TRANSFORMATIONAL ENERGY

》》 LEADS: Dr. Michael Mazzola, Dr. William Tolone, Dr. Badrul Chowdhury

》》 TARGET CATEGORY: Existing and Emerging Excellence

BELK COLLEGE OF BUSINESS
Economics

COLLEGE OF ARTS + ARCHITECTURE
Architecture

COLLEGE OF COMPUTING & INFORMATICS
Computer Science, Ribarsky Center for Visual Analytics, Software and Info Systems

COLLEGE OF LIBERAL ARTS & SCIENCES
Geography and Earth Science, Mathematics and Statistics

WILLIAMS STATES LEE COLLEGE OF ENGINEERING
Civil and Environmental Engineering, Electrical and Computer Engineering, Engineering Technology and Construction Management, Energy Production and Infrastructure Center, Mechanical Engineering and Engineering Science, Systems Engineering and Engineering Management

⟫ EXECUTIVE SUMMARY

UNC Charlotte is emerging as a national leader and is an established regional leader for research, education, and engagement in _Transformational Energy_. The established societal goal of _Transformational Energy_ is to decarbonize energy use in the domestic and global economy. The pathway to _Transformational Energy_ is motivated by science, framed/required by international diplomacy (e.g., the Paris Climate Agreement), and supported within the United States by substantial funding from numerous agencies and foundations, including the U.S. Department of Energy (DOE), U.S. Department of Homeland Security, the National Science Foundation, Bill & Melinda Gates Foundation, and many others. Achieving this goal requires close multidisciplinary partnerships between academia, industry, and the public sector. As this proposal demonstrates, UNC Charlotte already possesses such partnerships and is making significant multidisciplinary contributions toward this goal.

UNC Charlotte is a pioneer in _Transformational Energy_ research with a large cohort of multidisciplinary faculty from four colleges and numerous disciplines; faculty who are well-known in their respective fields of research for results that promote energy transformation. The Energy Production and Infrastructure Center (EPIC) serves as a central hub for innovation and excellence in _Transformational Energy_ research, education, and engagement in alignment with the University's goal to foster intra-connectivity with industry professionals and organizations. One example of EPIC's leadership in _Transformational Energy_ (of many) is the Center for Advanced Power Engineering Research (CAPER), a multi-university, multi-industry partnership for _Transformational Energy_ research. UNC Charlotte, under EPIC, is the lead university for CAPER. Through efforts such as this, EPIC is able to deliver on its mission: to educate a new generation of workers that will meet society's energy needs while promoting a healthy climate.
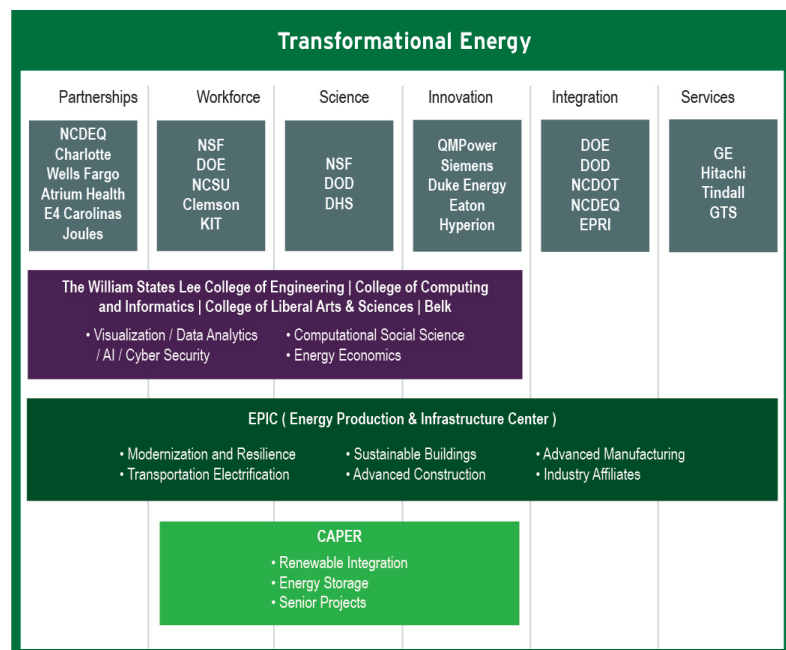
UNC Charlotte faculty also possess a strong record of scholarship in _Transformational Energy_, both in the quantity and quality of publications - publications that recognize the social, technical, computational, and economic barriers to energy decarbonization. UNC Charlotte faculty and students publish extensively in top venues in all participating fields of study. This scholarship reveals high-quality research that spans the spectrum of basic, use-inspired, and applied work. It also demonstrates an established culture and practice of multidisciplinary research as well as the importance of public and private partnerships when facing societal challenges of the scale of energy decarbonization.

UNC Charlotte research, education, and partnerships align with state, regional, and national priorities that drive the societal need for _Transformational Energy_. The State of North Carolina is a leader in renewable energy, ranking 2nd among all states for solar energy production. UNC Charlotte is the technical lead for the North Carolina Department of Environmental Quality's electrical grid resiliency program funded by the U.S. Department of Energy (DOE) that was recognized by a recommendation in North Carolina's Clean Energy Plan published by Governor Roy Cooper in October 2019. UNC Charlotte is on the national stage on multiple fronts including two large multi-institutional research projects totaling more than $8,000,000 that were competitively selected for award to UNC Charlotte by the Solar Energy Technology Office of the U.S. DOE in 2019 and 2020. These are two of numerous examples of UNC Charlotte leadership of large, multi-institution _Transformation Energy_ projects. In addition, UNC Charlotte possesses an extensive and impressive record of extramural funding in _Transformational Energy_ with well in excess of $50M in new awards since FY2015.

The accomplished faculty working in *Transformational Energy* at UNC Charlotte range across all academic ranks. Early career faculty are rising rapidly. For example, Dr. Fareena Saqib (Assist. Prof. ECE) helped organize three workshops for Women in Hardware Systems Security (2018-2019), a topic crucial for securing critical energy infrastructure. Mid-career faculty, such as Dr. Valentina Cecchi (Assoc. Prof. ECE) and Dr. Zach Wartell (Assoc. Prof. CS), have forged a cross-college collaboration between EPIC, the Ribarsky Center for Visual Analytics, and the College of Computing and Informatics (CCI) to extract actionable knowledge from large datasets created by advanced electric metering infrastructure. Senior faculty are internationally known, such as Dr. Badrul Chowdhury (Prof. of ECE and SEEM) who is Editor-in-Chief of the IEEE Transactions on Sustainable Energy, Dr. Peter Schwarz (Prof. Economics) who is author of the textbook Energy Economics published by Routledge, and Dr. William Tolone (Assoc. Dean CCI) is a PI in the graduated NSF Research Network entitled: Predictive Modeling Network for Sustainable Human-Building Ecosystems (SHBE). SHBE is a network composed of more than 100 convergence researchers and scholars from numerous domains working on *Transformational Energy* including architecture, engineering, computer science, construction, and the human behavioral, social, economic, and political sciences. Dr. Robert Cox (Assoc. Prof. ECE) is an advisor to North Carolina policy maker Sushma Masemore (State Energy Director) on the issue of grid modernization to improve resiliency. EPIC research staff led by Dr. Madhav Manjrekar (Assoc. Prof. ECE) and James Gafford (EPIC Professor of Practice), deliver innovative solutions "at the speed of the client" for industrial partners of EPIC. For example, they manage a fast-paced program of technical innovation sponsored by industry partner QMPower and the U.S. DOE. This program is developing high-efficiency motor control products and electric motors for manufacturing and electric transportation. These are just a few of the many examples of UNC Charlotte success in *Transformational Energy*. Faculty, staff, and students are the keystone to *Transformational Energy* research at UNC Charlotte. These successes exist, live, and thrive through the multidisciplinary work and multi-institutional partners of the faculty that have joined this application as reported in their CVs.

Transformational Energy research at UNC Charlotte is organized across six themes representing the value chain required for excellence. UNC Charlotte contributions to *Transformational Energy* span this value chain of: scientific discovery and technology development; fast-paced applied research; technology integration; technical and laboratory services; workforce development; and public/private partnerships. The first of these six is **scientific discovery and technology development**. This theme is led by faculty associated with this application. The research is often performed in multidisciplinary clusters in departments and among

Transformational Energy

Partnerships	Workforce	Science	Innovation	Integration	Services
NCDEQ Charlotte Wells Fargo Atrium Health E4 Carolinas Joules	NSF DOE NCSU Clemson KIT	NSF DOD DHS	QMPower Siemens Duke Energy Eaton Hyperion	DOE DOD NCDOT NCDEQ EPRI	GE Hitachi Tindall GTS

The William States Lee College of Engineering | College of Computing and Informatics | College of Liberal Arts & Sciences | Belk
• Visualization / Data Analytics / AI / Cyber Security
• Computational Social Science
• Energy Economics

EPIC (Energy Production & Infrastructure Center)
• Modernization and Resilience
• Transportation Electrification
• Sustainable Buildings
• Advanced Construction
• Advanced Manufacturing
• Industry Affiliates

CAPER
• Renewable Integration
• Energy Storage
• Senior Projects

the colleges. There are clusters of faculty researchers in four principal colleges: (1) William States Lee College of Engineering (WSLCOE); (2) College of Computing and Informatics (CCI); (3) College of Liberal Arts and Science (CLAS); and (4) Belk College of Business (BCOB). This application has faculty support from every department within WSLCOE, two departments in CCI, several departments in CLAS, and one department in BCOB. The second theme is innovation in the form of **fast-paced applied research**, often led by EPIC research faculty and staff, that help industry partners transition knowledge into new products. EPIC perhaps may be the most visible organization representing the *Transformational Energy* research area of excellence; EPIC is both a research center and a unit of the WSLCOE. EPIC was formed as a public/private partnership with the electric energy industry in North Carolina and has grown to become a vibrant intersection of partnerships with industry, government, and academia. EPIC had three impacts on UNC Charlotte: a) Beginning in 2012 EPIC funded a large cluster hire of new faculty placed in every department in the WSLCOE. b) In 2013 a $76 million LEED certified building was completed to house the research center and two departments in WSLCOE. This building was recently dedicated to distinguished alumni Craig and Darla Albert. c) EPIC is a catalyst for attracting extramural funding for applied research in support of the transition to low carbon energy. EPIC manages a diverse portfolio of *Transformational Energy* research totaling over $13 million in active research awards from state/federal agencies and industry. EPIC is the prime recipient of an additional $4.7 million award in the final stages of negotiation with the DOE.

The third theme is **technology integration** in which large multi-institutional projects advance enabling technology to urgently needed highlevels of technology readiness. These are the types of projects that attract funding from the DOE such as, "Resilient Community Microgrids with Dynamic Reconfiguration to Serve Critical Loads in the Aftermath of Severe Events," a three-year project led by EPIC to improve the technology readiness of community microgrids by improving control and protection algorithms in partnership with Duke Energy, the DOE National Renewable Energy Laboratory, and several universities and an industry consultant. The fourth is **technical and laboratory services** that typically support middle Atlantic-based companies using industry relevant laboratories with unique equipment and staff expertise. The EPIC High Bay Structures Laboratory is currently supporting Tindall Corporation (South Carolina) to test preformed concrete structures used in the utility industry. The Duke Energy Smart Grid Laboratory (DESGL) in EPIC performs modeling and computer simulation for various companies in North Carolina and Virginia such as the Siemens Energy Hub in Charlotte and Global Technical Systems in Virginia Beach. The latter is an aspiring manufacturer of utility scale flywheel energy storage.

The fifth theme is **workforce development**. *Transformational Energy* requires that we train and develop a multidisciplinary workforce at scale to meet this societal challenge. Within the energy industry proper, it is well-documented that there is a workforce crisis. UNC Charlotte is well-positioned with academic programs aimed to produce graduates well-prepared to make positive societal impacts. One of EPIC's founding missions was to ensure a steady graduation of engineers ready to be employed in the Charlotte and North Carolina energy industry. By leveraging public-private partnerships, UNC Charlotte works closely with industry to offer students energy-related internships, scholarships, senior design projects, mentorships, and networking opportunities. At UNC Charlotte, all engineering Baccalaureate and Masters programs offer an energy concentration, as does the Belk College of Business' highly-rated MBA program. Students from the multiple colleges and schools at UNC Charlotte collaborate with EPIC on *Transformational Energy* research. Finally, the sixth theme is **partnerships** that engage local, regional, state, and federal agencies with key stakeholders in business to further an orderly transition to clean energy (details are provided in the next section).

Addressing climate change may be the most singular issue of the twenty-first century. The sheer volume of programs and funding available for *Transformational Energy* research reflects the global impact and importance of transitioning the global energy economy to low or net-zero carbon emissions. Prominent figures such as Bill Gates are driving private investment in this area. President Biden has clearly made addressing climate change with *Transformational Energy* among the highest priorities of his administration. UNC Charlotte is a regional leader in *Transformational Energy* and is helping to set regional and state priorities. EPIC organized a partnership that was recognized in the NC Clean Energy Plan. The City of Charlotte, the Centralina Regional Council, the NC Department of Environmental Quality, and the DOE partners with EPIC on *Transformational Energy* initiatives. E4 Carolinas, which is the energy industry trade organization in the Carolinas and is headquartered in the Portal Building, also partners with EPIC on important *Transformational Energy* efforts. UNC Charlotte also works with national organizations located in the Carolinas (e.g., EPRI) to perform *Transformational Energy* research. Faculty in EPIC and CCI partner with companies such as Atrium Health and Wells Fargo to support data analytics for sustainable buildings through the Center for Sustainably Integrated Buildings and Sites (SIBS), a graduated NSF I/UCRC directed by Dr. Cox.

Arguably the most collaborative partnership in the region on *Transformational Energy* research is CAPER, which is focused on the Carolinas but with national partnerships and funding viability. The work done at CAPER transcends the Southern Region so that lessons learned are applied nationally. UNC Charlotte is the lead university for CAPER in a partnership that includes North Carolina State University (NCSU) and Clemson University. Leadership of CAPER demonstrates that UNC Charlotte is recognized as one of the top energy universities in the region. CAPER operates on the model of a NSF I/UCRC and is funded by: Duke Energy and Dominion Energy, investor-owned utilities serving the Carolinas and Virginia; Siemens, a global energy-related technology company; and the Savannah River National Laboratory, which is part of the DOE laboratory complex. CAPER is led by EPIC and partners UNC Charlotte researchers with NCSU and Clemson researchers on multi-campus research projects funded by the industry and government members. In addition, CAPER facilitates student education at both the undergraduate and graduate levels.
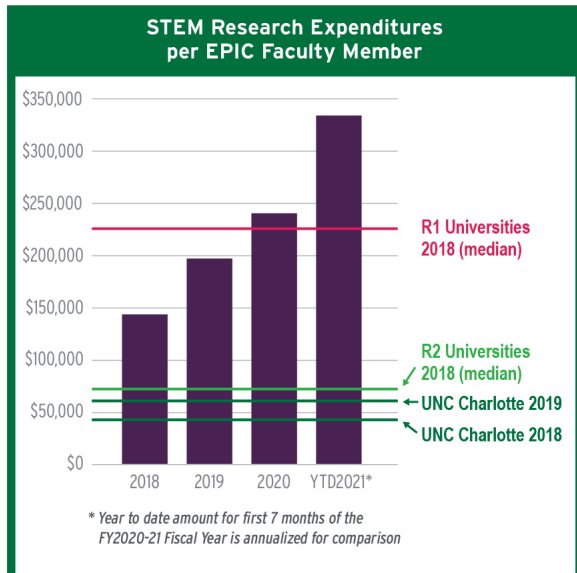
The level and growth in extramural funding in *Transformational Energy* at UNC Charlotte places it at the forefront of this societal challenge. EPIC research expenditures alone from fiscal year 2018-19 through the first seven months of the 2020-21 fiscal year demonstrate UNC Charlotte's leadership, impact, and alignment with regional and national priorities. Accelerating growth is observed each year from a base in FY2018 that was already three times the per capita STEM research expenditures at UNC Charlotte and twice the median for universities classified as R2 by the Carnegie index. Most significantly, however, EPIC's annualized FY2020 per capita STEM expenditures are significantly larger than the median for R1 Carnegie institutions in 2018, which was the last year Carnegie ratings were published.

STEM Research Expenditures per EPIC Faculty Member

R1 Universities 2018 (median)

R2 Universities 2018 (median)

← UNC Charlotte 2019

UNC Charlotte 2018

* Year to date amount for first 7 months of the FY2020-21 Fiscal Year is annualized for comparison

Faculty	Title	College	Department	Area(s) of Expertise
Azarbayjani, Mona	Associate Professor	COAA	Architecture	Energy performance of buildings; climate-responsive building design
Bai, Linquan	Assistant Professor	COE	SEEM	Electricity markets; demand response; energy optimization and scheduling
Braxtan, Nicole	Assistant Professor	COE	CEE	Non-destructive testing; condition assessment
Browne, Aidan	Associate Professor	COE	ETCM	Sensors & Signal Conditioning; Control Systems; Robotics; Applied Energy/Electro-mechanical Systems
Cecchi, Valentina	Associate Professor	COE	ECE	Frequency and temperature-dependent power flow; renewable energy integration; power system modeling
Chen, Chen	Assistant Professor	COE	ECE	AI applications; convolutional neural networks; computer vision; image processing
Chen, Shenen	Professor	COE	CEE	Civil infrastructure resilience; power transmission structures; Carbon storage in geological formations; remote sensing; forensic investigation; transportation electrification
Chowdhury, Badrul	Professor	COE	ECE & SEEM	Renewable energy integration; demand response; power system resilience; energy storage; electricity markets; energy data analytics; power system moldeing
Cox, Rob	Associate Professor	COE	ECE	Energy data analytics; power system resilience; smart and sustainable buildings
Daniels, John	Chair & Professor	COE	CEE	Geotechnical and geo-environmental engineering testing of materials; Barrier material
Dou, Wenwen	Assistant Professor	CCI	CS & Ribarsky Center for Visual Analytics	Statstical and machine learning; Visual Text Analytics; social media analytics
Ebong, Abasifreke	Professor	COE	ECE	Design; modeling; characterization and analysis of solar cells; solid state lighting
Fan, Wei	Professor	COE	CEE	Big data analytics for transportation; Connected and autonomous vehicles; network optimization
Han, Tao	Assistant Professor	COE	ECE	Wireless edge Computing; Big data driven network design and optimization; wireless networks; Internet of Things; Network and system security
Hong, Tao	Associate Professor	COE	SEEM	Big data analytics; energy forecasting
Jiang, Jiancheng	Professor	CLAS	Mathematics and Statistics	Bayesian statistics; financial econometrics; quantile regression; statistical learning with big data; time series analysis
Kamalasadan, Sukumar	Distinquished Professor	COE	ECE	Power system control and optimization; renewable energy integration; energy storage; microgrid
Kernicky, Timothy	Research Assistant Professor	COE	EPIC	Structural health monitoring; nondestructive testing and evaluation
Khan, Taufiquar	Chair & Professor	CLAS	Mathematics and Statistics	Deep neural networks; transportation electrification; synchrophasors; impedance tomography
Khire, Milind	Professor	COE	CEE	Waste containment systems; field-scale testing of soil; water; and waste systems; electrochemical treatment of contaminated water
Manjrekar, Madhav	Associate Professor	COE	ECE	Utility applications of power electronics; variable speed motor drives; interfaces for renewable power generation and energy storage; Cybersecurity
Mazzola, Michael	Director & Professor	COE	EPIC & ECE	Power semiconductor devices; power electronics; electric vehicles; energy storage; high performance computing
Moyer, Thomas	Assistant Professor	CCI	SIS	Cybersecurity; trustworthy computing
Noras, Maciej	Associate Professor	COE	ETCM	Electric and magnetic field sensors for health monitoring of power grids
Ogunro, Tobi	Associate Professor	COE	CEE	Environmental; Geoenvironmental & Geotechnical Engineering; waste containment systems; Waste containment barrier material properties and durability; sustainable construction
Pan, Yinghao	Assistant Professor	CLAS	Mathematics and Statistics	Semiparametric inference; machine learning; causal inference
Parkhideh, Babak	Associate Professor	COE	ECE	Power electroncis systems and control; AI in power electronics; Wide Bandgap Semiconductor devices and packaging
Pulugurtha, Srinivas	Professor	COE	CEE	Transportation planning and modeling; intelligent transportation systems; Geographic Information Systems
Roy, Arindam	Assistant Professor	CLAS	Mathematics and Statistics	Combinatorics and Number Theory
Saqib, Fareena	Assistant Professor	COE	ECE	IoT security; hardware security and trust; supply chain risk management and security; high performance computing
Sarunac, Nenad	Research Professor & Associate Professor	COE	EPIC & MEES	Solid state and molten salt thermal energy storage; heat and mass transfer; waste heat utilization
Schwarz, Peter	Professor	COB	Economics	Energy and environment; electricity-pricing; demand response
Shaikh, Samira	Assistant Professor	CCI	CS	Natural language generation; computational sociolinguistics and social computing; AI
Sherman, Rachel	Assistant Professor	COE	CEE	Power infrastructure planning; capital planning; power infrastructure resiliency; energy policy
Smith, Michael	Assistant Professor	COE	ETCM	Modeling and control of process systems and energy systems; Electro-Mechanical Systems and Magnetic Shielding System Dynamics; Manufacturing / Machining
Song, Jun	Assistant Professor	CLAS	Mathematics and Statistics	Multivariate analysis; dimension reduction
Sridhar, Meera	Assistant Professor	CCI	SIS	Model-checking; language design and analysis; IoT security; program-proof co-development; security for cyber-physical systems
Tabkhivayghan, Hamed	Assistant Professor	COE	ECE	Real-time embedded vision; Mobile-Edge Computing (MEC); novel architecture for emerging deep learning and machine learning algorithms
Tarbutton, Joshua	Assistant Professor	COE	MEES	Mechatronics; system identification; system dynamics; control design and implementation
Thill, Jean-Claude	Distinguished Professor	CLASS	Geography and Earth Science	Sustainable urbanization and sustainable mobility; Transportation and Mobility Systems; Geospatial Data Science; Urban Analytics and Smart Cities; Spatial Modeling
Tolone, William	Assoc. Dean & Professor	CCI	SIS & Ribarsky Center for Visual Analytics	Collaborative Systems; Enterprise Integration; cognitive social sciences; critical infrastructures
Wang, Chao	Professor & Chair	CCI	SIS	Privacy enforcement in wireless networks; Secure and private location based routing and services; Self-organized intrusion detection and intruder identification methods
Wang, Weimin	Assistant Professor	COE	ETCM	Modeling; analysis; and control of building systems; Sustainable building design and operation; Building grid integration
Wartell, Zachary	Associate Professor & Co-Director	CCI	CS & Ribarsky Center for Visual Analytics	2D and 3D geo-spatial interactive visualizations and stereoscopic display systems
Weggel, Dave	Professor and Director	COE	CEE & ISERRT	Response of structures subjected to extreme loading (blast; wind; seismic; wave); Wavelet-based signal diagnostics; Nonlinear static/dynamic analysis of structures
Whelan, Matt	Associate Professor	COE	CEE	Embedded and Wireless Sensor Design for Structures; Structural Health Monitoring and Experimental Diagnostics; Low-Power RF Networks for Terrestial and Underground Sensing Applications
Williams, Wesley	Associate Professor	COE	ETCM	Magnetic Gearing; Additive Manufacturing; Automation and Controls
Xu, Jun	Assistant Professor	COE	MEES	Multiphysics modeling; multiscale simulation of lithium-ion battery safety; machine-learning based modeling; Design and development of multifunctional energy storage system
Zhao, Tiefu	Assistant Professor	COE	ECE	Grid Edge Power Electronics; Solid State Transformer and Solid State Circuit Protection; Wireless Power Transfer; Microgrid and Renewable Energy Integration; Wide Bandgap Device Applications
Zhu, Lei	Assistant Professor	COE	SEEM	Smart Mobility and Spatial Sensing; Big data and AI in transportation; Shared and Automated Mobility and Micro-mobility Modeling and Simulation; transportation sustainability