Office of the President
TASK FORCE ON CARBON NEUTRALITY AND CLIMATE RESILIENCE

Solutions Assessment: Energy and Buildings

Report of Working Group 1

January 2021

Working Group Membership

Clinton Andrews, *Co-Chair, Rutgers Center for Green Building and Bloustein School of Planning and Public Policy, New Brunswick*
Michael Kornitas*, Co-Chair, Facilities, Institutional Planning and Operations*
Rachael Shwom*, Co-Chair, Rutgers Energy Institute and School of Environmental and Biological Sciences, New Brunswick*

Laura Berman*, Institutional Planning and Operations*
Holly Berman*, Bloustein School of Public Planning and Policy, New Brunswick*
Dunbar Birnie, *School of Engineering*, *New Brunswick*
Kathleen Black, *Rutgers Environmental and Occupational Health Sciences Institute, Rutgers Biomedical and Health Sciences*
Janice Davey*, Institutional Planning and Operations*
Ahmed Ezzat*, School of Engineering*, *New Brunswick*
John Fritzen*, Institutional Planning and Operations*
Serpil Guran*, Rutgers EcoComplex*
Carol Hazlet*, PSE&G*
Boyd Moore*, Institutional Planning and Operations*
Mollie Passacantando*, School of Environmental and Biological Sciences, New Brunswick*
Nirav Patel*, Honors College, New Brunswick*
Shailesh Patel*, Institutional Planning and Operations*
Mark Rodgers*, Rutgers Business School*, *Newark*
Kinan Tadmori*, Business & Science program, Sustainability concentration, New Brunswick*
Glenn Vliet*, Institutional Planning and Operations*

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EXECUTIVE SUMMARY

Rutgers University is a large energy consumer, with a varied portfolio of 700+ buildings covering 28 million square feet. The New Brunswick campuses together have the largest amount of occupiable square feet, followed by RBHS, Newark, and Camden. Most of the building stock was built between 1970 and 1987, although some buildings are much newer and others date back more than 200 years. The Busch and Livingston campuses, which include RBHS Piscataway, together have the highest energy utilization index at 161 kBtu/sqft-year, followed by Newark (which includes RBHS Newark) at 155 kBtu/sqft-year. The non-science campuses are much less energy intensive. The university-wide energy utilization index is 126 kBtu/sqft-year, lower than the median for U.S. colleges and universities[1] (180 kBtu/sqft-year).

Rutgers' baseline greenhouse gas emissions associated with the building sector total 359,541 tonnes CO_2e. A majority comes from purchased electricity. Also important are the electricity and heat produced through cogeneration fueled by natural gas at the Busch/Livingston campus and the Newark RBHS campus. Almost every campus has some amount of central heating and cooling production using natural gas that serves multi-building networks. The Livingston campus hosts just under 10 MW of solar electric capacity.

This working group focused on identifying options for reducing the University's Scope 1 and Scope 2 emissions associated with building energy supply and consumption. A challenging related problem is Scope 3 emissions associated with building energy demand, such as those associated with off-campus housing. This report makes a first attempt to quantify these emissions, but identifying solutions requires further work.

There are three key questions related to the reducing and eliminating greenhouse gases emissions associated with the University's physical plant.

1. What is the current status of the University greenhouse gas emissions from buildings? To address this, we developed an analysis of our carbon footprint using the SIMAP tool.
2. How do we measure emissions reductions? This will require active measurement, monitoring, and control of campus energy usage, production, and emissions.
3. How can the University eliminate fossil fuel use associated with the physical plants? Ultimately, this must rest on a combination of energy efficiency investments and renewable energy investments, including the purchase or production of renewable energy and the renovation of existing thermal and electric producing equipment with equipment that works reliably with renewable energy.

Currently the university is focused on reducing energy consumption in its buildings with 200 KW demand or less. This is being done with support from the NJ Clean Energy Direct Install Program. Contractors will perform energy audits of the buildings and will come up with customized solutions for each building. NJ Clean Energy will cover 70% of the construction cost along with the free audits. Thereafter the university will formulate a plan to audit the larger buildings. It will be looking at energy usage and cost along with building age and size to determine priority.

A study is being done on where metering is needed at a building level for electric, chilled water, high and medium temperature water, and domestic water. An in-depth study and plan will be required to find the best solutions for installing controls and monitoring for the central plants and individual buildings. The university is lacking in monitoring and controls that are needed to regulate energy usage during part-load

[1] Median source energy use intensity for college and universities in the U.S. has been calculated for Energy Star's portfolio manager, a benchmarking tool, using Department of Energy Commercial Buildings Energy Consumption Survey data. Documentation can be found at https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf

operations, which is most of the time. Without controls and variable-frequency motor drives in place it is difficult to operate in partial load conditions and energy is wasted.

On the supply side of the energy equation, while looking at renewable energy, the university will also look at methods for degasification, that is, removing carbon from flue gasses. The goal is to compare the relative cost-effectiveness of (a) substituting non-fossil fuels for fossil fuels, (b) capturing and storing carbon as it is emitted, and (c) sequestering carbon independently in order to offset continued emissions. We cannot be 100% carbon neutral if we cannot account for our fossil fuel usage through sequestration or elimination using some other type of energy. A Request for Information will go out to various consultants to find which are best suited. The next step will be to send out a request for proposals to the consultants that are qualified and choose one to help formulate a reduction plan for natural gas.

Table 1.1: Potential Mitigation Options

Greenhouse Gas Emissions Category	Specific Options for Mitigation
Production Source: Thermal Energy	Small-scale carbon capture and sequestration
	Purchase offsets
	Purchase of Biogas
	Transition to geothermal energy
	Electrification of heating
Production Source: Electricity	Purchase of renewable energy credits or offsets
	University built and owned solar
	Power purchasing agreement for solar onsite
	Power purchasing agreement for solar offsite
	Power purchasing agreement for wind offsite
Consumption Reduction: Existing Buildings	Electrical efficiency upgrades
	Mechanical efficiency upgrades
	Envelope efficiency upgrades
	Behavioral energy conservation measures
Consumption Reduction: New Buildings	New construction standards like Above ASHRAE 90.1, a specific energy intensity, or alternative standard

1.1. Rutgers' current baseline

1.1.1. Rutgers' greenhouse gas emissions in Energy and Buildings

Existing Campus Energy Production and Campus Electricity Purchasing
We generally have a good estimate of the amount of energy produced and electricity purchased by Rutgers and their associated greenhouse gas emissions. For example, Rutgers-New Brunswick purchases about 60% of its electricity from PSE&G. The remainder comes from natural gas boilers, furnaces and co-generation plants (approximately 35%) and from solar (approximately 5%). Rutgers' solar facilities are on Livingston campus and include a 1.4 MW solar array with 7,993 solar panels and 8 MW of solar parking lot canopies, composed of about 33,000 solar panels. These solar facilities reduce annual utility costs by about $1.3 million a year and allow Rutgers to earn Solar Renewable Energy Certificates. In addition to the renewable electricity from solar, Livingston campus also hosts another renewable energy facility, in the form of a geothermal bore field that heats and cools the Rutgers Business School building and provides 700 refrigeration tons (2.5 MW) of heat-extraction power. Across all Rutgers campuses, the largest on-campus electricity generation facilities are the Busch/Livingston and RBHS-Newark cogeneration plants, which together produce approximately 157 million kWh/year. The cogeneration plants are undergoing upgrades to increase the efficiency by which they convert their natural-gas fuel to electricity and heat by 50%. The co-generation plant upgrades have an expected life of 35 years at which point we expect they will be de-commissioned and replaced with electricity that is carbon-free. Analysis of early de-commissioning will be conducted.

Table 1.2. Energy-Related Greenhouse Gas Emissions

Source	Energy	Greenhouse Gas (t CO_2e)	GHG Intensity
Co-gen Electricity	155,704 MWh electricity 2,099,151 MMBtu total	43,056	0.28 t/MWh electricity 0.032 t/MMBtu total
Co-gen Steam		67,033	
Other On-Campus Stationary	1,954,169 MMBtu	105,526	0.054 t/MMBtu
Purchased Electricity	419,326 MWh	136,907	0.34 t/MWh
Electricity T&D Losses		7,027	
Total Fossil Electricity-related	564,030 MWh	179,963	0.32 t/MWh
Total Fossil Energy-related	**5,484,100 MMBtu**	**359,549**	**0.038 t/MMBtu**
Solar (Livingston)	10,000 MWh		

Table 1.3. Rutgers–New Brunswick Energy Greenhouse Gas Emissions FY2019

Source	Energy	CO_2 (tonne)	CH_4 (kg)	CH_4 (t CO_2e)	N_2O (kg)	N_2O (t CO_2e)	Total (t CO_2e)
Co-gen Electricity	99,602 MWh electricity / 1,384,261 MMBtu total	30,959	3,080	86	62	16	31,061
Co-gen Steam		40,863	4,066	114	81	22	40,999
Other On-Campus Stationary	1,354,691 MMBtu	73,394	7,302	204	146	39	73,637
Purchased Electricity	164,345 MWh	53,372	4,547	127	596	158	53,658

T&D Losses		2,739	233	7	31	8	2,754
Solar	10,000 MWh						

Table 1.4. Rutgers-Camden Energy Greenhouse Gas Emissions FY2019

Source	Energy	CO_2 (tonne)	CH_4 (kg)	CH_4 (t CO_2e)	N_2O (kg)	N_2O (t CO_2e)	Total (t CO_2e)
Other On-Campus Stationary	97,204 MMBtu	5,154	513	14	10	3	5,171
Purchased Electricity	25,551 MWh	8,298	707	20	93	25	8,342
T&D Losses		426	36	1	5	1	428

Table 1.4. Rutgers-Newark Energy Greenhouse Gas Emissions FY2019

Source	Energy	CO_2 (tonne)	CH_4 (kg)	CH_4 (t CO_2e)	N_2O (kg)	N_2O (t CO_2e)	Total (t CO_2e)
Other On-Campus Stationary	194,003 MMBtu	10,286	1,023	29	20	5	10,320
Purchased Electricity	67,670 MWh	21,976	1,872	52	246	65	22,094
T&D Losses		1,128	96	3	13	3	1,134

Table 1.5A. Rutgers Biomedical and Health Sciences – Newark Energy Greenhouse Gas FY2019

Source	Energy	CO_2 (tonne)	CH_4 (kg)	CH_4 (t CO_2e)	N_2O (kg)	N_2O (t CO_2e)	Total (t CO_2e)
Co-gen Electricity	56,102 MWh electricity / 714,890 MMBtu total	11,955	1,189	33	24	6	11,994
Co-gen Steam		25,949	2,582	72	52	14	26,035
Other On-Campus Stationary	200,513 MMBtu	10,631	1,058	30	21	6	10,666
Purchased Electricity	132,464 MWh	43,019	3,665	103	481	127	43,249
T&D Losses		2,208	188	5	25	7	2,220

Table 1.5B. Rutgers Biomedical and Health Sciences – New Brunswick Energy Greenhouse Gas Emissions FY2019

Source	Energy	CO_2 (tonne)	CH_4 (kg)	CH_4 (t CO_2e)	N_2O (kg)	N_2O (t CO_2e)	Total (t CO_2e)
Other On-Campus Stationary	107,758 MMBtu	5,713	568	16	11	3	5,732
Purchased Electricity	29,296 MWh	9,514	811	23	106	28	9,565
T&D Losses		488	42	1	5	1	491

* t CO_2e is tonne carbon dioxide equivalent, using 100-year global warming potentials to convert non-CO_2 gases to CO_2 equivalents.

Characterizing the Buildings at Rutgers University

Buildings are responsible for over half the greenhouse gas emissions at Rutgers University. Improving building energy performance and decarbonizing the source of the energy is critical for achieving the University's carbon reduction targets. Sixty-eight percent of Rutgers New Brunswick's greenhouse gas emissions comes from buildings (co-gen electricity, co-gen steam, other on campus stationary, purchased electricity, transmission and distribution losses) as shown in Table 1.3 This section characterizes key features of the population of buildings owned or leased by Rutgers, a necessary first step in developing viable solutions. Cogen Electricity 155,704,281 KWh Cogen Steam 654,704,281 MMBtu Stationary 4,053,247 MMBTU Purchased 364,478,608 KWh

Figure 1.1 shows the floor area of buildings by Chancellor unit. Rutgers New Brunswick dominates the picture and has more floor area than the other campuses combined.

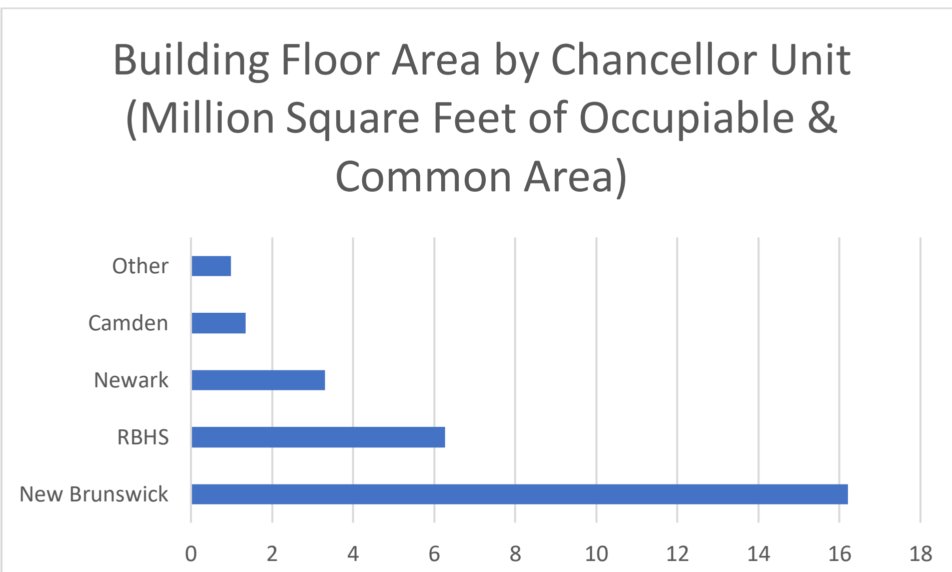

Figure 1.1. Floor Area by Chancellor Unit

The amount of floor area on each campus appears in Figure 1.2. Newark and Busch campuses are the largest. Both include a substantial number of science-intensive buildings used by Rutgers Biomedical and Health Sciences.

Ownership status is important for determining whether energy efficiency improvements can be easily undertaken. Tenants are often limited in the amount of change they can make to leased buildings. It is good news that, as Figure 1.3 shows, the vast majority (96%) of the floor space used by Rutgers is also owned by Rutgers.

A key determinant of energy consumption is the use or principal activity performed in the building. Figure 1.4 summarizes the amount of floor area devoted to major uses in Rutgers buildings. It shows that residential, research, and academic uses predominate. Of these, research is particularly energy intensive because laboratories often have fume hoods and energy-consuming equipment.

Building vintage also plays an important role in explaining energy consumption. Newer buildings often employ more efficient technologies for lighting, heating ventilating and air conditioning (HVAC). However, older buildings may offer fewer amenities such as air conditioning, and therefore operate more thriftily. The most energy-intensive commercial buildings in the Mid-Atlantic region were built during the 1970s, before more stringent building and appliance efficiency codes took effect following an energy supply crisis. See Table 1.6. Rutgers has a mix of building vintages in its vast portfolio and its building stock is older than the nation's (based on the 2018 CBECS survey), with the largest amount of floor area built during the 1970s, as Figure 1.5 shows. There are clear differences by campus, as seen in Figure 1.6. Douglass campus has the oldest square footage, with an average construction year of 1957. College Avenue and Cook campuses are the next oldest group. Busch, College Avenue, Cook, and Camden campuses all have an average year built for their square footage falling in the problematic 1970s vintage, although this is partly due to a multi-modal pattern of some very old and very new buildings.

Given the importance the use to which a building is put in explaining its energy performance, it is useful to understand how building vintage relates to building use. Figure 1.7 shows that athletics and student life have the oldest facilities, but the uses with their average square foot of floor area built during the wasteful 1970s include academic, administration, student life, and support. Research, medical, and residential buildings are relatively newer.

Rutgers has invested in many energy efficiency upgrades in recent decades, many the "effective" age of most buildings newer than shown in this analysis. The most common upgrades have been to lighting systems and HVAC controls.

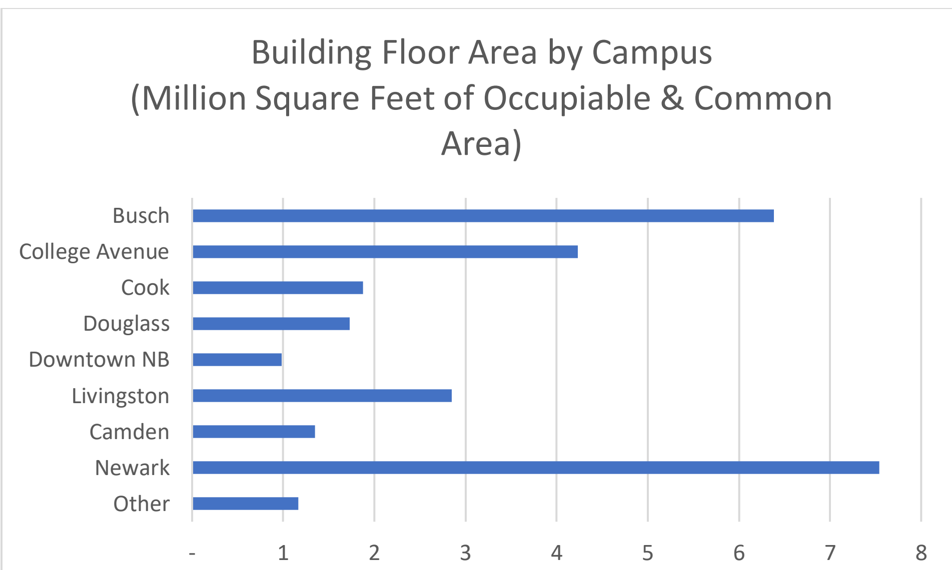

Figure 1.2. Floor Area by Campus

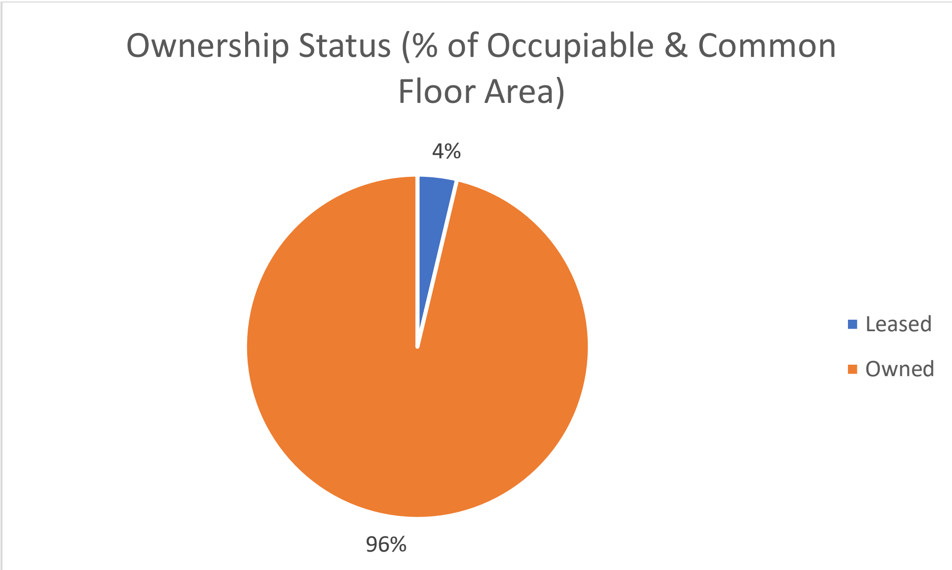

Figure 1.3. Ownership Status (percent of floor area)

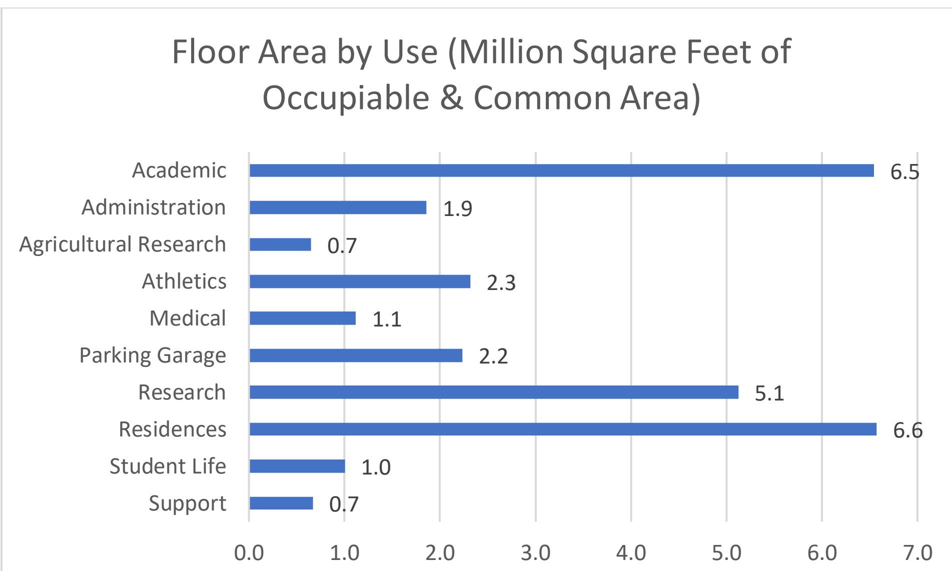

Figure 1.4. Floor Area by Use or Principal Activity (million square feet)

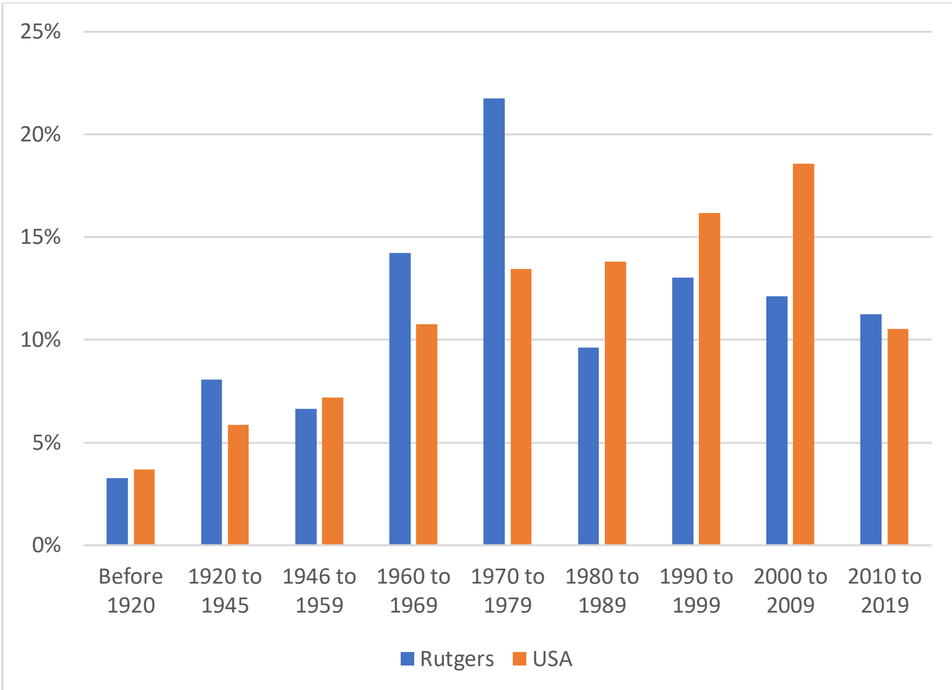

Figure 1.5. Percent of Floor Area by Year Built, Rutgers University vs USA

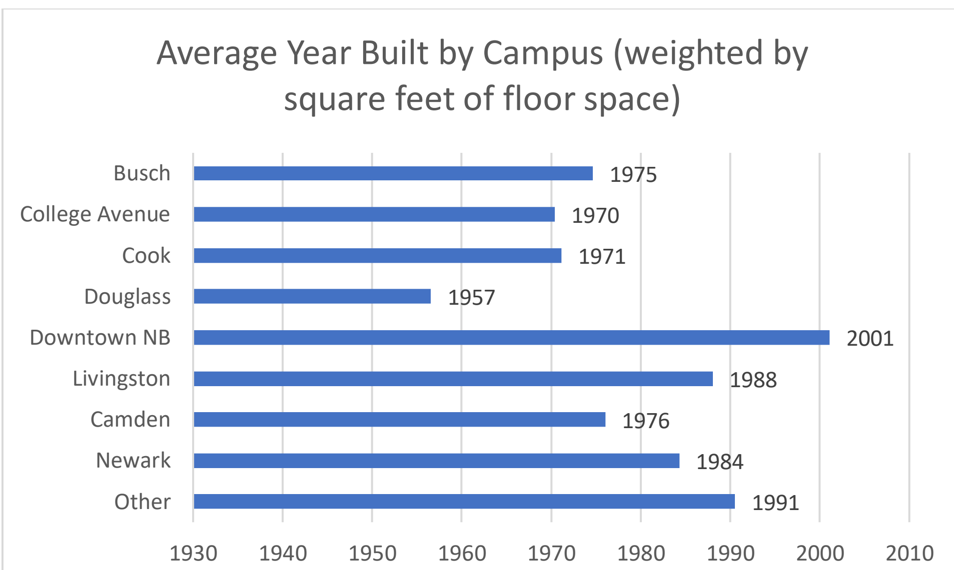

Figure 1.6. Average Year Built by Campus (weighted by floor area)

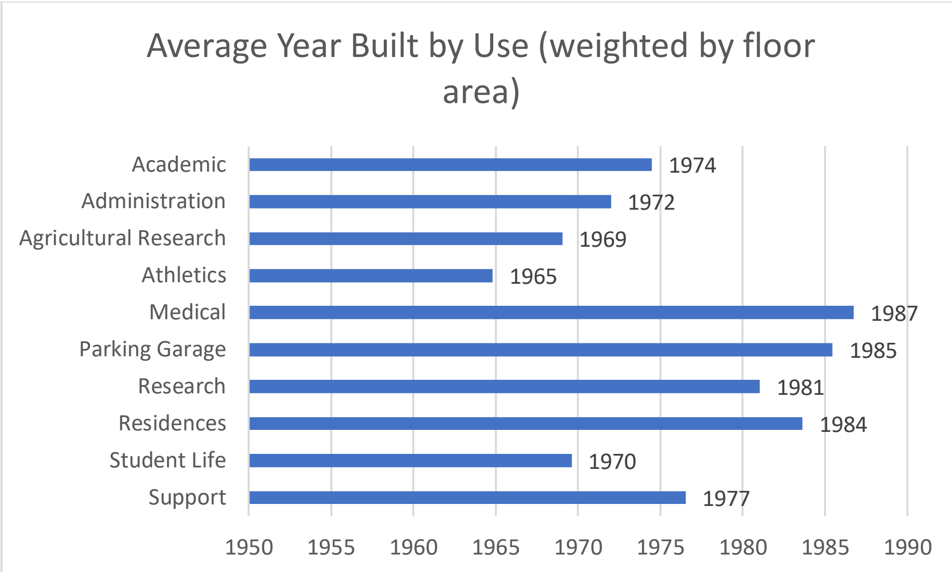

Figure 1. 7. Average Year Built by Use (weighted by floor area)

Energy Use Intensity (EUI) is a helpful metric for comparing the energy performance of buildings. It is measured in annual on-site energy consumption normalized by the floor area of a building (multi-fuel site kBtu/ft^2-year). The university-wide EUI is 126 kBtu/ft^2-year. Figure 1.8 shows the average EUIs by campus at Rutgers University. As expected, the campuses with more science and biomedical activity have higher EUIs.

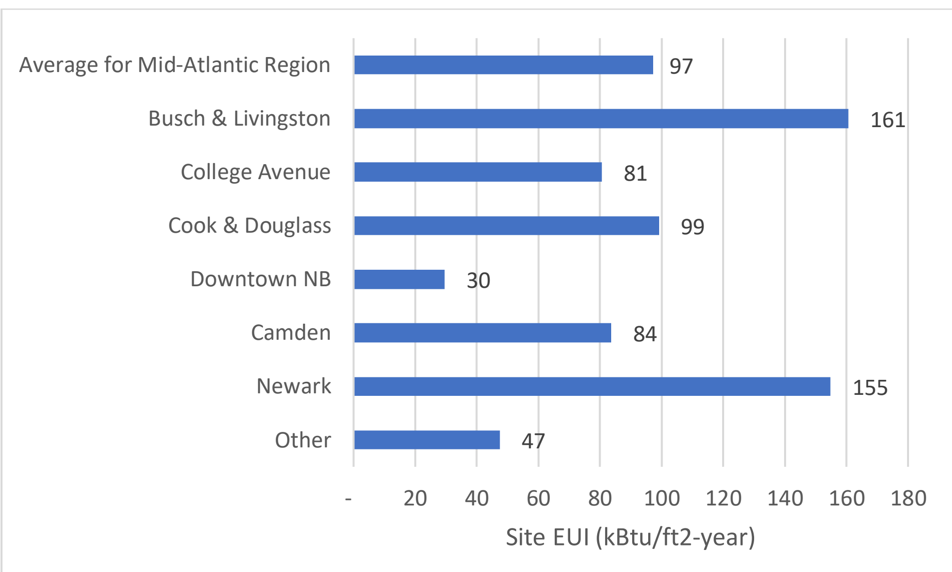

Figure 1.8. Average Energy Intensity for Buildings at Rutgers University by Campus (multi-fuel kBtu/ft^2-year) and the CBECS Average for Buildings in the Middle Atlantic Region

The median EUI for commercial buildings in New Jersey is 81 kBtu/ft^2-year, as shown in Figure 1.9. The median is less than the mean for this right-skewing distribution. The wide variation in EUIs is due to differences in the climate zone, principal activity, age, size, design, and operating strategy of each building. Because the variation in climate is minimal within New Jersey, much of the variation visible in Figure 1.9 is due to differences in principal building activity.

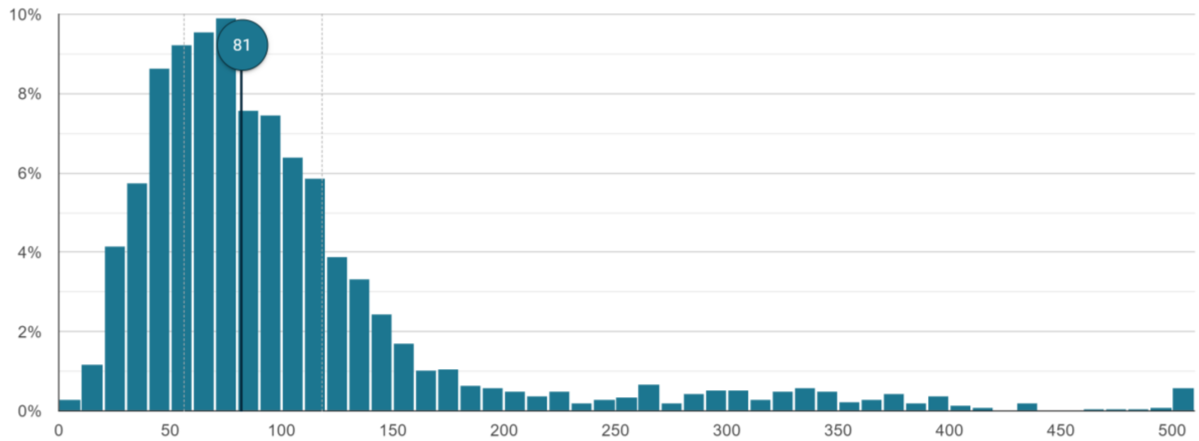

Figure 9. Distribution of Site Energy Use Intensity for Commercial Buildings in New Jersey (multi-fuel kBtu/ft^2-year)
Source: Building Performance Database, U.S. Department of Energy, Lawrence Berkeley National Laboratory. Accessed October 24, 2020 at https://bpd.lbl.gov/explore.

The Rutgers campus-level EUIs need some context, provided in Table 1.6, which shows average (mean) EUIs for different types of commercial buildings in the Mid-Atlantic region based on the 2012 Commercial Buildings Energy Consumption Survey (EIA 2016).

Table 1. 6. Average Energy Intensity for Commercial Buildings in the Mid-Atlantic Region by Category (multi-fuel kBtu/ft^2-year)
Source: 2012 Commercial Buildings Energy Consumption Survey, Table C7, U.S. Department of Energy, Energy Information Administration (EIA), published May 2016. Accessed October 24, 2020 at https://www.eia.gov/consumption/commercial/data/2012/.

Category	**EUI**	**Category**	**EUI**
All buildings	97	**Building floorspace (square feet)**	
Principal building activity		1,001 to 5,000	119
Education	88	5,001 to 10,000	81
Food service	288	10,001 to 25,000	74
Health care	161	25,001 to 50,000	69
Inpatient	227	50,001 to 100,000	91
Outpatient	103	100,001 to 200,000	122
Lodging	94	200,001 to 500,000	106
Mercantile	100	Over 500,000	102
Retail (other than mall)	67	**Year constructed**	
Enclosed and strip malls	142	Before 1920	57
Office	104	1920 to 1945	85
Public assembly	113	1946 to 1959	91
Religious worship	46	1960 to 1969	90
Service	61	1970 to 1979	143
Warehouse and storage	32	1980 to 1989	96
		1990 to 1999	120
		2000 to 2003	89
		2004 to 2007	75
		2008 to 2012	81

Off-Campus Residential Buildings That House Rutgers Students, Staff & Faculty

A survey conducted during the summer of 2020 provides a glimpse of the types of housing used by the Rutgers community. This housing uses energy and produces greenhouse gas emissions. Table 1.7 summarizes the proportions of building types reported by survey respondents, weighted by the respective Rutgers population cohorts. The table also includes typical EUIs taken from the U.S. Department of Energy's Residential Energy Consumption Survey within the Northeastern region.

Half of the Rutgers population lives in single-family homes, which are not very energy-intensive on a per-square-foot basis, but are so on a per-person basis. Fifteen percent live in apartments, which are more energy-intensive per square foot but less so per-capita. Finally 35% live in dormitories, which are very energy intensive per square foot but not at all so per-person.

In aggregate, the energy consumption, and therefore carbon emissions, associated with the residential arrangements of Rutgers community members are significant, and those owning their own homes should be encouraged to improve energy efficiency and pursue access to renewables. Those who rent should be encouraged to work with their landlords to achieve similar improvements, admittedly a more difficult task. The Existing Residential section of the New Jersey Green Building Manual (cited in Table 1.8) recommends specific actions to take in these contexts.

Table 1.7. Off-Site Residential Building Energy Use by Rutgers Community Members
Source: Rutgers Survey; and Energy Information Administration (EIA), U.S. Department of Energy. 2018. 2015 Residential Energy Consumption Survey, Table CE 1.2. Accessed on November 1, 2020 at https://www.eia.gov/consumption/residential/data/2015/. The Dormitory EUI is from EIA. 2016. 2012 CBECS Survey, Tables C7 and PBA 3. Accessed on November 1, 2020 at https://www.eia.gov/consumption/commercial/data/2012/.

Housing unit type	Household Energy Consumption (MMBtu/yr)	Energy Consumption per Household Member (MMBtu/yr)	EUI (kBtu/SF-yr)	Percent of Rutgers Community Living in this Type (weighted by population)	Total Energy Consumption of Rutgers Community Members (excluding other household members, MMBtu/yr)
Single-family detached	126	46	42	46%	1,577,880
Single-family attached	93	37	45	4%	110,362
Apartments in buildings with 2–4 units	70	27	64	7%	140,935
Apartments in buildings with 5 or more units	41	23	49	8%	137,207
Mobile homes	81	35	72	N/A	
Dormitory (150 SF/person)	N/A	11	76	35%	287,091

Existing and New Construction – Current Activities

For most existing buildings owned and leased by Rutgers, energy consumption is known but is not consistently sub-metered at Rutgers. Water use at the building level is not known for most buildings. While we can track broad monthly commodity use categories by campus, our ability to track commodity use by building is limited. Rutgers facilities implement energy savings results in our daily operations and construction efforts but lack a comprehensive tracking strategy. Students are currently working with Mike Kornitas to build a database of buildings to help prioritize audits and retrofits.

Rutgers University has executed numerous initiatives to conserve energy. Upgrades such as premium motors, variable frequency drives, burners on gas boilers, and new lighting fixtures have been installed to improve energy efficiency. Energy efficiency upgrades require significant initial investments, which are justified by future energy savings. The "payback period" refers to the amount of time it takes for the savings of an upgrade to equal its total cost. To mitigate the initial investment costs associated with energy efficiency upgrades, Rutgers applied to incentive programs and received funding from several institutions. One such program, the New Jersey Clean Energy Program (NJCEP), provided Rutgers with $1,153,952 for a project costing $1,538,603, shortening the payback period to only 2.3 years. The project involved the installation of interior lighting upgrades, occupancy sensor controls, and high-efficiency motors for HVAC, vacuum, and domestic water supply systems.

In another case, Rutgers received funding from the American Reinvestment and Recovery Act (ARRA) to install burners on gas boilers that supplied heat to the Eco Complex office. The burners allowed the gas boilers to use carbon-neutral landfill gas for about 80% of operating hours, saving $104,600 annually. ARRA contributed $63,100 to the project, reducing the total cost to $115,000 and the payback period to just over a year.

Some project managers are already being realigned with the focus of decreasing use. The facilities Mechanical/Electrical/Plumbing (MEP) project group is evaluating existing and proposed projects to define commodity and emission savings. The group is managed by John Fritzen, PE, Director of MEP projects who holds a Master of Science in Energy Management.

For new construction Rutgers employs a design/construction project management group with a focus on the development of projects intended to reduce consumption. Rutgers also designs and constructs to standards that meet at least the U.S. Green Building Council's guidelines for LEED-rated Silver buildings, which serves to reduce our overall carbon footprint, thereby promoting energy conservation in accordance with building codes.

Solutions for Improving Energy Efficiency

The New Jersey Green Building Manual was prepared by the Rutgers Center for Green Building on behalf of the New Jersey Department of Community Affairs (RCGB 2019). It provides recommendations on cost-effective and feasible solutions for four cohorts of buildings in New Jersey: existing and new commercial buildings, and existing and new residential buildings. The recommendations for existing commercial buildings are particularly relevant as potential solutions for improving the energy performance of the Rutgers building portfolio.

Table 1.8. Solutions Recommended by the New Jersey Green Building Manual
Source: New Jersey Green Building Manual, Version 2.0, prepared by the Rutgers Center for Green Building for the New Jersey Department of Community Affairs. Accessed on October 24, 2020 at http://greenmanual.rutgers.edu/.

Envelope	Air Infiltration Daylighting Exterior Wall Systems Glare and Heat Gain Reduction Roof Replacement and Upgrades Windows and Skylights
Lighting	High-Efficiency Lighting and Networked Lighting Controls Light Pollution Reduction

HVAC	Chilled Beams Demand Control Ventilation (DCV) High-Performance HVAC Equipment and Controls Variable Frequency Drives (VFD)
Energy Supply	Combined Heat and Power (CHP) Green Power Thermal Energy Storage On-site Renewable Energy and Geothermal Systems

Most of the solutions listed in Table 1.8 are building-specific, and given that the University has hundreds of buildings, there is a need to audit them to determine which solutions are most appropriate for implementation in each specific building. Hence, several of the potential climate solutions recommended in this report are programmatic rather than projects.

There are some solutions that take advantage of the campus context and focus on efficiency gained and carbon emissions avoided at the utility level. These include improvements to central utility plants, better controlled district heating and cooling loops, alternative primary energy sources, and power purchase agreements. Some of these ideas are actionable in the short term (better controls, power purchase agreements) and others will become feasible within a multi-decade time horizon (new central utility plant architectures that augment or replace gas-fired cogeneration with heat recovery chillers and thermal storage).

1.1.2. Ongoing Analysis to reduce emissions and vulnerabilities

1. Metering and Monitoring: All building energy managements systems need to be evaluated and upgraded along with metering. A majority of the energy management systems are pneumatic and cannot be monitored or adjusted remotely. In order to see the changes in energy usage from monitoring and making changes remotely, metering will have to be i installed. A majority of time buildings run at part energy. In order to right size delivery of the thermal needed to maintain building needs in real time, monitoring and control needs to be in place at the building level and plant level. By doing this a significant amount of energy can be saved.
2. Equipment retrofit/replacement: Rough initial estimates of potential savings via equipment retrofit/replacement will be determined using the database of Rutgers buildings and their characteristics. (Mike Kornitas, Mollie Passacantando).
3. Energy upgrades: Facilities will be working with PSE&G and state programs to assess incentivized building upgrades based on building-level energy audits.

1.1.3. Related ongoing educational, research, and service activities

Rutgers professors and students have been working on several projects to inform potential solutions. Rutgers Energy Institute worked to coordinate students online research with professors in summer of 2020 with students working on projects such as the assessment of Rutgers potential and cost/benefit analysis for building more low carbon power generation capacity including thermal storage water tanks, ground source heat pump systems, and additional solar with Dr. Ahmed Aziz Ezzat. Dr. Jennifer Senick and Clint Andrews are working on a cost/benefit assessment of new construction standards.

1.2. Potential solutions

1.2.1. Potential solutions

The opportunities for reducing greenhouse gas emissions from Rutgers University's buildings can be summarized in a simple accounting identity based on Ehrlich and Holdren (1971)[2]:

CO_2 Emissions = People x (Floor Area/Person) x (Energy Use/Floor Area) x (CO_2 Emissions/Energy Use)

People: How many students, faculty and staff should be at Rutgers? Keep it the same? Make admissions more selective? Narrow the university's scope to exclude research or service?

Floor Area/Person: How much space do we need? Are there underutilized buildings that could be sold or demolished? Are there more efficient arrangements, ranging from shared offices to working remotely?

Energy Use/Floor Area: How efficiently do our buildings use energy? Are there energy efficiency investments to make, and new operating practices to adopt?

CO_2 Emissions/Energy Use: How carbon-intensive is the University's energy supply mix? Is it possible to substitute renewable energy for fossil energy sources? Is carbon sequestration to limit effective emissions feasible?

The range is potential solutions to the carbon emissions reduction challenge is broad and it forces us to consider fundamental changes to the future trajectory of the university. The question of how many people should be at the university is difficult and tightly intertwined with other objectives such as ensuring equitable access to education and contributing to the New Jersey economy. The question of how much space we need has an easy and a hard part. It is straightforward—and already a standard practice at Rutgers—to perform space utilization studies and eliminate space that is obsolete or unwanted. The shut-down due to the COVID pandemic has shown that remote work is a potential solution for many students and employees, although we have not yet fully assessed how the quality of our work is affected. The questions of how efficiently our buildings use energy and the carbon-intensity of our energy supplies are more amenable to study by the current task force, because they have technical answers. The sections below introduce potential solutions for improving energy efficiency and getting the carbon out.

Eliminating greenhouse gas emissions from the physical plant requires both a reduction in overall energy use and a transition to clean energy sources to supply both thermal and electric demands. The reduction in overall energy use requires a systematic evaluation of building stock and a determination of best use of stock, followed by a building-specific evaluation of energy efficiency options for buildings that are being kept in use. The key areas to address are the electrical, mechanical, and building envelop efficiency. On the energy supply side, two areas need to be addressed. One is increasing efficiency of the energy supply system. The second is eliminating fossil fuels from that supply.

Options for buildings include:

- Decommissioning inefficient buildings.
- Right-sizing building HVAC and electric
- Increase the energy efficiency of buildings lighting, HVAC, and envelope.

[2] Ehrlich, P.R., and John P. Holdren, J.P. Impact of Population Growth. *Science* 26 Mar 1971: Vol. 171, Issue 3977, pp. 1212-1217. DOI: 10.1126/science.171.3977.1212

- Upgrading appliances and equipment used by occupants.
- Setting a standard for energy intensity of new buildings.

Options for Supply:
- Upgrade overall plant systems and controls to increase efficiency
- Transitioning to non-fossil options for thermal and electric production.

Buildings can be identified for decommissioning on the basis of three criteria: (1) whether the building is condemned and not suitable for occupancy, (2) whether the building has outlived its usefulness, or (3) whether a building's use value and life-cycle cost is less than the value and cost of a new capital project to be built in its place.

Right sizing building HVAC and electric: Over the years, existing buildings' programming and usage change. An example of this is the Psychology building, where the HVAC system can no longer adequately provide the necessary heating, cooling, humidification, and dehumidification. Replacing the system with a new updated system provide an opportunity to reduce the buildings carbon footprint.

Options for increasing the energy efficiency of buildings lighting, HVAC, and building envelope include:
- Replace lighting fixtures with more efficient fixtures.
- Installing lighting controls to take advantage of daylight harvesting and to increase and decrease lighting output for specific tasks.
- Direct replacement of HVAC equipment with higher efficiency equipment
- Upgrading HVAC control systems to run systems efficiently at part load.

To encourage upgrading of appliances and equipment used by occupants, the University may need to fund incentives for energy efficient appliances, lab, and office equipment and/or establish procurement standards. At present, under the current budget system, the price signal of increasing energy demand associated with inefficient equipment is essentially not conveyed to individuals making procurement decisions, thus necessitating these alternative options.

Maximum energy intensity standards can be set for new buildings on the basis of building type and usage.

Reductions in the energy usage associated with thermal and electric production can be achieved through a combination of: (1) upgrading to more efficient equipment and (2) using controls and monitoring to right size load output to load needs. For most of the time, systems run at part load, and we expect these to increasingly be the case as the University transitions to more heavy reliance on intermittent renewable energy sources for electricity supply.

Transitioning to non-fossil fuels will require evaluation and upgrading or replacement of existing systems and to upgrade or replace systems to work with non-fossil fuels. For thermal energy, options include: transition to biogas as a drop-in replacement for natural gas, transitioning to geothermal energy, or electrification. Small-scale carbon capture and sequestration is another possible option by does not currently exist in a deployable form.

For electricity, options include the expansion of on-campus solar energy and the purchase of off-campus solar and wind energy. For on-campus solar generation, the University could, at significant up-front cost with relatively short payback periods, chose to own and operate units, as it does currently, or it could choose to pay smaller amounts to a third party on an annual basis. Technologically, the electric options are more straightforward than thermal options and are already demonstrated at modest scale on campus via the ~10

MW of solar capacity. Figuring out the best way to expand the University's renewable energy generation is primarily a question of financial and legal engineering.

1.2.2. Next steps

Energy Audits: Buildings with 200 KW demand will be analyzed through the NJ Clean Energy Direct install program for energy efficient upgrades. 70% of the cost will be paid for through the NJ Clean Energy Program. Larger buildings will be audited using the Local Government Auditing program again though NJ Clean Energy. The cost will be covered up to $100,000 annually for the audits. Once audited and Rutgers agrees with the audit then the building will be upgraded with a minimum of 15% energy reduction in the buildings.

Fossil Fuel Elimination and or Sequestration Analysis: Hire a consultant to formulate plans to eliminate usage of fossil fuels and or sequestration of fossil fuels.

Building Standards: Assessment of Building standards.

Metering, Monitoring & Control Systems: Assessment of monitoring and controls for buildings and central energy systems. Install electricity, heating hot water, and chilled water metering in individual buildings served by district energy systems

1.2.3. Cross-cutting issues arising in the exploration of potential solutions

Cross-cutting issues include the increase of electricity demand associated with the electrification of transportation (Working Group 2) and the development of standards for procurement of energy-using devices (Working Group 4). A potential anerobic digester for biogas production ties to the discussion of food waste disposal by Working Groups 3 and 4.

1.3. Assessments of potential climate solutions

1.3.1. Energy Supply: Expanding On-Campus Solar Generation and Purchasing Off-Campus Solar or Wind Energy

Rutgers has nearly a decade of experience in operating solar generation facilities on campus, including building what was at the time of its construction in 2013 the largest campus solar facility in the nation. Rutgers' solar facilities are on Livingston campus and include a 1.4 MW solar array with 7,993 solar panels and 8 MW of solar parking lot canopies, composed of about 33,000 solar panels. Based on this experience, a natural opportunity for decarbonizing the campus electricity supply is to displace grid electricity (about 0.3 t CO_2/kWh) with more on-campus solar production.

Over the last decade, solar prices have dropped considerably; according to the National Renewable Energy Lab, for a 200 kW commercial system, installed system costs dropped from \$5.43/W in 2010 to \$1.83/W in 2018.[3] Based on the average capacity factor for Rutgers' existing installations, a 1 kW solar installation would produce about 1.1 MWh of electricity over the course of a year. Over the course of 20 years, such a system would produce about 22 MWh of electricity and avoid about 7 tonnes of carbon dioxide emissions, at an initial cost of \$1830.

The costs of such a system are offset both by avoided grid electricity purchases and state subsidies. Assuming an avoided cost of \$90/MWh in grid electricity purchases, the aforementioned 1 kW system would avoid \$1,980 of expenditures over the course of 20 years, for a net benefit of \$150, and would break even in 20 years. Currently, New Jersey Transition Renewable Energy Credits (TRECs) provide an additional subsidy of \$152/MWh for 15 years for rooftop and carport systems. Factoring this in increases the 20-year net benefit of a 1 kW system to \$2,430 and reduces the payback period to 7 years. While this calculation does not account for the cost of capital, factoring in this cost at either the 4.75% rate currently used by the Rutgers internal bank or the 3.92% rate of Rutgers' 2019 century-bond offering does not eliminate the substantial net present benefit.

Total Generation (20 y, MWh) per kW	22	22	22
Avoided Emissions (20 y, t CO_2) per kW	7	7	7
Discount Rate	**0%**	**3.92%**	**4.75%**
Initial Cost per kW	(\$1830)	(\$1830)	(\$1830)
NPV Avoided Cost (20 y) per kW	\$1,980	\$1,390	\$1,300
NPV TREC (15 y) per kW	\$2,280	\$1,750	\$1,660
Total NPV per kW	\$2,430	\$1,310	\$1,120

Solar electricity generation comparable to current grid electricity purchases would require about 380 MW installed, covering an area about 1400 acres, for an initial cost of about \$700 M and a net present benefit of about \$450 M. This is not to suggest that such expansive solar investments are a viable option; rather, they suggest that expanding solar generation on Rutgers land has the potential to be a key climate solution, and that scalability is limited primarily by available rooftop/carport area and the availability of capital.

Further analysis is needed to determine the practical on-campus potential, but the ability to accommodate large-scale solar investment within the university's debt capacity constraint is likely to limit Rutgers' ability to

[3] https://www.nrel.gov/analysis/solar-installed-system-cost.html

debt finance a large-scale expansion of on-campus solar power. Third-party financing will therefore likely be necessary.[4]

Two alternative financing vehicles are available to overcome this limitation. In an operating lease, the University would lease and operates the solar equipment from a private builder for part of the equipment's operating life (typically 7-10 years) and subsequently purchases the equipment at fair market value. The University would bear the risks associated with system maintenance and, depending on the terms, receive subsidies under the New Jersey TREC policy. In a purchase power agreement (PPA), a third party owns and operates the solar equipment, bearing the risks associated with system maintenance and receiving state subsidies. Purchase power agreements can also be used to procure electricity generated off of University grounds. Given the rapid emergence of the off-shore wind energy industry in New Jersey, off-shore wind energy PPAs should be considered as potential options as well as solar PPAs.

1.3.2. Purchase Power Agreements

Power Purchase Agreements (PPAs) are financial agreements between developers of renewable energy supplier and customers. Through a PPA, an entity such as Rutgers would enter into a legal contract with a generator of renewable electricity (in our geographic location this would likely be a solar or wind farm) for the power output or a portion of power output, for a dedicated period of time (can be anywhere from 5-20 years). This contract to purchase electricity would replace power purchased from the grid to help reduce emissions associated with electricity use.

The PPA can be for a project 1) on University property itself (onsite PPA), whereby the developer assumes responsibility for all construction and maintenance of the system, 2) within the same grid as the entity (for Rutgers, a project could be somewhere within PJM), or 3) can be located elsewhere in the US, what is known as a virtual or financial PPA. Note, the reputational benefits may be stronger for a PPA that is on-site or within the same electrical grid as Rutgers, but from a GHG accounting perspective all 3 are accepted methods to reduce GHG emissions as long as Renewable Energy Credits (RECs) are included in the PPA and retired in the name of the university.

PPAs are widely used by Universities. Harvard was among the first to enter into such a contract, entering into an agreement with the Stetson II wind project in Maine.[5] Georgetown University is similarly using a PPA with Origis Energy to procure solar energy to cover about half of campus electricity.[6] The University of Michigan has entered into a PPA with DTE to procure off-campus renewable energy, produced in Michigan, to cover about half the consumption of its Ann Arbor campus.[7]

Compared to Rutgers-owned and -operated renewable energy generation, PPAs may be able to cover a larger percentage of electric power load than on-site generation, due to fewer siting constraints, and could be implemented more quickly. The generating compare would bear some of the risk that would be borne by Rutgers for on-site generation, and Rutgers would not be exposed to depreciation or maintenance costs. However, these benefits would come at an increased present-value cost to Rutgers compared to full ownership.

[4] https://betterbuildingssolutioncenter.energy.gov/financing-navigator/primer/higher-education-energy-financing-primer
[5] https://green.harvard.edu/topics/climate-energy/site-emissions-reduction
[6] https://www.georgetown.edu/news/new-off-site-solar-project-to-provide-nearly-half-of-georgetowns-electricity-needs/
[7] https://record.umich.edu/articles/u-m-cut-emissions-through-renewable-energy-purchase-dte-energy/

1.3.1.1. Emissions reductions and resilience improvements

Determining the potential emissions reduction from expanded solar generation requires further analysis of the solar potential of Rutgers property, particularly the rooftop and carport areas that are most heavily subsidized under the New Jersey TREC policy. A solar energy system large enough to cover all of Rutgers' grid electricity purchases would reduce annual emissions by about 137,000 tonnes.

When combined with battery storage or the backup gas generation capacity, such as that provided by the co-gen facilities, solar photovoltaic facilities can help power an islanded microgrid, maintaining an electric power supply when grid electricity is no longer available.

1.3.1.2. Financial costs and savings

As indicated above, when factoring in both avoided electricity costs and state subsidies, a typical, directly owned solar photovoltaic system has a payback period of about 7 years and offers a significant net-present benefit at current interest rates. Procuring a large enough solar system to cover all the electricity Rutgers currently purchases from the grid would have an initial cost of about $700M and generate about $100M/yr in avoid electricity purchases and TRECs.

For a purchasing power agreement, typical rates are about $3-$5/MWh on top of current electricity rates. Thus, a PPA large enough to cover all campus grid electricity purchases would cost about $2-$3M/yr, a cost for avoided CO_2 emissions of about $20/tonne. If Rutgers makes a large PPA, it may wish to explore partnership arrangements in which it is a partial owner of the plant operator and thus recovers some of the added net-present cost of the PPA compared to direct ownership. It may also wish to explore cooperative ownership arrangements (e.g., entering into a partnership where multiple educational institutions own a company that operates solar facilities), to similar effect and with additional co-benefits for equitable economic development.

1.3.1.3. Benefits to the University's educational and research mission and to campus culture

On-campus solar photovoltaic systems are highly visible, charismatic climate solutions, and can also be integrated into educational projects using the campus as a living lab. If the University is not the direct owner of new renewable energy facilities, it should attempt to maintain the educational benefits of ownership in its partnership agreement. If the University enters into an off-shore wind PPA, it may wish to do so as part of a broader off-shore wind industry partnership with defined educational and research objectives.

1.3.1.4. Implementation Timescale

The 32-acre solar canopy on Livingston Campus was approved by the Board of Governors in April 2011 and was completed three years later, in March 2014. Given adequate capital availability, it should be possible to go from approval to completion in a shorter time period.

A power purchase agreement could be implemented over the course of 6 months to 1 year. The time involved would include potentially identifying a consultant to identify opportunities and help negotiate a contract. The review by internal stakeholders (Facilities, Legal, etc.), and approval by these groups could also take several months.

Timing is also dependent on whether the generating project (i.e. the solar or wind farm) is already existing, under construction, or has not yet begun construction. If Rutgers is interested in pursuing an on-site PPA for solar built on Rutgers property, the timeframe would be longer as the developer would need to work with the University to obtain the required permitting and approvals to build the project.

1.3.1.6. Needed research and planning

The next available analysis needed to expand solar generation on campus is a survey to identify areas suitable for solar deployment. Given the structure of TREC subsidies, priority should be given to rooftops and carports, particularly those associated with structures expected to have a remaining lifetime of at least 30 years.

In addition, more through exploration is needed of the trade-offs of different financing schemes and how other Universities successfully executed PPAs – steps taken, solicitation process, stakeholders involved, etc. A consultant may be necessary to help facilitate the PPA, identify project opportunities, and provide market expertise. Financial and legal research is needed to explore viable partnership models that would allow the University to recover some of the incremental net-present cost of a PPA relative to direct ownership.

1.3.1.8. Management roles

Facilities (Institutional Planning and Operation) is the lead office for implementation. The Board of Governors must approve projects. Treasury must be involved in the provision of capital Both Treasury and the General Counsel must be involved in the exploration of partnership models. The University's academic units can leverage for educational and research activities as part of living-lab efforts.

1.3.1.9. Institutional, Organizational and Cultural Challenges to Implementation

The principal institutional barrier to implementation is capital availability and the identification of suitable partnership models.

1.3.1.10. Contribution to Climate-Positive, Equitable, Sustainable Economic Development

Large-scale solar construction would create short-term construction jobs and contribute to overall state goals for grid decarbonization. Consistent with state goals, Rutgers could work with the Supplier Diversity Development Council to increase opportunities for minority-, woman- and veteran-owned businesses. In some areas, it may be appropriate to pursue community solar projects, allowing residents in neighboring communities to purchase power from solar projects, with state subsidies for low- to moderate-income households. Cooperative ownership of a plant operator with multiple educational institutions could also facilitate equitable economic development.

1.3.5.5. Equity Concerns

While direct ownership of a solar system will lead to long-term cost reductions, a PPA may raise utility costs. Care should be taken to ensure these costs are minimized and not passed onto students.

1.3.3. Energy Supply: Transitioning Away From Fossil Natural Gas

Fossil natural gas is a key part of the current campus energy system, powering both the co-generation facilities in New Brunswick and Newark and central heat plants on most campuses (see Appendix A). Combustion of fossil natural gas is responsible for about 215,000 tonnes of annual CO_2 emissions, nearly half of the total Rutgers emissions inventory.

As the ongoing co-generation plant upgrades have a planned lifetime of 35 years, achieving any carbon neutrality target before 2055 without offsets will require either early retirement of these facilities or substitution of renewable alternatives to fossil natural gas. This challenge is common to large universities, and a recent University of California (UC) study assessed alternative solutions.[8] This study identified three

[8] Alan Meier et al., "University of California Strategies for Decarbonization: Replacing Natural Gas," 2018, https://doi.org/10.17605/OSF.IO/HNPUJ.

core solutions: (1) reducing energy demand through investments in deep energy efficiency, (2) replacing fossil natural gas with renewable biogas or hydrogen, and (3) electrifying end uses and employing carbon-free electricity sources. It also noted that small-scale carbon capture and storage might be a potential future solution, but does not currently exist in deployable form.

Deep energy efficiency investments are a core strategy for the buildings sector, and are addressed below. While further study is needed to determine the energy efficiency potential for Rutgers, the UC system estimated the potential for cost-effective retrofits to reduce natural gas consumption by 29% and electricity consumption by 39%. The UC study viewed biogas as an interim solution, with electrification being the ultimate option. The report recommended electrification should be made a standard for all buildings not connected to co-generation plants, and that electrification of existing buildings begin with those on the periphery of central heating loops.

The Rutgers New Jersey Agricultural Experiment Station (NJAES)'s Sustainable Energy Working Group[9] has substantial expertise on bioenergy, including biogas. In 2015, NJAES's Rutgers EcoComplex completed a revised assessment of biomass energy potential in New Jersey.[10] This study found that New Jersey has about 4.1 million dry tons of biomass potentially available for energy production, which could with appropriate technologies and infrastructure produce 650 MW of electric power.

UC has adopted an approach of funding pipeline-injected biogas projects, in which the university funds projects – located anywhere in the country – that inject biogas into a natural gas pipeline, and then draws out an equal volume of natural gas at another location. In general, the molecules withdrawn at the receiving location are not the same as those injected at the source, but the project investment leads to a reduction in the overall carbon intensity of the gas supply. They have found a premium of about $4-$5/MMBtu for pipeline-injected biogas over fossil natural gas; applying a comparable approach would cost Rutgers about $16-$20 M/year to fully offset its fossil natural gas consumption, at a cost of about $75-$90/t CO_2. However, such approaches, relying on "renewable natural gas credits" are not risk-free and should be approached carefully. As an example, California RNG credit buyers trusted a large project called "Heartland Biogas Project" in Colorado, but the project developers were not successful and could not inject promised amount of gas into the pipelines.

Currently, there is only one company in the state, Trenton Renewables, that generates biogas from Anaerobic Digestion (AD) of organic waste (food waste), but they are not injecting biogas into a pipeline. Also, a few wastewater treatment facilities are using AD technology and generate biogas, which they utilize for their own facility energy needs. A few wastewater facilities flare the biogas because their gas generation is minimal. In addition, landfills generate landfill gas and, which can be upgraded and injected into pipelines; however, the process leaks methane into the atmosphere and the carbon benefits may be negated by the leaked amount of methane.

At likely lower cost than the purchase of RNG credits, Rutgers could collaborate with a developer for a state-of-the-art anaerobic digester (AD) facility. While Rutgers does not generate enough food waste for an efficient facility, it could collaborate with surrounding communities. This facility can be located on-campus or off-campus and a developer can pay for the project. Rutgers may utilize its gas either directly or purchase credits with a negotiated rate. The AD facility can also generate compost, which will reduce the biogas carbon footprint further as by-product credit. The AD facility can be run by the developer, so it would not be an operational burden for Rutgers, and as a technology provider the developer would have the performance responsibility. Rutgers can also request funding/opportunities for internships for our students,

[9] https://bioenergy.rutgers.edu/
[10] https://bioenergy.rutgers.edu/biomass-energy-potential/

gas clean-up and upgrading tech, compost testing research for our faculty research etc., as part of the negotiation.

1.3.2.1. Emissions reductions and resilience improvements

Fossil natural gas is responsible for a large share of Rutgers' carbon footprint; taken together, some combination of efficiency, electrification, and fuel substitution should eliminate these emissions.

Co-generation plants can provide backup power for solar electric systems and thus enable islanding of microgrids when the grid electricity supply is disrupted. Premature retirement of co-generation facilitations, before substantial, cost-effective battery storage is available, can thus decrease campus resilience. Central heating plants should therefore be prioritized for early retirement over co-generation facilities.

1.3.2.2. Benefits to the University's educational and research mission and to campus culture

Rutgers currently has some research activities related to renewable natural gas. Serpil Guran of the Rutgers EcoComplex is on the Academic Advisory Group of the Renewable Natural Gas Coalition (RNG). Guran, Gal Hochman (Department of Agriculture, Food, and Resource Economics), and a student are conducting a technoeconomic analysis of viable approaches for a New Jersey RNG industry. The EcoComplex is also collaborating with the Northern New Jersey Community Foundation to assess for a potential anaerobic digester to biogas project in Bergen County.

As with on-campus electricity generation, the thermal energy system can be integrated into educational projects using the campus as a living lab.

1.3.2.3. Needed research and planning

Additional analysis is needed to evaluate alternative approaches for transitioning away from fossil natural gas. While some relevant expertise exists on campus, a thorough analysis will likely require hiring an external consultant.

1.3.2.4. Benefits to the University's educational and research mission and to campus culture

Rutgers currently has some research activities related to renewable natural gas. Serpil Guran of the Rutgers EcoComplex is on the Academic Advisory Group of the Renewable Natural Gas Coalition (RNG). Guran, Gal Hochman (Department of Agriculture, Food, and Resource Economics), and a student are conducting a technoeconomic analysis of viable approaches for a New Jersey RNG industry. The EcoComplex is also collaborating with the Northern New Jersey Community Foundation to assess for a potential anaerobic digester to biogas project in Bergen County.

As with on-campus electricity generation, the thermal energy system can be integrated into educational projects using the campus as a living lab.

1.3.4. Energy Demand: Building Retrofits

It is almost axiomatic that the least expensive energy is that energy which is never used. For example, energy efficiency programs run by electric utility have an average cost of about $46/MWh,[11] roughly half the price Rutgers pays for grid electricity. For that reason, reducing energy demand is a core part of all climate change mitigation strategies. The core challenge of scaling this solution is one of financing, as energy efficiency investments involved up-front costs for sustained returns.

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[11] Ian M. Hoffman et al., "Estimating the Cost of Saving Electricity through U.S. Utility Customer-Funded Energy Efficiency Programs," *Energy Policy* 104 (May 1, 2017): 1–12, https://doi.org/10.1016/j.enpol.2016.12.044.

Over 2005-2014, the University of California made energy efficiency investments that reduced its annual expenditures by about $24M (about 10%), and projects potential savings by 2028 of another approximately 22%.[12] Such investments often have a payback period of 3-5 years.

In order to identify opportunities for cost-effective retrofits, it is necessary to conduct building-level energy audits. The State of New Jersey runs multiple programs that help identify and subsidize retrofits. Buildings with 200 KW average peak demand can be analyzed and retrofitted through the NJ Clean Energy Direct install program, which covers 70% of the cost. Larger buildings can be audited using NJ Clean Energy's Local Government Auditing program, which covers up to $100,000 annually for the audits.

Based on energy efficiency audits, Rutgers can submit an energy efficiency plan under the NJ Clean Energy Program (NJCEP) Large Energy Users Program. If the plan meets the program's criteria, Rutgers can receive subsidies up to the smallest of: (a) $4 million, (b) 75% of total project(s) cost, (c) 90% of total NJCEP fund contribution in previous year, which is typically about $2 million, and (d) $0.33 per projected kWh saved and $3.75 per projected Btu saved annually.

1.3.1.1. Emissions reductions and resilience improvements

While more detailed analysis is necessary, assuming an energy efficiency potential comparable to that identified by the University of California assessment suggests that about 30% of energy-related emissions can be avoided through efficiency measures. This suggests a potential of about 110,000 t CO_2.

1.3.1.2. Financial costs and savings

Financial costs and savings will vary from building to building. Typical payback periods are 3-5 years. In average it is a three to five-year payback. Given annual energy expenditures of about $60 million, our initial estimate is a total potential savings through energy efficiency investments of about $20 million/year for an initial cost of about $80 million. Savings from energy efficiency investments can be recycled through a Green Revolving Fund to fund further revenue-positive emissions-reducing measures. As with solar power, third-party financing options are available. For compliant energy efficiency proposals, based on Rutgers' NJCEP fund contribution, NJCEP will cover about 75% of projects totaling $2.4 M/yr.

1.3.1.3. Benefits to the University's educational and research mission and to campus culture

Facilities is working with students to put together packages to submit to NJ Clean Energy, which gives students a basic understanding of utilities and how buildings use them. More broadly, energy retrofits into campus-as-living-lab educational opportunities.

1.3.1.5. Implementation Plan and Timescale

From (1) requesting support for a building audit, to (2) getting the building audited, to (3) retrofitting takes about nine months.

1.3.1.6. Needed research and planning

Building-level energy audits are needed to identify specific retrofit opportunities. Financial research is needed to assess tradeoffs between debt financing and third-party financing.

1.3.1.7. Evaluation plan

Facilities (Institutional Planning and Operation) is the lead office for implementation. Treasury must be involved in the provision of capital.

[12] Meier et al., "University of California Strategies for Decarbonization."

1.3.1.8. Management roles

This project will be led by Facilities.

1.3.1.11. Contribution to Climate-Positive, Equitable, Sustainable Economic Development

Building retrofits create short-term construction jobs and contribute to overall state goals for energy efficiency. Consistent with state goals, Rutgers could work with the Supplier Diversity Development Council to increase opportunities for minority-, woman- and veteran-owned businesses.

1.3.5. Energy Demand: New Building Standards

New Jersey's 2019 Energy Master Plan calls for building state-funded projects to the "highest attainable, above-code building performance standard using a whole-building approach, such as Passive House design." Rutgers already builds all new buildings to LEED Silver, but can explore elevating this to LEED Gold and requiring a certain portion of the points in the Energy and Atmosphere category within the standard to be associated with energy efficiency standards. It could also set quantitative energy-intensity maxima for buildings by type and usage. In addition, the design and powering of new buildings should be evaluated within the context of plans to gradually transition the campus away from natural gas.

1.3.3.1. Emissions reductions and resilience improvements

The adoption of building standards will allow the potential energy savings associated with demand reduction in the discussion of existing buildings above to be captured as the University builds new structures and decommissions old ones.

1.3.3.2. Needed research and planning

A thorough analysis of alternative building standards is the next step in this endeavor, and should be able to be completed within a year.

1.3.3.3. Management roles

The evaluation of options should be undertaken as a collaboration between Facilities and Planning & Design. Once developed, standards will be enforced by Planning & Design.

1.3.4. Energy Demand: Metering, Monitoring and Control Systems

Building energy efficiency generally degrades over time. On top of the potential savings from energy efficiency retrofits, systematically detecting, diagnosing, and correcting operational problems using automated or semi-automated processes can reduce energy consumption by 10-30%.[13]

Opportunities include: metering of all utilities at the building level and plant levels, upgrade of control systems in plants to better operate the distribution of energy to buildings on the plant loops, building controls for building operations and monitoring of building to better distribute energy form the plants.

There is a direct linkage between monitoring and controls on the one hand and emissions reduction and resilience improvements on the other. Smart metering and real time measurement, interconnected with controls, can ensure a building is being operated at peak efficiency for the building load at a particular time. The truism that you can't manage what you don't measure underlies this solution. For the most part, buildings operate part load. Real-time monitoring and control allow the load produced to be adjusted to

[13] Nicholas EP Fernandez et al., "Impacts of Commercial Building Controls on Energy Savings and Peak Load Reduction" (Pacific Northwest National Lab.(PNNL), Richland, WA (United States), 2017).

meet the load required. When not metered or monitored the thermal load produced to accommodate the buildings load will be at full load and waste energy.

Metering will also make the performance of individual buildings more visible, which in turn helps identify poor energy performers that warrant priority investments in energy upgrades. Metering also provides a quantitative basis for incentivizing units to perform better operationally. Both the prioritized capital improvements and incentivized operational improvements will yield emissions reductions. Upgraded building monitoring and control systems will enhance situational awareness, operational performance, and coordination among building users and central utilities personnel, and lead to quicker problem-solving.

The U.S. General Services Administration estimates that installation of metering potentially has four sets of associated savings based on experiences within their portfolio: (1) a temporary behavioral impact of up to 2% energy cost savings when meters are installed; (2) a 2.5% – 5.0% permanent energy cost savings when costs are actually allocated to building users; (3) a 5% - 15% permanent energy cost savings when buildings are subsequently tuned up and when demand management strategies are put in place; and (4) a 15% - 45% permanent energy cost savings when an ongoing regime of building commissioning continues to maintain the building and actively manage it.[14] The benefits outweigh the costs most frequently when meter installation (item #1) is accompanied by some level of active management commitment (items #2-4). Note that the largest potential savings are associated with active management, not incentivized behavioral changes.

Improved monitoring and control of utility plants and district energy distribution loops will also result in savings. Though we cannot say by reducing X we save Y we do now that better control and monitoring will ensure that only the energy needed will be produced and used.

1.3.1.1. Emissions reductions and resilience improvements

While more detailed analysis is necessary, assuming an energy efficiency potential comparable to that identified by the GSA suggests that about 30% of energy-related emissions can be avoided through efficiency measures. This suggests a potential of about 110,000 t CO_2.

1.3.1.2. Financial costs and savings

More information is needed to assess the costs of monitoring, controls, and education needed to achieve the potential identified in the GSA study. The potential savings in terms of reduced energy expenditures are estimated to be about $20 million/year if applied in isolation, or about $30 million/year if combined with building retrofits discussed above.

Savings from energy efficiency investments could be recycled through a Green Revolving Fund to fund further revenue-positive emissions-reducing measures.

1.3.4.3. Benefits to the University's educational and research mission and to campus culture

When systems are monitored and controlled the data collected can be used for education and research on many levels. Metering empowers building users to participate in energy management. It "gamifies" participation by providing a means of score-keeping, for example in inter-dormitory energy saving competitions. The combination of metering and monitoring also makes buildings useful living laboratories for studying a variety of physics, mechanical engineering, psychology, and social science topics.

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[14] General Services Administration, U.S. 2012. Submetering Business Case: How to calculate cost-effective solutions in the building context. Accessed on November 1, 2020 at https://www.gsa.gov/cdnstatic/Energy_Submetering_Finance_Paper_Knetwork_2012_11_269%28508%29.pdf.

1.3.4.4. Implementation Plan and Timescale

From RFP to starting construction will take about one year. Installation of meters will take about two years. Installation of controls will take about five to ten years, depending on how aggressive the pace of investment is.

1.3.4.5. Needed Research and Planning

The Rutgers Utilities office will write a request for proposals to have all campus buildings metered to identify the costs and next steps for this high priority action to manage building energy. Metering and measuring will make it apparent where building controls will need to be upgraded in order to monitor and control in real time. At a building-level, an assessment of each building and system is needed to determine what meters are needed and how best to upgrade existing control systems. At a system level, control systems to allow building and central plant controls need to be identified.

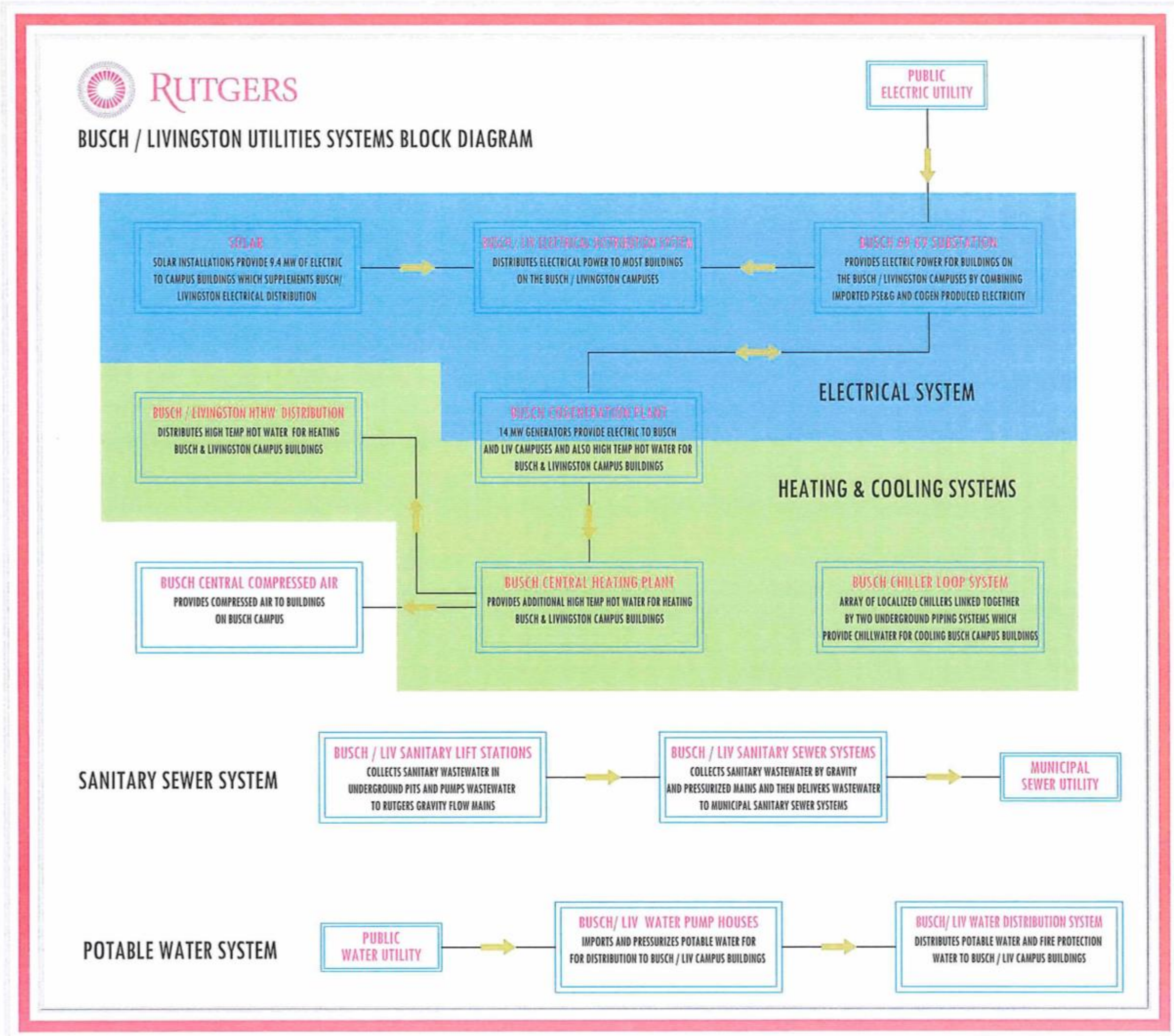
1.3.4.6. Evaluation plan

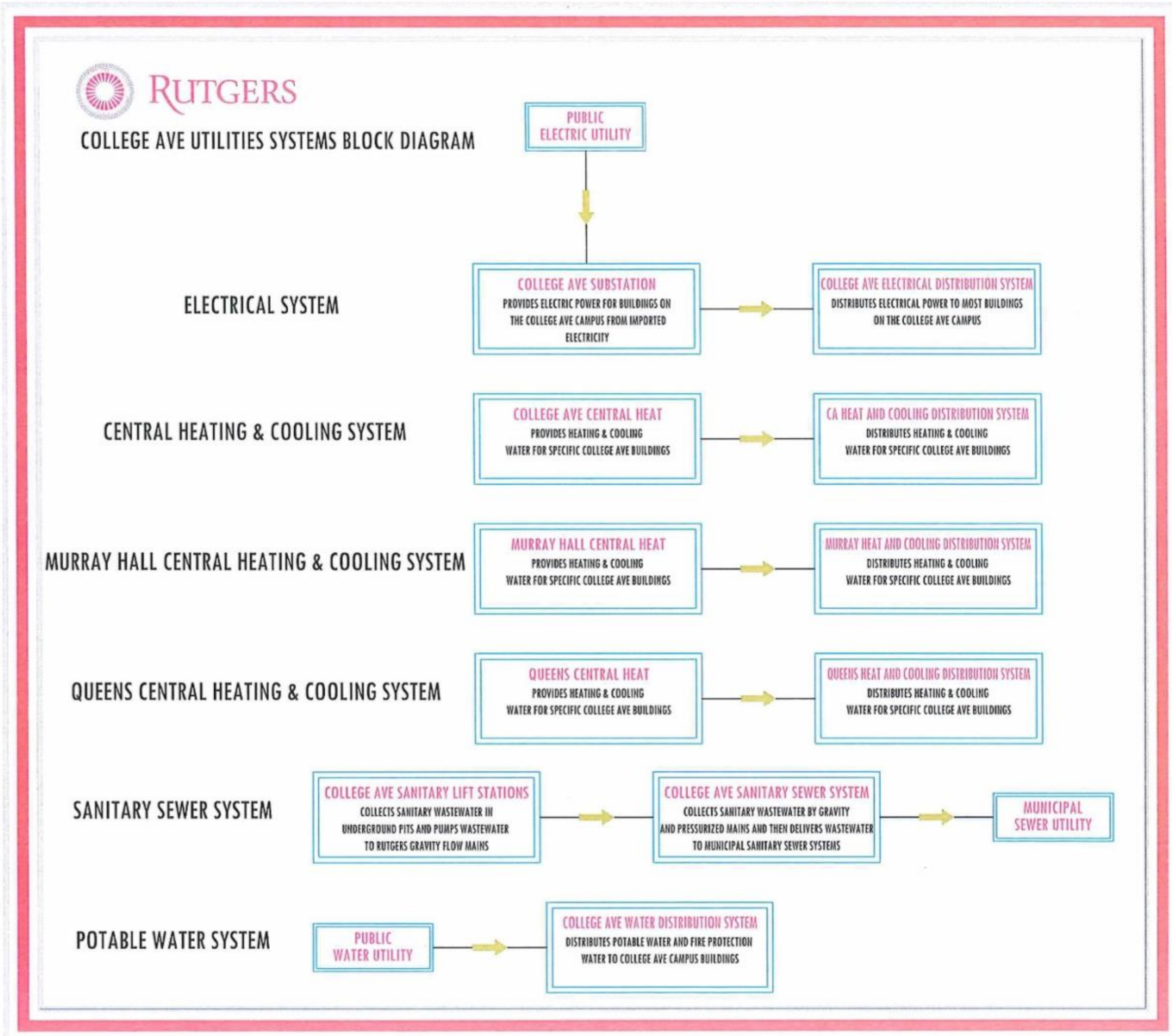
Success will be evaluated by the installation and operation of controls and metering and the resulting energy savings.

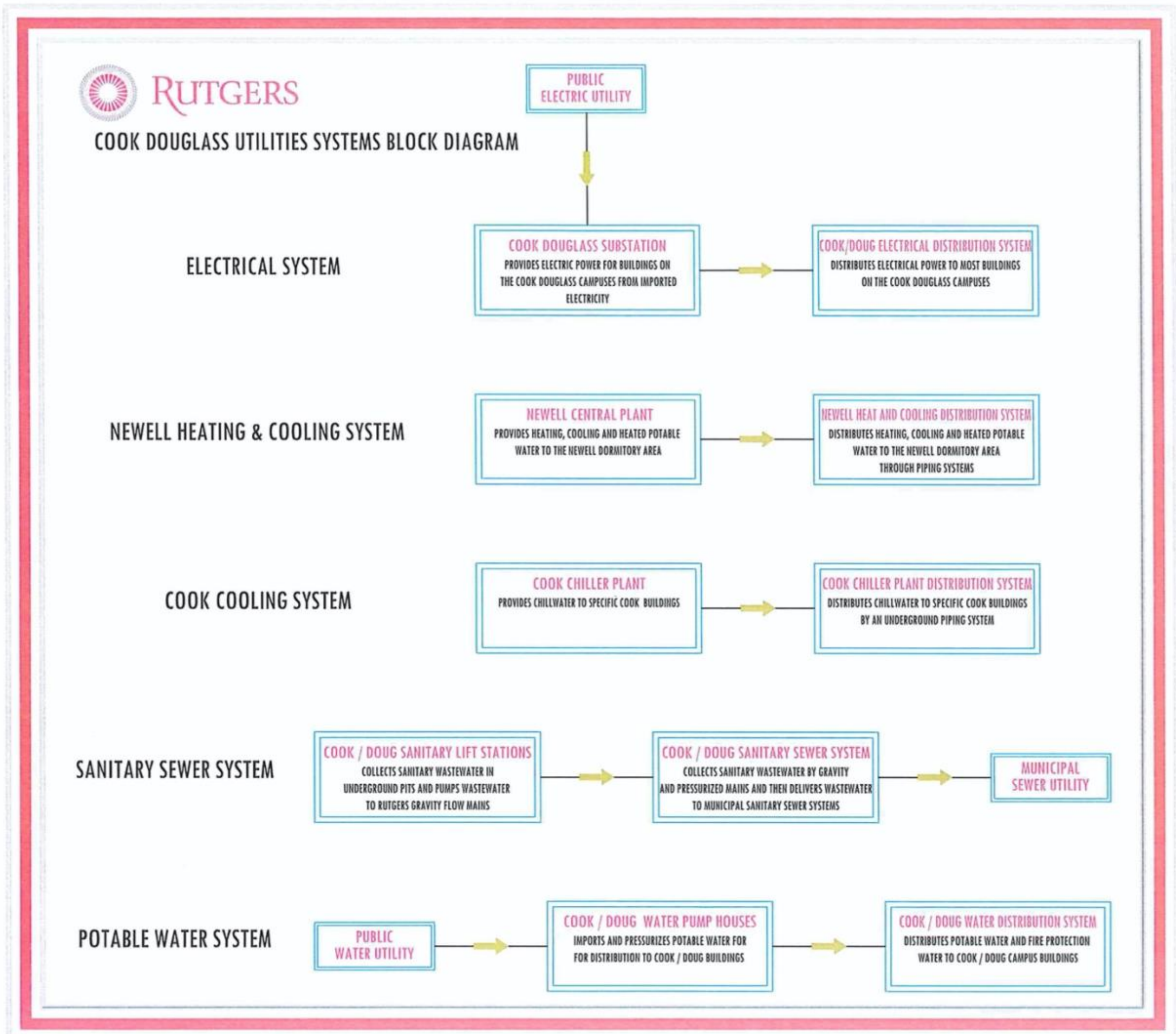
1.3.4.7. Management roles

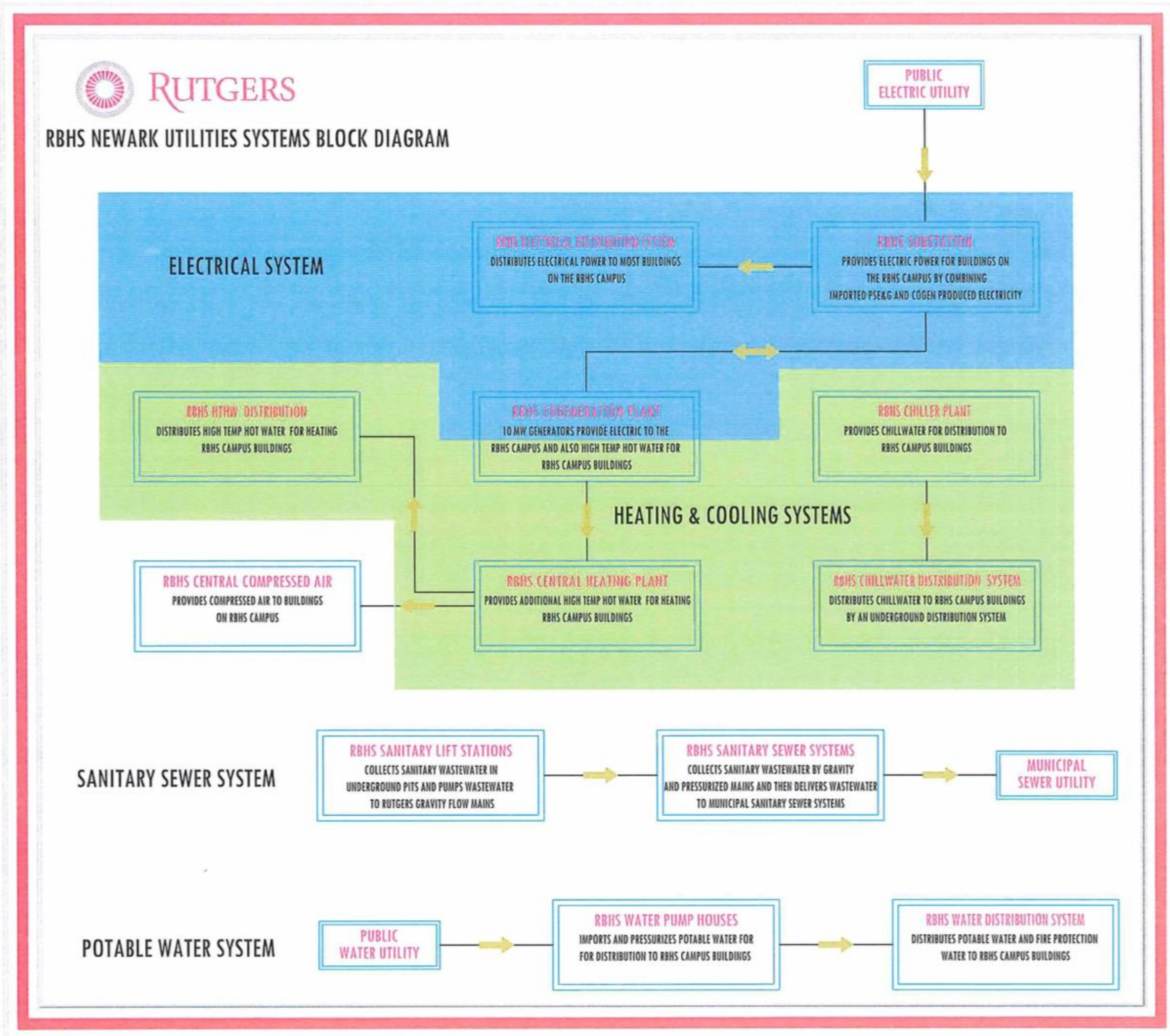
This project will be led by Facilities.

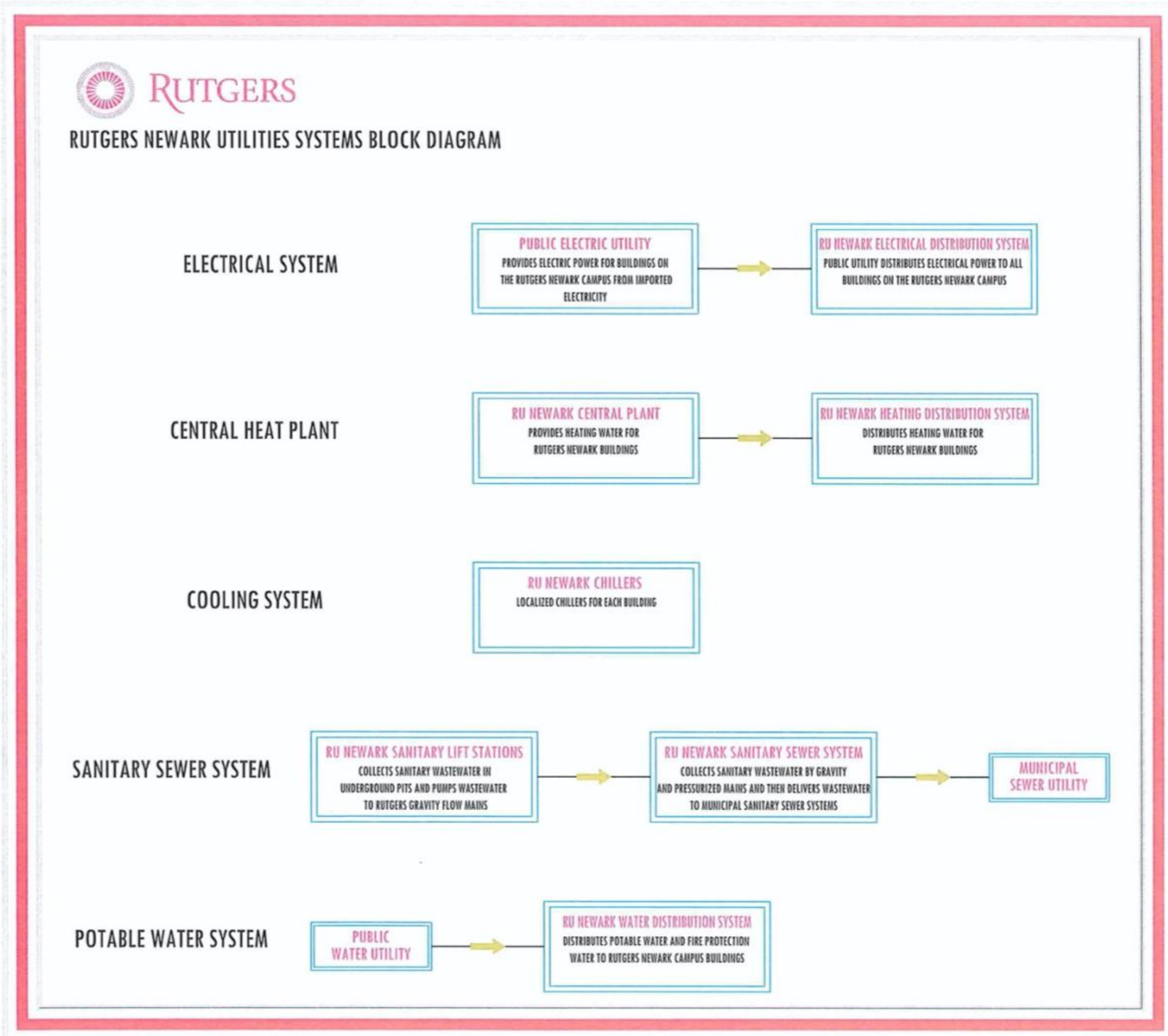
APPENDIX A – Campus Utility Systems

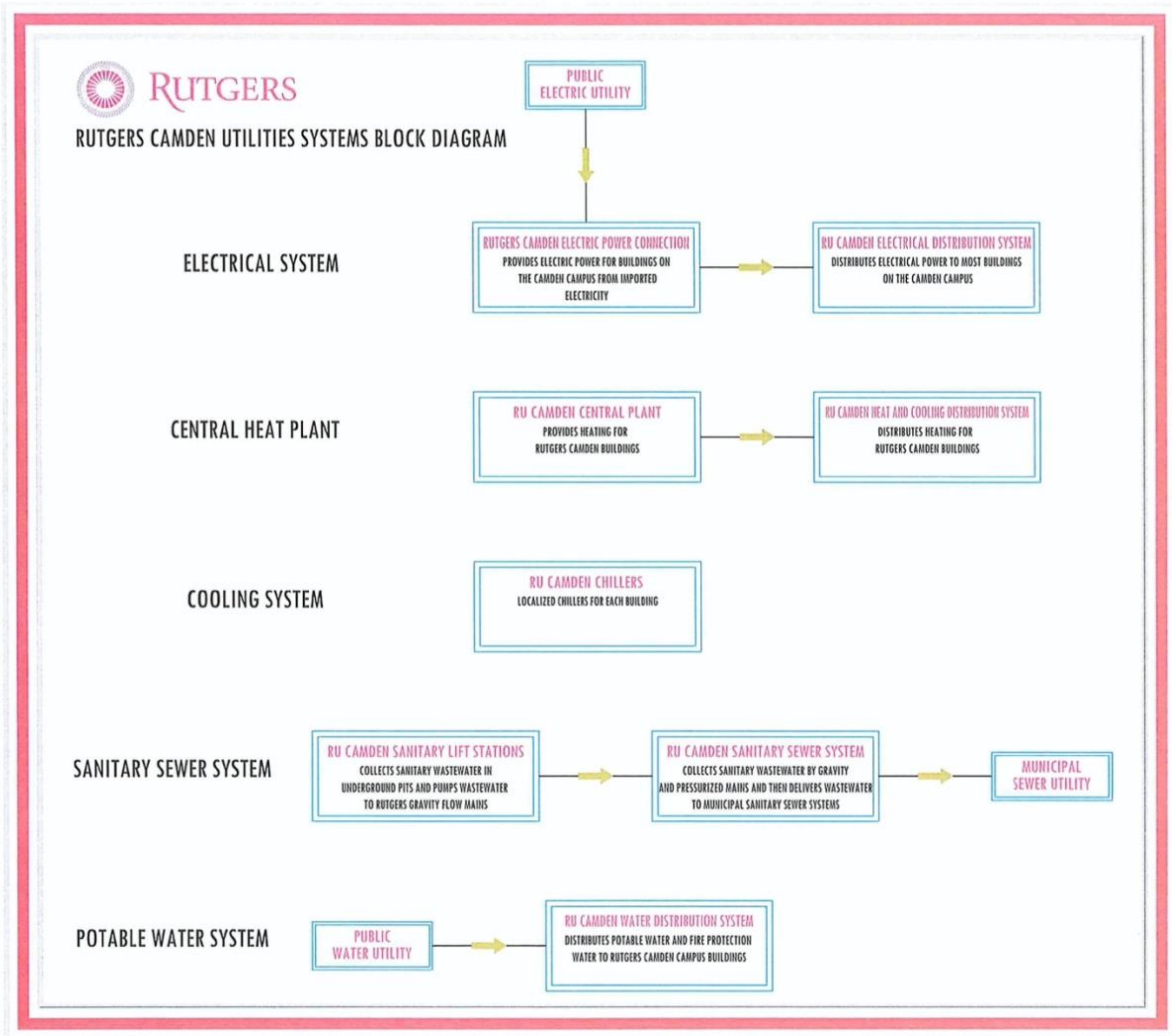



RUTGERS
COLLEGE AVE UTILITIES SYSTEMS BLOCK DIAGRAM
PUBLIC ELECTRIC UTILITY
ELECTRICAL SYSTEM
COLLEGE AVE SUBSTATION
PROVIDES ELECTRIC POWER FOR BUILDINGS ON THE COLLEGE AVE CAMPUS FROM IMPORTED ELECTRICITY
COLLEGE AVE ELECTRICAL DISTRIBUTION SYSTEM
DISTRIBUTES ELECTRICAL POWER TO MOST BUILDINGS ON THE COLLEGE AVE CAMPUS
CENTRAL HEATING & COOLING SYSTEM
COLLEGE AVE CENTRAL HEAT
PROVIDES HEATING & COOLING WATER FOR SPECIFIC COLLEGE AVE BUILDINGS
CA HEAT AND COOLING DISTRIBUTION SYSTEM
DISTRIBUTES HEATING & COOLING WATER FOR SPECIFIC COLLEGE AVE BUILDINGS
MURRAY HALL CENTRAL HEATING & COOLING SYSTEM
MURRAY HALL CENTRAL HEAT
PROVIDES HEATING & COOLING WATER FOR SPECIFIC COLLEGE AVE BUILDINGS
MURRAY HEAT AND COOLING DISTRIBUTION SYSTEM
DISTRIBUTES HEATING & COOLING WATER FOR SPECIFIC COLLEGE AVE BUILDINGS
QUEENS CENTRAL HEATING & COOLING SYSTEM
QUEENS CENTRAL HEAT
PROVIDES HEATING & COOLING WATER FOR SPECIFIC COLLEGE AVE BUILDINGS
QUEENS HEAT AND COOLING DISTRIBUTION SYSTEM
DISTRIBUTES HEATING & COOLING WATER FOR SPECIFIC COLLEGE AVE BUILDINGS
SANITARY SEWER SYSTEM
COLLEGE AVE SANITARY LIFT STATIONS
COLLECTS SANITARY WASTEWATER IN UNDERGROUND PITS AND PUMPS WASTEWATER TO RUTGERS GRAVITY FLOW MAINS
COLLEGE AVE SANITARY SEWER SYSTEM
COLLECTS SANITARY WASTEWATER BY GRAVITY AND PRESSURIZED MAINS AND THEN DELIVERS WASTEWATER TO MUNICIPAL SANITARY SEWER SYSTEMS
MUNICIPAL SEWER UTILITY
POTABLE WATER SYSTEM
PUBLIC WATER UTILITY
COLLEGE AVE WATER DISTRIBUTION SYSTEM
DISTRIBUTES POTABLE WATER AND FIRE PROTECTION WATER TO COLLEGE AVE CAMPUS BUILDINGS


RUTGERS
COOK DOUGLASS UTILITIES SYSTEMS BLOCK DIAGRAM
PUBLIC ELECTRIC UTILITY
ELECTRICAL SYSTEM
COOK DOUGLASS SUBSTATION
PROVIDES ELECTRIC POWER FOR BUILDINGS ON THE COOK DOUGLASS CAMPUSES FROM IMPORTED ELECTRICITY
COOK/DOUG ELECTRICAL DISTRIBUTION SYSTEM
DISTRIBUTES ELECTRICAL POWER TO MOST BUILDINGS ON THE COOK DOUGLASS CAMPUSES
NEWELL HEATING & COOLING SYSTEM
NEWELL CENTRAL PLANT
PROVIDES HEATING, COOLING AND HEATED POTABLE WATER TO THE NEWELL DORMITORY AREA
NEWELL HEAT AND COOLING DISTRIBUTION SYSTEM
DISTRIBUTES HEATING, COOLING AND HEATED POTABLE WATER TO THE NEWELL DORMITORY AREA THROUGH PIPING SYSTEMS
COOK COOLING SYSTEM
COOK CHILLER PLANT
PROVIDES CHILLWATER TO SPECIFIC COOK BUILDINGS
COOK CHILLER PLANT DISTRIBUTION SYSTEM
DISTRIBUTES CHILLWATER TO SPECIFIC COOK BUILDINGS BY AN UNDERGROUND PIPING SYSTEM
SANITARY SEWER SYSTEM
COOK / DOUG SANITARY LIFT STATIONS
COLLECTS SANITARY WASTEWATER IN UNDERGROUND PITS AND PUMPS WASTEWATER TO RUTGERS GRAVITY FLOW MAINS
COOK / DOUG SANITARY SEWER SYSTEM
COLLECTS SANITARY WASTEWATER BY GRAVITY AND PRESSURIZED MAINS AND THEN DELIVERS WASTEWATER TO MUNICIPAL SANITARY SEWER SYSTEMS
MUNICIPAL SEWER UTILITY
POTABLE WATER SYSTEM
PUBLIC WATER UTILITY
COOK / DOUG WATER PUMP HOUSES
IMPORTS AND PRESSURIZES POTABLE WATER FOR FOR DISTRIBUTION TO COOK / DOUG BUILDINGS
COOK / DOUG WATER DISTRIBUTION SYSTEM
DISTRIBUTES POTABLE WATER AND FIRE PROTECTION WATER TO COOK / DOUG CAMPUS BUILDINGS


RUTGERS
RBHS NEWARK UTILITIES SYSTEMS BLOCK DIAGRAM
PUBLIC ELECTRIC UTILITY
ELECTRICAL SYSTEM
RBHS ELECTRICAL DISTRIBUTION SYSTEM
DISTRIBUTES ELECTRICAL POWER TO MOST BUILDINGS ON THE RBHS CAMPUS
RBHS SUBSTATION
PROVIDES ELECTRIC POWER FOR BUILDINGS ON THE RBHS CAMPUS BY COMBINING IMPORTED PSE&G AND COGEN PRODUCED ELECTRICITY
RBHS HTHW DISTRIBUTION
DISTRIBUTES HIGH TEMP HOT WATER FOR HEATING RBHS CAMPUS BUILDINGS
RBHS COGENERATION PLANT
10 MW GENERATORS PROVIDE ELECTRIC TO THE RBHS CAMPUS AND ALSO HIGH TEMP HOT WATER FOR RBHS CAMPUS BUILDINGS
RBHS CHILLER PLANT
PROVIDES CHILLWATER FOR DISTRIBUTION TO RBHS CAMPUS BUILDINGS
HEATING & COOLING SYSTEMS
RBHS CENTRAL COMPRESSED AIR
PROVIDES COMPRESSED AIR TO BUILDINGS ON RBHS CAMPUS
RBHS CENTRAL HEATING PLANT
PROVIDES ADDITIONAL HIGH TEMP HOT WATER FOR HEATING RBHS CAMPUS BUILDINGS
RBHS CHILLWATER DISTRIBUTION SYSTEM
DISTRIBUTES CHILLWATER TO RBHS CAMPUS BUILDINGS BY AN UNDERGROUND DISTRIBUTION SYSTEM
SANITARY SEWER SYSTEM
RBHS SANITARY LIFT STATIONS
COLLECTS SANITARY WASTEWATER IN UNDERGROUND PITS AND PUMPS WASTEWATER TO RUTGERS GRAVITY FLOW MAINS
RBHS SANITARY SEWER SYSTEMS
COLLECTS SANITARY WASTEWATER BY GRAVITY AND PRESSURIZED MAINS AND THEN DELIVERS WASTEWATER TO MUNICIPAL SANITARY SEWER SYSTEMS
MUNICIPAL SEWER UTILITY
POTABLE WATER SYSTEM
PUBLIC WATER UTILITY
RBHS WATER PUMP HOUSES
IMPORTS AND PRESSURIZES POTABLE WATER FOR FOR DISTRIBUTION TO RBHS CAMPUS BUILDINGS
RBHS WATER DISTRIBUTION SYSTEM
DISTRIBUTES POTABLE WATER AND FIRE PROTECTION WATER TO RBHS CAMPUS BUILDINGS


RUTGERS
RUTGERS NEWARK UTILITIES SYSTEMS BLOCK DIAGRAM
ELECTRICAL SYSTEM
PUBLIC ELECTRIC UTILITY
PROVIDES ELECTRIC POWER FOR BUILDINGS ON THE RUTGERS NEWARK CAMPUS FROM IMPORTED ELECTRICITY
RU NEWARK ELECTRICAL DISTRIBUTION SYSTEM
PUBLIC UTILITY DISTRIBUTES ELECTRICAL POWER TO ALL BUILDINGS ON THE RUTGERS NEWARK CAMPUS
CENTRAL HEAT PLANT
RU NEWARK CENTRAL PLANT
PROVIDES HEATING WATER FOR RUTGERS NEWARK BUILDINGS
RU NEWARK HEATING DISTRIBUTION SYSTEM
DISTRIBUTES HEATING WATER FOR RUTGERS NEWARK BUILDINGS
COOLING SYSTEM
RU NEWARK CHILLERS
LOCALIZED CHILLERS FOR EACH BUILDING
SANITARY SEWER SYSTEM
RU NEWARK SANITARY LIFT STATIONS
COLLECTS SANITARY WASTEWATER IN UNDERGROUND PITS AND PUMPS WASTEWATER TO RUTGERS GRAVITY FLOW MAINS
RU NEWARK SANITARY SEWER SYSTEM
COLLECTS SANITARY WASTEWATER BY GRAVITY AND PRESSURIZED MAINS AND THEN DELIVERS WASTEWATER TO MUNICIPAL SANITARY SEWER SYSTEMS
MUNICIPAL SEWER UTILITY
POTABLE WATER SYSTEM
PUBLIC WATER UTILITY
RU NEWARK WATER DISTRIBUTION SYSTEM
DISTRIBUTES POTABLE WATER AND FIRE PROTECTION WATER TO RUTGERS NEWARK CAMPUS BUILDINGS


RUTGERS
RUTGERS CAMDEN UTILITIES SYSTEMS BLOCK DIAGRAM
PUBLIC ELECTRIC UTILITY
ELECTRICAL SYSTEM
RUTGERS CAMDEN ELECTRIC POWER CONNECTION
PROVIDES ELECTRIC POWER FOR BUILDINGS ON THE CAMDEN CAMPUS FROM IMPORTED ELECTRICITY
RU CAMDEN ELECTRICAL DISTRIBUTION SYSTEM
DISTRIBUTES ELECTRICAL POWER TO MOST BUILDINGS ON THE CAMDEN CAMPUS
CENTRAL HEAT PLANT
RU CAMDEN CENTRAL PLANT
PROVIDES HEATING FOR RUTGERS CAMDEN BUILDINGS
RU CAMDEN HEAT AND COOLING DISTRIBUTION SYSTEM
DISTRIBUTES HEATING FOR RUTGERS CAMDEN BUILDINGS
COOLING SYSTEM
RU CAMDEN CHILLERS
LOCALIZED CHILLERS FOR EACH BUILDING
SANITARY SEWER SYSTEM
RU CAMDEN SANITARY LIFT STATIONS
COLLECTS SANITARY WASTEWATER IN UNDERGROUND PITS AND PUMPS WASTEWATER TO RUTGERS GRAVITY FLOW MAINS
RU CAMDEN SANITARY SEWER SYSTEM
COLLECTS SANITARY WASTEWATER BY GRAVITY AND PRESSURIZED MAINS AND THEN DELIVERS WASTEWATER TO MUNICIPAL SANITARY SEWER SYSTEMS
MUNICIPAL SEWER UTILITY
POTABLE WATER SYSTEM
PUBLIC WATER UTILITY
RU CAMDEN WATER DISTRIBUTION SYSTEM
DISTRIBUTES POTABLE WATER AND FIRE PROTECTION WATER TO RUTGERS CAMDEN CAMPUS BUILDINGS