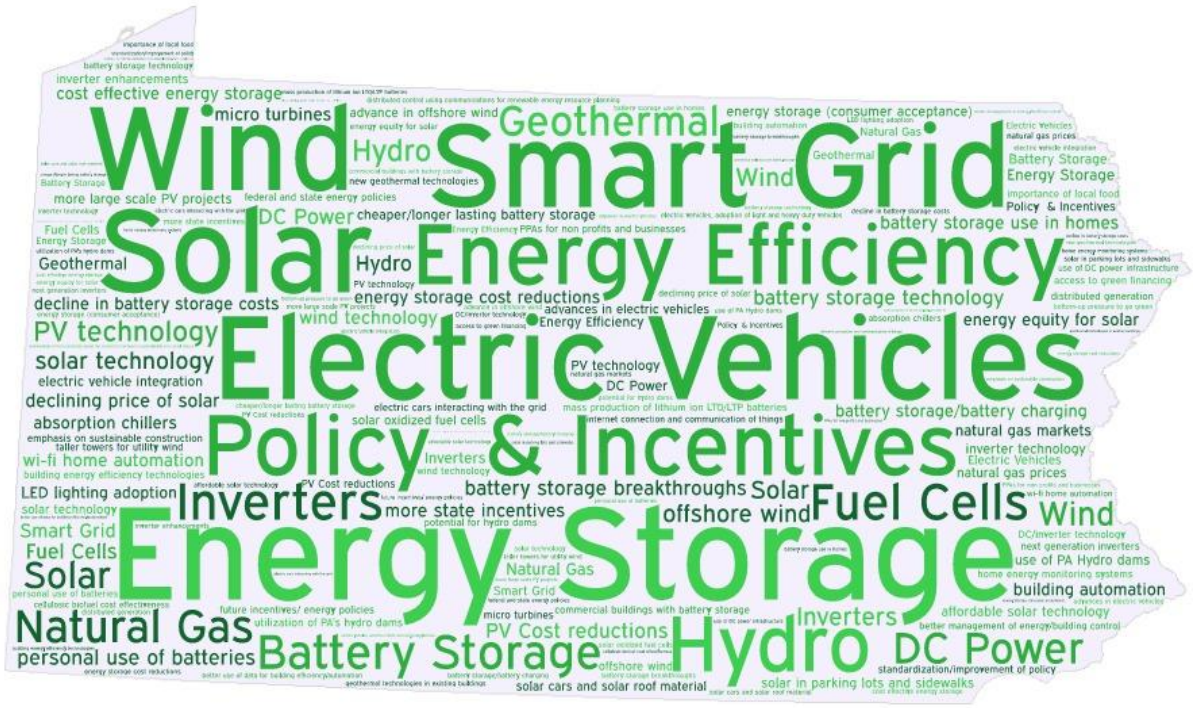
*Communication of Costs/Benefits*

There are issues communicating the costs and benefits of a renewable energy or energy efficiency upgrade project, as cited by the survey participants. For energy efficiency projects, many people were wary to perform upgrades because typical audits are completed by for-profit contractors looking to get the upgrade work. Penn State has been working to address this issue by developing an "energy auditor" like program for students. A similar endeavor has been undertaken by Sustainable Energy Education and Development Support (SEEDS) Group where they have trained students to perform energy audits for free. Saint Francis University Institute for Energy has provided low cost energy assessments without pressure to perform upgrades too. Respondents also noted that compiling renewable energy development information into one online, easy to use location could be a valuable investment likely to spur more renewable development across the state.

*Loss of Federal Research Funds*

Many individuals cited the loss or freeze of federal research funds as a barrier. To continue growth in the renewable sector, research is essential. Offering funds to researchers over the next few years may be a critical funding opportunity, especially in the fields of battery storage and solar technology.

## Identified Clean Energy Game-Changers




As renewable energy projects continue to emerge, energy storage was identified as the biggest potential breakthrough technology. The graphic above depicts the various game-changing responses that were stated by the survey participants, in a “word art” form. In general, larger words or phrases indicate that a given game-changer was noted by a number of respondents, while smaller words and phrases may be less commonly mentioned. Some words and phrases may appear more than once. See Appendix D for a listing of all terms cited.

At the time of the founding of the Sustainable Energy Funds, in 2000, the development of renewable energy projects in the state was in its infancy. There was no AEPS, Act 129, or utility scale wind or solar farms. Since that time, great strides have been made in bringing clean energy systems to the state. Sustainability topics have gone from being niche to a common part of many businesses and organization's goals. Only 4.5% of PA's net electrical generation currently comes from renewable energy.[2] Breakthroughs in energy storage technologies, consistent declining costs of solar PV, electrification of vehicles, and many other prospects identified in this report will offer more opportunities to bring additional renewables to the grid.

[2] “Pennsylvania Profile Overview,” U.S. Energy Information Administration, July 25, 2018, https://www.eia.gov/state/?sid=PA.

# APPENDIX A

## Definitions/Classification of Clean Energy Technologies for this survey:

**Alternative Vehicles** are those that utilize a fuel source other than traditional gasoline, such as plug-in electric vehicles, hydrogen fuel cells, biodiesel, and others. Organizations were classified as having these in operation if they used these types of vehicles, were researching this type of technology, or if they had alternative vehicle charging stations.

**Anaerobic Digestion** is the use of microorganisms to break down organic material, typically yielding a biogas. Such gas can either be combusted to generate electricity and heat, or it can be processed to be used as a transportation fuel.

**Biofuels** are fuels that originate from organic material or the process of anaerobic digestion that can be used for electricity generation, heat, or transportation purposes.

**Biomass** is an organic material from plants or animals that can be burned for heat or to generate electricity. Wood, compost, and animal waste are typical biomass feedstocks.

**Energy Efficiency**, for this report, encompasses a very broad definition, and includes any upgrades to existing infrastructure or construction of new infrastructure that reduces the overall typical energy consumption of the building.

**Energy Storage** allows energy to be stored for later. Battery technology to store electromechanical energy is a common example. It is extremely relevant to the renewable energy field because it provides a way for intermittent renewable technologies to be dispatchable.

**Game-Changing Technology:** A clean energy technology or strategy currently in its infancy but with great potential to have significant effects on the future field of renewable energy.

**Geothermal** technology uses the consistent, moderate temperature of the earth to provide more efficient heating and cooling through the use of ground source heat pumps, and in some locations, generate electricity (although the latter technology is not used in Pennsylvania).

**Hydro Power** converts the kinetic energy of moving water (streams) to electrical power. It is used in both large and small (micro-hydro) applications.

**Alternative Energy Credits (AECs)**, also called Renewable Energy Credits (RECs), are non-tangible credits produced from a renewable generator. They are not a physical purchase of power. In Pennsylvania, each alternative energy credit represents 1 MWhr of electricity produced by an alternative energy source.

**Power Purchase Agreement (PPA)** is an agreement between an energy generation facility and large offtaker to purchase a specified amount of power. Many organizations surveyed sign PPAs with renewable generators.

**Solar, Concentrated** uses mirrors or lenses to concentrate the heat from the sun. The heat can be used to make steam and generate electricity, or it can be used to heat water.

**Solar, Hot Water** technology collects the solar thermal energy to heat water.

**Solar, Photovoltaic (PV)** technology produces an electrical current when sunlight strikes the PV cells. This is the technology utilized in typical solar panels.

**Wind** energy technology uses a rotor with large blades to harness the kinetic energy in the wind and convert it to electrical power.

**Other** projects noted in this study included the use of microgrids, DC energy systems, and efficient natural gas technologies that replaced coal technologies.

# APPENDIX B

## Survey Questions

The following questions were used as a guide throughout each phone interview. They were also the questions asked in each online survey. Questions were adapted slightly depending upon the audience.

Institution:
Name of Interviewee:
Position at Institution:
Date:

1. Do you have a clean or renewable energy project currently in operation at your institution? Check all that apply.

- Alternative Vehicles
- Anaerobic digestion
- Biofuels for transportation
- Biomass
    - Heating
    - Electricity
- Energy efficiency upgrades
- Energy storage
- Geothermal heating/cooling
- Micro-hydro
- Purchases alternative energy credits
- Solar
    - PV
    - Hot water
    - Concentrated solar
    - Passive solar
    - Utility scale (greater than 1MW)
- Wind
    - Small wind (less than 1 MW)
    - Utility scale (greater than or = to 1 MW)
    - For water pumping
- Other: _____

2. Do you have a clean or renewable energy project currently in development at your institution? Check all that apply

- (Same choices as question 1)

3. Are you researching any renewable energy technologies at your institution? Check all that apply

- (Same choices as question 1)

4. Do you currently have a technologically feasible clean or renewable energy project that is not going into development because of lack of financial resources? If yes, explain.

5. What is your motivation for installing a clean or renewable energy project? Rank top 3
- Educational/teaching tool
- Organization's sustainability goals
- AEPS goals
- Publicity
- Save money
- Environmental benefits
- Other:_____

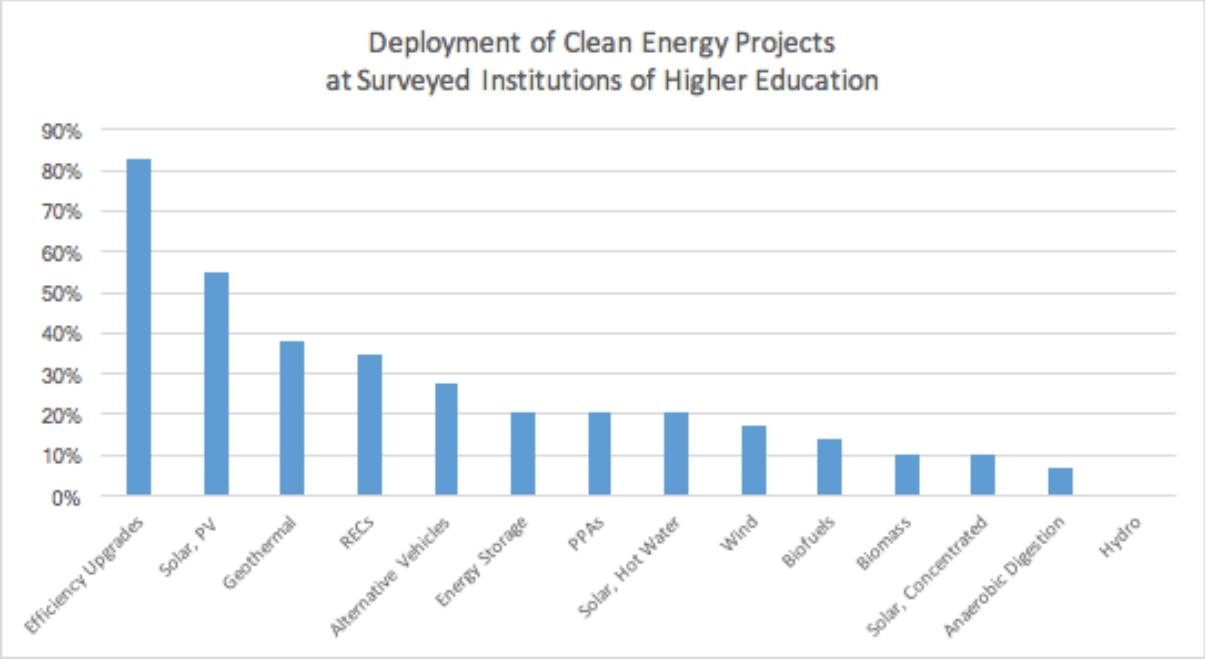
4. If you currently have a clean or renewable energy project at your institution, what was the biggest obstacle you overcame to deploy it? Chose top three barriers:
- Capital investment
- Access to operations and maintenance support
- Community opposition
- Institutional pushback
- Environmental issues
- Safety concerns
- Other:_____

5. Is your organization assisting any other organizations or community members in the development or clean and/or renewable projects? If yes, in what capacity?

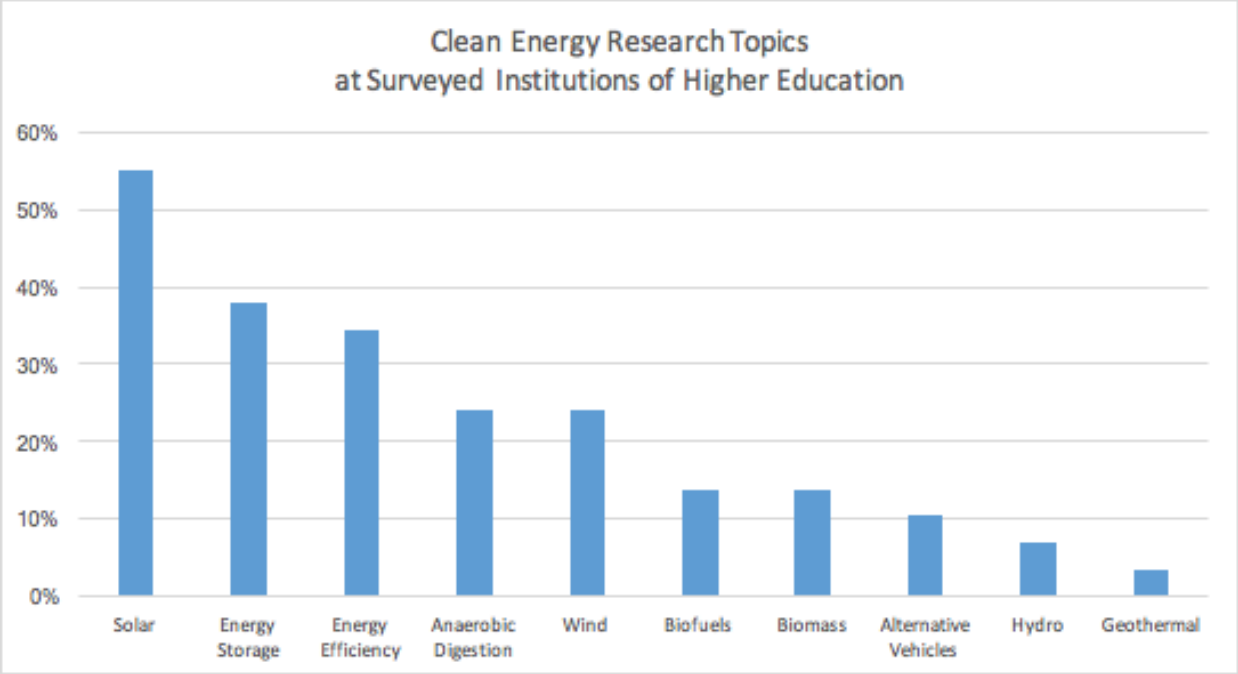
6. What is the most important technical advance/breakthrough/game-changer that could happen in the next five years in sustainable/renewable energy field?

# APPENDIX C

## Additional Data




The above chart contains a list of clean energy sources deployed at the institutions of higher education surveyed for this report. For each energy source, a bar depicts the percentage of the surveyed universities deploying said source. The most commonly deployed technologies are shown towards the left, while the least deployed technologies are show towards the right. For instance, the most commonly deployed technology was energy efficiency upgrades, which was calculated to be utilized at slightly more than 80% of institutions. The second most commonly deployed technology was solar photovoltaics at around 55%. No institutions were directly using a hydro resource (although some organizations had hydro-power PPAs).




The above chart contains a list of clean energy sources being researched at the institutions of higher education surveyed for this report. For each energy source, the percentage of universities researching said source has been calculated. The most commonly researched technologies are shown to the left, while the least deployed technologies are show to the right. For instance, the most commonly researched technology was solar, which was calculated to be researched at around half of the surveyed institutions. The second most commonly researched technology was energy storage. Research into alternative vehicles, hydro and geothermal was not as common.

# Appendix D

## Game-changers

Below is a complete list of the "game-changing" technologies cited by our interviewees (some terms were cited by multiple respondents, but each term only appears once on this list):

| **Energy Storage** |
|---|
| Battery storage |
| Battery storage technology |
| Battery storage breakthroughs |
| Battery storage/Battery charging |
| Cheaper/longer lasting battery storage |
| Cost effective energy storage |
| Decline in battery storage costs |
| Energy storage cost reductions |
| Energy storage (consumer acceptance) |
| mass production of lithium ion LTO/LTP batteries |
| Personal use of batteries, homes, buildings w/ battery backup |
| **Solar** |
| Dramatic reduction in cost of solar panel installation and/or solar in parking lots and sidewalks |
| Solar technology |
| More large scale PV projects |
| Affordable solar technology |
| Declining price of solar |
| PV technology |
| PV cost reductions |
| Solar cars and solar roof material |
| energy equity for solar |
| More PV PPAs for non profits and businesses |
| **Electric Vehicles** |
| Electric vehicle integration |
| Electric vehicles, adoption of light and heavy duty vehicles |
| Advances in electric vehicles |
| electric cars interacting with the grid |
| **Smart Grid** |
| Distributed control using communications for renewable energy resource planning |
| Home energy monitoring systems |
| Wi-Fi home automation |
| Better management of energy/building control |
| Better use of data for building efficiency/automation |
| Internet connection and communication of things |
| **Policy & Incentives** |

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| Federal and state energy policies |
| Future incentives/ energy policies |
| More state incentives |
| Standardization/improvement of policy |
| **Energy Efficiency** |
| Building energy efficiency technologies |
| Emphasis on sustainable construction, with energy a big factor |
| LED lighting adoption |
| **Wind** |
| Offshore wind |
| Taller towers for utility wind |
| Advance in offshore wind |
| Wind technology |
| **Hydro** |
| Utilization of PA's hydro dams |
| Use of PA Hydro dams |
| Potential for hydro dams |
| **Fuel Cells** |
| Solar oxidized fuel cells |
| **Natural Gas** |
| Changes in the natural gas markets |
| Natural Gas prices |
| **Inverters** |
| Inverter enhancements |
| Inverter technology |
| Next generation inverters |
| **Geothermal** |
| Improvements to geothermal technologies in existing buildings |
| New geothermal technologies |
| **DC Power** |
| Use of DC power infrastructure |
| DC/inverter technology |
| **Cellulosic biofuel cost effectiveness** |
| **Micro turbines** |
| **Access to green financing** |
| **Bottom-up pressure to go green** |
| **Importance of local food** |
| **Distributed Generation** |
| **Absorption Chillers** |
| **Communication from scientists about the connection between sustainability and social issues** |

# Image Credits

**On the Cover**:
Row 1:

- *Penn State University,* University Park: A solar bus shelter, gift from the Class of 2015, credit Allison Rohrs.
- *Clean Energy Co-op*: In 2015 the organization installed a 28 kW solar electric system on the roof of the Cooperage, a non-profit community center in downtown Honesdale that is home to the non-profit organization, SEEDS. The building also features a high-efficiency pellet boiler, credit Clean Energy Co-op.
- *Northampton Community College*, Monroe Campus: including a wind turbine and solar panels that produce 40% of the campus energy needs. Under the parking lot are 161 geothermal wells, 450 feet deep, that provide 100% of the campus heating and cooling needs, credit NCC staff.

Row 2:

- *Carnegie Mellon University*: A Solar Decathlon House researcher uses a computer to control the system, which includes energy storage. It is part of the DOE-funded SHINES solar project, credit Carnegie Mellon University.
- *Wilson College:* Electric vehicle charging station. credit Wilson College
- *Franklin & Marshall College*: Students using bikes to generate energy to make smoothies and play a radio, credit Franklin & Marshall College.

Row 3:

- *Penn State University*, University Park, Whisper 500 wind turbine used for research, credit Penn State University.
- *Dickinson College*, solar installation, credit Dickinson College.
- Blower door used for assessing building air tightness, credit Michael Sell.

Row 4:

- *Saint Vincent College,* The Dupré Science Pavilion is a LEED certified facility featuring a 22.2 kilowatt solar array and geothermal heating and cooling, credit Saint Vincent College.
- *Carnegie Mellon University*, A Carnegie Mellon University student assembles a research polymer electrolyte fuel cell in Carnegie Mellon Professor Shawn Litster's Laboratory for Transport Phenomena in Energy Systems. The device is used to evaluate new catalyst materials and electrode designs, credit Carnegie Mellon University.
- *Bloomsburg University* - Solar Kiosk comprising automatic and manual two-axis solar trackers, power and energy displays, and an interactive touchscreen, credit Nathaniel Greene.

**In the Report:**
Patton Wind Farm, credit Michael Sell
Carlisle Area School District solar farm, credit Michael Sell