

Rice University's Integrated Climate and Energy Master Plan

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ABSTRACT

Beginning in 2012, Rice University partnered with Sebesta, Inc., to develop a 30-year integrated climate and energy master plan for Rice University that would address several of Rice's requirements, including:

1. Serve campus growth of facilities and associated energy requirements;
2. Improve energy performance of campus facilities and utility systems;
3. Meet campus sustainability goals.

Recognizing the interdependence of all system components to meet Rice's climate commitment, an integrated approach was taken to address campus steam/electricity/chilled water production and distribution systems in conjunction with the demand-side performance of energy using facilities. This article presents the process used for the master planning effort, and the findings and recommendations of the master plan.

The major findings were:

1. By implementing aggressive but achievable demand-side improvements to existing and new facility energy-using systems (30% thermal and 20% electric reduction) and central plant op-

erational improvements, Rice could grow their campus while reducing energy purchases, maintaining existing levels of utility production, and improving plant redundancy and reliability.

2. By investing in expansion of campus cogeneration facilities, Rice University can significantly reduce campus operating costs while providing increased responsiveness to fluctuating energy prices. Expanded cogeneration would also reduce campus CO₂ emissions by 70%, substantially helping Rice meet its net zero carbon goal.
3. Upgrading campus instrumentation, and metering and communications systems will provide the data necessary for energy purchase strategies and improved operations.
4. In conjunction with implementation of the strategies above, a plan was developed to allow Rice University to achieve a net zero carbon goal by 2038 that included renewable energy generation and sequestration.

INTRODUCTION

The configuration, operation and environmental performance of the utility and associated campus facilities served by the utility infrastructure should incorporate the values and mission of the university. A core value of the university is "...increasing access to both education and knowledge, fostering a commitment to excellence, promoting leadership, integrating knowledge across disciplines, creating a strong sense of community and valuing its diverse members, and contributing to the solution of local, national, and global challenges."*

This core value and mission statement formed the impetus for the sustainability policy of Rice University:

Mission Statement of Rice University

As a leading research university with a distinctive commitment to undergraduate education, Rice University aspires to groundbreaking research, unsurpassed teaching, and contribution to the betterment of our

*<http://www.professor.rice.edu/Mission.asp?SnID=1364445239>

world. It seeks to fulfill this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor.

Rice University recognizes the critical importance of sustainability. Its present needs must be met while protecting the interests of future generations. The Shell Center for Sustainability, the Center for the Study of Environment and Society, the Environment & Energy Systems Institute and student organizations should be utilized to foster environmental consciousness and mitigate the University's ecological footprint. Rice University works with students, faculty, and staff to improve environmental sensitivity. University practices will evolve along with the Rice community to keep abreast with changing needs and new technologies. The University believes that students who graduate from Rice need to understand the concepts of sustainability and possess a sense of responsibility for the future.

Rice University is a signatory of the American College and University President's Climate Commitment (ACUPCC). The Rice Integrated Climate and Energy Master Plan (RICEMaP) is an expression of that commitment and university values, mission and policy, as well as a planning initiative for a general framework that will leverage campus assets and resources, existing and future, and facilitate optimization of sustainability in terms of energy, economics and environment. The three primary elements of this initiative are an empirical recognition of the interdependence of performance and capacity of campus utility infrastructure, performance and efficiency of campus facilities served by the utility infrastructure, and metering and data systems to monitor and manage the performance of utility production and consumption of utility service:

Report 1: Energy Production, Distribution, and Storage Plan

Report 2: Building Level Energy Efficiency

Report 3 Energy System Metering, Measurements and Controls

The intent of RICEMaP is to develop an integrated climate and energy master plan that:

1. Provides guidance on future plant- and campus-level energy investments and decisions, while setting a pathway and a date for achieving no net greenhouse gas emissions (fulfilling Rice's obligation as a signatory of the ACUPCC);

2. Develops a menu of specific building-level energy reduction and conservation projects for demand-reduction capital investment and long-term deferred maintenance in a coordinated manner;
3. Assesses the university's metering and telemetry infrastructure and develops a menu of investments necessary for a consistent baseline.

The utility infrastructure must have the capacity necessary to deliver cost-effective and reliable service to the campus, but also the resiliency to respond to the dynamic conditions beyond the border of the campus.

The development of RICEMaP has been guided by a steering committee comprised of representatives from academia and administration. The steering committee of RICEMaP crafted six guiding principles for campus and utility performance, and alternate campus scenarios for utility system configurations.

GUIDING PRINCIPLES FOR UTILITY DEVELOPMENT, CONFIGURATION AND OPERATION

1. Provide connectivity between facilities for campus resilience, redundancy and flexibility
2. Consider goal of a net-zero energy campus
3. Have protection from and exploitation of volatility in energy prices
4. Improve performance of facilities—reduce energy consumption by at least 30%
5. Improve performance of existing utility infrastructure assets
6. Understand /debate appropriate investments in layers of building systems /campus systems

These principles establish a general framework to examine the existing utility configuration and delivery of utility services, the inter-relationship of utility provider and consumer of utility services, and the capital implications of campus development and utility development. Within this framework it is possible to quantify the status quo and iden-

tify strategies and measures to respond to anticipated changes to higher education and the environment in which it operates.

Guiding Principle	Planning Elements: Report 1							Report 2	Report 3
	Central Plant Operational Improvements	Equipment Useful Life	Interconnection of North & South Plants	Expand Cogeneration	Expanded Participation in Utility Programs	Energy Use Flexibility	Renewable Energy	Building Demand Side Management	Energy System Meters & Controls
1. Connectivity of Campus Facilities									
2. Net Zero Goal for Campus									
3. Respond to Energy Prices									
4. Improve Campus Facility Performance									
5. Improve Campus Utility Performance									
6. Understand Layers of Campus Investment									

Figure 1

Changing student demographics and integration of new technologies are also changing methods of teaching. Delivery of services/knowledge must consequently change with potential implications for campus infrastructure. All traditional university revenue streams are under stress. The cost of campus infrastructure is now the largest component of the university’s budget. Energy resources necessary for campus utilities are likely to become limited and expensive in the next 20 to 25 years. Planning for utilities and campus infrastructure must provide the flexibility and resilience to accommodate these trends.

Seven planning elements of utility configuration and utility operations emerged from these principles:

1. Central plant operational improvements
2. Equipment useful life for best use of investment
3. Interconnection of north and south plants
4. Expanded cogeneration
5. Expanded participation in utility programs
6. Energy use flexibility
7. Renewable energy

Each planning element supports the guiding principles, and all the planning elements and guiding principles are complemented by building-level energy efficiency (Report 2) and energy system metering, measurement and controls (Report 3). The performance of the utility infrastructure establishes the efficiency of production. The performance of facilities connected to the utility drives the efficiency of overall utility service. Meters and controls provide the basis for managing utility assets and effective delivery of utility service.

CONCLUSIONS

Four general utility scenarios were identified and evaluated in terms of capital cost, fuel and electric expense, and associated environmental performance.

Scenario 1: Business as usual

Scenario 2: Campus demand-side management (DSM) and plant operational improvements

Scenario 3: Expanded cogeneration at the south plant

Scenario 4: Expanded cogeneration at the south and north plants

The scenarios incorporate various aspects of the guiding principles established for Rice Integrated Climate and Energy Master Plan: connectivity of campus facilities, contribution toward net zero goal for campus (energy or CO₂ emissions), flexible operations for response to fluctuating energy prices, improvement of campus facility energy performance, improvement of campus utility efficiency, and effective capital investment for the campus. Participation in utility programs and other complementary measures to improve energy use flexibility, such as thermal storage or steam drive turbine chillers and condensing turbine generation, are stand-alone business cases that can be applied to any of the scenarios.

Scenario 1:

Scenario 1 quantifies the fuel and energy expense and capital cost of utility operations for the existing campus and anticipated campus growth reflecting in-kind replacement of systems.

Scenario 2:

Scenario 2, Campus DSM and Plant Operational Improvements, is a corresponding forecast of expense and capital cost which applies the demand-side management findings of Report 2 to the existing campus and campus growth and reflects the improved performance of identified energy conservation measures at the central plants. Each of these scenarios is based on maintaining the existing utility plant configuration.

Scenario 3:

Scenario 3 evaluates the effect of expanded cogeneration at the south plant—a combined cycle system with total capacity of 6,240 kW and 50,000 PPH (pounds per hour) of HRSG (heat recovery steam generator) steam production operational in 2015.

Scenario 4:

Scenario 4 includes a second combined cycle system of the same capacity at the north plant, replacing the existing solar turbine and HRSG-2 in 2024. Scenarios 3 and 4 are inclusive of campus DSM and plant operational improvements, serving the same campus utility requirements as Scenario 2, which includes the effect of campus DSM and plant operational improvements.

Figure 2 provides a graphical present value comparison of the scenarios in terms of natural gas, purchased electric service and anticipated capital costs. The present value expense of natural gas and purchased electric service ranges from approximately \$248.49 million with Scenario 1, to \$157.97 million with the expanded cogeneration of Scenario 4. The present value expense of natural gas and purchased electric service with Scenario 2 is about 18% less than Scenario 1. The corresponding present value expense of Scenario 3 is about 10% less than Scenario 2, and that of Scenario 4 is about 13% less than Scenario 3.

The evaluation of existing utility operations and service requirements (present and future with anticipated growth) indicates that no additional steam production capacity or chilled water production capacity is necessary through 2040. However, given the age and annual load requirements of the utility system, the replacement of all major production equipment (boilers, heat recovery steam generators, chillers, cooling towers, etc.) and the incoming substation (north plant) should be expected. The estimated capital cost of replacing existing production

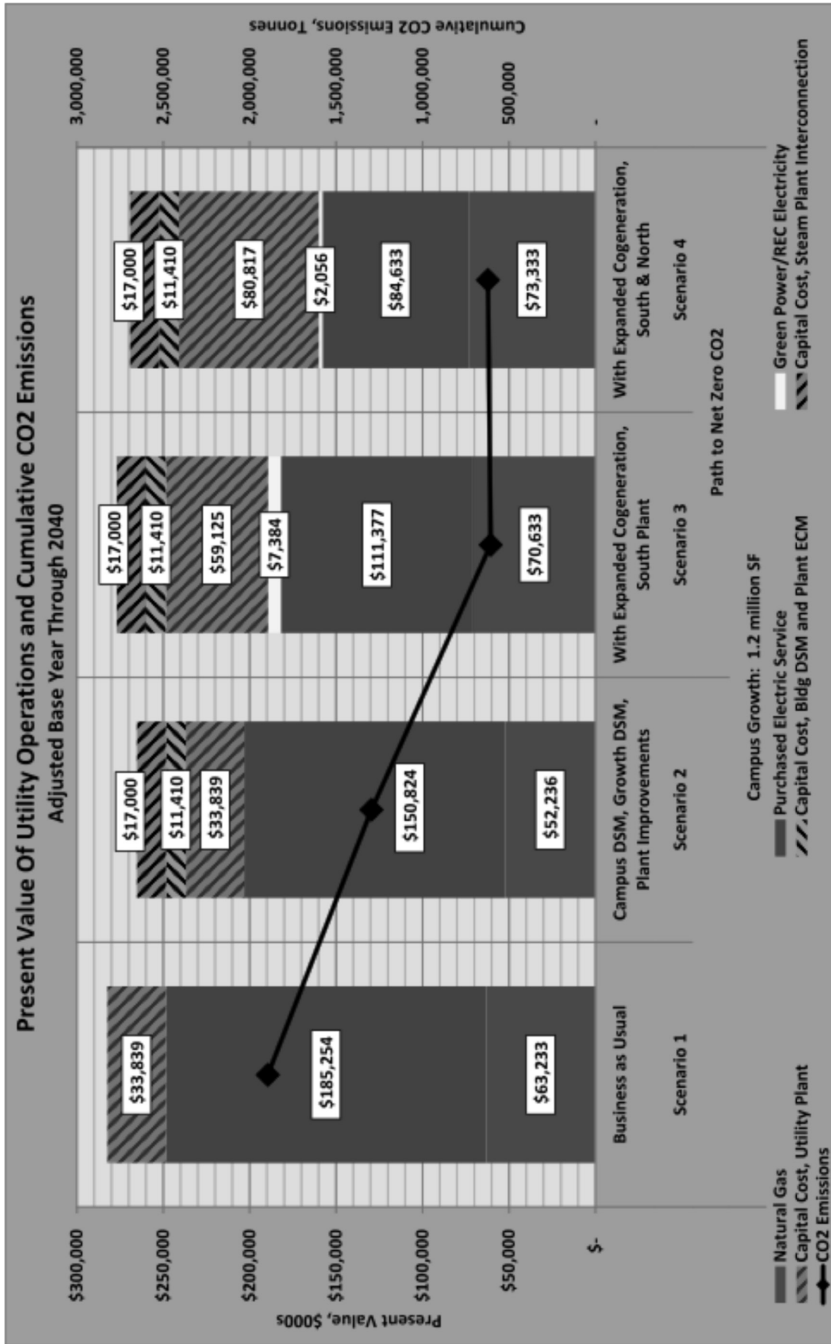


Figure 2

equipment and the incoming substation is \$33.84 million (2013\$). The total present value of Scenario 1 is then \$282.33 million (\$248.49 million + \$33.84 million).

The anticipated capital cost of Scenario 2 is approximately \$54.94 million, inclusive of \$33.84 million for utility equipment replacement from Scenario 1, \$11.41 million for campus DSM and plant operational improvements, and \$17.00 million for steam interconnection of north plant and south plant. The steam interconnection improves the reliability of campus steam service and allows better management of capacity for load requirements. The total present value of Scenario 2 with capital cost and natural gas and purchased electric service is \$265.31 million, or about 6% less than Scenario 1.

Expansion of cogeneration increases the capital cost of the utility plant to \$59.13 million for Scenario 3 (south plant) and \$80.82 million for Scenario 4 (south plant and north plant). The estimated capital cost of campus DSM and plant operational improvements and steam interconnection is the same: \$4.10 million and \$17.00 million, respectively. The total estimated capital cost of Scenario 3 and Scenario 4 is therefore \$87.54 million and \$109.23 million, respectively.

Table 1 provides a present value comparison of the utility scenarios for energy expense and capital cost. Scenario 2 carries an incremental capital cost of \$28.41 million over Scenario 1 for campus DSM and plant operational improvements. The anticipated performance of the Scenario 2 measures and improvements reduces the present value of energy expenses by approximately \$45.43 million with a present value reduction of energy expense being \$45.43 million. Similarly, Scenario 3 has an incremental capital cost of \$53.70 million relative to Scenario 1 with a \$59.09 million reduction in the present value of energy expenses. Scenario 4 shows an \$88.47 million reduction in the present value of energy expenses and an incremental capital cost of \$75.39 million. The incremental capital investment in cogeneration represents a fixed component of the present value that reduces the proportion of present value expenses susceptible to energy market fluctuations.

Figure 1 and Table 2 provide a general comparison of total CO₂ emissions (cumulative through 2040) for each scenario. The total emissions include the sequestration of carbon from Rice Land Lumber Company (RLL). The ability to use sequestered carbon, about 57,640 tonnes per year, is at the discretion of Rice Management Company (RMC) which owns RLL:

Table 1: Present Value Comparison of Utility Scenarios

(\$000s)	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Natural Gas	\$63,233	\$52,236	\$70,633	\$ 73,333
Purchased Electric Service	\$185,254	\$150,824	\$111,377	\$84,633
Green Power Electricity	\$0	\$0	\$7,384	\$ 2,056
Energy Expense	\$248,487	\$203,060	\$189,394	\$160,022
Capital Cost	\$33,839	\$62,249	\$87,535	\$109,227
Total	\$282,326	\$265,309	\$276,929	\$269,249

Table 2: Comparison of CO₂ Emissions by Utility Scenario

Scenario	Cumulative CO ₂ Emissions with Sequestration
1: Business as Usual	1,894,621 tonnes (metric tonnes)
2: Campus and Growth DSM and Plant Operational Improvements	1,294,884 tonnes
3: Expanded Cogeneration, South Plant	605,069 tonnes
4: Expanded Cogeneration, South Plant and North Plant	621,204 tonnes

The expanded cogeneration scenarios also include a path to net-zero emission of CO₂, indicated in Figure 1 as green power electricity or electricity having renewable energy credits (or REC electricity). Expanded cogeneration and sequestration significantly reduce CO₂ emissions, but not to the point of net zero. Procurement or acquisition of REC electricity can achieve net-zero emissions for the campus. The present value of REC electricity is \$7.38 million for Scenario 3 and \$2.06 million for Scenario 4, based on a price premium of \$0.02/kWh (for evaluation purposes, it may be possible to negotiate the purchase of such electricity without a price premium). The total present value of Scenario 3 is \$276.93 million, inclusive of capital costs, and natural gas and purchased electric service and REC electricity. Scenario 4 has a corresponding present value of \$269.25 million.

A reasonable target year for net-zero CO₂ emissions is 2038 with

implementation of either Scenario 3 or Scenario 4 in conjunction with acquisition of renewable energy credit electricity and sequestration of carbon through Rice Land Lumber Company.

These results indicate that prudent capital investment in utility infrastructure to improve the efficiency of utility operation and performance of facilities will reduce operating expenses but will also provide responsiveness to fluctuating energy prices, improve connectivity of facilities, and support the goal of net-zero CO₂ emissions.

PRIMARY RECOMMENDATION

Establish a utility development and operating strategy with a goal of increased energy efficiency and net-zero CO₂ emissions for the university by 2038 through:

1. Implementation of campus-wide demand-side management
2. Implementation of central plant operational improvements
3. Development of expanded cogeneration
4. Use of sequestration to offset carbon emissions
5. Acquisition of renewable energy credit electricity
6. Development of on-site renewable energy systems when economically and environmentally justifiable

References

1. <http://news.rice.edu/2014/10/20/rice-sets-plan-to-be-climate-neutral-by-2038/>

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