

U.S.-PAKISTAN CENTERS FOR ADVANCED STUDIES IN ENERGY

ENERGIZER

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PROFESSOR CLARK MILLER URGES STUDENTS TO CONSIDER THE SOCIAL VALUE OF ENERGY AND CREATE SYSTEMS OPTIMIZED FOR COMMUNITY GAIN.

Noor Muhammad, a former exchange student from UET Peshawar, is working on a joint research project with Clark Miller to study social value creation using small hydropower projects in Khyber Pakhtunkhwa.

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EMPOWERING OFF-GRID COMMUNITIES

USPCASE applied research projects are focused on finding indigenous energy solutions for communities throughout Pakistan.

Pakistan has plenty of hydro-power resources: more than 300 potential sites could be used to electrify remote villages in the northern part of the country. There's plenty of sunshine, too. As many as 40,000 remote villages could use solar power for electricity generation, according to expert estimates.

Likewise, the nation has plenty of trees and agricultural by-products to fuel biomass generation. It's the fifth largest sugarcane producer worldwide, and sugarcane has the highest energy-to-volume ratio among energy crops, says the International Sugar Organization.

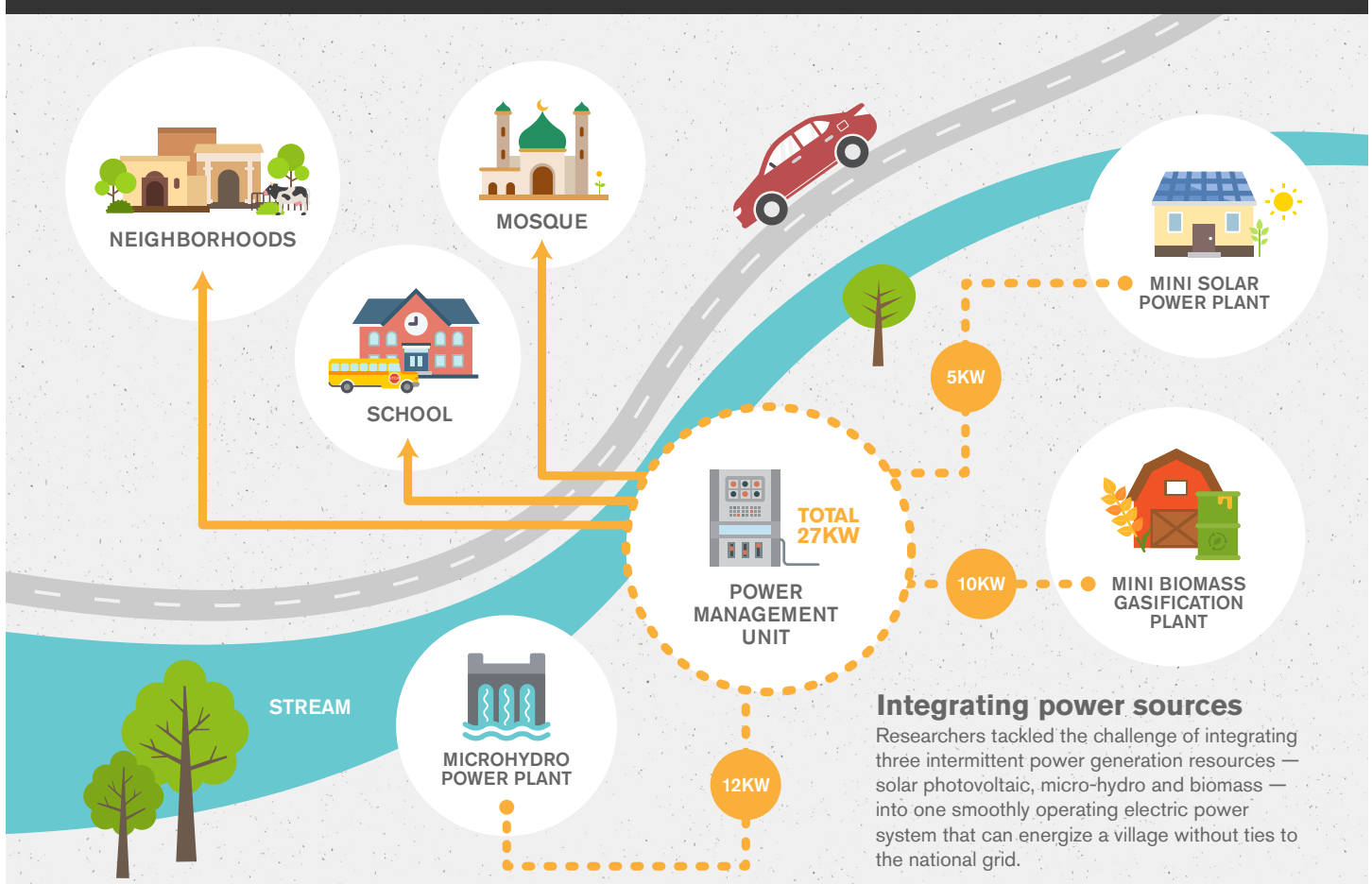
After extracting sugar from the plant's stalk, what's left is bagasse, a ton of which has an energy content similar to one barrel of crude oil.

"More than 16 million tons of bagasse is available annually in Pakistan, and there is a potential to produce up to 1000 MW of electricity from bagasse industry," wrote researchers Muhammad Shoaib Khalid and Abdul Basit in a report to the U.S. Agency for International Development.

Here's the problem with all that potential: Two of the three resources – solar and micro-hydro – have intermittency built in because the sun doesn't always shine, and water doesn't always flow consistently. That's why Khalid and Basit – both professors at The University of Engineering and Technology, Peshawar (UET-P), are primary investigators on an applied research project being conducted by the U.S.-Pakistan Centers for Advanced Studies in Energy (USPCASE).

Illustration by Qiudi Zhang

MICROHYBRID JOINT RESEARCH PROJECT





Microhydro generator (left) and solar installation (right) at remote location (Sakhakot) in Northern Pakistan.

Working with collaborators at Arizona State University and Oregon State University, the researchers installed and tested a microgrid with multiple generation resources in a remote northern Pakistani village. Called the “Hybrid Energy Testbed for Remote Communities,” the project integrates generation from three renewable resources: solar photovoltaic, micro-hydro and biomass. Researchers from Arizona State University and Oregon State University joined Khalid and Basit in tackling the challenge of integrating three intermittent generation resources into one smoothly operating electric power system that can energize a village without ties to the national grid.

TAKING IT TO THE STREETS

According to a 2018 renewables readiness assessment report from the International Renewable Energy Agency (IRENA), half of Pakistan’s rural population still lacks electricity, relying instead on candles, kerosene and wood to fulfill daily energy needs. Some urban residents endure load shedding or rolling blackouts that occur when power providers lack capacity and must de-energize parts of their system. Many others are beyond the national grid. No power lines come their way.

Such power shortages “negatively affect social-, economic- and health-related development goals” of these communities, explains Govindasamy Tamizhmani, a research professor of engineering in the Photovoltaic Reliability Laboratory at Arizona State University’s Ira A. Fulton Schools of Engineering. “This applied research project was focused on designing and prototyping a community-level microgrid that could work with different generation types.”

Northern Pakistan has several resources to tap, and tying them together is as effective as storage.

Control and synchronization of that generation were the big challenges the research team faced.

It’s far simpler to use one generation resource and, if it’s intermittent like solar, add battery energy storage to keep lights on at night. But, storage is cost-prohibitive for most Pakistani villages, Basit says. It also won’t work with micro-hydro facilities, which have generation that fluctuates on a seasonal basis.

But, northern Pakistan has several resources to tap, and tying them together is as effective as storage.

When the sun goes down, hydro can pick up the slack, explains Ahmed Sohail Khan, ASU’s technical advisor for USPCASE project at UET-P.

“In the winter, there’s no water flowing, but you can still have power from the sun. If there’s no power from the sun and no power from hydro, you can use biomass gasification-based power. Together, they can supply stable power to fill community needs.”

At the same time, the microgrid had to ensure that the fluctuating energy generation could be regulated in-sync with the changing energy demand — also known as the load side — of the community.

“Multiple types of intermittent power synchronized together and delivering a smooth 50 hertz. It’s not an easy task,” Khan says.

“We have loads fluctuating from 15 to 27 kilowatts all of the time,” Basit explains.

Now the team uses two approaches to balancing electricity supply and demand, an absolute requirement for safe, reliable power flow. First, they developed an electronic load controller associated with the hydro generation. Khan says it has a “a dumping load,” activated on surplus energy from the system, that can be turned on and off as needed when the community load fluctuates. *[Continued on page 4]*

GOING LOCAL WITH MICROGRIDS

This action keeps system frequency at a steady 50 hertz, which is the standard in Pakistan and the frequency of household appliances use. The dumping or ballast load, however, doesn't go to waste. It heats water for use the following day, Khan explains.

After stabilizing the micro-hydro generation, the team integrates the solar and, ultimately, the biomass generation as well.

A programmable logic controller or PLC – a type of industrial computer – monitors the voltage, frequency and other power-quality parameters of the solar and biomass generation. If both of these generation facilities have matching parameters, the PLC allows power to be integrated. If there are power quality mismatches, it sends signals to correct them. And, when load exceeds generation, algorithms within the PLC determine which load gets priority: industry, school, mosque or households.

COMBINED POWER FROM COMBINED RESEARCH

This testbed was a part of the applied research component of the USPCASE program. Through it, researchers from the National University of Sciences and Technology (NUST) and UET-P team up with U.S.-based colleagues at ASU and OSU to pool time and talents. These collaborations ensure that stateside researchers have in-country expertise to support and guide activity while Pakistani researchers can tap the resources of academic facilities with more mature research environments. That, in turn, fine-tunes skills and helps the Pakistani scholars more effectively vie for research funding.

The applied research arm of these collaborations takes aim at creating solutions that can be quickly and affordably address Pakistan's electricity shortfall.

“The overarching goal for this project was to design, prototype and field-test the microgrid concept in a real-world remote community.”

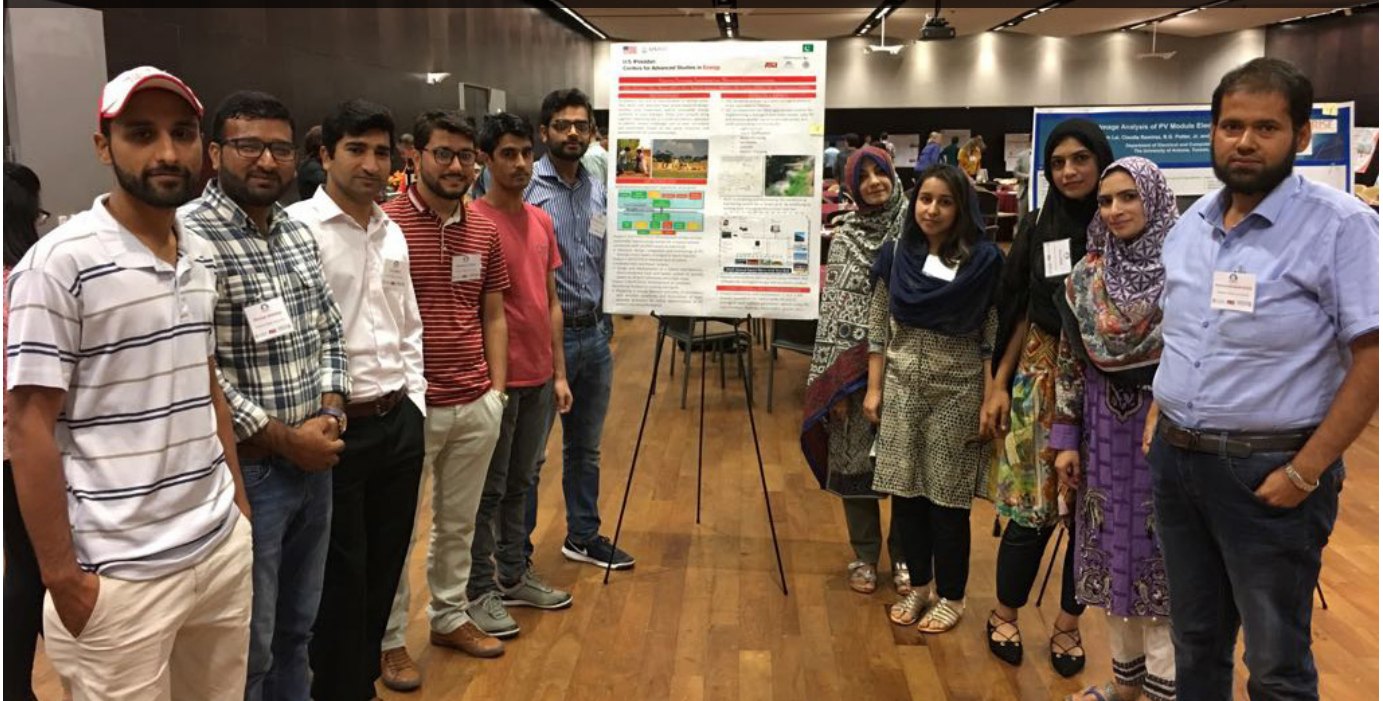
– Prof. Govindasamy Tamizhmani

“The overarching goal for this project was to design, prototype and field-test the microgrid concept in a real-world remote community,” says Tamizhmani. This was done, he says, “with the expectations that the successful completion of the project will result in a nationwide roll-out of the concept to many other remote communities.”

In fact, this project is a ground-breaker in Pakistan.

“It's the only hybrid microgrid in the northern area,” says Basit.

Dr. Muhammad Shoaib Khalid, Principal Investigator at the University of Engineering and Technology (far right) with USPCASE exchange students at the Arizona Student Energy Conference (AzSEC 2017). This joint research project poster won the best poster award among 25 American universities.



SPREADING THE LIGHT

Not only does the microgrid combine multiple renewable energy resources into one stable, reliable power system, it also leveraged local construction to create an affordable, efficient power system.

On the efficiency side, the biomass facility weighs in. It uses a gasification process to transform leaves, wood and crop waste into syngas, a synthetic gas made up mostly of hydrogen and carbon monoxide.

"The syngas directly burns in the generator," says Khan. It's a low-polluting fuel, "a much cleaner process, he adds. "It produces power and, in the winter, it can heat homes in the village."

Even the waste product from the facility is useful. It can be used by local farmers as fertilizer.

On the affordability end of things, this microgrid leverages local production and in-country manufacturing to keep costs down — way down.

"Instead of importing commercial biomass gasifiers from abroad, our project team partnered with a local manufacturing company to design and produce the unit in Pakistan," says Tamizhmani. "This approach has not only provided significant savings — we estimate up to 50 percent — but it will also support the local and national economy."



"For the entire microgrid project including all three components, the team managed to cover the costs within budget, amounting \$40,000 in total," says Basit. "This is a testbed, and a testbed costs more. If you want to replicate it, you might be able to reduce costs even more."

Meanwhile, this bargain delivers multiple societal benefits. Because it uses biomass, a microgrid like this diverts agricultural waste from landfills and eliminates problematic slash. It also has the ability to aid in the elimination of energy shortages throughout rural areas, support local industry, add to the economy and, once grid-connected, it may help the national grid manage transmission and distribution system constraints.

What's more, the microgrid concept can help USPCASE facilities in Peshawar stay strong by providing a source of income and funding.

"There is no such solution available in the local market with such level of accuracy, intelligence, and reliability," Khalid and Basit note in their report to USAID. "This solution has a high level of commercialization potential, and is in high demand for replication in remote areas by the local government."

REAL-WORLD EXPERIENCES IN A REAL-WORLD TESTBED

USPCASE is preparing graduate students to meet the demand for energy engineers in Pakistan, so it's fitting that students were an integral part of the project. They contributed to several aspects of research, including:

- System design and development, with particular attention to integrating the three generation resources for reliable power-system operation
- Cost optimization research to ensure least-cost approaches
- Creation of voltage and frequency control approaches, including the design of the electronic load controller that enables the micro-hydro facility to accommodate fluctuating consumption
- Economic modeling and optimization of the generation resources

"The respective principal investigators from all three universities have heavily involved their students during the planning, design and implementation of this project," Tamizhmani says.

Ahead, the researchers and their student assistants will analyze field data from the pilot microgrid and refine the concept to make it ready for deployment throughout Pakistan.

BY BETSY LOEFF



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MESSAGE FROM THE DIRECTOR

We will begin the final year of the USPCASE project having achieved a number of important milestones. We have over 700 graduate students enrolled in PCASE at NUST and UET-P. The center offers 11 MS and PhD degree programs with over 80 new classes and 15 labs in the centers. ASU has facilitated 12+ technical workshops and 30+ applied research projects – and we are on track to host 200+ exchange scholars over the life of the project. Our first PCASE Think Tank discussion was held over the summer. Attendees from Pakistan's energy sector met to discuss critical issues relevant to the Pakistan's energy future.



We also kicked off important pedagogical training for the faculty in the centers. The methods and practices of teaching change over time and we want the centers to be at the forefront of learning, ready and able to provide students with an outstanding educational experience, one that prepares them to be industry and academic leaders and more importantly, creates a mindset that prepares them for the lifelong learning that their profession requires.

Tomorrow's energy landscape will be different than the one we know today. New technologies, new challenges, economic realities and social changes will push the frontiers of energy engineering. We want the young engineers of Pakistan to be well equipped to face the future.

DR. SAYFE KIAEI
PROJECT DIRECTOR, USPCASE



CREATING NEW RESEARCH OPPORTUNITIES IN ENERGY POLICY

USPCASE UET-P signed a memorandum of understanding (MoU) with National Electric Power Regulatory Authority (NEPRA). (Pictured left: Vice-Chancellor from UET-P and the Chairman from NEPRA sign the MoU document.) This MoU will create new research opportunities in energy policy for UET-P.

TAKING TIME TO EXPLORE

The sixth cohort of exchange scholars took their first cultural excursion in August. They visited the Heard Museum in Phoenix. Cultural excursions are an important component of the USPCASE exchange program increasing intercultural awareness and competence.





ENERGY THINK TANK

Energy Think Tank meets to discuss energy needs of Pakistan

On July 9 2018, the U.S.-Pakistan Center for Advanced Studies in Energy (USPCASE) at Arizona State University organized the First Energy Think Tank meeting in Islamabad, facilitated by Dr. Clark Miller. A total of 37 faculty and staff from NUST and UET Peshawar, representatives of Government, USAID officials, and private industrialists participated in this think tank dialogue.

Many felt that Pakistan needs to take up the challenge of expanding robust and diverse energy research institutions and capabilities, guide the work of those institutions to meaningfully advise policy, grow the training programs to ensure the availability of highly trained energy policy and engineering professionals, and create the networks and institutional engagement for ensuring that high-quality research effectively informs energy policy choices.

The creation of an energy think tank at USPCASE offers a critical opportunity to establish an effective partnership between universities and policy institutions to oversee the pursuit and achievement of these goals.

This meeting provided an opportunity for numerous stakeholders to weigh in on how such a think tank should be designed and operated.

"A good thought provoking session. The need is to transfer knowledge and technological developments into competitive policy regimes that encourages applied research," remarked a participant.

POWERING UP CONFERENCE PRESENTATIONS

Five USPCASE projects presented at 16th Power Systems Conference

The presented research conveyed the practical implications and research gaps in the modeling, simulation and physical deployment of hybrid microgrid systems in remote areas of Pakistan.

The U.S.-Pakistan Centers for Advanced Studies in Energy are conducting research that directly relates to on-going and anticipated challenges in the energy sector, challenges that affect the lives of Pakistanis and impede economic growth. Under the USAID-funded program, research funding is provided to academic researchers at UET Peshawar and NUST along with ASU faculty and Pakistani industry partners to jointly conduct energy-related research that will address Pakistan's energy future.

Dr. Affaq Qamar, assistant professor at USPCASE UET Peshawar, works in the areas of power systems and power electronics and is currently an exchange scholar at ASU. He presented five papers at the 16th Power Systems Conference organized by Clemson University in collaboration with the IEEE Power and Energy Society and other prominent energy sector organizations.

The conference "Smart Grid Technologies and Innovation" was held in Charleston, South Carolina, from September 4-7, 2018. The conference provided an opportunity for electric power industry experts, electric utilities, government agencies and academic researchers to present and exchange new ideas to elevate the state-of-the-art of power engineering.

The collaborative research titled "Hybrid Energy Test-Bed for Remote Communities — Integration of Solar, Biomass and Microhydro Generator" was conducted by faculty from USPCASE UET Peshawar including Dr. Shoaib Khalid, Dr. Abdul Basit and Dr. Affaq Qamar, with Dr. Govindasamy Tamizhmani from ASU as the research lead. USPCASE master's students from the Electrical Energy System Engineering stream were also actively engaged in the

ongoing research as part of their theses and term projects.

The presented research conveyed the practical implications and research gaps in the modeling, simulation and physical deployment of hybrid microgrid systems in remote areas of Pakistan. The reliance on a microgrid system over a single or few renewable sources results in intermittency problems. Therefore, a hybrid generation approach was used in the proposed microgrid architecture to provide continuous electrical power in a cost-effective manner to off-grid remote areas. *[See page 2 to learn more.]*

The papers highlighted various approaches for the appropriate modeling of a PV, microhydro and biomass-based interconnected microgrid system in combination with energy storage element schemes and controls to maintain the steady supply of energy to meet load demands.

A novel distributed control scheme was also presented to control the frequency and voltage fluctuations and to prevent damage to attached equipment and residential appliances.

An analysis of the results was shared with attendees, showing the dynamic performance of microhydro and PV after the occurrence of transient disturbances due to a quick change in electric load. The presented work suggested the use of solar PV and microhydro as the primary sources to serve load demand, with biomass and battery provides backup in peak hours.

The research found that the use of a battery bank reduces biomass operation thereby reducing the system's Net Present Cost (NPC) and Levelized Cost of Electricity (LCOE) to make it more economically feasible and reliable.

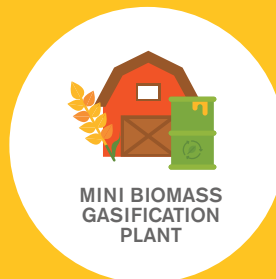


The fully automatic hybrid microgrid system fulfilling the peak demand of 25KW load is deployed in a village near the district Mardan of Khyber Pakhtunkhwa, Pakistan.

The system is now going through a rigorous testing and validation phase. The research team strongly believes that the outcomes of this research will provide a viable case study that the research can be replicated in various parts of the country to provide access to electricity in an environmentally friendly and cost-effective way.

THE PRESENTATIONS:

1. Rizwan Kamal, Muhammad Younas, Muhammad Shoaib Khalid, Affaq Qamar, "Cost Optimization of an Off-Grid Hybrid Renewable Energy System with Battery Storage for Rural Electrification in Pakistan"
2. Muhammad Salman, Abdul Basit, Muhammad Shoaib Khalid, Affaq Qamar, "Reduction in Total Harmonic Distortion of Cascaded H-Bridge Multilevel Inverter with Equal Phase Method"
3. Khurram Shahzad, Azmat Rashid Khan, Muhammad Shoaib Khalid, Affaq Qamar, "Voltage and Frequency Control of PV, Microhydro and Biomass-Based Islanded Microgrid"
4. Muhammad Younas, Rizwan Kamal, Muhammad Shoaib Khalid, Affaq Qamar, "Economic Planning for Remote Community Microgrid Containing Solar PV, Biomass Gasifier and Microhydro"
5. Azmat Rashid Khan, Khurram Shahzad, Muhammad Shoaib Khalid, Affaq Qamar, "Design Optimization and Reliability Enhancement of Community Based Islanded Microgrid through Frequency Stability"



SOLUTIONS-ORIENTED SCHOLARS

USPCASE scholar Faisal Nawab is focused on bringing renewable power to under-served communities in Pakistan



Which sector uses the most energy? Chances are, you already know it's the industrial sector, which accounts for about one-third of energy use in the U.S., and power-hungry manufacturing accounts for a little more than half of that fraction.

Chances are, you don't think about agriculture as being a big energy consumer, but Faisal Nawab does. "I belong to a family that depends on agriculture products such as wheat and melons," he says. And, the family farm requires electric pumps to irrigate crops.

"When I was in high school, there were about 18 hours a day of energy cut-offs," Nawab recalls. "Farmers in my village were not able to provide water to their fields, and all the crops got ruined. From that time, I decided to study energy engineering."

Nawab earned a bachelor's degree in electrical engineering, but he didn't sign on with an established utility or seek industry work. He kept thinking about the needs of villages like his hometown, and that's what prompted him to seek out a degree in renewable energy. He found what he was looking for at the University of Engineering and Technology, Peshawar (UET-P), where he became a USPCASE scholar.

TAKING THE RENEWABLE PATH

"The only solution to the energy crisis of Pakistan is decentralized, renewable energy, and there is not enough work done in that field," Nawab says. "Without sufficient energy, the economy of Pakistan cannot be stabilized and the country economy will always rely on foreign loans with high interest rates." Ending this cycle is what motivates Nawab. "It encourages me to enhance the energy security of Pakistan."

Currently, Nawab is a visiting scholar at Oregon State University. There, he's conducting research on the waste-to-energy system and the biomass potential of *Saccharum munja* forests in the Lakki Marwat District in Pakistan's Khyber Pakhtunkhwa Province. A master's candidate, Nawab has also interned for Peshawar Electric Supply Company, where he learned about distributing power throughout a district and protecting the power system from different faults.

In off hours, Nawab hikes, explores Oregon and practices culinary arts. "I'm an expert cook and can cook any Pakistani or Indian spicy food," he says.

What does Nawab plan to do with his Master's degree? Clear a path to bring energy home.

"There are two main problems in the Pakistani power sector. The first is production from expensive fuels, and the other is capacity of the transmission lines," he says. "The only solution to the problem is decentralized renewable power plants."

That's what Nawab hopes to bring to rural Pakistan by building a social organization intent on solving energy sector problems. Five years after picking up his diploma, he wants to be designing and installing small power plants in areas where no power lines currently run.

"I also will try to make different renewable energy technologies usable so they can be operated by less-trained people," he says. "The main focus will be usability of the technology because many people of rural Pakistan are not well educated."



BY BETSY LOEFF

WORKSHOPS & SEMINARS

ENDING POVERTY THROUGH ENERGY INNOVATION

The U.S.-Pakistan Center for Advanced Studies in Energy (USPCASE) at Arizona State University (ASU) held a one-day session focusing on energy poverty, for students and faculty of NUST and UET Peshawar. The session was facilitated by Dr. Clark Miller from ASU's School for the Future of Innovation in Society.

This interactive session provided a multi-level framework for approaching the challenge of providing clean energy in ways that significantly reduce poverty and enable progress, based on three key ideas: the social value of energy, socio-energy systems and enterprises, and energy innovation ecosystems. The participants learned that energy innovation requires coordination across these multiple levels and how new energy solutions are deployed, operated, maintained, owned, and scaled by various actors.



HARNESSING HYDROPOWER FOR PAKISTAN'S FUTURE



ASU hosted the workshop "Hydropower: Technical, Social and Regulatory Perspectives,"

September 24-26, 2018 in Islamabad. The objectives of this session were to discuss technical aspects and social impact of installing hydroelectric projects in Pakistani communities particularly in northern region, assessment of using micro-units of hydropower as part of Pakistan's energy strategy, and learning government perspective on hydro in renewable energy mix of the country.

The session was facilitated by Dr. Kendra Sharp, a renowned hydro expert from Oregon State University. More than 150 engineers from industry and academia participated in the session to exchange information and propose solutions focusing on hydropower.



VIRTUAL SEMINAR THERMAL ENERGY

Professor Taewoo Lee (ASU) delivered the seventh virtual seminar "Technical Issues in Thermal Power Generation and How to Solve Them" on September 18. The seminar was attended by more than 50 students and faculty from NUST, and 48 students and faculty from UET Peshawar.

THE POWER OF POLICY: USE ENERGY TO END POVERTY

USPCASE scholars who study energy policy with Arizona State University Professor Clark Miller are likely to learn this fact about The Grand Canyon State: Some 30 percent of the water used goes to pump, treat, process and deliver water, while more than one-third of that H₂O is consumed to produce energy.

Called the energy-water nexus, that symbiotic relationship plays out worldwide, not just in Arizona. So does the energy-poverty nexus, which reflects the reality that the more economic activity you want to pursue, the more energy you require, and the absence of energy hobbles economic opportunity. The associate director for faculty for ASU's School for the Future of Innovation in Society, and the Director of the Center for Energy and Society, Miller teaches these lessons and more to USPCASE scholars both stateside and abroad.

Miller's research takes a new approach to solving energy poverty. "Historically, we've defined energy poverty as a lack of access to energy technologies," he says. "This is too narrow. What we really need to do are to find ways to use energy innovation as part of a larger strategy for pursuing sustainable development."

MORE THAN WIRES AND WALL OUTLETS

The World Bank defines energy poverty as, "The state of being deprived of certain energy services or not being able to use them in a healthy, convenient, and efficient manner, resulting in a level of energy consumption that is insufficient to support social and economic development."

Until recently, measuring energy poverty was a binary proposition: Either you had access to electricity at your home or you didn't.

By that measure, nearly a billion people on the planet – about one in seven – do not have access to modern electricity services in their households, Miller says. But, he adds, "Increasingly, people are recognizing that access isn't a sufficient measure. When and how often people have energy matter, too, as does the price and the quality of the power provided."

When Miller mentioned this in a recent workshop he held in Pakistan, one student commented that in his home village, people often had electricity just one day out of four.



There needs to be a multi-tiered framework for measuring energy access, Miller says. "We must break down energy access by different characteristics."

He points to a seven-tier matrix used by the World Bank and United Nations. Among the factors this matrix measures include peak capacity, or how much electricity is available to households; duration, or how many hours per day those electrons flow; and reliability, which refers to outages and load shedding where the utility purposefully trips off power because enough capacity simply doesn't exist. The matrix also considers affordability, safety, power quality and legality of the connection.

A CLOSER LOOK

"The idea of a multi-tier framework is that you break down access into different components and measure it on different tier levels," Miller explains. So, for instance, on the duration measure, tier one means that you have at least four hours of electricity per day, and one of those hours occurs in the evening. Tier two also has a minimum of four hours of access daily, with two of those being evening hours. Tier three requires eight hours of electricity – three at night – but power quality and reliability are still big problems.

This approach, Miller says, enables power providers to look at access problems throughout a city or a region and pinpoint solutions to bring people up to a higher tier. For instance, if a neighborhood has tier-three power, the power supplier could look for solutions to power quality, reliability and safety issues that still plague those consumers.

This approach offers a more precise and helpful way of measuring access, but it's still a supply-side view, Miller says.

"We also need to look at the demand-side and how well people are able to use energy to advance development. Do people have the kind of electricity services they need to achieve the kind of economic and social goals they want to achieve?" he asks. "How much societal benefit are you providing compared to units of energy consumed?"

Miller urges students to consider the social value of energy and create systems optimized for community gain. "It's not just about technologies and prices. It's about what we're getting at the end of the day in terms of societal benefit," he says.

Therein lies the foundational idea behind his framework for optimizing social benefit per unit of energy produced.

THE GOOD, THE BAD, THE ELECTRONS

According to Miller, energy can create economic opportunity for a community through infrastructure construction, system operation and energy use itself. These activities do more than supply electricity. They provide an economic boost to a community. And, the flip side also is true. Energy can create economic drag.

"Puerto Rico is my go-to example of this," Miller says. "It is a very poor part of the USA. Its average income is half that of Mississippi, the poorest state in the United States.

But its average energy prices are twice those of the rest of the country because they're importing oil to create electricity."

This, Miller continues, resulted in expenditures of some \$8 million daily on oil imports – \$3 billion a year – and the equivalent of 3 million people each spending about \$1,000 per year over the past several years. "They took that money, effectively put it on the table and lit it on fire," he says.

These outlays helped put the Puerto Rican electric utility \$9 billion in debt and the whole island \$72 billion in debt before Hurricane Maria knocked the power out entirely in September 2017. Lack of funds left the electric system poorly maintained in a hot, humid place where power poles decay quickly. That, Miller says, is one reason Maria was so devastating. It also reflects the fact that, while energy can be generative, helping people create stronger economies and communities, it can also be degradative, pulling resources – like money – out of the community.

To ensure that energy delivers social value, Miller teaches students to keep two principles in mind. First, energy systems should be designed as socio-technical systems. "Sometimes we get caught up in the cool technologies, but we need to think about all the people who need to do what they need to do to make the systems actually deliver value," he says. *[Continued on page 14]*



Clark Miller meeting with exchange scholars at ASU.

CONSIDERING THE SOCIAL VALUE OF ENERGY



Clark Miller meeting with the research team working on improving the social value of energy in KP villages.

Second, the design must focus on creating systems that are indeed socially generative.

"It's not enough to have two light bulbs and a fan working in every house on the planet," he continues. "The goal is to create a positive feedback loop that keeps the community growing and developing."

These ideas about social value creation were explored in depth at a conference entitled "Eradicating Poverty through Energy Innovation" held at ASU in February 2018.

The conference was co-sponsored by USPCASE and attended by 30 USPCASE exchange students in addition to more than 75 other researchers and community energy advocates from 11 countries and 5 continents.

A report written for the conference, *Poverty Eradication Through Energy Innovation: A Multi-Layer Design Framework for Social Value Creation*, was co-authored by Nafeesa Irshad, a former USPCASE exchange student in Miller's lab who is now a PhD student at ASU.

RAISING THE BAR ... AND GROCERY STORE ... AND LOCAL MANUFACTURING PLANT

To help students design energy systems with community development and sustainability in mind, Miller teaches a seven-layer framework that considers energy as interconnected to other sectors in the economy. The first concept in that framework is that energy is a social investment.

"It's not about technologies and prices. It's about

what we're getting at the end of the day in terms of societal benefits," including as a strategy for poverty eradication, Miller says. "We like to think in terms of the UN Sustainable Development Goals. How can energy innovation contribute to reducing poverty and inequality, improving food and water security, empowering women and promoting strong institutions, or other facets of sustainable development?"

The second premise of the framework is that social value is not created by energy. It's created by energy services. "What are people able to achieve with that energy? Electrons have no social value whatsoever, but if those electrons can pump water to irrigate a field, then they have value," he explains.

Next, the framework stresses that the delivery of energy services is a product of sociotechnical assemblies. In other words, people have to do work to make those services happen.

In addition, energy systems require energy organization. "People install microgrids and renewables all over the world, but you come back a year later, and they're not working," Miller says. "They're not working because no one put in place a maintenance crew, a plan for keeping the system running."

Finally, the framework looks at the financial design of energy systems – how the system distributes benefits and costs across different groups – as well as policy that encourages sustainable development goals.

With these factors in mind, Miller and his colleagues and students have been involved in a number of projects designed to both deliver energy services and fight poverty. One is the creation of two solar water pumps in Nepalese villages.

The pumps will allow the communities to irrigate additional lands, and that will help locals move beyond subsistence farming to farming for crops that can be sold at market. That means the project decreases food insecurity and raises incomes simultaneously.

Because the community set up a water board primarily made up of women, there's a potential for enhancing the power of women in the communities.

There are, however, potential risks. With increased agricultural activity, there's a chance that students will skip school to work the crops instead. There's also the risk that folks may wind up drinking the non-potable water slated for irrigation. And, because the developer didn't do a financial assessment, it turns out the villages can't afford the money they were supposed to chip in.

Another project Miller is working on is with a Canadian First Nations community who are evaluating construction of a biomass combined heat and power (CHP) generation facility that would leverage the area's abundant forest lands.

CHP power plants make use of the waste heat created by electricity generation. This heat can be used for heating buildings or when directed to absorption refrigerators, it can be used for cooling. In this project, the waste heat would warm the village school during the winter, saving villagers the high price of diesel fuel.

During shoulder months when temperatures are between 45 and 65 degrees Fahrenheit, the school needs less heat, and excess heat would go into greenhouses that would be used to teach students about agriculture and provide nutritional help for the community.

During the summer, when the CHP plant's heat isn't needed for the school, it could power an ice production facility that would save money for local fishermen. Naturally, the CHP plant also would power the school and local homes, and providing wood to fuel the plant would employ local loggers.

What's more, those lumberjacks would have year-round employment – something they don't have now – which would enable them to add equipment and gain more contracts, such as forest-management contracts for the Canadian government. The plant, which would be carbon-neutral, could receive carbon credits as part of Canada's policy to combat climate change, which has the potential to contribute income to the village economy. It's not just a generation facility. It's an entire ecosystem of value creation.

While Miller says this project has yet to map out risks and potential burdens, it will. In the end, it will be a carefully evaluated electricity supply mechanism that delivers both electrons and economic gain.

RELATED JOINT RESEARCH PROJECTS

In Pakistan, Miller is involved in three joint research projects with faculty from USPCASE partner universities, NUST and UET Peshawar to provide Pakistan with national energy system modeling strategies and to develop a team to help alleviate poverty in the major Pakistan province of Khyber Pakhtunkhwa by providing access to energy.

1. "Developing the Strategy for Policy-Oriented Energy Research Modeling" with NUST faculty Kafait Ullah and Kashif Imran.
2. "National Energy Modeling Strategy for Pakistan and KP Province" with UET Peshawar faculty Irfan Mufti.
3. "Social and Hydrological Research to Improve Impact of Distributed Energy on Sustainable Development and Poverty Alleviation in Khyber Pakhtunkhwa" with UET Peshawar faculty Tanvir Ahmad.

The last, in particular, is focused on social value creation and combines hydrological and social research to improve the impact of distributed energy on sustainable development.

That's the kind of win-win approach Miller stresses as he teaches USPCASE engineers about policy to eradicate energy poverty.

"It's time to drop the word 'energy' from the phrase 'ending energy poverty,'" he says. "End poverty. That's what we should be working to achieve."

BY BETSY LOEFF

ABOUT USPCASE

The U.S.-Pakistan Centers for Advanced Studies in Energy (USPCASE) is a five-year program implemented by partners National University of Sciences and Technology (NUST), University of Engineering and Technology (UET) Peshawar and Arizona State University (ASU).

The project focuses on applied research relevant to Pakistan's energy needs.

The program has multiple goals including curriculum development, applied research, the establishment of new laboratories, and international visitor programs.

Partnering Universities:



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