

CAN NORTH CAROLINA'S RESEARCH TRIANGLE BECOME A CLEANTECH HUB?

A comparison of cleantech hubs around the world through the Triple Helix Model

*Nicole Affleck, Kaitlyn Ave'Lallemant, Sydney Dobrzynski, Hart Evans,
Heloise Hedlund, Jess Hoffman, Diego Miller-Hernandez, Ryan
Theurer*

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Executive Summary

Introduction

Thanks to its high-ranking universities, industry-leading companies, and inviting communities, the Research Triangle has become a leader in fast-paced innovation and growth. Despite its origins in the biotech, pharmacy, and dot-com sectors, the region is poised to become a leader within the world of clean technology (“cleantech”) and establish itself as a cleantech hub.

This report articulates how the Research Triangle region can better leverage its resources to become a leading cleantech hub. The Triple Helix Model serves as the basis for analyzing collaborative innovation between government, industry, and universities. Cleantech hubs around the world are examined to identify strategies and resources that have allowed these regions to develop successfully. The Research Triangle itself is analyzed and compared with those existing cleantech powerhouses to determine areas of strength and opportunities for growth. Recommendations follow regarding how the Triangle can most effectively leverage its resources, specifically examining its most unique and valuable resource: its concentration of top ranking universities.

Cleantech Hub

Cleantech is a broad term that includes any technology that “can reduce environmental pollution and diminish employment of raw materials, natural resources, and energy”.¹ Some examples of these technologies include smart electricity meters that reduce energy usage, biofuels, electric cars, and solar panels. Hubs are geographic centers that successfully leverage their resources to stimulate innovation and economic development through economies of scale, knowledge exchange, and attraction of talented labor. Together, a cleantech hub is a center of innovation that emphasizes supporting sustainable business and research, as well as the green products and services that come from those entities. Industry, government, and academia each play their own key role in creating and supporting innovation throughout the hub. Each specializes in a specific niche, and their cooperation creates a positive feedback loop of benefits that stimulates local economic growth and innovation.

The collaborative relationship between the entities of this trifacta – industry, government, and academia – is referred to as the Triple Helix Model and is a valuable tool to analyze cleantech hub development. Within this model, industry serves as the main investor, providing capital and resources to incubate startups within a region. The government’s role is the provision of leadership and policy that are required to initiate and maintain innovation within a region. This role is crucial in championing new technologies and creating goals and mandates for hubs to follow. Finally, universities are important to hubs because they supply a skilled workforce and places to conduct cutting edge research. By leveraging its universities, hubs can become what is known as a knowledge society, a variant of the Triple Helix Model that concentrates on the importance of knowledge resource collaboration between universities, industry, and government. This

formulation of the model gives specific significance to how the university entity can be leveraged to create innovation.

Existing Hubs

To further understand the inner workings of cleantech hubs and how they came to be, this paper investigates how San Diego, California, Austin, Texas, and Berlin, Germany have developed into successful hubs of cleantech innovation.

San Diego

San Diego's cleantech industry greatly benefits from strong municipal government support; the city's mayor is committed to cleantech and provides support to innovation across the city. Furthermore, the city's thriving industrial sector takes advantage of San Diego's university resources and available adjacent land to grow their businesses. Finally, San Diego is home to the University of California San Diego (UCSD), a well-respected research university that spurs innovation and economic advancement within the area through startup incubators, which bring the works of students and professors to the marketplace.

Austin

Austin's greatest resource is the University of Texas at Austin (UT-Austin), one of the country's most highly regarded public universities. UT-Austin has not only provides a wealth of well-educated citizens to the area, but also works closely with the city's industrial sector to create innovative technologies. Specifically, UT-Austin has created the distinguished IC² institute, which is dedicated to the incubation and development of tech startups across the Austin region. The Austin city government creates legislature that promotes the implementation of clean technologies and supports the collaboration between UT-Austin and Austin's tech industry. The city also takes advantage of the unique deregulated energy market in the state of Texas by pioneering alternative energy initiatives and technologies.

Berlin

The City of Berlin is recognized globally as a leader in innovation, particularly in the cleantech sphere. One of the ways Berlin has established itself as a leader in this field is through government investment in clean and sustainable technologies. Berlin's influential and expansive network of cleantech clusters sets the city apart from other cleantech regions. Under this cluster model, the government sets aside funding and space for the colocation of universities and industry to initiate efficient knowledge sharing and problem solving. These parks have their own incubators and accelerators that provide resources for cleantech solutions at every stage, from product inception through entrepreneurship and company growth. Examples of this model are Berlin Adlershof, a science and technology park, the CleanTech Innovation Center and the CleanTech Business Park. Finally, Berlin universities, such as Humboldt University and Beuth University, have been major players in providing the knowledge resources to create Berlin's cleantech hub.

Summary of the Research Triangle

The corners of the Research Triangle region of North Carolina are formed by three municipalities, each with its own top-ranked university: Chapel Hill with the University of North Carolina at Chapel Hill (UNC), Raleigh with North Carolina State University (NCSU), and Durham with Duke University. Thanks in part to these three universities, the workforce of this area is highly educated; almost half of the population has *at least* a bachelor's degree and seventeen percent of the population has a graduate degree.ⁱⁱ The Triangle area also has strong economic policies such as the country's lowest corporate tax rate (3%) and strong green policies like Renewable Portfolio Standards that spur rapid solar energy development. Another valuable feature of the Triangle is the Research Triangle Park (RTP). The largest research park in the country, RTP is home to some of the world's most innovative companies, including Cisco and IBM. Given its existing strengths, most specifically its concentration of highly ranked universities, the Research Triangle region is well poised to become a leader in cleantech innovation.

Recommendations and Conclusion

Based on the evidence collected for this paper, there are several recommendations that the Research Triangle area could implement to assist them in becoming a leading and globally recognized cleantech hub. First, it is crucial that state and local governments commit to creating a cleantech hub. This commitment can come in many forms, such as creating green energy mandates, similar to the ones in Germany, and institutionalizing government “champions” of cleantech, who advocate for cleantech-friendly policies. Our second recommendation is to universally strengthen and construct new triple helix connections to promote innovative growth. The creation of a cleantech park within the confines of the RTP, with incentives for faculty, students, and industry to work side-by-side on cleantech research, would demonstrate a clear commitment to a cleantech mentality. The final overarching recommendation is for greater inter-university collaboration. Allowing each university to do what it does best on ambitious, collaborative projects can be a great driver for creating cleantech innovation and attracting cleantech companies into the Triangle area.

The Triangle has a reputation for producing technical innovations; the region was pivotal during the information technology boom of the 1990s.ⁱⁱⁱ Now the Research Triangle has the opportunity to become a cleantech leader, as well. Today, the Triangle has many of the same resources and opportunities as other leading cleantech hubs. It must now strategically leverage its resources to reach success in the cleantech field. While this report reveals that there is value in leveraging universities within cleantech hubs, it is apparent that the other elements and connections within the Triple Helix model are just as important in constructing a cleantech hub.

Introduction

The Research Triangle, and the state of North Carolina by extension, is in a unique position to leverage its resources and become a world-renowned cleantech hub. In order to do so, the local businesses, universities, and governments within the Triangle will have to coordinate their resources and abilities to maximize their collective potential.

The Research Triangle is a section of land in the heart of North Carolina whose vertices are made up of some of North Carolina's most innovative and prosperous cities: Raleigh, Durham, and Chapel Hill. The Research Triangle has been an attractive region for technology companies and innovators for decades, hosting such companies as IBM, Cisco, Lenovo, and many more. One of the most attractive aspects of the Triangle is its high concentration of nationally ranked universities. Each city vertex of the Research Triangle is paired with its own top research university. Chapel Hill has the University of North Carolina at Chapel Hill, Durham has Duke University, and Raleigh has North Carolina State University. By leveraging the academic strength of these schools in the past^{iv}, the Research Triangle came to the forefront of technical innovation during the Information Technology (IT) boom of the 1990s and 2000s and continues to be a leader in the industry today. In recent years though, the cleantech industry has begun to grow in the United States. Now, the Triangle is in an equally advantageous position to become a leader in this industry as it was during the IT boom. Our hypothesis for this report is that the Research Triangle can propel itself to the forefront of cleantech innovation by implementing a strategy that focuses on leveraging its universities.

Cleantech Hub

A discussion on the operation and function of cleantech hubs must be predicated by definitions of both cleantech and hub. Cleantech is a broad term that encompasses any technology that “can reduce environmental pollution and diminish employment of raw materials, natural resources, and energy”.^v These types of products and services span multiple industries and fields of work but are universally designed with sustainability as a priority. Some examples of these technologies are smart electricity meters that reduce energy usage, biofuels, electric cars, and solar panels. A hub is a closely-knit geographic region whose goal is to more efficiently initiate the exchange of knowledge and ideas between the government, businesses, and educational institutions to spur local innovation. These hubs are generally created and supported by local and state governments who believe that this collaborative innovation can be a major engine for economic development and growth in the region.^{vi} It follows, then, that a cleantech hub is a region that focuses its economic and intellectual resources on cleantech products and other sustainable innovations. The definition of a cleantech hub is often complex and difficult to pin down, though, because “it straddles several domains, from the city's physical capital to its intellectual and social capital”.^{vii} For the purposes of this paper, our definition will primarily define cleantech hubs as economic engines for promoting growth and innovation within the green and sustainable technologies industry.

A common theme amongst cleantech hubs is supportive government policy that encourages public and private investment in sustainable innovation. Green policy is critical to the success of cleantech hubs, because as Hall and Helmer state, “policy in this area confronts a double externality problem: the first is private underinvestment in R&D due to partial lack of appropriability and imperfections in the financial markets and the second is the fact that climate change mitigation and reduction in greenhouse gases is a classical public good, and one with a substantial international component”.^{viii} Support from both the public and private sectors allow cleantech hubs to prosper along with the companies that inhabit them which, in turn, can dramatically reinvigorate a region’s economy. Expansion of the existing cleantech industry in the Triangle region can re-invent the area’s economy for the 21st century.

Triple Helix

An effective way to view the operation of a cleantech hub is through the lens of the Triple Helix Model. As shown below in Figure 1, the three “strands” of the Triple Helix Model are universities, industry, and government. Or, in the broad terms of Deakin and Leydesdorff, “(1) intellectual capital of organized knowledge production; (2) wealth creation; and (3) reflexive control.”^{ix} The connection between each of these entities makes the Triple Helix Model effective.

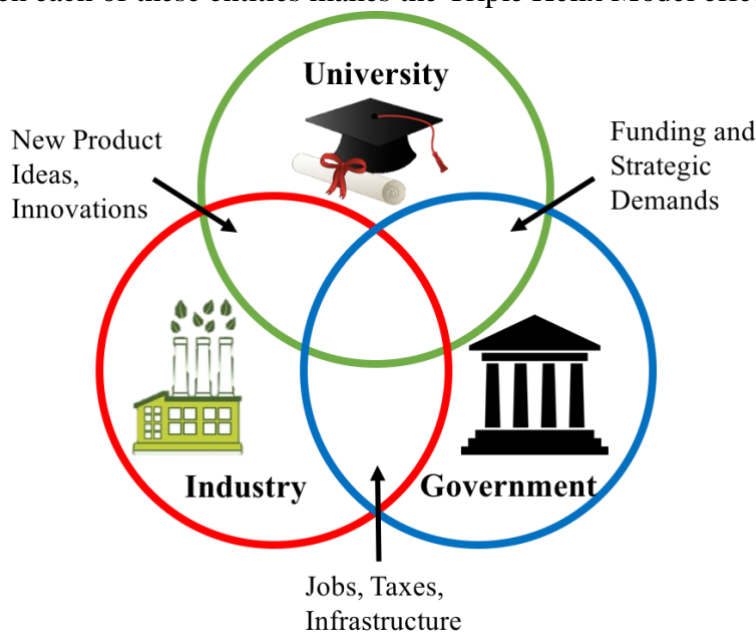


Figure 1: Adapted from Triple Helix Model (Kimatu, 2016)

Each entity within the Triple Helix Model interacts and supports the others in critical ways to contribute to the formation of a cleantech hub. University, for example, provides innovative ideas and technologies and a trained labor force to implement them. Industry and business contribute funding, jobs, and commercial infrastructure, while the government provides direction, policy, infrastructure, and grant funding. All three of these entities work together to create a complex and

dynamic system of innovation. Specialization and cooperation between these entities allows a region to sustain its economic growth and provide services and products to its inhabitants.^x

Industry

Industry's most important contribution to the Triple Helix Model is the provision of capital. Investments, often in the form of venture capital funding, are highly influential in the success of new startups.^{xi} The private sector also provides job-specific training and product expertise to a region and can facilitate intra-industry collaboration to quicken the pace of innovation.^{xii} In relation to the government, businesses create jobs within a region and can lobby for better market policies within their hub. Industry supports a region through the provision of tax dollars that can contribute to infrastructure development. Businesses also play a vital role in supporting universities. Existence of a thriving industrial sector in a region can not only retain talented university graduates but can also provide valuable training to students through internships. In highly articulated versions of the Triple Helix, industry can provide funding to university researchers to solve real-world, industry-specific problems.^{xiii} By leveraging and investing their resources in this way, businesses can be significant contributors to the success of their hubs.

Government

The government provides the leadership and policy initiative required for successful innovation in an area. Some of the most common policy actions governments take are offering subsidies or tax credits, providing regulations or mandates, and “internalizing [an] externality by granting property rights that allow some appropriation of the social benefits.”^{xiv} One highly beneficial action a government can take to support a cleantech hub specifically is creating policies that support startups and decrease the risk that venture capitalists take on when making such investments. Feed-in tariffs, for example, provide businesses long-term contracts with fixed electricity rates. By providing contracts that ensure steady and reliable cashflows, venture capitalists can invest with more confidence and limited risk exposure.^{xv} Governments at all levels can also directly fund innovation through grants or create government-sponsored research labs to conduct their own research.^{xvi} In this way, the government functions as a “public venture capitalist, an instigator, and financier of new firms based on new technology” but with the added significance of representing the voice of its constituents.^{xvii} Other than implementing innovation policy, a government has many tools to maintain a high quality of life within the region that can attract and retain new industries and skilled labor.^{xviii} This can be accomplished through maintaining infrastructure, supporting a high-quality education system, and keeping costs of living low. As may be apparent, many of the actions that a government can take to support business and innovation in an area in general are very applicable to government's support of cleantech innovation.

Academia

The university is a key source of innovation and creativity in the Triple Helix Model. One of the most fundamental resources universities provide for a hub is the skilled labor needed to research, develop, and operate innovative technologies. Human capital is an attractive incentive that a hub

can offer prospective companies. A study by Kim et al.^{xix} found that the two characteristics of a region that affect local entrepreneurship most are “university and college R&D expenditures per capita and number of people of who attained a university degree in the region.” The early stage research that universities conduct is often considered more high-risk than that which industry or government could undertake, so companies are especially interested in partnering with universities to have access to potentially groundbreaking new technologies.^{xx} Research universities also play an influential role in the “...patenting and licensing of academic inventions in supporting technology transfer between universities and industry.”^{xxi} Universities can also be leveraged to take a more direct approach to participating in the economic development of their region. A few examples of leveraging strategies are “the creation of intermediary offices, spin-off firms, science parks, and other interface mechanisms.”^{xxii} The leveraging of universities within the Triple Helix Model is essential to the idea of the cleantech hub and can be a major driver of new and groundbreaking technologies.

Knowledge Society

One of the major strengths of the Triple Helix Model is how it contributes to the creation of a Knowledge Society, or as a society where people (universities, industry, government) can apply publicly available information to accomplish tasks.^{xxiii} Their work in turn provides data from which new theories can be used to guide future actions, creating a positive feedback loop.^{xxiv} By working together under the framework of a Knowledge Society, all three entities within the Triple Helix Model have the opportunity to benefit substantially from resources and specialties that each entity can bring to the relationship. Universities hold a key role within the Knowledge Society, because they are major hubs for knowledge and innovation that drive governments and businesses towards more novel strategies. The core belief behind the Knowledge Society is that the potential for innovation and economic development within it lies in a more prominent role for the university and in the hybridization of elements from university, industry and government to generate new institutional and social formats for the production, transfer and application of knowledge^{xxv}. There are three approaches to the integration of the three players within the Triple Helix Model: the Statist approach, the Laissez-faire approach, and the Balanced approach. All three approaches can be seen visualized in Figure 2.

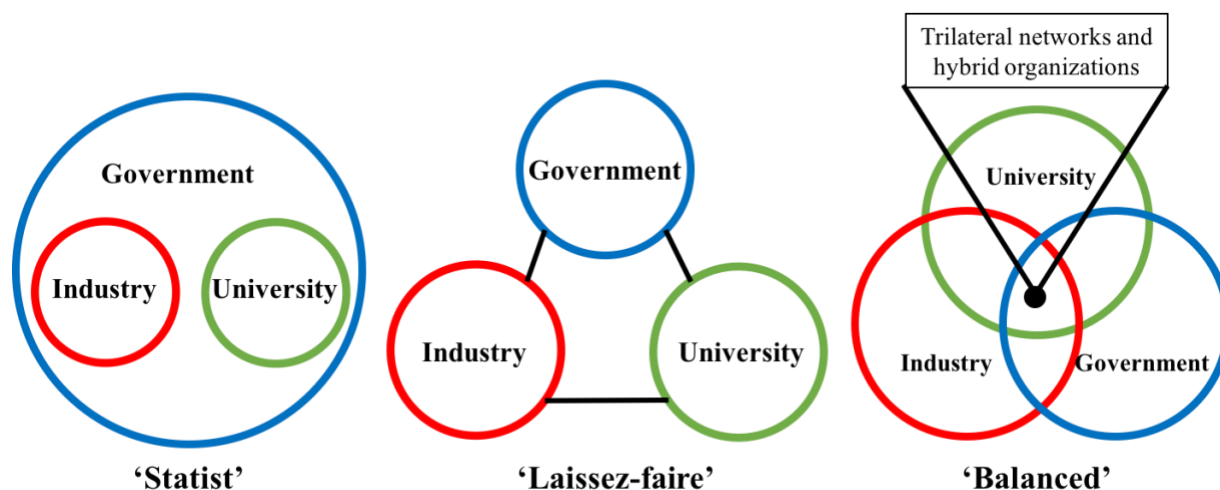


Figure 2: Adapted from *Triple Helix Formations* (Etzkowitz and Leydesdorff, 2000)

Under the Statist approach, the government assumes the lead in driving innovation by coordinating and limiting how the industry and university entities cooperate. The Laissez-faire approach, on the other hand, is characterized by very limited state intervention in the economy. In the absence of the state, industry becomes the driving force of innovation, with the university entity mainly providing skilled labor and the government entity mainly regulating social and economic mechanisms.^{xxvi} This type of configuration is the most common in the U.S. today. The final approach is the Balanced approach. This configuration occurs when the university and other knowledge entities work in tandem with both the government and industry to create innovation.^{xxvii} This approach is specifically tailored to societies that transition to a Knowledge Society. This paper mainly focuses on the Balanced approach of the Triple Helix Model and how universities can be leveraged in a way to create a successful Knowledge Society.

Existing Cleantech Hubs

In order to determine which aspects of the Triple Helix Model need strengthening in the Research Triangle, we assessed the history and shared qualities of three successful existing cleantech hubs: San Diego, Austin, and Berlin. Characteristics were selected from *The Effects of Regional and Neighborhood Conditions on Location Choice of New Business Establishments*, which discussed the conditions of cities that are most popular for new business establishments.^{xxviii} Using various metrics like property tax rates, venture capital, and education demographics, the strength of the Triple Helix is examined in these existing cleantech hubs. The most developed cleantech hubs are located in Europe. While the Triangle can aspire to emulate these European cleantech hubs, the examples of cleantech hubs in the United States, Austin and San Diego, are a more realistic goal for the near future due to their similar environments and available resources. Observing indicators from each of these hubs yields a trend of what political, industrial and academic climates foster a cleantech hub.

San Diego, California

San Diego represents a cleantech hub on the rise and is self-described as a place “small enough to get things done; large enough to make a difference.”^{xxix} The city is the birthplace of the Keeling Curve, the groundbreaking evidence of increasing atmospheric carbon dioxide levels, and has long been known as an environmentally conscious region. In fact, San Diego consistently leads the nation in solar panel installations and EV efforts.^{xxx} San Diego benefits greatly from its location and a progressive local government. Its eastern neighbor, Imperial County, provides resources and a cost-effective location for R&D, and the mayor’s office consistently offers support to startups. San Diego is also saturated in universities that educate the region’s workforce and collaborate with government and industry in cleantech projects.

Perhaps San Diego’s most notable asset is the support provided by mayors for innovation and startups. The Mayor’s office not only supports the creation of incubators, co-working spaces, and accelerators, but also commissions studies to review the local business landscape and understand the strengths and weaknesses of the city’s innovation economy. Additionally, the City of San Diego Economic Development Department assists with site selection, due diligence, tax incentives, permit assistance, fee reductions, financing, and other programs that assist large and small businesses.

The region also benefits from a thriving industrial sector in adjacent Imperial County, nicknamed “California's clean energy playground.” The region receives 263 days of sunshine that supports a year-long growing season and contributes to biofuel development.^{xxxii} Imperial County also contains large amounts of available private and public lands which provide cost-effective facilities to companies for production and commercialization. Industry is encouraged to demonstrate and test prototypes in Imperial County as well as work with the students and faculty at the San Diego State University Imperial Valley campus.

University Highlight: University of California – San Diego

San Diego’s efforts in cleantech are bolstered by a strong network of universities in the area, perhaps the most prominent being the University of California San Diego (UCSD). With a total enrollment of around 35,000 students, the institution boasts strong entrepreneurship and innovative research initiatives that are well integrated within the greater San Diego area.

UCSD is the area’s largest and most prestigious university, currently ranked as the ninth best public university in the country by the US News and World Report.^{xxxii} The university plays a major role in the city’s economy; the UCSD campus is the largest employer based in San Diego County. Additionally, the retention of the talented UCSD alumni is notably high: 73% remain in California, 26% of which remaining in San Diego County. A thriving research atmosphere exists at UCSD as well as a commitment to the environment and entrepreneurship.

Ranked 6th in the world by the journal *Nature* for total research output, over 1,870 patents have been issued to UCSD research.^{xxxiii} UCSD also receives ample research funding – \$1.16 billion for

"AMERICA'S FINEST CITY"

Forbes'

**5th happiest city
for young
professionals¹**



151 craft breweries²



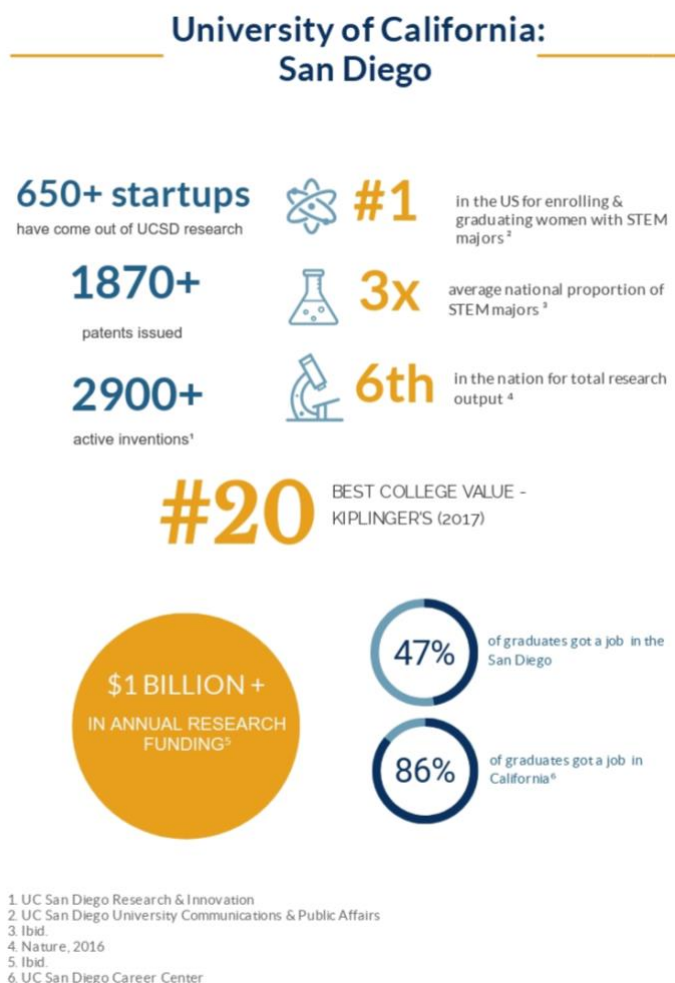
3rd fittest US city³



263 days of
sunshine⁴

AMONG TOP US CITIES FOR
DIVERSITY IN
**race, ethnicity,
language, and place
of birth⁵**

1. CareerBliss
2. California State University San Marcos
3. CBS News
4. Current Results
5. City of San Diego Economic Development Office



the fiscal year 2016/17. A strong focus on environmental research has earned UCSD a ranking of fourth nationally and fifth worldwide for earth and environmental research.^{xxxiv}

The focus on entrepreneurship at UCSD is spearheaded by the Von Leibig Entrepreneurism Center, which aims to “catalyze commercialization of UCSD inventions through grants, education, and business mentoring.”^{xxxv} Over six years, sixteen startups have been founded from projects incubated at the Center which have attracted \$78 million in capital investment and created 130 jobs. The number of co-working spaces on and off campus as well as multiple innovation competitions drive creative work at the institution. In total, more than 750 startups have come from UCSD projects, and nearly 3,000 products have been brought to market.

San Diego’s path to cleantech stardom has been led primarily by the municipal government in the area, which has provided support for cleantech startups and the development of new, green technologies such as solar photovoltaics, electric vehicles, and biofuels. The prominent university in the area has certainly played an important role in furthering the innovative efforts in the area, but did not prove to be the driving force propelling the city to become a leading cleantech hub. The following cleantech hub case study, Austin, Texas, followed a slightly different trajectory to land at the forefront of the cleantech world.

Austin, Texas

Chosen as the capital of Texas in 1839, the City of Austin first experienced major economic and population growth during the early 20th century Texas Oil Boom. Later in the 1980s, the city emerged as a high-tech center for semiconductors and software. Around the same time, its largest university, UT-Austin, grew into one of the nation’s top public universities. Today, the city can be referred to by its various nicknames: The Live Music Capital of the World, Hippie Haven, the “Blueberry in the Red State,” or the Silicon Valley of the South. Capitalizing on Texas’s

deregulated electric grid and the rich source of talent from UT-Austin, the city has become a leader in cleantech innovation.

Government has always contributed significantly to Austin's economy and currently makes up 18% of the workforce.^{xxxvi} The University of Texas at Austin, Texas' premier public university, has served the region with a wealth of talent since opening its doors in 1883. While the concept of government-university cooperation is not new to this region, the development of a high-tech hub and triple-helix collaborations initially began in the 1970s and 1980s with the concurrent creation of the IC² Institute at UT-Austin and establishment of Dell and SEMATECH. Both factors served to create a high-tech boom that lured talented engineers, created an entrepreneurial ecosystem favorable for startups, and cultivated a lively and progressive culture.

In the mid-1980s, Austin attracted major companies that significantly helped the city transition into a tech hub. In 1983, the city gained Microelectronics and Computer Technology Corporation and in 1988 SEMATECH, a not-for-profit consortium for research and development of advanced chip manufacturing. SEMATECH followed the triple-helix model in pooling public and private investment to compete with semiconductor threat, Japan. Notably, Dell, one of the largest tech corporations in the world, began in 1984 from a UT-Austin dorm. The creation of these tech industries attracted young, talented workers who developed a unique culture and progressive identity for the City of Austin. The growth of this youthful culture spurred the creation of festivals like South by Southwest, a music, entertainment, and tech conference that draws in thousands of people annually.

Around the same time, one of the country's oldest incubators, the IC² Institute, was created by UT-Austin's Dean of the College of Business Administration, George Kozmetsky, for the purpose of



"Silicon Valley of the South"



1. CNBC Metro20
 2. Zagat, 2017
 3. Nestpick, 2017
 4. National Geographic, 2017
 5. Austin Technology Incubator
 6. UT Austin Career Services

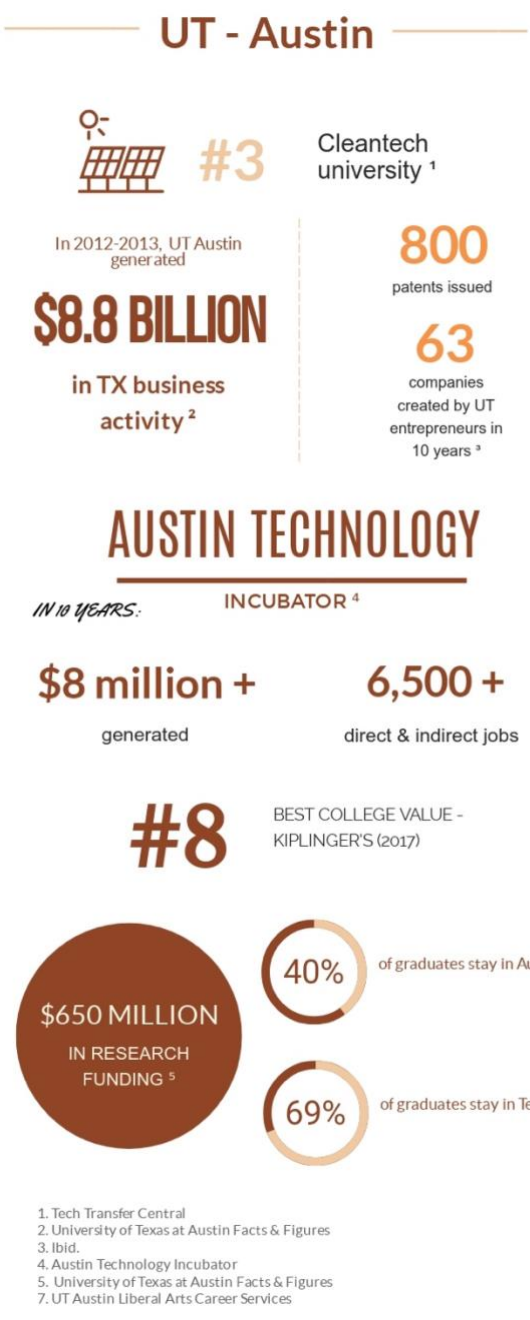
spurring economic development through government, industry, and UT-Austin collaborations.^{xxxvii} Since then, the Austin Technology Incubator (ATI), spun from the IC² institute, has become a prominent force in the region, supporting tech startups by providing mentorship, seed money, and connections to venture capitalists. Companies born from ATI have gone on to support other newer ATI companies and have added 6,500 jobs and \$880 million to the Austin economy.^{xxxviii} One significant company born out of ATI is CleanTX, a cluster development organization founded in 2006 and supported by the Austin Chamber of Commerce and Austin Energy, dedicated to track the growth of the cleantech economy and identify future opportunities for this sector in Central Texas. Founded in 2008, Pecan Street is an R&D collaboration between Austin Energy, the Environmental Defense Fund, the City, and UT-Austin focused on advancing energy and water technology. Heavily financed by the 2009 federal stimulus bill, Pecan Street sought to create a “smart grid” market similar to SEMATECH’s creation of the semiconductor sector.^{xxxix}

Finally, the main factors for the industrial growth of the area have been the deregulation of electricity and favorably low taxes. Texas is highly attractive to businesses and workers by being one of only seven states without income tax. While Texas has no corporate tax rate as well, there is a franchise tax for very limited cases and entities with revenues less than \$1.13 million.^{xl} Another unique aspect of the region is the deregulated electricity grid. The Electric Reliability Council of Texas gives clean energy companies access to the independent grid and strives to provide an efficient, open access grid. A traditionally monopolized sector, deregulation forces utilities to compete for profits by investing in technologies that help their customers use less energy. Renewable portfolio standards begun by the Austin local government in 1999 further encourages companies to “go green” by requiring a certain amount of electricity to come from renewable energy. Austin recently set an ambitious goal to reach 65% renewables by 2025.^{xli} This region’s competition has allowed the energy market to experiment, making Austin a hub for energy innovation.

Overall, established connections between government, industry, and UT-Austin have pushed the region into the forefront of the high-tech and later cleantech space. The establishment of a few large companies and the IC² incubator have created a positive feedback loop of attracting talent and developing startups which went on to support other ventures. While Austin faces the typical growing pains of traffic and transportation problems, its vibrant culture continues to draw in talent and grow the region’s cleantech sector.

University Highlight: University of Texas at Austin

The university component of the triple helix in Austin comes almost exclusively from the UT-Austin community, the flagship institution of the University of Texas system and the eighteenth best public university in the US.^{xliii} UT-Austin is ranked 5th for undergraduate business programs and has many top 10 engineering programs, including #5 in environmental engineering programs and #4 in civil engineering programs.^{xliiii} Given the distinction as the 3rd best cleantech university, UT-Austin has emerged as a leader in this field through its commitment to entrepreneurship and innovation.^{xliiv}



While UT-Austin’s enrollment is greater than 50,000, this large state school successfully creates a sense of community by integrating different departments and creating various certificate programs and specialization tracks. In particular, undergraduates are given the opportunity to participate in bridging disciplines programs (BDPs) to develop a second area of specialization, complementary to their major. Environment & Sustainability and Innovation, Creativity & Entrepreneurship are just two of these 16 interdisciplinary concentrations.^{xliv} MBA students at the McCombs School of Business can choose a cleantech concentration and learn about the policy and technology behind this industry.^{xlvi}

The major driver in UT-Austin’s entrepreneurial spirit is the IC² Institute. Mentioned previously, the IC² Institute and ATI have helped startups succeed for decades. Newer initiatives like the Longhorn Startup Lab, Herb Kelleher Center for Entrepreneurship, and Office of Technology Commercialization have continued this tradition. The Longhorn Startup Lab allows undergraduate students to receive mentoring and co-working space to develop their own tech startup, all while obtaining course credit.^{xlvii} The Herb Kelleher Center for Entrepreneurship strives to link entrepreneurs with students and faculty across many fields to encourage collaboration. Finally, the Office of Technology Commercialization works to translate UT-Austin’s discoveries to the

market by assisting in licenses and providing outreach and opportunities to connect with industry and investors.

Lastly, it is important to note the engineering talent at UT-Austin. The Cockrell School of Engineering awards over 300 degrees a year and houses seven different departments. One of these, the Civil, Architectural and Environmental Engineering department, focuses on areas such as building energy and environments, environmental and water resources engineering, and sustainable systems. Recently, the school launched the Center for Infrastructure Modeling and

Management in 2016 to develop open source water infrastructure models and assist local communities in water management and sustainability.^{xlviii}

While the municipal government of San Diego led the way in that region's movement toward becoming a cleantech hub, in Austin it was academia and industry that played more prominent roles. For Berlin, Germany, a city considered the global leader in cleantech, the story is slightly different still.

Berlin, Germany

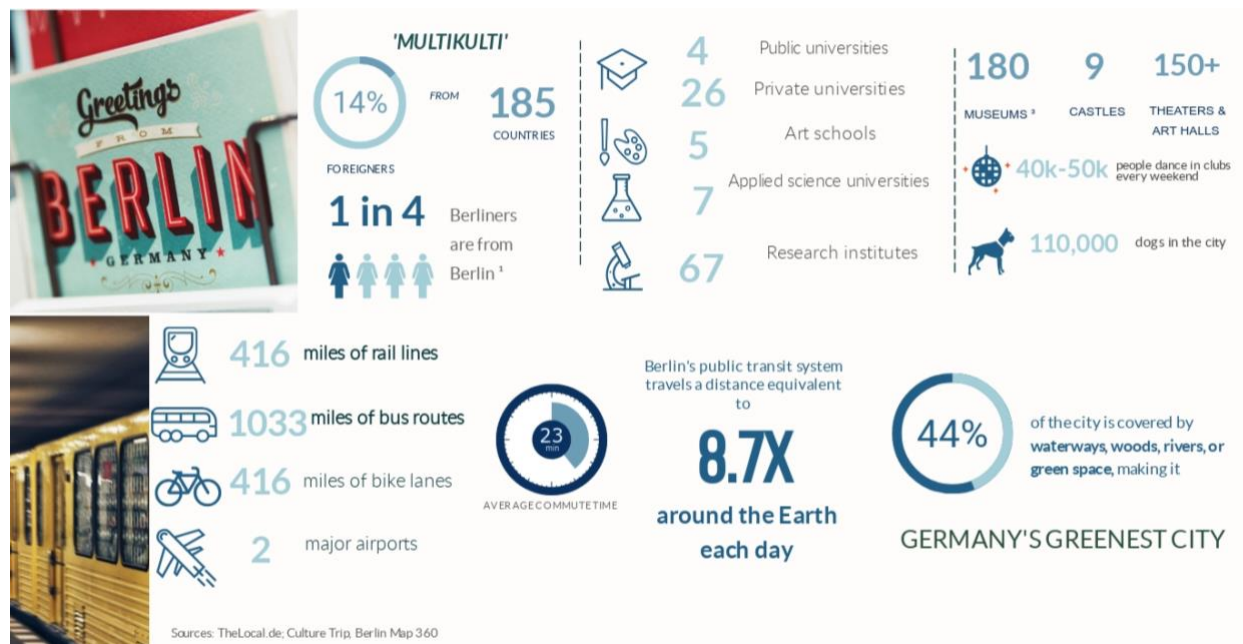
The City of Berlin began as a medieval trading center in the 13th century.^{xlix} Since then it has experienced frequent, radical change through golden periods and darker eras. Nonetheless, the previously divided city has flourished as a lively metropolis in the center of Europe, making Berlin a gateway to the burgeoning markets of Central and Eastern Europe while providing access to the economic regions of Western Europe.¹

The culture of Berlin is vibrant and full of creativity, art, and spontaneity. The rich culture attracts young minds and entrepreneurs to its city center and promotes Berlin as a popular location for business and cleantech. The city has a plethora of available industrial and commercial space in a central, connected, urban location, while two major urban airports promote Berlin's regional, national and international connections. The positive mentality and support of the *Energiewende*, the country's aggressive energy transition to renewable energies, have influenced the culture of innovation and startup ecosystem of Berlin's cleantech sector. The federal government plays a significant role in the success and progress of cleantech with funding and support, emphasis on the triple helix concept, and the implementation of initiatives to form clusters and networks.

The German government is unwaveringly committed to sustainability and innovation. In 2000, 90% of Germany's electricity was produced from fossil-nuclear energies. One of the goals of the *Energiewende* is to decrease the fossil-nuclear produced electricity to 55% by 2025 and to 20% by 2050. To support that vision, Germany officially announced its intention to phase out nuclear power in 2000. All reactors will be closed by 2022.^{li} Germany also has more than a 16% share in international cleantech trade.^{lii} Not only has Germany taken the initiative to transition to more renewable energies, it has also strengthened its approach to promote innovation. In 2014, Germany implemented the New High-Tech Strategy which aims to propel Germany forward as a worldwide innovation pioneer. This strategy outlines solutions in such areas as sustainable urban development, environmentally friendly energy, individualized medicine and the digital society. Today, the High-Tech Strategy is being developed even further as a comprehensive, multidisciplinary innovation strategy.^{liii} While supporting high-tech strategies, the country also focuses its resources on research and development, spending 3.56% of their GDP on R&D.^{liv} With this dedication to sustainability and innovation, Germany is one of the best regions for the development of the cleantech sector.

Additionally, the federal government and the states have initiated a series of projects that focus on establishing networks and clusters to promote new technologies through the collaboration of businesses, research institutions, universities, government, and other organizations – in other words, through the Triple Helix Model.^{lv} Networks and clusters allow for quick and efficient knowledge transfer, create a positive climate for a startup ecosystem, and promote new partnerships. In addition, the City of Berlin supports its entrepreneurs by providing numerous tech centers and business incubators, including several that cluster cleantech industries with incubators, research institutes or universities, and venture capitalists. The cleantech cluster and research activity account for a majority of employment opportunities in Berlin.^{lvi} With this solid foundation of state and federal support to create clusters and networks, Berlin has built several technology parks, as well as specialized cleantech parks, to promote the region as a cleantech hub.

An excellent example of Berlin’s triple-helixed clusters is Adlershof, the largest science and technology park in Europe. It lies southeast of the center city, is only a 6-minute car ride or a 10-minute S-Bahn trip from a major airport, and contains well-developed guest houses, hotels, restaurants, sports facilities, scientific institutions, and Humboldt University’s STEM departments.^{lvii} There are 16 scientific institutions, 6700 Humboldt students, 1041 companies and more than 400 innovative high-tech small to medium sized enterprises.^{lviii} To connect industry with academia, Adlershof has implemented the Joint Initiative of Non-University Research Institutions in Adlershof to “create synergy and new knowledge in Adlershof by facilitating cooperation among research institutes as well as with universities and the business sector.”^{lix} Adlershof centers on innovation and incubation as well, containing pre-incubation facilities, Humboldt University’s Humboldt-Innovation GmbH and business plan competition, and a broad range of services, from coaching and financing to subsidized labs and technological infrastructure. Science and technology parks like Adlershof play an influential role in creating an environment for a cleantech hub to develop by providing infrastructure for research, startups, and education.



Berlin is shifting its focus to cleantech by developing a number of cleantech-specific parks in central locations. The CleanTech Innovation Center (CIC) provides young companies and startups with a focus on cleantech and sustainability with cost-effective working spaces and flexible workshops in an inspiring environment. The CIC supports many manufacturing start-ups in their growth phase through an attractive mentoring program.^{lx} The CIC is in the immediate vicinity of the CleanTech Business Park, which is “Berlin's largest industrial park - optimally geared to the needs of production-oriented companies from the forward-looking cleantech sector.”^{lxi} The young companies mentored by the CIC have the opportunity to grow into available land in the CleanTech Business Park. This cluster of business park and innovation center provides an environment for cleantech companies that is geared towards success and prosperity.

Additionally, the Tegel Projekt is in development and aims to be a new research and industrial park for urban technologies on the land of the former Berlin Tegel Airport. Once complete, it will contain space for businesses, the Beuth University of Applied Sciences, and the Schumacher Residential Quarter. The park will focus on the efficient use of energy, sustainable building, environmentally-compatible mobility, recycling, the networked control of systems, clean water, and the use of new materials. The residential quarter will also have high energy standards and implement progressive solutions for climate-neutral energy supplies.^{lxii} Cleantech Parks like CIC and the Tegel Projekt have enhanced Berlin's cleantech sector and advanced its position as a leading cleantech hub.

Sites like the CIC and Tegel Projekt are emblematic of Berlin's tremendous potential to interlink science and business and promote Berlin as cleantech-savvy city where science-oriented companies can transform innovative ideas into marketable products.

University Highlights

The universities within Berlin have led innovation to create Berlin's cleantech hub. The universities receive 250 million Euros from third party funding alone. Berlin has four public research universities and twenty-seven private colleges, with Humboldt University and Beuth University of Applied Sciences having the biggest influence on the cleantech sector.

Humboldt University

Humboldt University is the oldest university in Berlin and is associated with 55 Nobel Prize winners, major breakthroughs in science, and infamous alumni and professors like Albert Einstein.^{lxiii} Although the university is well known for its prestigious arts and humanities departments, Humboldt provides creative innovators and entrepreneurs with ample resources to foster their ideas and effectively leverages its STEM departments within its campus at Adlershof. The university offers extensive research expertise, comprised of a total of nine research departments including: energy and environment, information and communication, logistics and mobility, markets, finance and insurance, and new materials, procedures and methods.^{lxiv} The university offers patent services to ensure the university's research and inventions are legally protected. The shining star at Humboldt University is Humboldt-Innovation GmbH. This company

acts as the knowledge and technology transfer office of the university and as a liaison between the university and industry. Here, they manage research and development agreements between third parties and research students, find venture capital for university startups, and offer marketing and events services. Humboldt-Innovation also offers professional training, events, and workshops on knowledge and technology transfer to students at the university.^{lxv} Given all of the innovation and research that is fostered at Humboldt University, it is clear that Berlin prepares to develop their cleantech industry even further.

Beuth University

Berlin is on track to develop into an even more sustainable city in the future, and Beuth University of Applied Sciences is the perfect tool to achieve that goal. The slogan for the school itself is “Study the Future”. The university offers 34 bachelor’s and 35 master’s programs and all of them revolve around this slogan.^{lxvi} The three research focuses of the school are media and communication technologies, urban technologies, and life sciences, and all of these groups, in their own way, aim to answer questions like:

“How can we sustain our needs for energy consumption against the backdrop of rapidly declining fossil resources?

How can an increase in mobility and economic advancement be ensured while at the same time bringing about a decrease in energy consumption?

What can be done to avoid traffic congestion and yet continue developing an urban life worthy of living through the employment of green areas and open spaces?

How should buildings be constructed with all modern conveniences in the City of the Future while at the same time reducing their carbon footprint?”^{lxvii}

Beuth University is a college directly preparing their students to further the development of cleantech in their communities. They partner with companies through their co-op program where students are able to gain work experience through big name companies like Audi, Burger King, and Deutsche Bahn.^{lxviii} Beuth University connects this cleantech minded talent with industry in the area to accelerate the achievement of the city’s sustainability goals.

Between the STEM talent available in Adlershof, the innovation and entrepreneurship resources at Humboldt University, collaboration with industry in multiple methods, and a school dedicated to preparing the city for a sustainable future, the universities within Berlin are an irreplaceable asset to its creation as a successful global cleantech hub.

The Research Triangle

The Research Triangle region of North Carolina, often called the Triangle, is widely recognized as a center of innovation and progressive culture in the state. The Research Triangle contains multiple municipalities, but each of the Triangle’s three vertices includes a municipality and a top ranked university: Chapel Hill is proud to be centered around the University of North Carolina at

Chapel Hill, Durham is home to Duke University, and the state capital of Raleigh is where North Carolina State University is located.

The region is well on its way to becoming a leader in cleantech and sustainability, thanks in part to many state-level policies. The solar industry in North Carolina has been propelled by an aggressive renewable energy portfolio standard; the state has mandated that by 2020, 12.5% of all retail electricity sales will come from renewable energies. In fact, North Carolina is the only state in the southeast with a renewable portfolio standard. Additionally, until December 2016, North Carolina also offered a state tax credit of 30% for renewable energy installation. These two surprisingly progressive sustainability policies have allowed North Carolina to be ranked second in the nation for installed residential solar.^{lxxix}

Much of the Triangle's development in recent years can be attributed to its rapidly growing population. The population in the Raleigh-Durham-Chapel Hill area tripled in the 40 years between 1970 and 2007.^{lxxx} According to the Census Bureau, eight of the twenty-five fastest-growing municipalities in NC in 2015 were located in the Triangle. This trend has brought about significant economic growth and has contributed to the accelerating pace of innovation. Additionally, the population in the area is relatively young, with a median age of 36.7, promising a continued workforce and economic growth in the region's future. However, demographic diversity is relatively low when compared to other cleantech hubs: 59% of the population is white, while 22% is black, and only 11% is Hispanic.^{lxxxi}

When analyzing which trends and characteristics attract the above-mentioned demographics to the Triangle, the surrounding higher education institutes influence becomes apparent. Due to the high concentration of top ranked universities in the region, the population of the Research Triangle is among the highly educated in the nation. Over half of the population has at least a bachelor's degree, which is 1.4 times the national average, and 17% of the population has a graduate degree.^{lxxii} It is no surprise that Raleigh and Durham are ranked two and three, respectively, as "Most Educated Cities in the U.S." by NBCNews.^{lxxiii}

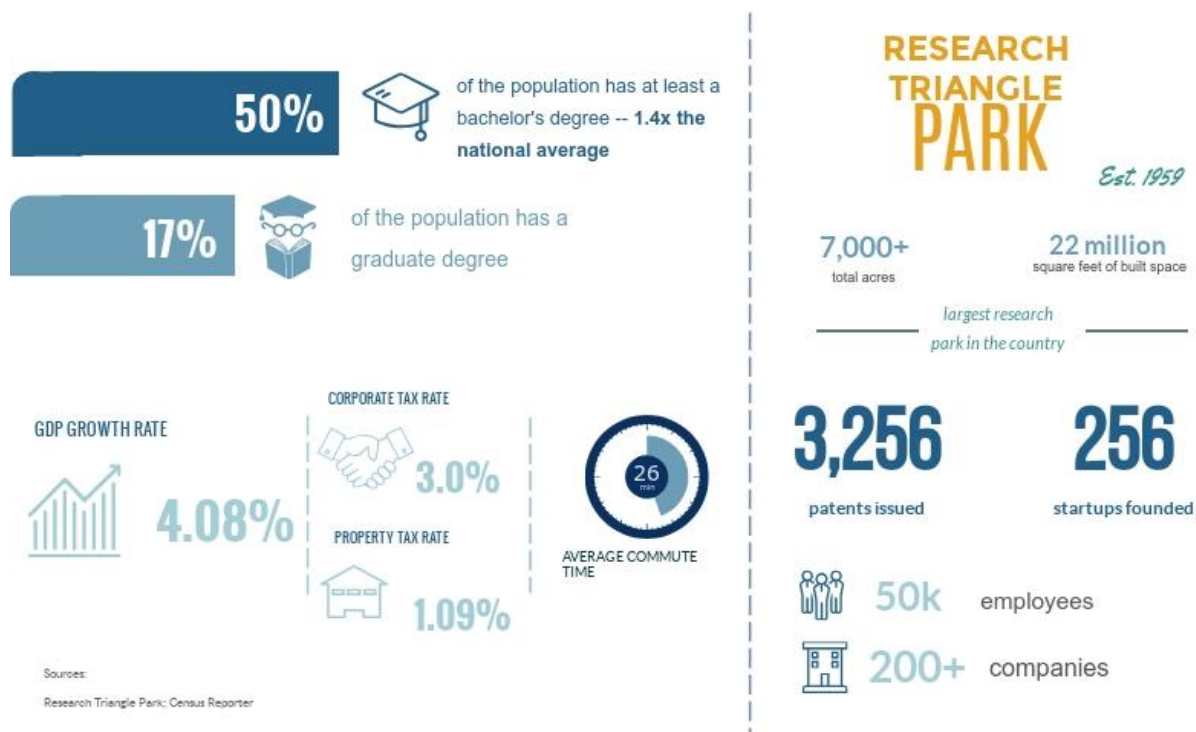
In addition to its highly educated population and favorable state policies, the region also enjoys an attractive business climate. The low property tax rate of 1.09% and large amount of available space for urban and suburban growth support increased development in the area. A corporate tax rate of just 3.0% is attractive to business, and a lower than average cost of living can attract and retain a professional workforce.^{lxxiv} While there is not a particularly strong network of public transportation (although a light-rail project is in the engineering stages), the average commute time is only 26 minutes.^{lxxv} One of the most attractive elements to prospective businesses, however, is the Research Triangle Park.

Research Triangle Park

One of the Triangle region's greatest assets is the Research Triangle Park (RTP). At 7,000 acres, this unincorporated district is the largest research park in the United States with over 22.5 million square feet of built space.^{lxxvi}

Originally, the Research Triangle Park (RTP) was created by the state government in an effort to revitalize North Carolina's economy in light of a significant post-war decrease in the state's textile and tobacco industry. The original visionaries accredited for creating the RTP are Brandon Hodges, the state treasurer of North Carolina (and later governor), Robert Hanes, the president of Wachovia Bank and Trust, and Romeo Guest, a Greensboro builder. Notable RTP pioneers are Chemstrand Corporation, the first company to join the park in 1959, the National Environmental Health Sciences Center, and International Business Machines (IBM). All three companies significantly contributed to the economy of the region and the success of the Research Triangle Park.^{lxxvii} It was not only government and industry contributing to the growth of the park, however. UNC sociology professor, George Simpson, promoted the park and met with over 200 companies in order to develop the groundwork for a tech-based economy.^{lxxviii} The presidents of Duke University and UNC-Chapel Hill also collaborated with the RTP to create a "park within the park," officially known as the Triangle Universities Center for Advanced Studies, Inc.^{lxxix} This substantially increased university involvement in the RTP's growth. Presently, North Carolina State University has a much more significant role with the RTP, as its business school, Jenkins MBA is located in the park.^{lxxx}

Currently, the RTP is home to 250 companies and employs over 50,000 people. A staggering 3,256 patents have been awarded to RTP research since its creation, averaging to around 50 patents per year. Additionally, 245 company startups have been founded at the RTP and 1,970 trademarks have been received for cleantech products.^{lxxxi} Microelectronics, telecommunications, biotechnology, chemical development, pharmaceuticals, renewables, and environmental sciences are all fields of expertise found in the RTP. According to Susan Sanford, Executive Director of



the Research Triangle Cleantech Cluster (RTCC), three historical industrial waves have influenced the growth and focus of the RTP: Informational Technology, Life Sciences, and Cleantech. Starting with the initial push towards Information Technology in the 1950s, the RTP worked to keep up with the technological trends of the time period. A trend towards Life Sciences most likely mirrored the neighboring universities' push towards the same subject matter. For example, UNC-Chapel Hill's increasing role in chemistry, biology, microbiology, medicine and biostatistics^{lxxxii} coincided with the Life Science era of the RTP. Finally, the significant transition towards clean technologies supports the RTP's quest for cutting edge research. The cleantech conversation is not only centered on environmental protection, but also on economic profitability; cleantech appears to where the market is headed. With an increasing demand for cleantech, this field will continue to grow in this region, propelled by resources and assets unique to the Triangle.

What really defines the Triangle region is not the Research Triangle Park or favorable tax rates; it is the cluster of top-tier universities. These institutions have an unmistakable impact on the workforce and economy of the region and are certainly the area's greatest asset.

Research Triangle Universities

The University of North Carolina at Chapel Hill

The University of North Carolina at Chapel Hill (UNC) is a public research university located in Chapel Hill, North Carolina. UNC nationally ranks 30th among all universities and boasts a 90.1% graduation rate.^{lxxxiii} UNC has 18,862 undergraduates, 11,049 graduates, 8,765 staff, and 3,887 faculty.^{lxxxiv} The university ranks 5th in top public universities and the Kenan Flagler School of Business ranks 7th nationally.^{lxxxv} 82% of UNC students are from North Carolina.^{lxxxvi} The university has 77 undergraduate major programs, 111 graduate degree programs, 65 doctoral programs and 6 professional degree programs. Biology, Journalism, Exercise Sports Science and Economics are among the top undergraduate programs at the university.^{lxxxvii}

Research

UNC is the 11th largest research university in the nation with over \$1 billion in funding. It ranks 6th nationally in federal research. Out of all research carried out in the UNC system, 61% comes directly from UNC.^{lxxxviii} There are 15 research labs, 15 research institutes, and 36 centers for research. In 2015, UNC created the Office of Entrepreneurship and Economic Development to foster support and funding for students, faculty, and staff who have inventions and technologies that could make it to the market.^{lxxxix} The office also secures external partnerships with various industries and businesses in order to bring UNC research to market. In addition, the office fosters an innovative startup environment. They provide training, mentorship, funding, and assistance with securing incubator space. The Corporate and Foundation Relations and Talent Management Office encourages collaboration between the university, corporations, and foundations. This

UNC CHAPEL HILL

a total of:

768

patents and

116 startups

have come out of UNC research,
receiving

\$989 million

in funding ¹

58%

of graduates stay in
NC ⁴

#1

BEST COLLEGE VALUE -
KIPLINGER'S (2017)

\$1 billion +

in annual research
expenditures ²

RANKED

11TH

FOR ANNUAL
RESEARCH OUTPUT ³

1. UNC Office of Commercialization and Economic Development
2. UNC Facts & Figures
3. Ibid.
4. Undergraduate First Destination Report

touches on the Triple Helix Model that pairs the university with businesses in order to create meaningful partnerships that benefit both parties. From UNC research alone, 74 products went to market in 2017.^{xc}

Entrepreneurship

While UNC prides itself on its research and nationally recognized liberal arts education, the university also places a great deal of emphasis on entrepreneurship and business education. With the Kenan Flagler Business School ranking 7th nationally among all business programs, one of UNC's top priorities is honing in on programs to help the business school continue to flourish.^{xcj} The school has an entrepreneurship concentration for the MBA programs, which ranks 8th nationally by U.S. News and World Report.^{xcii} Additionally, Chapel Hill ranks 5th nationally for the best cities for entrepreneurs by Livability.^{xciii}

UNC has created and partnered with several entities to create 4 entrepreneurial initiatives that foster a thriving startup ecosystem. The Office of Commercialization and Economic Development helps with these initiatives and connects innovators with investors and other resources. The office is also responsible for the creation and maintenance of industry partnerships. Connecting university research and startups with industry is a key link to a successful region. UNC has strategic partnerships with Glaxo Smith Klein, Eastman, and iRODS Consortium, which is operated by RENCI.^{xciv} Startup UNC is a program that offers a number of classes to help students and faculty launch commercial businesses and social ventures. Since 1999, the program has started over 60 new businesses and nonprofits.^{xcv}

The second program, Launch Chapel Hill, is a business accelerator program that was created through collaboration between UNC, The Town of Chapel Hill, Orange County and Chapel Hill Downtown Partnership. The program is lasts 22 weeks and includes mentorship from one of three entrepreneurs-in-residence. These entrepreneurs have had success as founders and leaders of multiple startups throughout their careers. Launch also connects startups with experts in marketing, legal, accounting, and business fields, and oftentimes these services are pro bono or offered at preferential rates. Additionally, Launch offers collaborative office space at an affordable rate to provide meeting spaces for startups.^{xcvi}

The Small Business and Technology Development Center is a business and technology extension of UNC and is administered by NC State. The center provides management and educational resources to young businesses free of charge. 1789 Venture Lab is a central hub for upcoming entrepreneurs. The lab offers free workspace as well as free mentoring and is located in the heart of downtown Chapel Hill.^{xcvii} The last initiative is Innovate Carolina, which aims to embed innovation into the teaching and research realms at UNC. From this initiative, UNC has established Be A Maker (BEAM) Spaces in 3 campus locations. These spaces have 3D printers and metal and woodworking shops, providing students with resources and training to create their own products.^{xcviii}

Graduates

UNC conducts a yearly survey in order to gauge what graduating students will be doing post-graduation. Of the students surveyed in 2016, 72.4% were employed within 6 months of graduation. Another 22.2% were planning to continue their education. Of those continuing their education, the most popular education paths were arts and sciences, medicine, law, and accounting. The overall success rate of the class of 2016 was 95.8%. Graduates tend to remain on the East Coast, with 81% staying in this region for either career or education opportunities, but only 58% of UNC graduates remain in North Carolina after graduation.^{xcix}

Duke University

Duke is a private research university located in Durham, North Carolina. Duke ranks 9th among all universities in the United States and prides itself on its 94.5% graduation rate.^c The Pratt School of Engineering also ranks 20th nationally and encompasses civil, biomedical, mechanical, electrical, environmental and computer engineering. Other highly regarded schools at Duke are the Fuqua School of Business, the Nicholas School of the Environment, and the Sanford School of Public Policy. Duke has 3,637 faculty, 6,532 undergraduate students, and 8,660 graduate students. The most popular majors are public policy, economics, biology, biomedical engineering and computer science. The majority of students are from North Carolina, California, Florida, New Jersey and New York.^{ci} 34% of all students remain in North Carolina after graduation.^{cii} Duke's alumni network consists of 167,484 alumni all around the world and has a median age of 47 years.^{ciii}

Research

Duke ranks 10th nationally in research with \$1.055 billion spent on R&D in 2016.^{civ} Of these funding expenditures, approximately \$500 million comes from government agencies.^{cv} With top tier medical and engineering schools, a great deal of research emerges from Duke. In 2017, 315 products were brought to market and 85 patents were issued through research at Duke.^{cvi}

Duke has 11 research centers and institutes. Notable examples include the Global Health Institute and the Information Initiative at Duke. In addition, the Fuqua School of Business has 5 research institutes that delve into business-specific research. The Center for Entrepreneurship and Innovation serves to connect Fuqua with businesses that are known for top-notch research and

innovation. The institution's competitive environment makes it one of the top innovation and entrepreneurship centers nationally. The Center separates itself from other centers through "two core ideas: a strong, interdisciplinary research foundation, and a multifaceted integration of research, teaching, and practice"^{cvii} Through this center and others at Duke, startup companies in 2013 were able to contribute \$69.3 million to regional income, which is equivalent to 297 jobs.^{cviii}

The Pratt School of Engineering has worked diligently to connect university engineering research efforts to industry. The program at Pratt puts students in contact with top corporations through internships, fairs, and research sponsorship. The MEDx initiative fosters collaboration between engineering and medical research conducted at Duke in order to create a strong network that produces leading research in these two fields. Pratt School of Engineering had 7 new startups, 37 patents, and 18 new license agreements from inventions in 2017 alone.^{cix}

Entrepreneurship

There are numerous programs that foster innovation and entrepreneurship at Duke, which has led to many success stories. There are also a number of entrepreneurship-related degree tracks as well as classes. Trinity School of Arts and Sciences offers a certificate in entrepreneurship and innovation; Fuqua School of Business has an entrepreneur and innovation concentration as well as a social entrepreneurship concentration for the MBA program; Sanford School of Public Policy has the Hart Leadership Program and the Social Entrepreneurship and Policy Initiative; Duke Law School has an entrepreneurship-focused program; and Nicholas School of the Environment has the Environmental Certificate in Innovation and Entrepreneurship.^{cx}

In 2017 alone, Duke had 11 startups, 7 of which came exclusively from Pratt School of Engineering. \$1.2 billion has been raised in private and public financing for startups at Duke over the last 10 years and has led to the creation of 74 new companies and 5 initial public offerings (IPO).^{cx} The Duke Innovation and Entrepreneurship Initiative is housed in Downtown Durham in a building known as the Bullpen. The Bullpen provides resources for entrepreneurs, including working space. The Innovation and Entrepreneurship Initiative is also responsible for the creation of the new Duke Incubation Fund. The fund is designed to provide awards of up to \$20,000 for novel ideas that have potential to create new companies, fund non-profits and bring products to



market.^{cxii} The Duke Angel Network is another great resource for entrepreneurs, which is designed to connect the Duke Alumni network with the Duke entrepreneurial world and secure investments for these ideas. To qualify for this program, the investors and the entrepreneurs need to be Duke alumni.^{cxiii}

Graduates

The starting salary for a Duke graduate is \$62,700. In 2017, 1,668 students graduated from Duke. A post-graduation survey was conducted with a 58% response rate. Of the respondents, 72% are taking a full-time position, 21% are continuing their education, 3% are planning to take time off to travel, 2% are undecided and 2% are starting their own business. Of those continuing their education immediately after graduating in 2017, 35% are pursuing a master's degree, 29% are going to medical school, 20% are getting their Ph.D., and 12% are going to law school. The top industries employing the Class of 2017 were finance, computer technology, business, science and research, biotech, and engineering.^{cxiv}

North Carolina State University

North Carolina State University (NCSU) is the largest four-year college in North Carolina with roughly 24,000 undergraduate students. Ranked 81st by the US News & World Report, the university has 300 undergraduate and graduate degrees in 65 departments. The most popular major is engineering, making up 27% of the undergraduate population.^{cxv}

One thing that makes NCSU stand out from its regional peers is its Cooperative Education (co-op) Program. This unique program allows students to gain valuable experience in the field by alternating their full-time academic load with full-time employment. Not only does this provide students with industry experience, but it also provides partnered employers with talented labor.^{cxvi} Over the past 15 semesters, the number of students who found their co-op experience “very helpful” in securing a full-time job has steadily been above 65%.^{cxvii}

Research

North Carolina State University is ranked fifth in the nation for industry-sponsored research, boasting nine federally-funded public-private partnerships, including two National Science Foundation research centers. The university has received more than \$400 million for new sponsored research, and it is ranked sixth nationwide for “commercialization agreements based on university research”, thanks in part to the strength of its engineering program. Over 950 patents have been issued for research coming from NCSU, and more than 575 products have been brought to market.^{cxviii}

NCSU is one of only two universities in the nation with two NSF research centers. The Nanosystems Engineering Research Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) researches wearable health monitoring nanotech sensors that derive the energy for their functions from the human body. The goal of the center is to develop ultra-low power sensors and has since developed three: one that monitors asthmatic breathing and

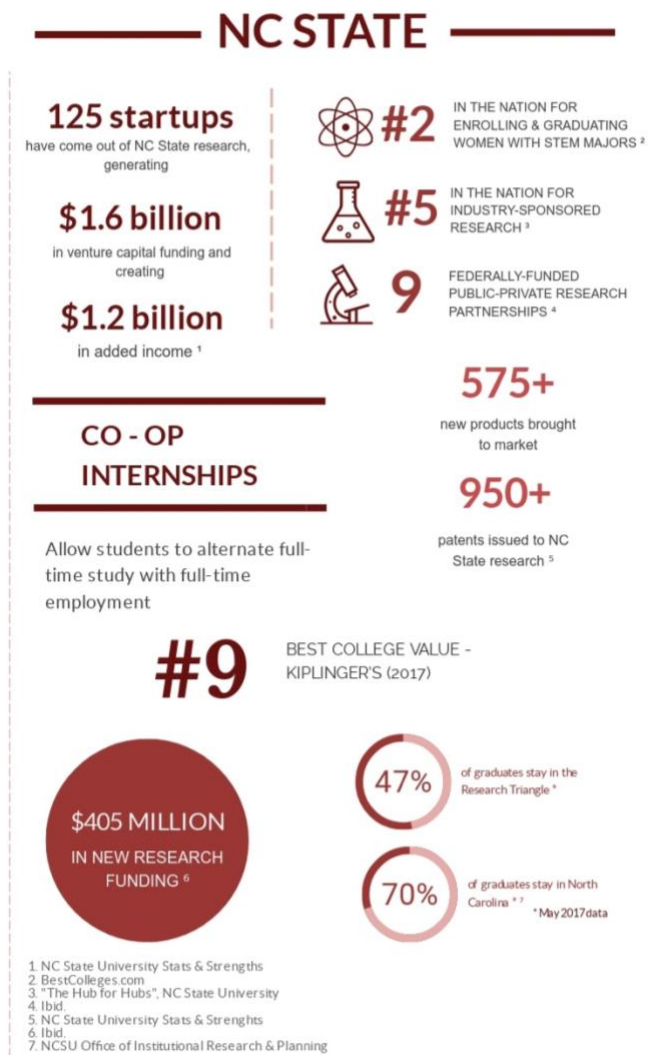
air quality; one that tests glucose levels through sweat; and one that monitors the cardiovascular system. The Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM) Center directs its NSF funding toward researching “an improved electric grid that can handle bidirectional energy flow and integrate larger percentages of renewable energy sources -- and the pieces that make it work.”^{cxix} Both of these impressive research centers are examples of a Triple Helix configuration: collaboration between the government, academia, and private industry to bring about revolutionary innovation.

In addition to their NSF research centers, NCSU is home to seven federally-funded public-private partnership research endeavors. These centers investigate climate change solutions for southeastern farmers, nuclear nonproliferation, advanced electronics manufacturing, modern nuclear reactors, big data analytics, and new manufacturing technologies.

Entrepreneurship

Although engineering and research are certainly a highlight of both the academia and culture of NC State, the university also supports a strong “Entrepreneurial Ecosystem.” The programs, spaces, competitions, and resources available to NC State students have contributed to the institution’s success as a hub of innovation. More than 125 startups have come from research taking place at NC State, generating \$1.6 billion in venture capital funding and creating \$1.2 billion in added income.^{cxx}

NC State has multiple physical spaces on campus for student entrepreneurs, including multiple “Makerspaces” with 3D printing and scanning tools, an electronics lab, and laser cutting; a Materials Lab with woodworking and metalworking tools; the eGarage, a game lab featuring technologies and tools for software development; and the Entrepreneurs Village, an experiential dorm community for student entrepreneurs that provides unique immersive resources and opportunities. The university also leverages its location in downtown Raleigh. The Entrepreneurship Clinic, run out of a co-working space in the city, offers students a chance to work with faculty and industry partners to solve real-world problems for class credit.^{cxxi}



The university understands the necessary linkage between successful research and successful entrepreneurship and capitalizes on its resources to provide for both through various collaborative programs. The Engineering Entrepreneurs Program provides innovative entrepreneurship education to seniors in the College of Engineering by simulating the process of conceptualizing a new product, creating it, and bringing it to market.^{cxxii} The MBA program's Product Innovation Lab was listed among Forbes' ten most innovative courses in 2010. This collaboration between the Poole College of Management, the College of Design, and the College of Engineering provides students across a range of disciplines with the challenge of product ideation and development.

Graduates

According to a survey conducted each semester on plans of recent graduates, a majority (between 45 and 65 percent) of NCSU students remain in the Triangle after graduation. Roughly one (1) percent of graduates (around 15-20 students) plan to start their own business each semester. Since December of 2012, the number of students graduating with a full-time job has been greater than the number seeking employment, and the highest employed major is consistently engineering.^{cxxiii}

Cleantech hub assets present in case-study regions	San Diego	Austin	Berlin	Research Triangle
<u>BUSINESS-FRIENDLY ENVIRONMENT</u>				
Under 30 min. average commute	✓	✓	✓	✓
International airport	✓	✓	✓	✓
Favorable tax rates and costs of living	✓	✓	✗	✓
Assistance for new businesses	✓	✓	✓	✓
Available space	✓	✓	✓	✓
<u>SUPPORT FOR SUSTAINABILITY AND CLEANTECH</u>				
Sustainable urban development plans	✓	✓	✓	✗
Cleantech park(s)	✗	✗	✓	✗
Cleantech research groups/programs	✓	✓	✓	✓
Renewable energy portfolio standard	✓	✓	✓	✓
<u>RESEARCH AND INNOVATION</u>				
Research institution/park	✓	✓	✓	✓
Incubator(s)	✓	✓	✓	✓
<u>INTEGRATED UNIVERSITY PRESENCE</u>				
Ranked universities	✓	✓	✓	✓
Highly educated population	✓	✓	✓	✓
Co-op	✓	✓	✓	✓
Co-working spaces	✓	✓	✓	✗
Business mentoring	✓	✓	✓	✓
Patent services	✓	✓	✓	✓
Innovation/entrepreneur competitions	✓	✓	✓	✓
Institute/center for entrepreneurship	✓	✓	✓	✓
Product development resources	✓	✓	✓	✓
Research collaboration with industry	✗	✓	✓	✗

Table 1: Cleantech Hub Metric Comparisons

Recommendations

On paper, the Research Triangle is similar to the other existing cleantech hubs mentioned throughout this report. Table 1 visualizes a comparison of our cleantech hub case studies according to metrics selected for their ability to stimulate and maintain growth in cleantech. As is apparent in the table, the area has a favorable financial environment for business, an educated population ready to offer their talents, and a growing list of distinguished cleantech companies that already call the Triangle home. The resources are here, but because the region has not achieved the same cleantech success as its peers, perhaps they are not being implemented in the most effective way. This paper provides recommendations for the Research Triangle to grow into a prominent cleantech hub that fits into three categories: state commitment to cleantech, stronger Triple Helix connections, and inter-university collaboration.

State Commitment to Cleantech

First, support for sustainability and cleantech adoption among the public, but especially the government, is an essential ingredient in any cleantech hub. This support can come in the form of general government policy and funding, and more specifically, a regional “champion” for cleantech. A champion in a position of power can promote cleantech and assert more aggressive sustainability goals and financial incentives for cleaner energy resources or increased energy efficiency. A prime example of a cleantech champion is the mayor of San Diego, Kevin Faulconer. Faulconer embraces cleantech by commissioning studies to ascertain potential areas of growth in the field. A similar model could be implemented in the Research Triangle. Considering the Research Triangle is comprised of multiple municipalities, each with their own mayor and local government, it would be difficult to have a single champion in cleantech. However, multiple cleantech champions from several of the Triangle’s municipalities can work together to promote the region as a cleantech hub.

Following Berlin’s example of cleantech parks, a portion of the Research Triangle Park must be dedicated specifically to the cleantech sector. This area of the RTP would specialize in providing space and support for cleantech startups and research, better allowing the sector to thrive and grow in the RTP and in the Triangle. In Berlin’s cluster of the CleanTech Innovation Center and CleanTech Business Park, young companies have the option to grow into available office space in the adjacent business park. This is a possible expansion option for the RTP. The startups that develop in the RTP can remain in the park and contribute to the regional economic growth as well as the transition to cleantech. This portion of the RTP can collaborate in the research, development, and production of new technologies to cultivate the sustainability goals local municipalities hope to achieve. Integration of universities into this area of the park – via internships, case competitions, or the like – would further solidify the innovative potential of this recommendation.

An environmentally-conscious populace and government creating demand for sustainable enterprise is a trend observed in all case study cleantech hubs. In each case, government policies protect and promote cleantech initiatives to some degree. Public sector policies like renewable

energy portfolio standards (REPS), tax credits for renewable energy generation, and deregulated energy markets all contribute to cleantech innovation and implementation. Texas's deregulated electric grid and REPS have spurred innovation in the energy industry in Austin, both in renewable energy and in energy efficiency technologies. Like Texas, North Carolina also has influential REPS. North Carolina's REPS and the state's tax credit for renewable energy installations, which expired in 2016, still drive the nation's second largest solar market.^{cxxiv} While deregulating the electric grid is an ambitious project, reinstating the renewable tax incentive is a simple measure that will maintain the region's status as a leader in solar. While the solar installation process requires extensive permitting and land evaluation work, the government can assist in this process by publicly allocating the Triangle's copious amounts of available land for renewable energy projects. As we have seen, however, the state is not the only power that can contribute to a progression toward cleantech success. A comprehensive strategy to achieve success as a cleantech hub requires government's integration with academia and business.

Stronger Triple Helix Connections

Although the individual sectors of academia, government, and industry within the Research Triangle are successful in their own rights, the interconnections between these sectors must be bolstered. Unlike the other existing cleantech hubs, the Research Triangle is composed of multiple separate cities and three independent universities. This poses a challenge to maintaining connection between universities, the RTP, and municipalities. Improvements in transportation could serve to much more effectively integrate universities with each other and with the RTP. Currently, there are bus routes that run between all of the universities, but they are limited to either peak times or on the hour, and only on weekdays. Specifically, the Triangle needs greater transportation connections between the Research Triangle Park and universities to bridge the gap between academia and industry by increasing access to collaboration opportunities. The new light rail system being built in the Triangle is the perfect opportunity to upgrade the transportation between all three universities and between universities and industry at the Research Triangle Park given there are stops at these locations and a convenient schedule. Increasing non-peak bus frequency as well as allowing buses to run later into the evening hours are a few changes that can be made in the short term while the region awaits the light rail system. It is imperative that the routes for the light rail and its feeder buses consider providing connection between universities and municipalities as well as between universities and industry in the RTP. The technology and cleantech parks that are found in Berlin are often associated with a university, however the Triangle has the unique opportunity to connect its research park with not one, but three exceptional universities, UNC, Duke, and NC State.

Traditional faculty funding models in the United States, particularly for tenured faculty, do not typically encourage industry collaboration. Course buy-outs, or, even better, incentives for faculty to involve students in collaborative, industry-funded research offer opportunities for students to work with cutting-edge technologies and interact with leading industry researchers. Berlin's Adlershof offers a great example of how industry-university research and collaboration can be combined with start-up incubators and business accelerators to maximize real-world learning while also launching new, successful companies.

Not only can the government create a specialized place for this collaboration, universities can also create programs that connect academia and industry. One option is through a co-op internship where students are able to take their summer or a full semester off to work full time for a company. This gives companies a great opportunity to utilize the talented college students in the region. Students learn about the inner-workings of industry and are able to apply the skills they are learning in classes to their careers. NC State and Duke already have this program available to their students, but students must fit a co-op within their class schedule in order to participate. UNC students are only able to take a full-time internship if they withdraw from school to take the semester off. Expanding internship programs, and specifically co-op programs, in all the schools in the Triangle gives companies in the region more opportunities to link up with the university students. Specific internship programs linked with the Research Triangle Park could further strengthen that university-industry connection element they are aiming towards and give their companies another advantage to being a part of the park. Although UNC does not have a co-op internship program, students are able to collaborate with companies through a client-based, research-intensive course, called a capstone. Similar to programs offered at Berlin's Humboldt University, capstone courses allow for companies to reach out to universities for assistance in performing research and developing new products.

Additional opportunities for collaboration between universities and the private sector can arise from innovative partnerships. University-based accelerators and incubators, like Austin Technology Incubator connected with the University of Texas at Austin, pair new companies with faculty expertise to accelerate product development at little or no cost to the company. San Diego provides cost-effective facilities in neighboring Imperial County, encouraging companies to join with San Diego State University's Imperial Valley campus for demonstrating and testing prototypes, production and research projects.

The Research Triangle Park's 2015 plan for the Park Center Development acknowledges the need to strengthen university and industry connections. They have listed intentions of "creating the types of shared spaces and amenities that encourage interaction – cafes and other retail uses, active open space, shared business support services and shared conference facilities," as well as creating and expanding joint research centers and continuing education programs.^{cxxv} NC State's MBA program is already intertwined with the Research Triangle Park, but to take it one step further, bringing in departments from the other two universities would not only allow more industry-university collaboration, but also further inter-university collaboration.

Inter-University Collaboration

The Research Triangle has a unique opportunity for inter-university collaboration. Each university in the region has its own strengths to bring to the table that can be accentuated through specialization and collaboration. UNC is well known for their business and public health programs, NC State for their engineering and agriculture programs, and Duke for their engineering and law programs. Applying the skills of the leading departments from each university to generating cleantech solutions can be an effective way to quicken the pace of innovation. Students from

different schools and different specialties can, for instance, contribute to the same research projects, compete in hackathons or invention competitions, have joint field experiences, and attend conferences together.

At present, it is difficult to participate at university events as a student from another university in the Triangle. A number of resources, competitions, conferences, fairs, classes and other events are unavailable to students that do not attend the host university. University policies make it difficult for students to connect with other universities as well. For instance, UNC students are only able to take one class a semester at another university in the Triangle, and taking this one course requires a long administrative process through both the host school and the student's home university. Additionally, most of the time, the course credit from the host school cannot count towards the student's degree. Degree programs that allow and even encourage students to take classes at other schools offer students a unique opportunity to transfer knowledge between these three universities and collaborate with students of different academic backgrounds.

Conclusion

North Carolina's Research Triangle is uniquely well-positioned to become a leader in cleantech. Our initial hypothesis posited that leveraging its universities would propel the region to the forefront of cleantech innovation. As university students, we were able to provide an insightful perspective to the matter and felt as though our institution was not as involved in the progression to cleantech as we thought it could, and should, be. However, our analysis of case study cleantech cities around the world provided different results. While universities are certainly powerful actors in each city, they were not the primary driver of their city's movement toward cleantech success and would not be so influential were it not for their connections to the other two entities of the Triple Helix. For instance, UT-Austin contributed significantly to the city's growth in tech, but the school's incubators could not have contributed what they did if it weren't for thoughtful collaboration with industry in a state with policies amenable to innovation. The universities of Berlin's cleantech clusters, similarly, would not be as influential if it weren't for government funding directed toward industry research. In other words, the Triple Helix is only functional if all three branches work in participation with the other two.

The Triangle, however, stands apart from these other hubs precisely because of its universities. The clustering of top research universities is a characteristic of the area that is unlike any of our case study cities, and unlike most cities in the country for that matter. By employing the recommendations set forth in this paper – a commitment to cleantech from the state, stronger Triple Helix connections, and inter-university collaboration toward cleantech – the region can more effectively take advantage of this powerful resource and propel itself forward on the path toward cleantech prestige. While the Triangle's access to three major research universities does leave it uniquely capable of leveraging this aspect of the Triple Helix Model, it will still need the support of the whole model to become a successful cleantech hub.

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