2023

ENERGY TRANSITION MASTER PLAN

NEW MEXICO STATE UNIVERSITY

EEA CONSULTING ENGINEERS

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INTRODUCTION

New Mexico State University has for many years established campus sustainability goals, most recently documented in the *2017 Climate Action Plan*, which itself was based on an earlier 2014 document. NMSU's voluntary goal of a completely decarbonized campus by 2045 is ambitious and indicative of its continued commitment to sustainability. This goal is above and beyond the State of New Mexico Executive Order 2019-003, which calls for a 45% reduction in statewide carbon emissions when measured against 2005 levels.

This Energy Transition Master Plan documents an analysis of NMSU's current carbon footprint, examines internal and external factors influencing current campus operations, and establishes potential approaches to meeting the campus's carbon reduction goals.

The scope of this study includes the impact of utility usage in the built environment on the Las Cruces campus, branch campuses, agricultural research centers, and proposed new campus developments.

Methodology

A three-phase approach was taken for this study consisting of data collection, concept development and testing, and reporting. The first phase, data collection, began with a thorough examination of historical energy usage, campus infrastructure systems, deferred maintenance needs, campus master plans, facilities and infrastructure funding sources, and strategic research programs. This involved a series of meetings with campus facilities personnel and other stakeholders including academic staff related to potential research opportunities and student body leadership. Site visits were also performed to gain a ground level understanding of system configurations and conditions. Analysis of utility consumption data in this phase also provided a benchmark of where the campus was in relation to its carbon emissions in 2005, which is a valuable data point in meeting both the Executive Order and internal campus goals.

The second phase, concept development and testing, began once the team had developed an understanding of existing and potential future conditions on campus. From here the team proceeded with identifying opportunities for carbon reduction, either through physical infrastructure changes, operational modifications, or purchased or utility related offsets. High level analysis and scoping of these strategies was performed to vet them as feasible candidates for the campus. Order of magnitude cost data was compiled from existing sources where available. Potential funding sources for the strategies, including new sources not currently utilized by NMSU, were identified and examined as part of this phase.

Reporting was the third phase of the study. This phase sought to distill the data collection and concept development and testing phases into a referenceable, updatable energy master plan format. The team acknowledges that this plan may need to adapt over time as internal and external influences on the campus change, as well as the campus's needs and strategic direction. The master plan document contains summaries of the team's data collection findings, carbon reduction strategies, and implementation paths, along with detailed supporting calculations, meeting notes, and associated analyses.

Reference Documents

The following documents are listed in reference and were provided by NMSU for consideration when developing this Energy Transition Master Plan. The documents are not listed in any specific order but served tremendous resource documents to varying extents. It was not the charge of EEA Consulting Engineers to align with all these documents, but to understand their respective recommendations.

DOCUMENT	SOURCE/CREATED BY
Architectural Master Plan (2017)	WDG, Studio G, Nine Degrees
Space Planning Survey	NMSU
Cogeneration System (2009)	GLHN Architects & Engineers
Chilled Water Satellite Plant Drawings (2011)	GLHN Architects & Engineers
Chilled Water System (2009)	GLHN Architects & Engineers
Steam System Study (2009) and Update (2022)	GLHN Architects & Engineers
Site Electrical Infrastructure Master Plan (2014)	Bohannon Huston, Inc.
Structural Study for Utility Tunnels (2013)	Bohannon Huston, Inc.
Information Technology Master Plan	Bridgers & Paxton
NMSU Sustainability Action Plan	NMSU
NMSU Grants HVAC Study	Bridgers & Paxton
NMSU Alamogordo HVAC Study	Bridgers & Paxton
Arrowhead Park Plan Update	NMSU
Aggie Uptown Plan Update	NMSU
Utility Bills for all NMSU Sites	NMSU

The current (2022) design standards and Facility Master Plan were not reviewed during the development of this document, as they were not complete or available.

Upon reviewing these reference documents, the following synergies were observed and should be planned for when considering decarbonization and energy master planning:

- ✓ Academic Program Growth Alignment is Paramount
- ✓ Consolidation of Main Campus (Physical Footprint) is Necessary
- ✓ Deferred Maintenance and Energy Use of Steam is Unmanageable
- ✓ Energy Use Varies Seasonally and Spare Sub-Station Capacity is not ready for Electrification
- ✓ Reducing Water Consumption should be Prioritized
- ✓ Quality Electricity for Laboratories and varying Voltage-Loop upgrades need Alignment

EXECUTIVE SUMMARY

The intent of this energy transition master plan is to study the impact of consumed utilities on campus and provide recommendations and several potential paths to align this usage with NMSU's established carbon reduction goals. This process examined current and historical utility usage, campus infrastructure systems and deferred maintenance needs, campus master plans, strategic research programs, and potential funding sources. This executive summary summarizes the team's key findings from the effort, identifies the potential carbon reduction paths, and illustrates the recommended phasing strategy to reduce carbon over time.

NMSU has taken considerable and commendable action in recent years toward energy reduction and decarbonization. Continued energy efficiency projects on campus, the large Aggie Power photovoltaic array, and repairs to the steam distribution system have all resulted in decreased utility consumption. These and other related projects have positioned the campus well to meet current State mandates on carbon emissions.

It is clear, however, that full decarbonization will require significant expense and investment in the campus's utility systems over the next decade and beyond. For example, likely paths to decarbonization will require extensive upgrades to the campus's medium voltage electrical system on the order of $60M. An effort of this magnitude would require phasing over time and likely be seven years or more in full duration. Beyond the major renewal of aging systems, projects such as this would typically have other ancillary benefits as well, such as improvements to utility flexibility, reliability, and resiliency on campus.

It should be noted that the scope of this report is limited to energy and carbon impacts by utility usage in the built environment at NMSU. Other sources of carbon on campus (vehicular travel, waste streams, embodied energy of new construction, etc.) certainly contribute to the campus's carbon footprint and are worthy of study and consideration. It is recommended that the findings of this report be included in the campus's comprehensive long-term carbon reduction plan.

A recent case study by Princeton University **"Evolution of Proxy Carbon Pricing Implementation and Princeton University"** provides an excellent example of how these other elements, as well as utility consumption, should be factored into discussions around decarbonization. Princeton University's current goal of carbon neutrality by 2046 led to development and usage of a "proxy carbon price" which is utilized in decision making processes surrounding campus operations.

Another multi-year study "Comprehensive evidence implies a higher social cost of CO2" recently found "that every additional ton of carbon dioxide emitted into the atmosphere costs society $185 — far higher than the current federal estimate of $51 per ton". The importance of sources of carbon other than utility consumption, as well as the true social cost of carbon emissions, should be considered when evaluating projects focused on decarbonization. For many of the recommendations contained in this report there is no simple economic payback or savings. The larger context of decarbonization must be kept front of mind.

Current Condition of Carbon Emissions (CO2 Equivalent)

DATASET	Metric Tons CO2e	Cost of Carbon @ $185
Main Campus	42,868	$7,930,493
Branch Campuses	4,043	$747,973
AES	1,127	$208,654
Total	48,038	$8,887,121

Current Carbon Equivalencies

- **Main Campus Electricity (25.6 GWh/Year – FY22)**
  - 2,389 Gasoline Powered Passenger Vehicles driven for one year
  - 1,397 Home's energy use for one year
- **Main Campus Natural Gas (6.1M Therms/Year – FY22)**
  - 80.4M Miles driven by an average gasoline-powered vehicle
  - 74,961 Barrels of oil consumed

Carbon Emissions after Eliminating Gas Consumption

DATASET	New CO2e	CO2e Savings	Cost of Carbon	CoC Savings
Main Campus	9,150	79%	$1,692,723	$6.2M
Branch Campuses	1,142	72%	$211,222	$0.5M
AES	688	39%	$127,212	$0.08M
Total	10,979	77%	$2,031,157	$6.9M

Key Findings and Recommendations

The following are key findings and recommendations that have served to provide direction to the team in this effort:

- Gas consumption at the Las Cruces campus is a major driver of overall NMSU carbon footprint
- Full decarbonization on the Las Cruces campus will require eventual shutdown of the turbine generator and steam systems, unless hydrogen infrastructure becomes present in the region
- The campus's medium voltage electrical system will require major investment for any legitimate decarbonization approach
- Solar photovoltaics (PV) is a proven technology on campus and should be continued
- New consumption of natural gas on campus should be avoided
- Right-sizing of the campus's built environment (footprint) is critical to success of any carbon reduction strategy
- Full decarbonization is likely to require multiple funding streams and be phased over many years
- Incorporating academic research into decarbonization efforts may elevate the visibility of these efforts and provide opportunity for alternative funding sources
- NMSU should continue its current efforts in carbon reduction and adapt design standards to align with these strategies

Potential Carbon Reduction Paths

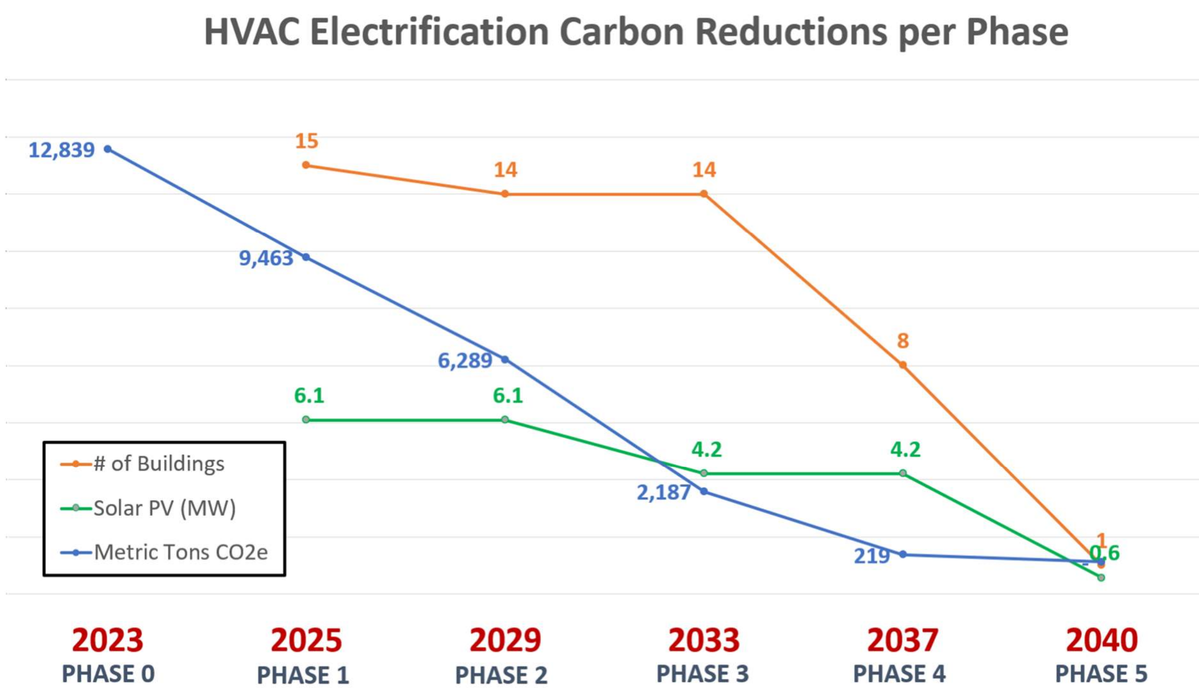
The following paths have been identified as potential means to reach campus decarbonization goals. All paths will require significant capital investments in the campus infrastructure systems, and some are highly dependent upon external influences. The magnitude of funding available and extent of external influence will impact how NMSU is able to ultimately implement these recommended options. The options are presented separately for clarity, but some combination of these paths is likely needed to feasibly reach the campus's carbon reduction goals.

- ✓ **Preferred Path:** Electrification Across Campus
  - Eventual shutdown of turbine generator and steam boilers and replacement of heating across campus with electrically based options. Investment in PV is recommended to mitigate potential fluctuations in electrical utility costs.
- ✓ **Secondary Path:** Electrification at Central Plant & Satellite Plant
  - Eventual shutdown of turbine generator and steam boilers and replacement of heating at central plant with electrically based options. Similar investment in PV is recommended.
- ✓ **Third Path:** Hydrogen Conversion
  - Retrofit of gas turbine and boilers to consume hydrogen as fuel source. Would require regional development of hydrogen infrastructure, likely a result of State and Federal funding.
- ✓ **Least Preferred Path:** Business as Usual
  - Continued usage of natural gas turbine and boilers on campus. Addition of PV and continuation of building energy efficiency projects will reduce carbon, but major annual investments in carbon credits would be needed and not result in "real" decarbonization.

Timeline / Phasing

Implementation of the strategies described in the paths established above will take significant time as well as investment. Phasing of multiple concurrent major projects over 15+ years should be anticipated. To illustrate this concept, the graphic below indicates the general approach to the first two paths described above.

Current on-campus gas consumption, existing photovoltaics, and current campus HVAC systems result in present carbon footprint (Phase 0). Stage-down of on-campus gas consumption over time is the key driver in carbon reduction, however this reduction in power and heating capacity must be accommodated by increases in photovoltaic generation (and storage) or other renewable sources and transition to alternate sources of heating. These transitions occur over time to result at the desired end state of decarbonization. This graph provides a recommended timeline, separated into 5-year intervals based on anticipated priority, and is further supported with additional analysis in Section 2 of this report.



This graph illustrates that funds are needed at specific intervals to decarbonize HVAC and add solar photovoltaic (PV) capacity to the campus. Solar PV is apportioned based on 31 projects across 21.18 MW of generation capacity. Appendix C illustrates potential projects on Main Campus based on three categories of projects:

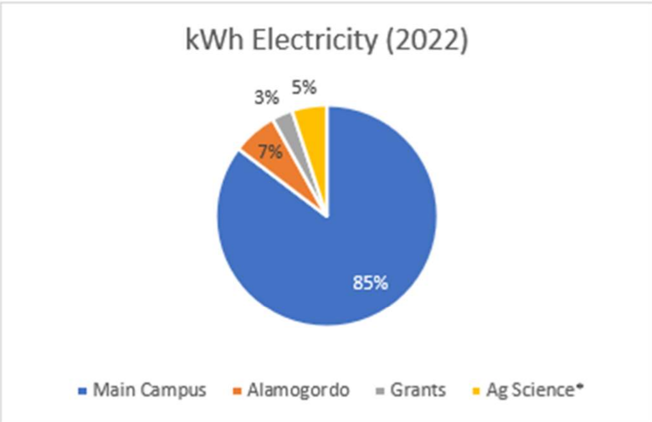
1. 12.2 Mega-Watts from NREL Student Competition Sites: Phase 1 and Phase 2
2. 8.4 Mega-Watts from EEA Ground-Mount Recommendations: Phase 3 and Phase 4
3. 0.6 Mega-Watts of Covered Walkways: Phase 5

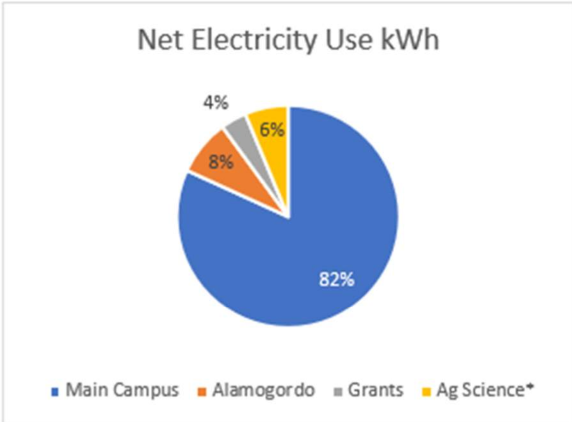
It should be noted that these projects will not “pay down” their debt service through energy savings, this is a strict decarbonization plan, “payback” will be seen in intrinsic social-improvements – a social payback or return on investment will be realized.

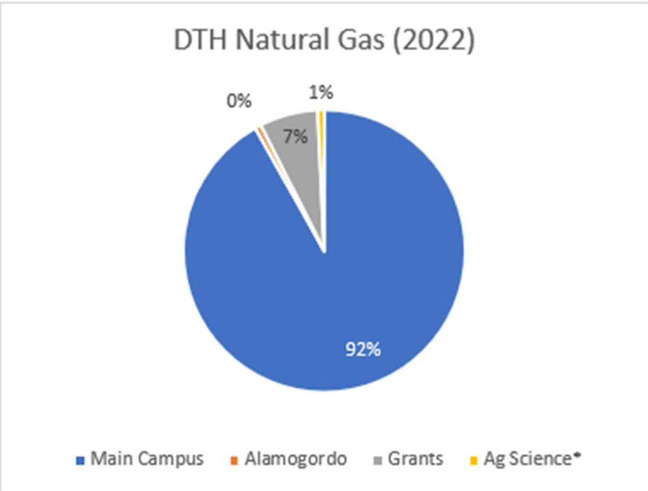
SECTION ONE

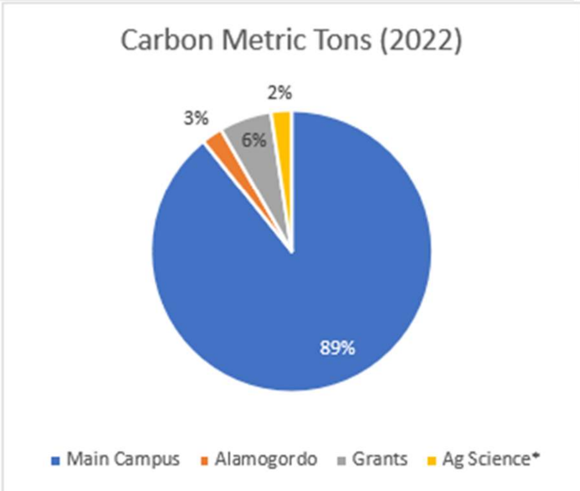
ENERGY + CARBON DATA ANALYSIS

The University system's energy use and associated carbon emissions are summarized below, using data from 2019 to ensure that data with atypical usage patterns from the COVID-19 pandemic was not used. Supporting documentation for this Section is provided in Appendix A, "Energy Data Analysis". In all cases, Main Campus data dominates institutional consumption/emissions.









INSTITUTIONAL CONSUMPTION & EMISSIONS: DATA ACROSS ALL PROPERTIES

- Electricity Use – Total electricity consumption:
  - 35,999,664 kWh per Year
- Net Electricity Use – Total consumption remaining after accounting for campus photovoltaics:
  - 28,999,664 kWh per Year
- Natural Gas – Total natural gas consumption:
  - 666,181 DTH per Year
- Carbon Metric Tons – Carbon footprint based on electrical and natural gas consumption:
  - 48,038 Metric-Tons CO2e

The team's study of the utility consumption on resulted in the following key findings:

- 89% of the NMSU's utility-based carbon footprint is a result of usage at the Las Cruces campus.

- The Las Cruces campus consumes 85% of total electricity. The solar PV arrays providing power to the Las Cruces campus reduce net consumption at the campus to 82% of NMSU's total.

- The Las Cruces campus consumes 92% of total natural gas. Steam boilers and gas turbine account for 87% of this consumption.

- The top ten consuming buildings (excluding central plants and per category of consumption) at the Las Cruces campus account for the following:
    - 30% of campus electricity consumption
    - 65% of natural gas consumption
    - 60% of steam consumption
    - 55% of chilled water consumption

  This indicates that gas and steam usage is concentrated in a smaller group of buildings than electrical on campus. This is important due to its implications on potential on-campus gas and steam consumption reductions.

- Electrical and natural gas consumption on the Las Cruces campus has reduced 36% and 56%, respectively, in the past 10 years. This is at least partially attributable to the continued energy conservation projects and infrastructure upgrades on the campus.

SECTION TWO

PATHS TO CARBON NEUTRALITY

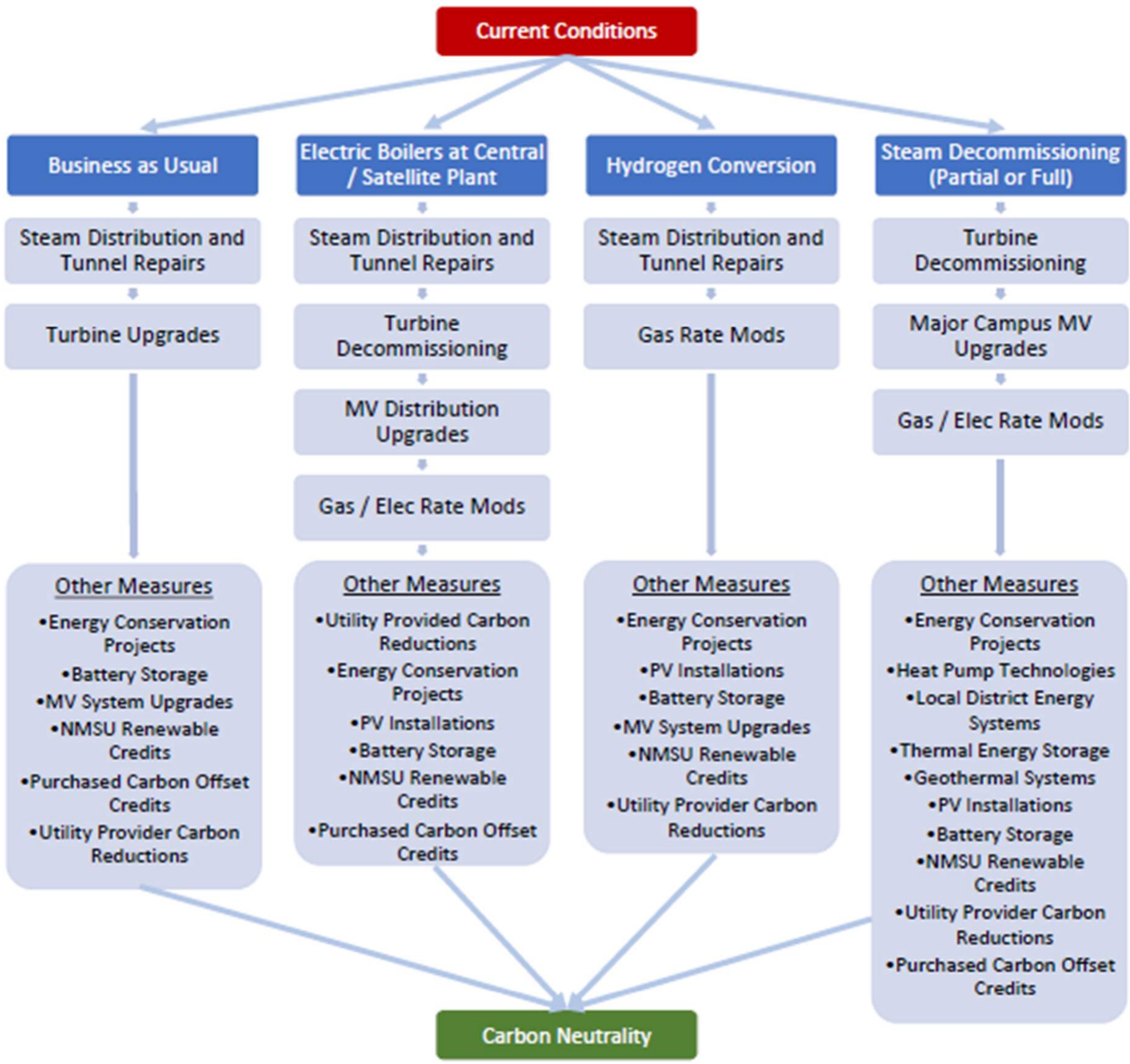
Through the team's study and review of existing campus utility consumption, infrastructure systems, deferred maintenance needs, and future campus plans, several key findings and recommendations were established. These items provided direction to the team in this effort and are listed below:

- Gas consumption at the Las Cruces campus is a major driver of overall NMSU carbon footprint
- Full decarbonization on the Las Cruces campus will require eventual shutdown of the turbine generator and steam systems, unless hydrogen infrastructure becomes present in the region
- The campus's medium voltage electrical system will require major investment for any legitimate decarbonization approach
- Solar photovoltaics (PV) is a proven technology on campus and should be continued
- New consumption of natural gas on campus should be avoided
- Right-sizing of the campus's built environment is critical to success of any carbon reduction strategy
- Full decarbonization is likely to require multiple funding streams and be phased over many years
- Incorporating academic research into decarbonization efforts may elevate the visibility of these efforts and provide opportunity for alternative funding sources
- NMSU should continue its current efforts in carbon reduction and adapt design standards to align with these strategies

To articulate how these key findings and recommendations could be utilized to impart real change on the campus's carbon footprint, several "Paths to Carbon Neutrality" were developed.

As indicated above and in the previous section, the two main consumers of natural gas at the plant are the turbine generator (used to generate electricity) and the boilers (used to generate steam for distribution to campus). How these systems are operated, both in frequency and strategy, will have a major impact on any path to carbon neutrality for the University.

Each potential pathway established by the project team therefore is based on a potential operational strategy for these two systems. The resulting impact on campus carbon footprint in each pathway is then further addressed through other strategies. While the options are presented separately for clarity, some combination of these paths and the elements they contain is likely needed to feasibly reach the campus's carbon reduction goals.



Primary Characteristics

1. **Business as Usual**
   a. Least invasive to campus
   b. More reliant on carbon offsets / credits
   c. Less on-campus capital investments required
   d. Least authentic / genuine path due to continuation of gas usage
2. **Electric Boilers at Central / Satellite Plants**
   a. Less invasive to campus
   b. Most reliant on purchased utility carbon improvements
   c. More probable to result in significant rate impacts
3. **Hydrogen Conversion**
   a. Less invasive to campus
   b. Most reliant on external influences (State/Fed hydrogen development)
   c. Less predictable implementation timeline
4. **Steam Decommissioning**
   a. Most invasive to campus
   b. Most on-campus capital investments required
   c. Longer implementation timeline (~25 years for full phasing)

PATHWAY DESCRIPTIONS

Business As Usual

In this scenario, usage of a natural gas turbine to generate power and natural gas boilers to generate steam is extended into the foreseeable future. Deferred maintenance and upgrades of the natural gas turbine and steam distribution system would be immediate priorities to improve system efficiency and reduce carbon emissions and operational costs. Usage of this large amount of natural gas on campus would conflict with the goal of carbon neutrality, so an array of other strategies would be needed to reduce energy needs on campus and offset carbon usage:

- Continuation of existing and expansion of energy conservation projects on campus would reduce total energy needs.
- Installation of PV systems on campus would provide some amount of renewable on-campus generation, further reducing natural gas turbine usage.
- Battery storage tied to PV systems or the grid could be used to store energy for later use and reduce natural gas usage. To allow for interconnection of these components, some improvements to the campus's medium voltage electrical system would be required.
- Carbon reductions from the utility provider could eventually eliminate the usage of the gas turbine for electrical generation.
- NMSU or purchased renewable credits could be used to offset any remaining natural gas usage for the steam system.

***Note:** This option is presented for illustrative purposes only and would not result in legitimate decarbonization as we understand the campus to be pursuing.*

IMAGE 1 – NMSU MAIN CAMPUS[1]

[1] https://admissions.nmsu.edu/virtual/

Electrification at Central Plant & Satellite Plant

In this scenario, the natural gas boilers serving the campus steam system would be replaced with large electric boilers. This would result in a major reduction in campus carbon emissions but would also drive the need to continue with repairs to the steam distribution system and tunnel infrastructure. Decommissioning of the natural gas turbine and reliance on power from the electric utility would further reduce carbon emissions. To support these measures and others listed below, some improvements to the campus's medium voltage distribution system would be required. Another consideration for this scenario is that the natural gas and electric rates from utility providers could be expected to change substantially, which would impact operational costs of the systems.

- This scenario would rely heavily on purchased power from the electrical utility, so carbon reductions in their portfolio would be an important piece of the overall reduction strategy.
- Continuation of existing and expansion of energy conservation projects on campus would reduce total electrical needs.
- Installation of PV systems on campus would provide some amount of renewable on-campus generation, offsetting the need of potentially carbon-based utility provided power.
- Battery storage tied to PV systems or the grid could be used to store energy for later use and be charged when utility provided power was made of higher percentage renewables.
- NMSU or purchased renewable credits could be used to offset any remaining carbon usage from the utility provider.

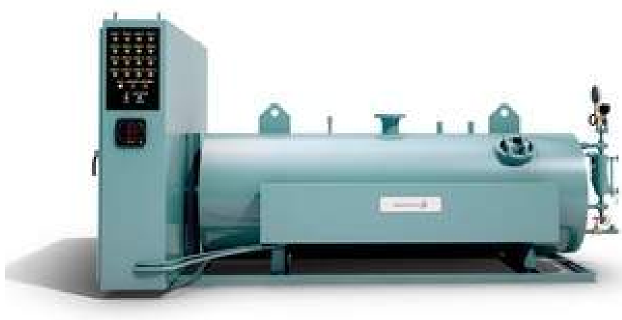


IMAGE 2 – EXAMPLE ELECTRIC BOILER[2]

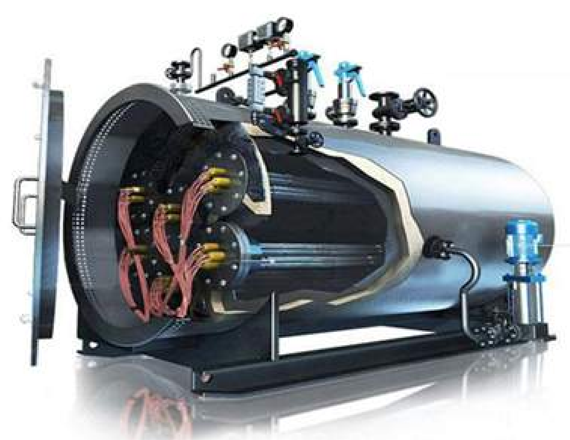


IMAGE 3 – ELECTRIC BOILER CUT-AWAY[3]

[2] Cleaver Brooks
[3] Sitong Boiler

Hydrogen Conversion

In this scenario, the campus's natural gas boilers and turbine would be retrofitted (or replaced) to use hydrogen as the primary fuel source. Hydrogen infrastructure to support this does not currently exist in New Mexico, so this scenario is highly dependent upon State and industry promotion of the technology. Along with conversion of the primary equipment, substantial infrastructure additions to the campus would be required including large-scale storage tanks and distribution piping. Deferred maintenance and repairs to the steam distribution system and tunnels would be immediate priorities to extend the operational life of these systems.

- This scenario would result in a new utility-provided fuel source to replace natural gas. The natural gas rate should be expected to change, though consumption on campus would be nearly eliminated.
- Continuation of existing and expansion of energy conservation projects on campus would reduce total electrical needs and hydrogen consumption.
- Installation of PV systems on campus would provide some amount of renewable on-campus generation, reducing hydrogen consumption.
- Battery storage tied to PV systems or the grid could be used to store energy for later use and be charged when utility provided power was made of higher percentage renewables.
- NMSU renewable credits could be used to offset any remaining carbon usage from the utility provider.
- Eventually, purchased power from the utility provider is expected to have a much smaller carbon footprint. This could eventually allow for gradual decommissioning of the campus steam and turbine systems and replacement with other electrical and renewable- technologies. This scenario allows for future flexibility; hydrogen could serve as a primary fuel source for the campus far into the future or only as a temporary measure to transition from on-campus combustion-based power and heat generation.

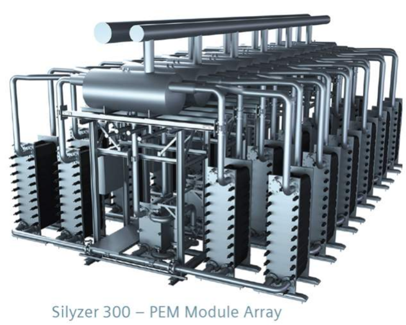


IMAGE 4 – SIEMENS PEM ELECTROLYZER

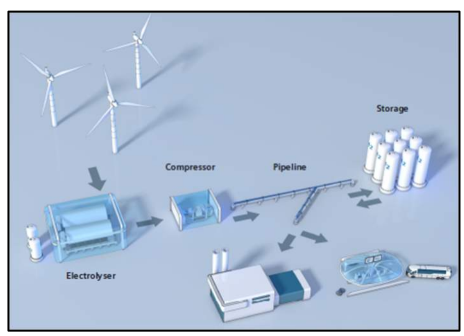


IMAGE 5 – GREEN HYDROGEN PRODUCTION[4]

It should be noted that development of hydrogen infrastructure of adequate size to support this scenario is not guaranteed and at minimum will take 5-10 years to establish. To mitigate risk associated with this delay (and also to reduce the amount of hydrogen eventually consumed), other carbon reduction strategies are recommended in parallel. Refer to Section 5 "Living Lab" for additional discussion on potential for hydrogen usage on campus.

[4] Siemens Energy Whitepaper: Hydrogen infrastructure – the pillar of energy transition

Electrification Across Campus

This scenario represents a transition from natural gas-based systems to fully electric and renewable-based systems for campus power and heat generation. This would be accomplished by decommissioning of the campus steam system and natural gas turbine. These systems would then be decentralized across the campus through development and implementation of many other strategies as listed below.

These other strategies would result in major investments to the campus infrastructure, far more than in any other scenario. Major improvements to the campus's medium voltage electrical system would also be required because of this decentralization since power consumption and generation would be distributed across campus instead of in two primary locations. This would include a new substation, conversion of some portions of campus from 5 kV to 25 kV, and installation of new primary switches and distribution duct-banks.

- Major reductions in natural gas usage and increases in purchased electricity would very likely result in rate changes from these utility providers.
- Rapid acceleration and expansion of energy conservation projects on campus would reduce total electrical needs and infrastructure investments.
- Replacement of steam heating and transition to fully electric systems could involve several strategies for building conditioning. These may be localized heat pump equipment (packaged direct expansion), localized electric boilers, smaller regional district energy systems (potentially including heat pump / heat recovery chillers and multiple-building heating water distribution systems), and thermal energy storage (chilled and/or heating water).
- Geothermal or ground coupled heat pump systems could be explored in some areas of campus where adequate space is available for bore fields to serve surrounding buildings. Test bores to investigate local soil temperatures would be required for any new geothermal systems.
- Phased decommissioning of the steam system is the most likely approach, beginning with eliminating farthest regions of the system first
- Installation of PV and battery storage systems on campus would reduce (or shift) electrical consumption from the utility provider.
- NMSU or purchased renewable credits could be used to offset any remaining carbon usage from the utility provider. New off-campus large scale wind or PV installations could increase the NMSU renewable credits available.
- This scenario would rely heavily on purchased power from the electrical utility, so carbon reductions in their portfolio would be an important piece of the overall reduction strategy.

SUPPORTING RECOMMENDATIONS

This section provides commentary on elements to support decarbonization on campus, including recommendations for future campus development, phase-out of the steam system, decarbonization of campus HVAC, implementation of addition solar PV, infrastructure system recommendations.

Future Campus Development

The following five elements are recommended for future campus development. These will support decarbonization efforts while also increasing the University's ability to market current and planned innovations to new students, staff, and faculty. These concepts are recommended regardless of decarbonization path.

1. **No new natural gas use in new buildings and phase out of existing natural gas use.** This recommendation is separate from gas usage at the central plants and focuses on stand alone facilities (such as branch campuses and Ag Research sites) and other gas use at main campus buildings. Improvements to the medium voltage electrical infrastructure will help bolster this initiative. Integrating this concept into the campus design standards is recommended to eliminate any new gas consumption.

2. **Development of a research district to consolidate labs.** Centralizing research spaces on campus allows consolidation of specific utility system needs to smaller geographic areas. Acknowledging that this concept must be aligned with faculty and researcher needs, there are many benefits to cost, carbon footprint, and reliability concerns. It is more practical to provide redundant feeds to smaller geographic areas than when distributed across an entire campus. Agile labs and multi-use facilities should be considered for new development. Gardner Hall is a potential good candidate for renovation.

3. **Housing as sustainability district.** The existing housing district is aging and utilizes inefficient utility systems that also can result in reduced occupant comfort. To improve aesthetic value and reduce urban heat island, redevelopment of this area to include district cooling and heating (possibly geothermal) is recommended.

4. **Right-sizing of campus footprint.** Aligning the campus footprint with actual needs across campus, not just within buildings, is critically important to reaching and maintaining decarbonization goals. New facilities may be constructed to operate very efficiently but the benefit is significantly reduced if continued use of older inefficient buildings is also allowed.

5. **Enhanced emphasis for Living Lab Concepts.** Continuation and enhancement of Living Labs Concepts on campus will increase visibility of campus efforts and may provide opportunities for additional funding sources. Solar photovoltaics, agrivoltaics, and advanced geothermal energy systems are several realistic and viable concepts that should continue to be pursued, among others.

Steam Phase-Out Analysis

Partial or full phase-out of the campus's steam system will be required for decarbonization on campus, even if regional hydrogen infrastructure becomes a reality in the next decade. The steam system represents both a large percentage of NMSU's total utility-based carbon footprint and utility system deferred maintenance backlog. **Detailed analysis and planning of this phase-out is beyond the scope of this report, but preliminary information on major steam users on campus and potential phasing is provided in Appendices "A" and "B".** One likely strategy for beginning the phase-out would be migrating buildings from steam that either need major piping upgrades for repairs or are on far-reaching branches of the steam distribution system. Further detailed study on phase-out of the steam system is recommended for planning and budgeting purposes.

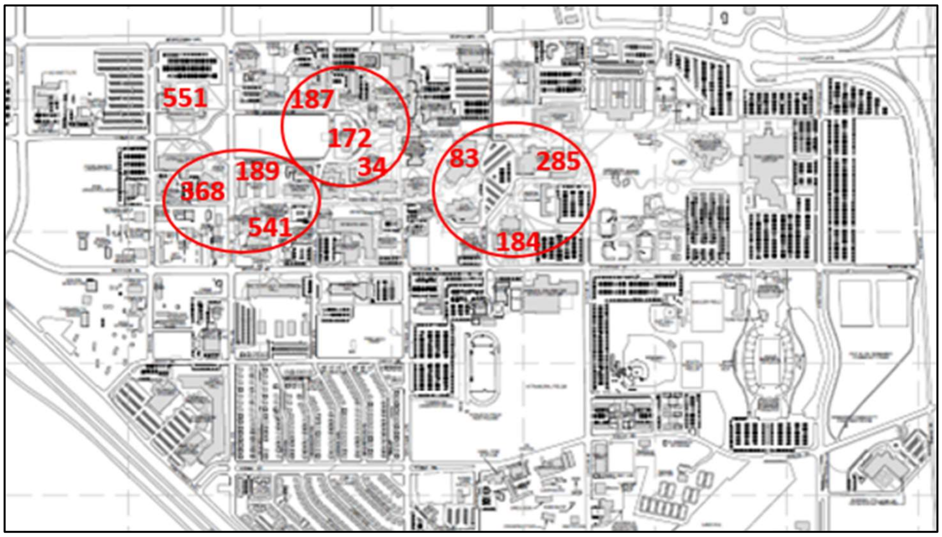


IMAGE 6 – PRIMARY STEAM USERS

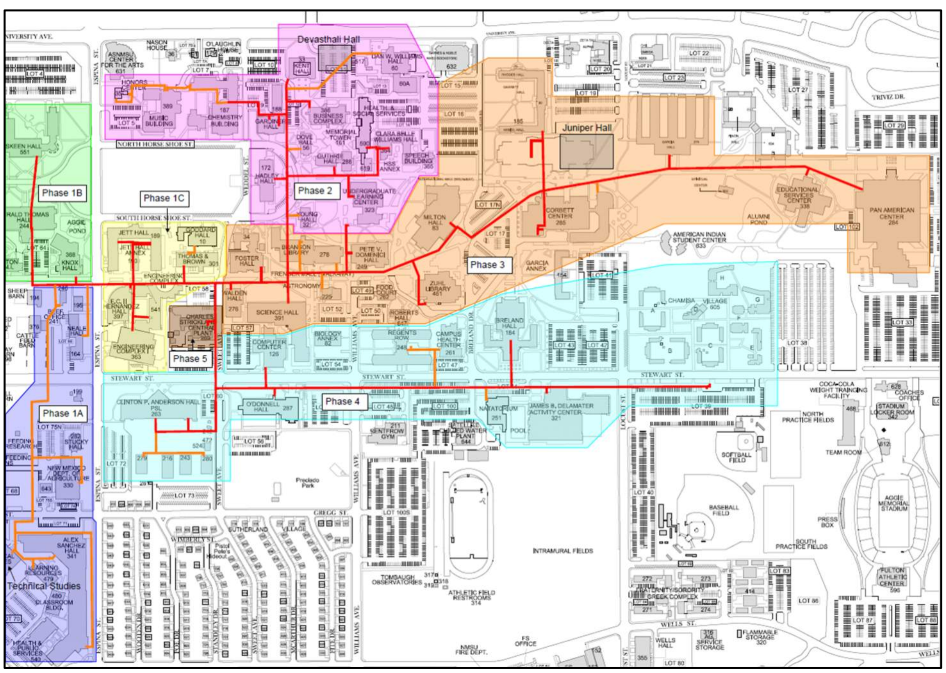


IMAGE 7 – POTENTIAL STEAM PHASE-OUT MAP

HVAC Decarbonization Analysis

The projected annual electricity consumption when electrifying HVAC systems on Main Campus are as follows, with three HVAC options identified for recommendation. In each case Main Campus buildings were assigned to an energy profile based on their HVAC system type and given a projected annual energy increase associated with each of the three options below. Each table is labeled as such:

- System – Primary HVAC system studied
- Count – Total buildings per System
- KW – Peak power increase if modified
- kWh – Annual consumption increase
- Cost – Total energy cost increase/year
- Carbon – Carbon emissions increase per year (Metric Tons CO2e)

The next sections describe potential for additional photovoltaic arrays on campus. Each Electrification Option below also lists how much of the total photovoltaic opportunity on campus would be utilized by each option, for context.

ELECTRIFICATION OPTION 1: Steam Boilers and HP-DHW					
System	Count	KW	kWh	Cost	Carbon
4 Pipe FC	20	137%	9%	$ 55,052	222
VAV	68	155%	30%	$ 528,257	2,129
VAV-EXH	16	521%	223%	$ 466,294	1,879
PSZ-RTU	104	89%	73%	$ 420,224	1,694
Total	208			$ 1,469,828	5,924
Average		226%	84%	$ 587,931	1,481

This **Steam Boiler** option **(#1)** represents a **30%** annual electricity consumption increase, from 40.4-GWh/Year to 58.1 GWh/Year.

The increase represents a 17.6 GWh/Year load growth, or **48%** of the total PV potential.

ELECTRIFICATION OPTION 2: VRF + ERV Systems (Demand Ctrl. Vent)					
System	Count	KW	kWh	Cost	Carbon
4 Pipe FC	20	85%	45%	$ 279,301	1,126
VAV	68	55%	20%	$ 358,044	1,443
VAV-EXH	16	140%	119%	$ 249,245	1,005
PSZ-RTU	104	89%	73%	$ 420,224	1,694
Total	208			$1,306,814	5,267
Average		92%	64%	$ 522,726	1,317

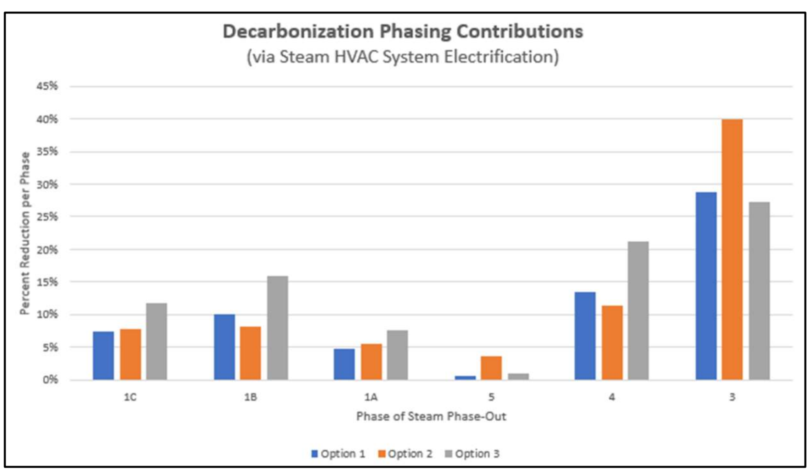
This **VRF** option **(#2)** represents a **28%** annual electricity consumption increase, from 40.4-GWh/Year to 56.0 GWh/Year.

The increase represents a 15.6 GWh/Year load growth, or **42%** of the total PV potential.

ELECTRIFICATION OPTION 3: Heat-Pump Chiller					
System	Count	KW	kWh	Cost	Carbon
4 Pipe FC	20	87%	54%	$ 332,448	1,340
VAV	68	248%	164%	$ 2,905,790	8,768
VAV-EXH	16	87%	54%	$ 112,300	764
PSZ-RTU	104	89%	73%	$ 420,224	2,755
Total	208			$ 3,770,762	13,626
Average		128%	86%	$ 1,508,305	3,407

This **Heat-Pump Chiller** option **(#3)** represents a **53%** annual electricity consumption increase, from 40.4-GWh/Year to 86.8 GWh/Year.

The increase represents a 46.4 GWh/Year load growth, or **125%** of the total PV potential.

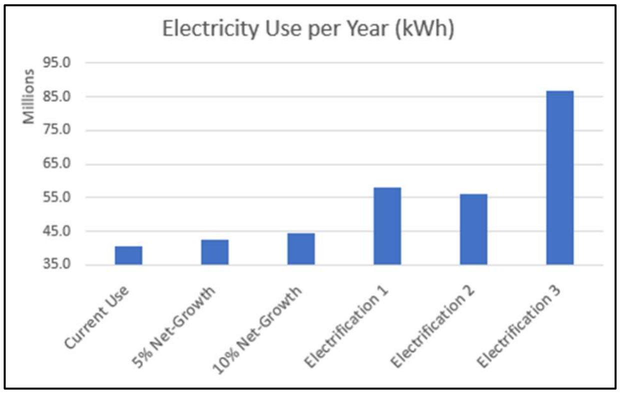


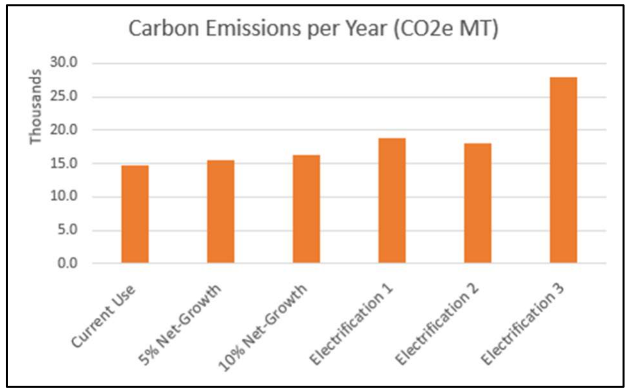
To better evaluate each option, this chart illustrates carbon reductions associated with the phase-out plan above. Here each phase is plotted side by side to compare contributions equally.

Each option provides a route to feasible decarbonization but as noted above, option #3 creates the most electrical load-growth and would therefore require the most solar power offsets.

It should be noted that none of the electrification options above consider organic load growth from the need to expand campus facilities to accommodate new programs. The graphs below illustrate a 5% and 10% net building area increase, compared to the electrification options above (assuming both demolition and additions will occur).

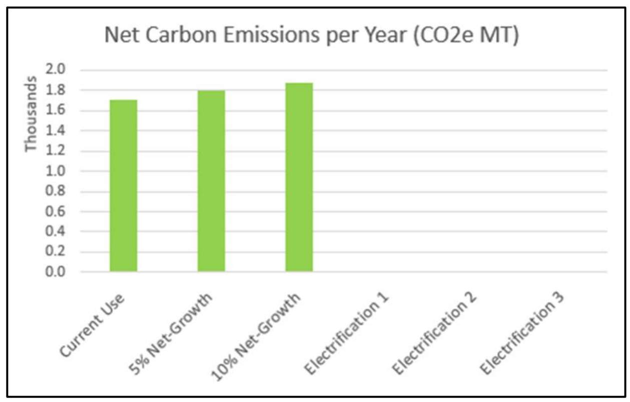
While the current annual usage and the two load-growth projections are a fraction of the electrification options presented, the graph below-right shows the carbon emissions associated with these scenarios.





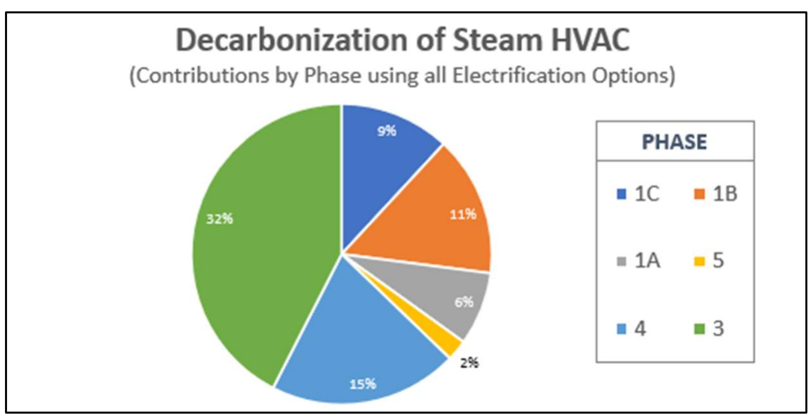
Should the University decide to pursue one of the HVAC electrification options above, the emissions from additional electricity consumption could be offset by solar, whereas the current use and the net-growth options would have significant emissions.

It is unlikely that the University would implement just one electrification option, therefore the following summarizes a projection using an average of the three options presented below.



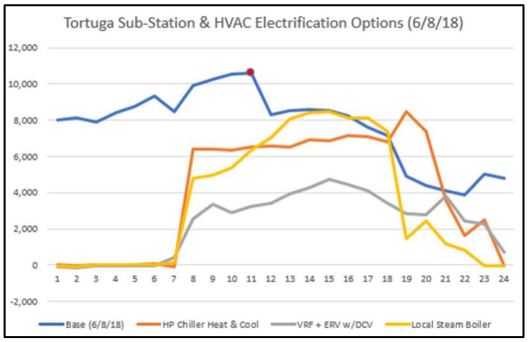
Average of Electrification Options #1, 2, 3

Upon implementing the three options presented above, it is recommended that a combination of approaches be taken. This will allow the University to diversify its HVAC infrastructure yet remain largely centralized in "districts." To illustrate this, simulations of an average of all three options were conducted. The results from these simulations suggest that 33,718 Metric Tons of CO_2e could be removed from campus.

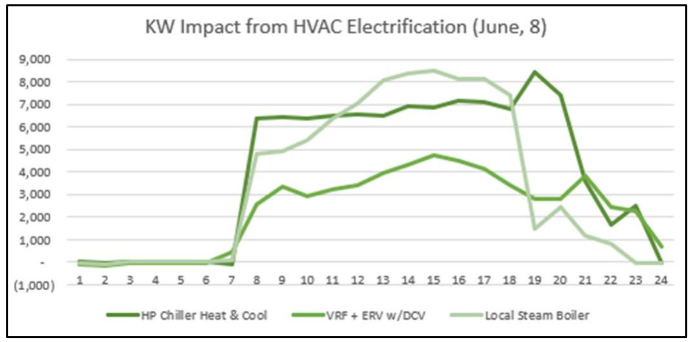


Performed in Phases, Decarbonization is Manageable

When comparing to the peak demand at the Tortuga Sub-Station without Cogen (near 11 MW), these system electrification options will add a significant load to the NMSU grid for a large portion of the year.

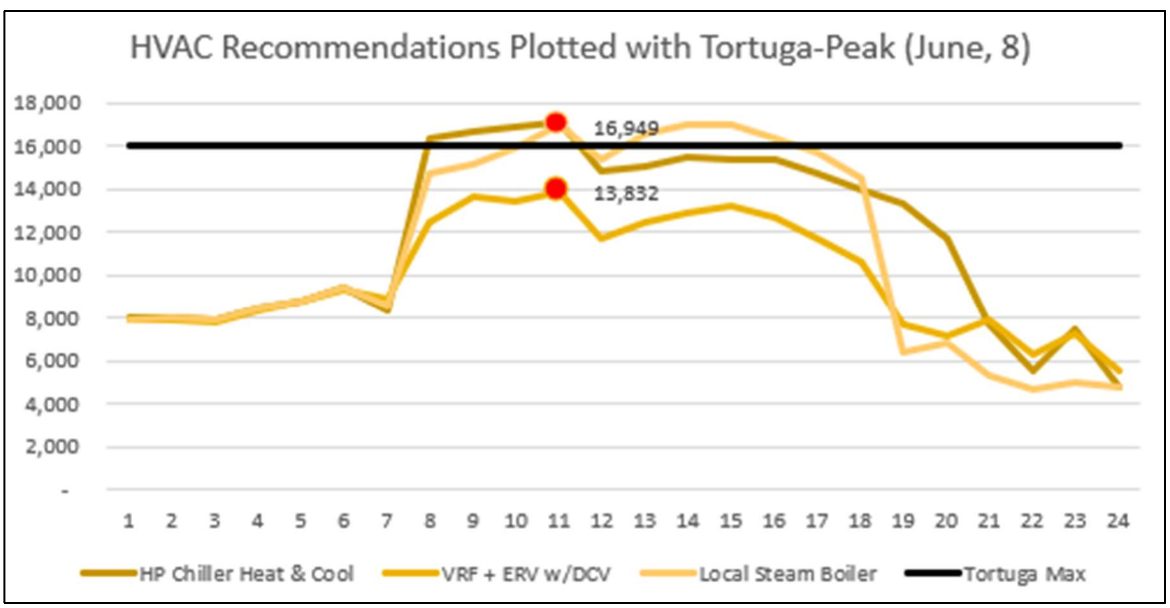


Single-Day Independent Power Demand



Single-Day Combined Power Demand

It is important that the University plan and prioritize solar PV projects because electrification will have an immense impact to electrical infrastructure and will exceed the Tortuga sub-station's capacity (below).



Additional data is provided in Appendix A and B to support these estimates, but it is clear that an "Electrical Evolution" is underway at NMSU, in both research and capital-projects among the many segments of the campus. This further supports the recommendation that the University must act now, and is more than capable of an electrification of this scale.

Main Campus Solar Photovoltaic Summary

EEA performed a review of highly visible ground-mounted campus sites for solar photovoltaic canopies, and reviewed data from a collegiate competition sponsored by the National Renewable Energy Lab (NREL) for NMSU. The summary of these 31 sites on Main Campus is included below, which has the annual generating potential for 37-million kWh/Year (or 37 GWh/Year). Appendix D contains more detailed information on the potential sites.

Metric	NREL Sites	Parking Lots	Walkways	Total
Capital Cost (Capex)	$59,933,329	$56,875,992	$2,870,000	$119,679,321
PV Capacity (MW)	12.19	8.42	0.57	21.18
Cost Savings per Year	$1,706,180	$1,077,990	$80,360	$2,864,530
Carbon Reduction (MT)	6,877	4,345	324	11,546

Estimated annual electricity figures are presented below, for an **average** of all three electrification options:

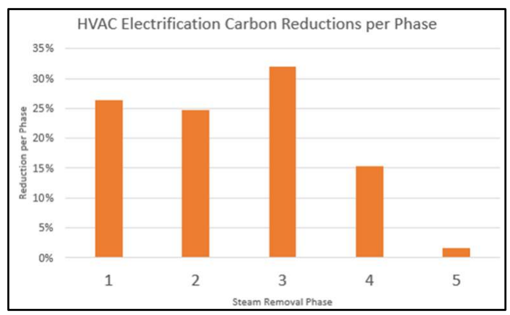
Electricity	Existing	New	Increase	Increase
kWh/Yr	40,444,714	66,982,452	40%	26,537,738
KW Peak	10,598	24,761	57%	14,163
Cost/Yr	$ 3,185,412	$ 5,358,596	41%	$ 2,173,184
Carbon/Yr	12,839	21,598	41%	8,759

Based on the "electrified" consumption of 66,982,452 kWh per Year above, the 37 GWh/Year of potential solar photovoltaic production would offset 56% of usage.

If solar and storage are located appropriately the 25 kVA electrical upgrades noted herein may be minimized, possibly costing less than the anticipated $60M.

It should be noted that these electrification estimates show a 41% increase in electricity emissions (21,598 MT CO_2e), but would offset by 11,545 Metric Tons from Solar PV. Combined with the 33,718 Metric Tons from gas using systems on main campus the net emissions would be greatly reduced compared to today's emissions.

The chart below illustrates the impacts of the recommended decarbonization phases, replacing existing HVAC with a combination of recommended systems. The data corresponds to the **average of all three electrification options**.



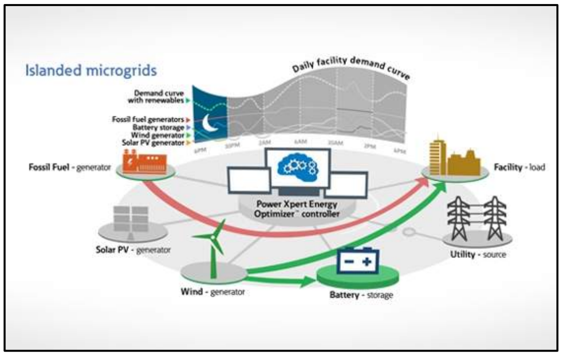
Informative Appendix F lists building recommendations by phase, with Phases 1-3 prior to FY 2037.

The University is an exemplar in solar photovoltaic implementation, with academic leadership among the brightest minds in academia. Electrical Engineering professor Olga Lavrova is pictured here with students, highlighting a Las Cruces Utilities and NMSU team-up for a solar/EV research project through the Electric Utility Management Program on Main Campus.

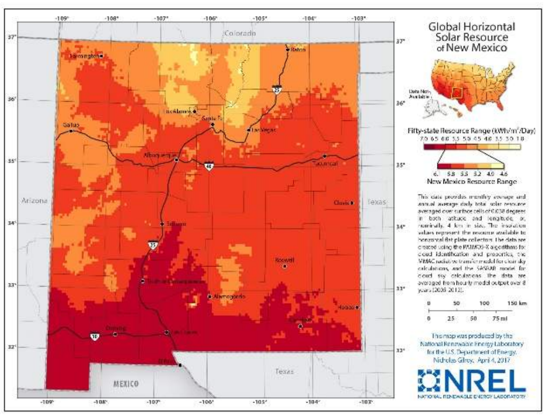
https://www.lcsun-news.com/story/news/local/community/2022/03/05/las-cruces-utilities-and-nmsu-team-up-solar-ev-research-project/9377586002/

Microgrid Resiliency and Opportunities

Grid resiliency during climate events is becoming one of the largest utility-planning objectives, and a smart grid will help weather storm-events. At NMSU a smart thermal grid is in place, providing real time energy diagnostics and response management, as one of the most progressive institutions in the southwest. Cutting edge backbone infrastructure is in place to take steps toward a smart grid, and NMSU desires to maintain control of power infrastructure, with the ability disconnect from the El Paso Electric grid and enter "island mode." In this case NMSU would own and operate a micro-grid, which is able to dispatch discreet power options without power from grid providers, based on availability and best use for cost or emissions reasons.



https://www.eaton.com/se/en-gb/company/news-insights/intelligent-microgrids.html

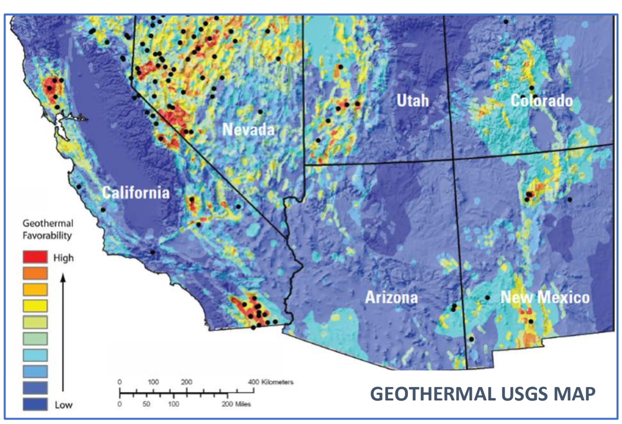


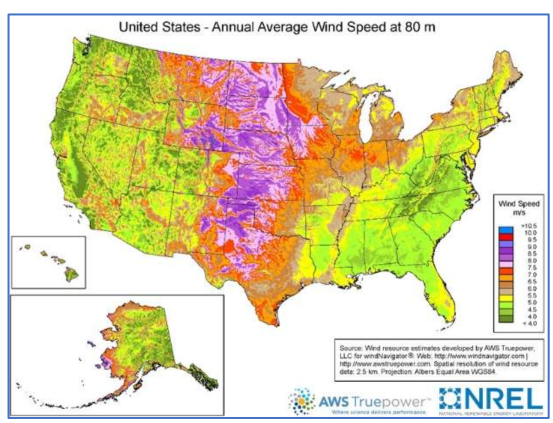
In islanding mode the University would "turn off" grid power and rely on localized power sources, similar to the example at left. To achieve carbon neutrality goals on a campus scale, without waiting for utility companies to decarbonize, the University will need to install additional power generation resources. The most logical resources would utilize solar technologies, notably Photovoltaics (PV). The NREL map at left illustrates New Mexico's solar resources measured in kWh/M^2/Day and Las cruces is in the most abundant solar region.

While other technologies such as wind and geothermal (below) may offer superior power options in other parts of the state, the University should pursue additional solar to meet electrification and islanding needs.

This report provides options to electrify HVAC systems, to eliminate natural gas heating, which will increase electricity consumption significantly, moving away from a centralized utility model.

While centralized utility systems are more manageable and easier to operate and requiring less investment at each building – it is more advantageous to decommission costly tunnel systems.



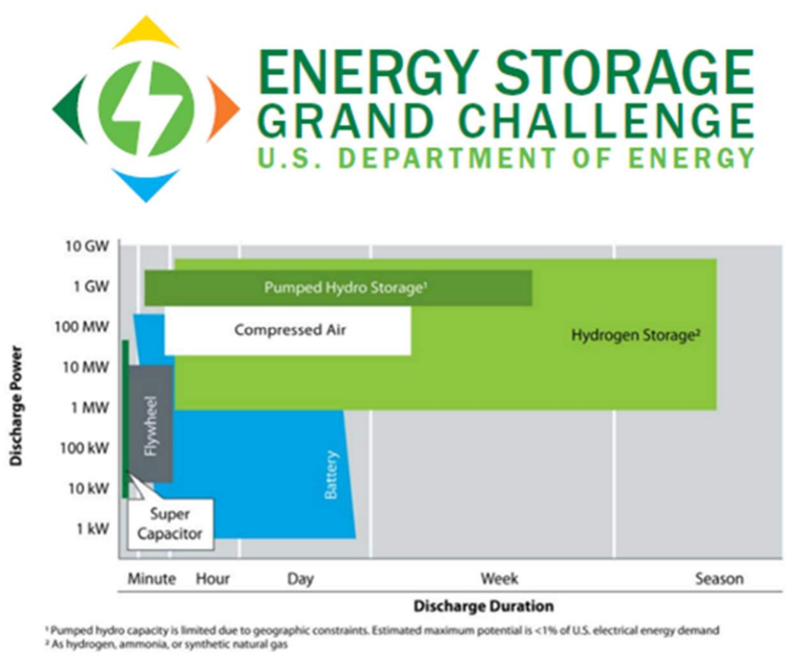


Renewable Energy Storage (Behind the Meter)

The University intends to implement an energy storage project on the NMSU grid, as a resilience measure and micro-grid project for which the University can control the flow of electricity and demand. This 2019 table illustrates mainstream storage technologies and their associated benefits/limitations,[5] which is a comprehensive summary of costs, life expectancy, efficiency, and times associated with response, discharge, and construction.

			Pumped hydro	Compressed air	Flywheel	Lithium-ion	Sodium-sulphur	Lead-acid	Vanadium redox-flow	Hydrogen	Super-capacitor
Investment cost - Power	$/kW	C_P	1129 (45%)	871 (35%)	641 (17%)	678 (17%)	657 (27%)	675 (23%)	829 (21%)	5417 (48%)	296 (31%)
Investment cost - Energy	$/kWh	C_E	80 (63%)	39 (58%)	5399 (67%)	802 (24%)	738 (12%)	471 (38%)	760 (17%)	31 (60%)	13560 (19%)
Operation cost - Power	$/kW-yr	$C_{P\text{-}OM}$	8 (26%)	4 (23%)	7 (8%)	10 (35%)	11 (50%)	8 (31%)	12 (52%)	46 (30%)	0 (0%)
Operation cost - Energy	$/MWh	$C_{E\text{-}OM}$	1 (60%)	4 (60%)	2 (60%)	3 (60%)	3 (60%)	1 (60%)	1 (60%)	0 (60%)	0 (60%)
Replacement cost	$/kW	$C_{P\text{-}r}$	116 (5%)	93 (5%)	199 (44%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1637 (48%)	0 (0%)
Replacement interval	cycles	Cyc_r	7300	1460	22500	3250	4098	1225	8272	6388	69320
End-of-life cost	%	F_{EOL}	0%	0%	0%	0%	0%	0%	0%	0%	0%
Discount rate	%	DR	8%	8%	8%	8%	8%	8%	8%	8%	8%
Round-trip efficiency	%	η_{RT}	78% (9%)	44% (16%)	88% (3%)	86% (7%)	81% (6%)	84% (0%)	73% (9%)	40% (13%)	91% (6%)
Self-discharge	%/day	$\eta_{self,idle}$	0%	0%	480%	0%	20%	0%	0%	1%	30%
Lifetime (100% DoD)	cycles	Cyc_{Life}	33250 (43%)	16250 (20%)	143402 (30%)	3250 (38%)	4098 (29%)	1225 (35%)	8272 (13%)	20000 (0%)	300000 (67%)
Shelf life	years	T_{shelf}	55 (9%)	30 (33%)	18 (14%)	13 (38%)	14 (20%)	10 (50%)	13 (20%)	18 (14%)	14 (33%)
Response time	seconds		>10	>10	<10	<10	<10	<10	<10	<10	<10
Time degradation	%/year	T_{deg}	0.4%	0.7%	1.3%	1.7%	1.6%	2.2%	1.7%	1.3%	1.6%
Cycle degradation	%/cycle	Cyc_{deg}	0.0007%	0.0014%	0.0002%	0.0069%	0.0054%	0.0182%	0.0027%	0.0011%	0.0001%
Construction time	years	T_c	3	2	1	1	1	1	1	1	1
Sources			1,7,12–15	1,7,12–14,16,17	1,3,7,12–14	7,9,13,14,18	1,7,9,13,14,18	1,7,12–14,19,20	1,7,9,13,14	7,13,14,21–25	7,12–14

Note: Cycles refers to full equivalent charge-discharge cycles.



Based upon the load-growth estimate posed in an average HVAC electrification on Main Campus it is difficult to recommend one storage technique. Multiple day discharge may become a resilience factor, and a variety of technologies may be best.

The DOE Energy Storage Grand Challenge should be considered as a resource, which was created to push innovation ahead of the year 2030. This "tipping point" milestone for decarbonization is pushing storage manufacturers to reduce cost and increase scalable/repeatable solutions.

While the University has experience with Tesla Mega-Pack batteries, Lithium-Ion technology is designed to discharge for 2-6 hours, which may suffice for future power management and resiliency needs.

[5] **SOURCE:** "Projecting the Future Levelized Cost of Electricity Storage Technologies" - Joule Volume 3, 81–100, January 16, 2019. Elsevier Inc. by Oliver Schmidt, Sylvain Melchior, Adam Hawkes, and Iain Staffell (Technical Paper)

Infrastructure Recommendations

The following infrastructure recommendations are provided to help the University plan for systems phase-outs, improvements, and modifications to achieve carbon goals. More detail is provided in the Appendix B, "Infrastructure Review."

Chilled Water System (Reference 2009 Report and 2010 Satellite Plant drawings)

1. The steam turbine chiller should be decommissioned when the gas turbine is decommissioned. The remaining electric motor driven chillers can handle the campus chilled water loads.

2. Continued operation of the ice storage and chilled water storage systems should be weighed against potential system inefficiencies. TES systems are typically utilized to save cost and not necessarily energy by shifting demand but can also provide additional resiliency to the systems. In any case, decommissioning of these systems is not considered a high priority.

3. Implementation of upgrades to individual buildings HVAC systems will over time serve to reduce the load on the central chilled water system.

Steam System Study (reference 2009 Report and 2022 Update)

1. The system steam leaks defined in the 2022 Update should be repaired as soon as possible. According to the 2022 Update, the existing steam leaks account for about 5% of the natural gas usage and would cost approximately $35M to implement. Many of these repairs should be relatively simple to implement and result in quick savings which could be applied to other projects.

2. One of the paths to carbon neutrality includes decommissioning the central steam system. Appendix B of this report presents a proposed methodology to accomplish this. Full decommissioning could be accomplished over the next 25 years and implemented through sequential 5-year phases.

3. The central steam system will likely remain in use for many years, even if the University decides to implement phased decommissioning. To minimize its contribution to the campus carbon footprint, it will be most important to maintain it properly and to operate it efficiently.

Electrical System Study (reference 2014 Report)

1. The path to carbon neutrality will require that the campus energy source move away from natural gas and towards electricity. In order to accomplish this movement, the campus electrical distribution system must be upgraded to a campus-wide robust 24KV system.

2. The cost to accomplish this was previously estimated at $60M. This figure should be recalibrated to account for inflation and general increases in construction cost.

3. A decarbonized campus will consume significantly more electricity. Electric usage costs are also likely to rise in coming years. The future portfolio and rate structure of the service provider (El Paso Electric) will have a significant carbon and financial impact on the campus. NMSU-owned photovoltaic generation (and other owned renewable sources) will serve to mitigate these impacts.

Potential Timeline

This section seeks to prioritize many of the specific items investigated in this study with the aim toward decarbonization by 2045. Urgent Items, 5-Year Plan, 10-Year Plan, and 2050 Plan categories are utilized in this prioritization. As is common in master plans, the more near-term items are presented with a higher degree of certainty than long-term items.

Amount and source of funding available, outside influences from industry and government regulation, and inside influences from campus operations and system interdependencies will all impact how and when these specific items can be implemented. Examining each of these elements in the broad context of planned decarbonization, however, provides perspective on the significant time and capital investments required to achieve the goal.

Urgent Items (2023-2025)

- Begin implementation of primary 24 kV electrical loop to improve reliability and redundancy and avoid catastrophic failures. This will also allow for future campus electrification.
- Start electrical upgrades at the individual building level in preparation for all-electric systems. Align these efforts with planned renovations and upgrades.
- Update University Design Standards for all campuses to align with decarbonization efforts.
- Align branch campus construction and renovations with HVAC, electrical, and domestic water conservation efforts.
- Continue and expand building energy audits, retro-commissioning, and re-commissioning. Minimize and eliminate VAV reheat and other parasitic heat sources to reduce impact of steam system on carbon footprint.
- Continue and expand summer and unoccupied dual-duct and multi-zone system setbacks.
- Perform detailed study, budgeting, and conceptual design on steam system decentralization and phasing plan.
- Perform detailed study, budgeting, and conceptual design on electrification of building HVAC systems.
- Performed detailed study, budgeting, and conceptual design on campus photovoltaic opportunities.
- Implement steam system repairs in alignment with planned system decommissioning.
- Renegotiate and renew natural gas and electrical contracts in alignment with decarbonization goals.

5-Year Plan (2023-2028)

- Begin implementation of agrivoltaics at Agricultural Science Centers (ASCs).
- Renovate HVAC systems at Alamogordo & Grants Branch Campuses for full electrification.
- Renovate HVAC systems at DACC Main Campus for full electrification.
- Vehicle Fleet – develop charging station master plan with electrical service extensions.
- Begin implementing planned removal of natural gas at Agricultural Science Centers (ASCs).

MAIN CAMPUS

- Continue implementation of 24 kV electrical loop.
- Continue individual building level upgrades in preparation for all-electric systems.
- Continue energy conservation measures in existing facilities.
- Implement first phase of steam system decommissioning. Migrate other utilities out of tunnel systems or repair tunnels if needed to contain other utilities (CHW, IT, electrical).
- Design and install additional photovoltaic and storage systems on campus.
- Migrate select buildings to fully electric systems. May include development of micro HW districts with electric boilers serving multiple buildings in alignment with steam phase-out.
- Finalize elimination of natural gas in new buildings and renovations on all campus facilities/campuses.
- Study and implement, if feasible, district geothermal systems at Arrowhead Park and Housing District.
- Develop plan for I-10/I-25 Interchange electric vehicle central charging station.
- Establish if NMSU decarbonization mandate is to apply to Arrowhead Park and Aggie Uptown. If so, establish design standards for these locations in alignment with decarbonization and strategic goals of developments.
- Increase Academic Integration and formalization of Campus as a Living Lab.

10-Year Plan (2028-2033)

- Complete implementation of 24 kV electrical loop.
- Complete individual building-level upgrades in preparation for all-electric systems.
- Continue energy conservation measures in existing facilities.
- Implement second phase of steam system decommissioning. Migrate other utilities out of tunnel systems or repair tunnels if needed to contain other utilities (CHW, IT, electrical).
- Migrate select buildings to fully electric systems.
- Design and install additional photovoltaic and storage systems on campus.
- Complete phase-out of natural gas in existing buildings and replace with electrified heat sources.
- Design and install additional photovoltaic systems on campus.
- Invest in virtual power plant infrastructure when purchasing Electric Vehicles (bi-directional)
- Implement wider Micro-Grid Capabilities (for Islanding), incorporating Direct Current Systems
- Explore, study, and implement new district thermal energy systems at Arrowhead, dorm, family housing, athletics, core classroom, and research districts. Refer to Section 3 for additional discussion on these potential systems.

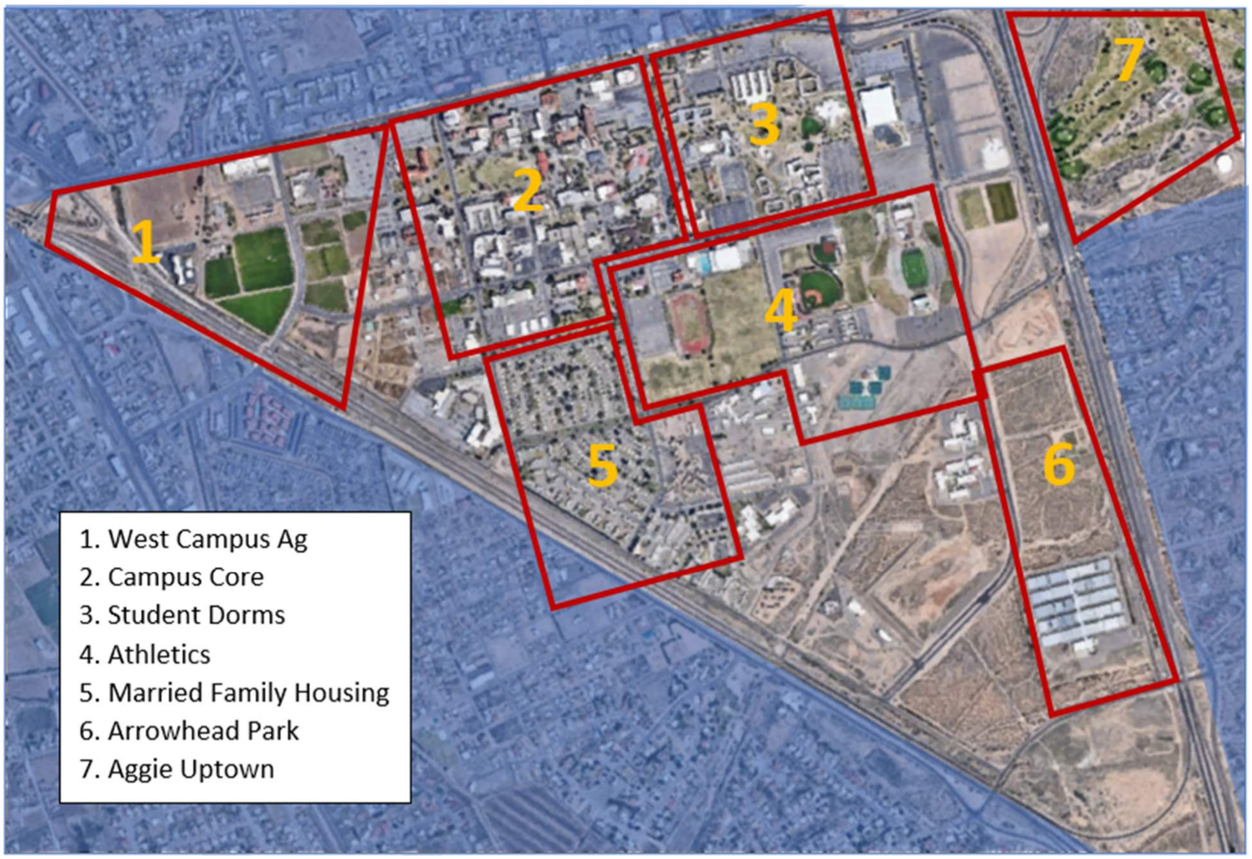
2040 Plan (2030-2040)

- Implement third, fourth, and fifth phases of steam system decommissioning.
- Migrate final buildings to fully electric systems.
- Design and install additional photovoltaic and storage systems on campus.
- Fully decommission and end use of use of natural gas turbine on campus.
- Fully decommission and end use of use of natural gas steam boilers on campus.
- Continue energy conservation measures in existing facilities.
- Study and implement carbon sequestration and carbon capture systems on campus.
- Expand district thermal energy systems.
- If present, study and implement hydrogen usage on campus.
- Achieve planned carbon neutrality of consumed utilities by 2040.

SECTION THREE

MAIN CAMPUS DISTRICTS

The map below illustrates seven distinct districts or zones within the main campus boundaries, each of which offers unique challenges and opportunities for decarbonization. The following pages provide options for decarbonization in each district with examples for implementation.

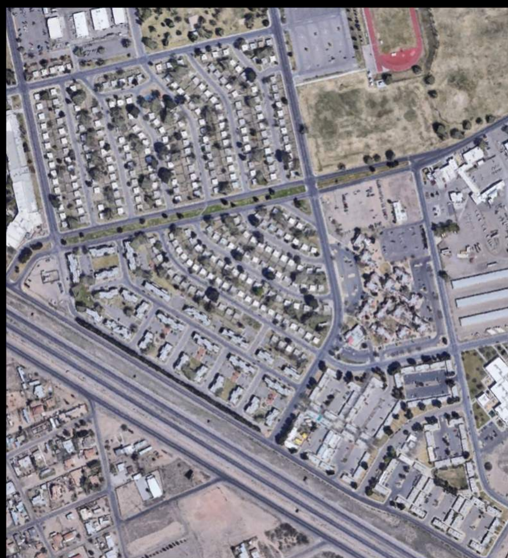


ENERGY REDUCTION CONCEPTS BY DISTRICT

This matrix is provided as a quick overview of the technologies recommended for each district.

District	Solar Thermal	Rooftop PV	Canopy PV	Energy Storage	Heat Pumps	Ground Source	Electric Boilers
AG-BUILDINGS	✓		✓		✓		
CAMPUS CORE		✓	✓	✓	✓		✓
DORMITORIES	✓	✓		✓	✓	✓	✓
ATHLETICS	✓		✓		✓		
FAMILY HOUSING	✓			✓	✓	✓	
ARROWHEAD PARK		✓		✓	✓	✓	
AGGIE UPTOWN		✓		✓	✓		

CAMPUS FAMILY HOUSING DISTRICT



Ground Coupled Heat-Pump Feasibility

SINGLE STORY UNITS:
- ✓ 518 Units x 2.5-Tons Cooling Each
- ✓ 1,295 Tons of Cooling (1,300 Bores)
- ✓ 520,000 sqft field (11.9 Acres)

TWO STORY UNITS:
- ✓ 154 Units x 2.5-Tons Cooling Each
- ✓ 385 Tons of Cooling (400 Bores)
- ✓ 160,000 sqft field (3.7 Acres)

Total of 15.6 Acres

Housing Opportunities:

- Energy performance contracting to:
    - Replace & Electrify HVAC
    - Install Solar Photovoltaic (PV) Canopies
- Create "Community Garden" areas, watering food crop with NMSU excess water rights
    - Incorporate "Living Lab" aspects from Ag Science program collaborations
    - Reducing Urban Heat Island
- Create community bike charging stations using solar canopies (below)

Housing Challenges:

- Structures have antiquated aluminum wire making electrification hard in family housing
- Currently 1950's era furnaces have problematic leaks and are a utility burden
- Housing pays their own O&M such as new furnaces, and rates are intentionally low to help married families, so public/private partnerships (P3) are not lucrative
- Traditional ground-source heat-pumps do not appear feasible (left)

Example Community Garden

DUG DENVER URBAN GARDENS

West Washington Park Community Garden
https://dug.org/garden/wwpcg/

Example eBikes + PV

(Aspen Colorado)

https://www.denverpost.com/2021/08/13/aspen-ebikes-wecycle-cycling-mountain-biking/

SOLAR THERMAL HOT-WATER HEATING

NMSU has mixed experience with Solar Thermal Hot-Water Systems

The Main Campus NMDA Building had a solar to HW with absorption chillers which was augmented with steam and decommissioned in mid-90's due to weight and frozen solar thermal tubes, nothing was automated and when recently re-roofed, the system was removed.

College of engineering building had solar to air (thermal storage - rocks) which was decommissioned in late 90's (below).

In both instances, maintenance was not performed regularly, and systems failed.

THE BEST CANDIDATE FOR SOLAR THERMAL

The Chamisa Dorms is water-loop heat-pump system, which has roughly 400 Tons of cooling among many terminal units (1-2 ton units each). Soffits with mechanical chases are in each building. Phase one and phase two were in "quad structures" with one common area. The main thermal vault for Chamisa is in the athletics parking lot (parking north of baseball - maintained by Auxiliaries/Parking). This installation would be adjacent to heat exchangers, pumps and VFDs are in that same location.

Solar America Solutions Example

The Aquatic Building is also a good candidate due to its high gas usage, but in any instance new systems must be automated and maintained. Due to cost per Therm there is likely significant cost savings in solar thermal, unlike previous years.

ATHLETICS DISTRICT (EAST CAMPUS)

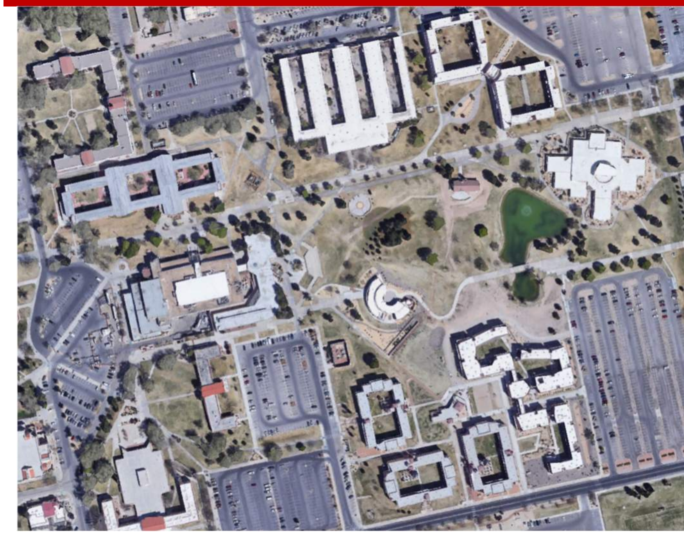
ATHLETICS OPPORTUNITIES:

- Showcase “Green-Tech” in highly public areas of campus
- Solar Thermal pairs well with showers and large hot water users
- Heat-Island reductions with PV canopies could reduce HVAC usage

ATHLETICS CHALLENGES:

- Solar Infrastructure may be restricted to parking areas only

STUDENT HOUSING (DORMITORIES)

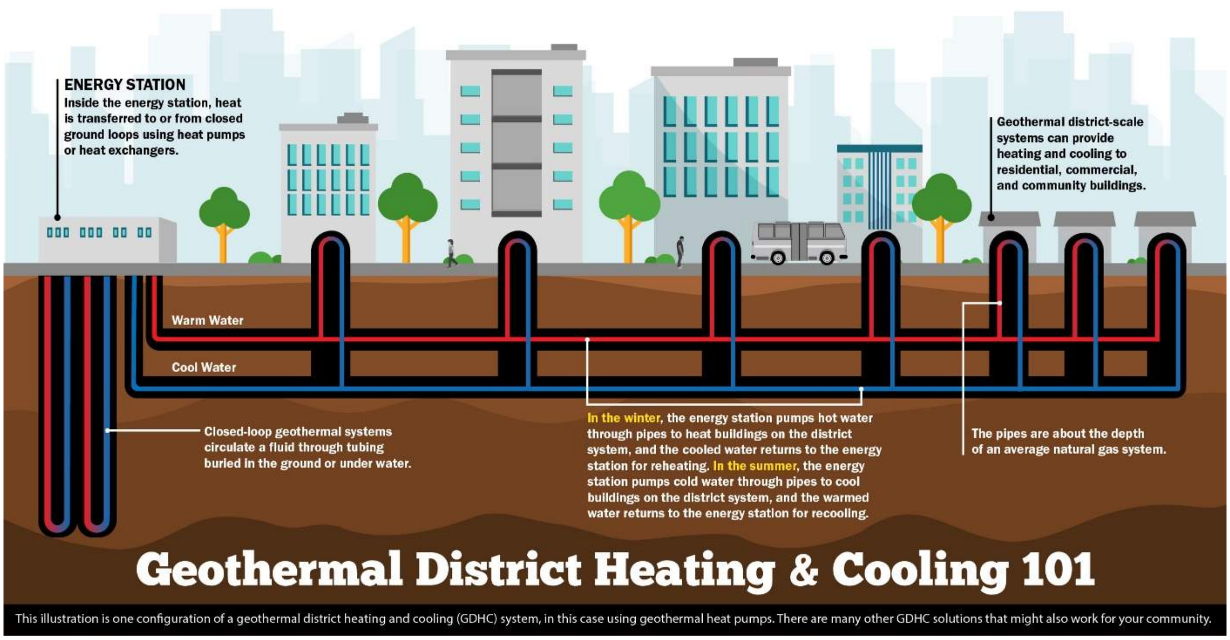


DORMITORY OPPORTUNITIES:

- Chamisa Dorms have ideal water-source heat-pumps already
- Heat-Pump Chillers are Possible for other Dorms, with four-pipe HVAC
- Solar thermal hot water aligns well with large hot-water loads

DORMITORY CHALLENGES:

There does not appear to be any immediately adjacent groundwater for diffusing ground coupled heat-pump heat, and ground properties in the Las Cruces foothills are notably adverse



https://www.energy.gov/eere/geothermal/geothermal-heating-and-cooling

Chamisa Dormitory High-Level Ground Coupled Heat-Pump Feasibility

- 400 Tons of Cooling Load = 400 Bores
- 400 Bores on 20' Centers = 160,000 sqft
- 160,000 sqft bore-field = 3.7 acres

Bore-Holes can be placed below parking lots, though repaving costs increase system costs

Adjacent Parking Lot is 170,000 Square-Feet

CORE CLASSROOM BUILDINGS

CLASSROOM OPPORTUNITIES:

- Most visibility for flashy projects, within arms reach of students and aligned academic programs
- Pairing projects with programs for Campus as a Living Lab is made easier

CLASSROOM CHALLENGES:

- Close proximity among buildings for new ground-mounted equipment such as Chillers, Boilers, and Energy Storage
- Ability to group buildings under new small CUB's
- Aging roofs for PV

Because classroom buildings represent the largest district on campus, there are many unique opportunities for incorporating decarbonization concepts within and around buildings. While building level systems are often an eye-sore (below) careful integration will be necessary to avoid campus sprawl.

San Diego Gas & Electric System[6]

Example 26 Mega-Watt Hour Battery Energy Storage System (BESS)

This battery energy storage system in San Diego, CA requires space for both the containerized battery modules, as well as their associated cooling systems. Based on the load-growth and solar PV recommendations in this report, a 26 MWh system at NMSU is possible.

[6] https://www.globalenergyworld.com/news/traditional-energy/2017/05/24/powin-energy-deliver-26-mwh-energy-storage-system-san-diego-gas-electric

Classroom Building Solar Energy Projects

The Section 2 summary in this report includes NREL Collegiate Solar Competition project sites, as well as parking lot and walkway sites identified by EEA as ideal candidates for highly public opportunities to showcase decarbonization as well as reduce urban heat island.

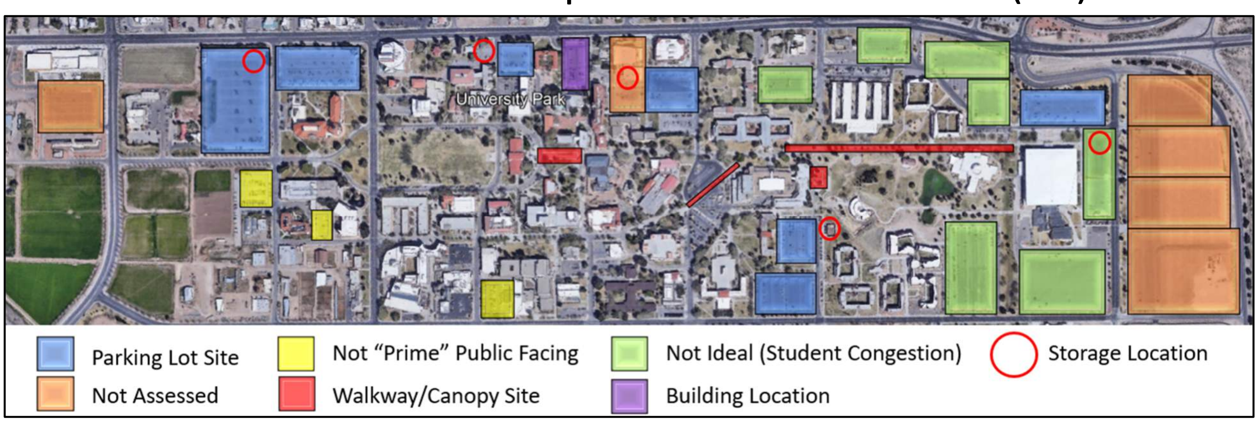
Cumulatively the 31 sites may generate 37 Mega-Watt Hours per Year, which is 55% of the future electricity consumption, after electrification/decarbonizing HVAC.

The map below illustrates locations of some of the arrays, while Appendix C has a detailed breakdown, including Ag Science Center sites. These examples of artfully designed Solar PV Shade Structures are provided to illustrate that decarbonization can be designed to be both visible and seamless. Other examples are in Appendix C as well, where solar PV is seamlessly integrated into large shade canopies on other University campuses in the Southwestern U.S.

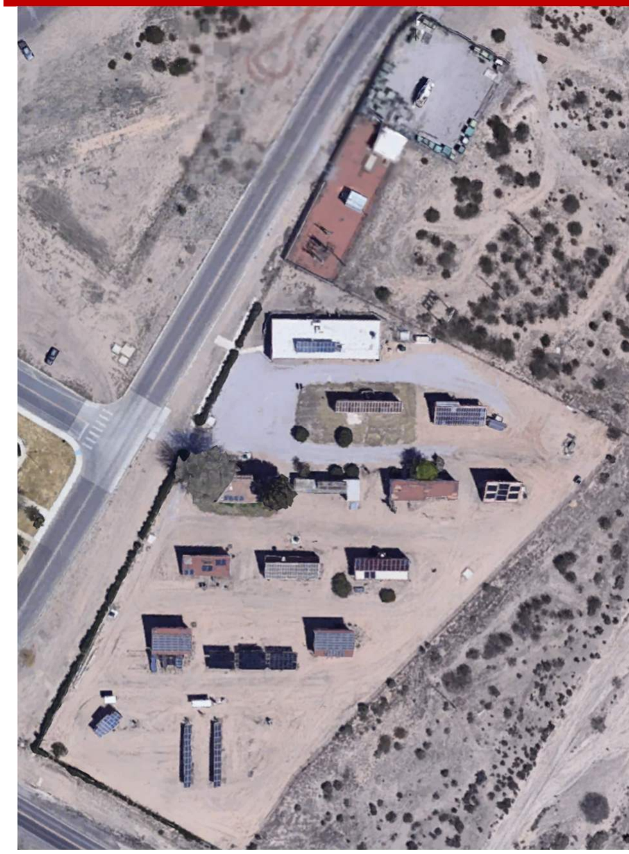
http://thesolarhomestead.blogspot.com/2011/09/bifacial-pv-solar-canopy.html

https://www.prismsolar.com/carport-case-study

Recommended Main Campus Solar Photovoltaic (PV) Sites



ELECTRICAL ENGINEERING (Southwest Technology Development Institute)



SW-TDI CHALLENGES:

- The Institute's remote Location vs. Public Access and Visibility is not well aligned for optimal community and stakeholder exposure
- The location does not compliment campus footprint reduction and management strategies

SW-TDI OPPORTUNITES:

- Micro-Grid research is underway and can be leveraged for campuswide adoption of learned-lessons/successes
- Decarbonization Technology Testing and Prototyping prior to adoption
- Grid-Forming inverter in parallel to Tortuga (EPE may have a spare inverter that they may sell to NMSU, with 3 MW transformer capacity for micro-grid operation islanding)
- Potential for a new R&D Facility (see I.D.E.A.L Facility on next page)

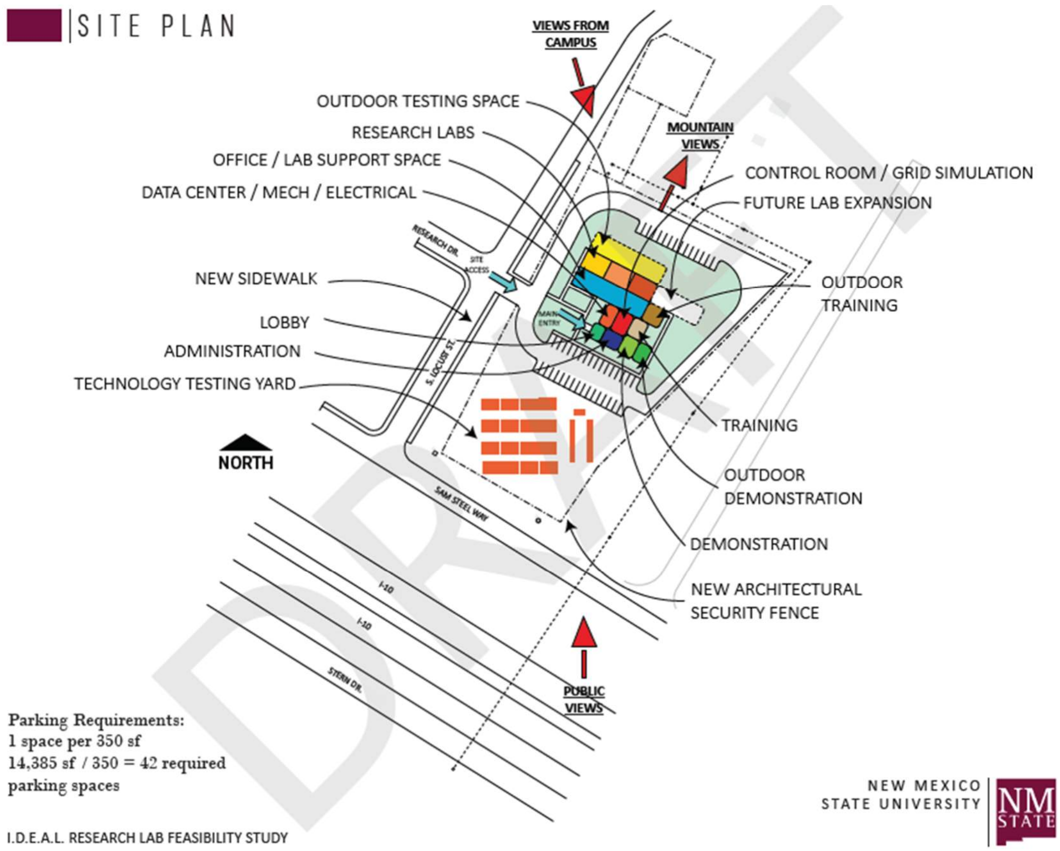
More about Grid Forming Inverters

To aid in the University's ability to recover after a blackout, and to bring power stability to the campus grid, researchers and faculty are evaluating the use of Grid Forming Inverters:

> *Inverters provide the interface between the grid and energy sources like solar panels, wind turbines, and energy storage. When there is a large disturbance or outage on the grid, conventional inverters will shut off power to these energy sources and wait for a signal from the rest of the grid that the disturbance has settled and it is safe to restart—known as "grid-following." As wind and solar account for increasing shares of the overall electricity supply, it is becoming impractical to depend on the rest of the grid to manage disturbances. Grid-forming inverters are an emerging technology that allows solar and other inverter-based energy sources to restart the grid independently.*

National Laboratories, Universities, and the U.S. Department of Energy (DOE) Solar Energy Technologies Office (SETO) are outlining plans to utilize renewables to "hard-start" the grid instead of using traditional energy sources with short start/ramp times like coal and gas.

https://www.energy.gov/eere/solar/articles/powering-grid-forming-inverters (January 2021)



The I.D.E.A.L. facility aims to accomplish the following:

- Enhance the existing site to support the functions of the new research lab.
- Incorporate state-of-the-art visual demonstration and grid-simulation technologies to conduct tours and demonstration events to inform the public on emerging energy technologies and the future of energy policies.
- Provide flexible training spaces for trade organizations to conduct training and seminars for workforce development.
- Provide state of the art, flexible lab spaces to support STEM and outreach activities. The flexible spaces are intended to be used by multidisciplinary industry leaders in emerging electrical technologies to collaborate on research and development of efficient and sustainable energy systems.
- Provide office spaces and collaboration spaces for visiting researchers, staff, students, and specialists.
- The architecture aims to incorporate multiple forms of emerging energy technologies to be used as a teaching tool for students and the public.
- The building will be a landmark that establishes New Mexico State University's presence as a leader in energy research and will be used as a marketing tool to attract industry leaders.

DESERT PEAK ARCHITECTS

311 N. MAIN ST., LAS CRUCES, NM 88001
575.528.0021
desertpeakarchitects.com

EXISTING ARROWHEAD BUILDINGS

ARROWHEAD CHALLENGES:

- Proforma for Outside Developers does not lend to decarbonization initiatives that do not have a positive cashflow
- High-profile long-term leases require an anchor tenant which has yet to arrive

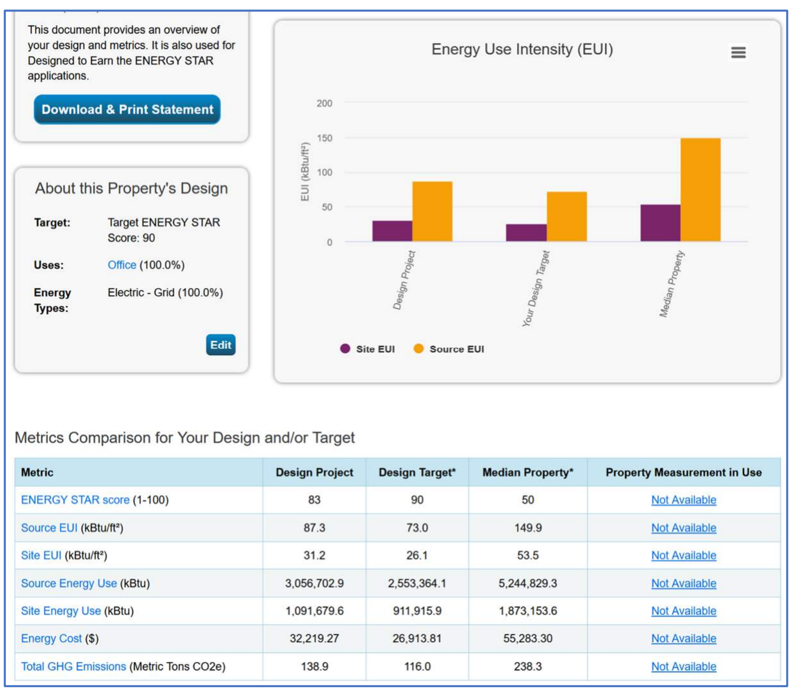
ARROWHEAD OPPORTUNITIES:

- Ground Source or Hydrogen systems could be highly visible due to location
- Federal and State Tax Credits and Incentives for Green-Tech are transferrable and may be used as a means for incentivizing development (see the Informative Appendix F).

https://programs.dsireusa.org/system/program/nm

New Arrowhead Office Building

Based on a potential 35,000 square-foot (sqft) all-electric office building for Arrowhead use, the Energy Star Target Finder Tool suggests that the building would emit 138.9 MT CO2e per year, which is capable of 100% decarbonization, compared to a building utilizing natural gas for heat and hot water.



Metric	Design Project	Design Target*	Median Property*	Property Measurement in Use
ENERGY STAR score (1-100)	83	90	50	Not Available
Source EUI (kBtu/ft²)	87.3	73.0	149.9	Not Available
Site EUI (kBtu/ft²)	31.2	26.1	53.5	Not Available
Source Energy Use (kBtu)	3,056,702.9	2,553,364.1	5,244,829.3	Not Available
Site Energy Use (kBtu)	1,091,679.6	911,915.9	1,873,153.6	Not Available
Energy Cost ($)	32,219.27	26,913.81	55,283.30	Not Available
Total GHG Emissions (Metric Tons CO2e)	138.9	116.0	238.3	Not Available

EPA Energy Star Target Finder Results
(Using 31.2 kBtu/sqft-yr Site EUI)

New Campus Buildings

For alignment with this Energy Transition Master Plan, it is recommended that new facilities use no natural gas or steam, that all-electric buildings are put in service going forward.

The two buildings known to be presented for Summer Hearings with the NM Higher Education Department, planned for 2027 construction, are as follows:

1. 49,000 Sqft (2 Story) for a Creative Media Institute
2. 25,000 Sqft (1 Story) for KRWG Studios

If these facilities were all electric, as intended by this Master Plan, 3,445 MT CO2e during their 50-Year useful-life could be diverted from the atmosphere.

Per Energy Star EUI of 45.2 kBtu/sqft-yr and assuming El Paso Electric is 100% clean.

Dona Ana Community College + Branch Campuses

DONA ANA COMMUNITY COLLEGE (DACC)

MAIN CAMPUS AREIAL IMAGE

Energy projects include LED's and lighting controls system-wide (instituted four years ago, as low hanging fruit) and have sufficient funding to accomplish this – the past four years have kept utility spending flat even with utility cost-escalation. It should be noted that community colleges can use BRR and mill-levy funding for capital infrastructure projects which is renewable (unlike main campus, which cannot take advantage of tax base funding).

Immediate projects include LEDs/lighting-controls, HVAC upgrades from packaged single zone (primary system type at Gadsden, Sunland, Workforce, East Mesa, and Espina campuses). Espina campus has CHW system and looking at the design for a new chiller/tower system, which serves all but one building and will be moving off NMSU steam system to move to electric boiler systems for upcoming 2-3 year capital outlay funding request.

EAST MESA AREIAL IMAGE

SUNLAND PARK CAMPUS AREIAL IMAGE

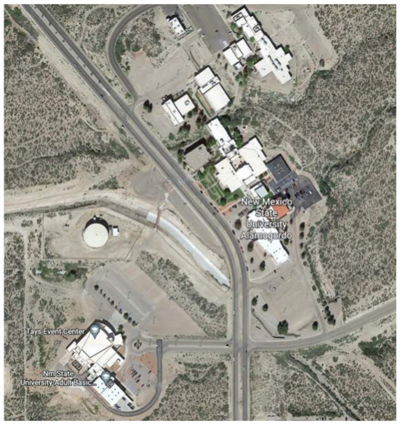
Should the Main Campus location decarbonize its natural gas and steam energy consumption, and move to electricity consuming equipment only, the site's carbon footprint will be significantly reduced. The actual amount of gas and steam used by DACC is unknown due to lack of metered data, but Appendix C includes recommendations to offset existing electricity consumption.

Electricity use among "Learning Resources," "General Classrooms," and "Technical Studies" meters is 473,038 kWh per year. This annual use could be offset 100% by rooftop solar (420 KW in 14 groups).

BRANCH CAMPUSES

During interviews with Branch Campus building managers it was determined that the design standards and motivations to pursue carbon-neutrality were not translated from Main Campus. Planned projects at both sites are considering natural gas fired heating systems which is contradictory to decarbonization.

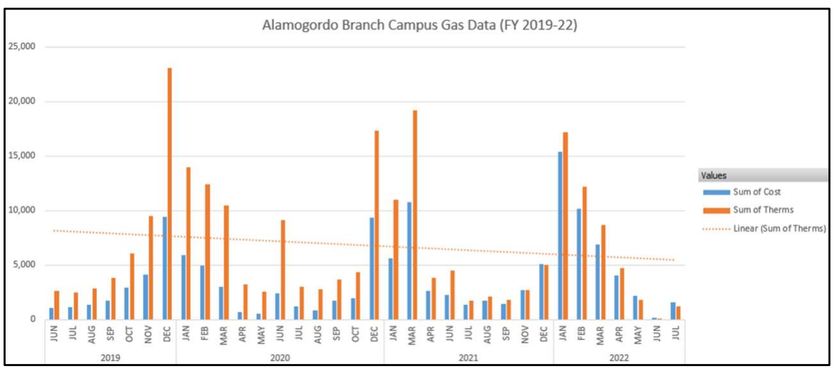
ALAMOGORDO CAMPUS



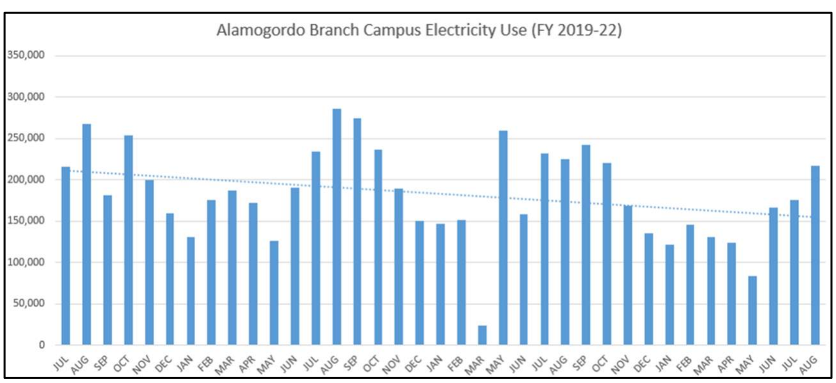
In a 2021 HVAC Assessment conducted by Bridgers & Paxton consulting engineers it was recommended that all HVAC systems be replaced with Variable Refrigerant Flow (VRF) Heat-Pumps and new Packaged Rooftop Units. The study included the following:

On May 24th through May 26th a site investigation by Bridgers & Paxton was conducted on the following buildings:

A.	Pro-tech (292N)	27,315 sqft	(Also includes Small Business Dev Center)
B.	Reidlinger Science Center (292U)	35,626 sqft	(Also includes Allied Health)
C.	Tays Center (292C)	45,484 sqft	(includes Adult Ed. and Adv. Tech Center)
D.	Fettinger Student Services (292H)	15,425 sqft	(Also Includes Bookstore)
E.	Student Union (292J)	7,267 sqft	
F.	Townsend Library (292Q)	13,791 sqft	
G.	Campbell Fine Arts (292M)	8,605 sqft	
H.	Academic Support Center (292V)	3.060 sqft	(Also includes Testing Center)
I.	Faculty Building (292L)	4,849 sqft	



Slight Trend Observed in the Downward Direction



Slight Trend Observed in the Downward Direction

Electricity Consumption (bottom left) suggests that there is very seasonal variation as expected.

Peak consumption occurs in August (FY21), and typically peaking summer, but some months do not follow overall trends. Due to the unpredictable pattern in peak use, it is recommended that this site undergo retro-commissioning (RCx) to tune HVAC systems.

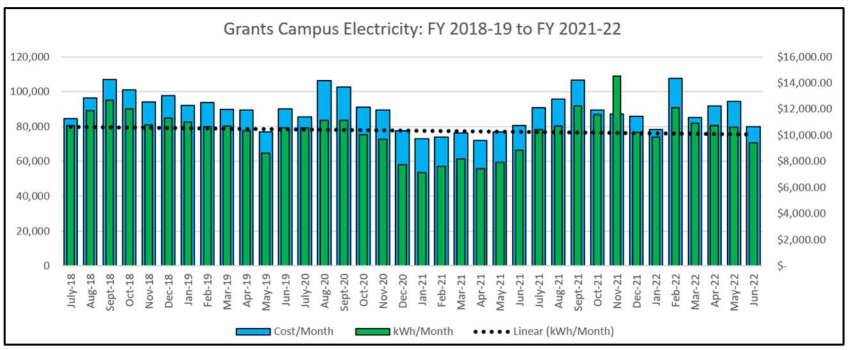
Gas consumption (top left) is more predictable, with peaks occurring in winter as expected. RCx would likely reduce future usage spikes, that the one in December of 2019 and March of 2021.

GRANTS CAMPUS

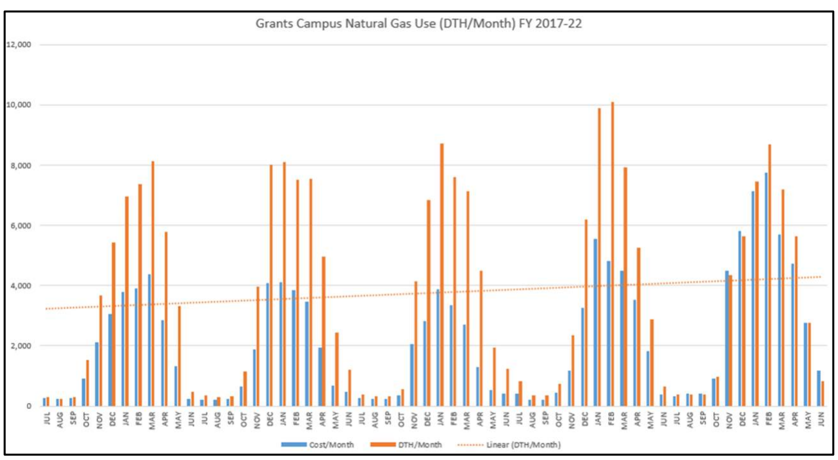
Most capital funds for the Grants Campus are directed to Martinez Hall for the 5-Year cycle (with 2 years remaining), which has not received energy efficiency upgrades, aside from LED's.

Most LED projects on the Grants Campus are implemented to save manpower (due to longer useful life of LED's), and the Campus is now 80% LED.

The site's facility manager would like to be able to monitor energy use at the meter via Niagara (the new building daycare is RTUs and integrated and lighting is also automated for scheduling).



Slight Trend Observed in the Downward Direction



Slight Trend Observed in the Upward Direction

Electricity Consumption (top left) suggests that there is very little seasonal variation and is consistent in the three years of data provided.

Peak consumption occurs in November (FY21) but is peaking in FY18 in September and in FY19 as well. Due to the unpredictable pattern in peak use, it is recommended that this site undergo retro-commissioning (RCx) to tune HVAC systems.

Gas consumption (bottom left) is more predictable with peaks occurring in winter as expected, though RCx would likely reduce use.

SECTION FOUR

AGRICULTURAL EXPERIMENT STATION

AGRICULTURAL SCIENCE/RESEARCH CENTERS

The agricultural programs at NMSU are the heart of the University and essential for the southwest, and Main Campus AES is a gateway to the University. This historic district has begun a transformation, adopting digital agriculture technologies for the "Farm of the Future," furthering both the Agricultural Experiment Station (AES) program and the State of New Mexico as a whole.

With proximity to main campus and access to complimentary program areas within the University, such as the Environmental Engineering department, Main Campus is afforded the opportunity to interface with many of the statewide agricultural research initiatives.

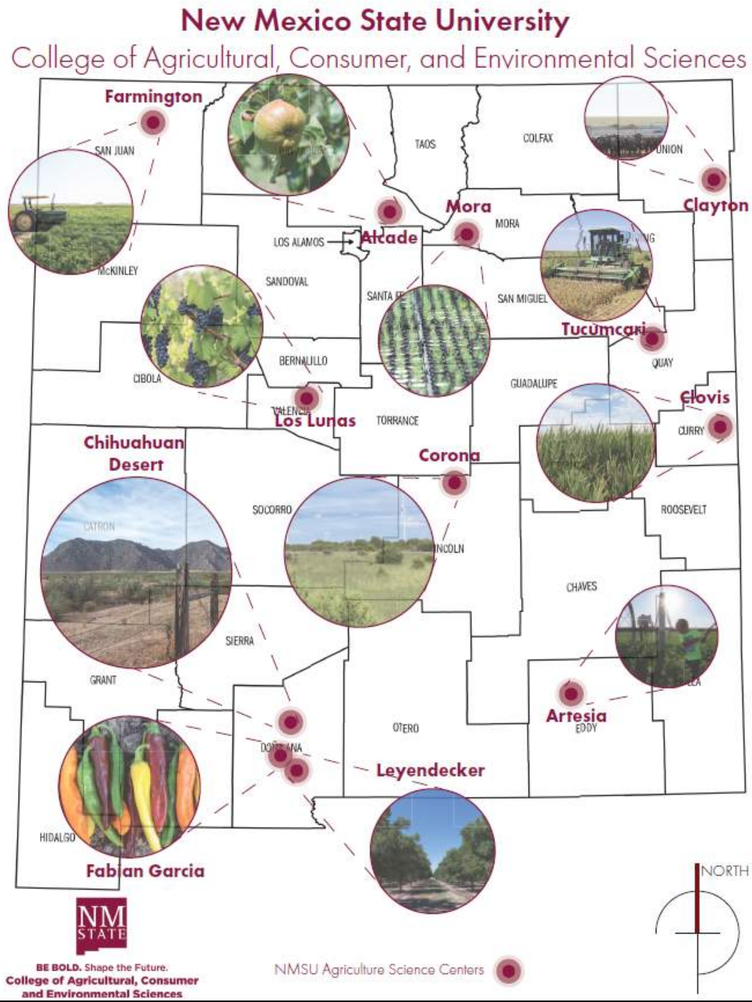
With a history and heritage based in crop and livestock production, the future of the AES program is headed in an exciting direction. With small desalinization projects and a demonstration Agrivoltaics structure powering drip-irrigation, AES sites on Main Campus provide a working glimpse of digital agriculture technologies and the “Farm of the Future.” With a strong focus on the Energy/Water Nexus students and stakeholders on Main Campus can see examples of the amazing work without traveling to the 12 sites around New Mexico.

PatternEnergy.com

The twelve unique statewide Agricultural Science/Research Centers (ASC) support research to meet these overarching program goals:

- Enhance agricultural profitability.
- Improve the quality, safety & reliability of food and fiber products.
- Stimulate economic development using natural resources.
- Sustain and protect the environment with ecologically sound practices.
- Manage and protect natural resources.
- Improve the quality of life for the people of New Mexico.

These goals come with a new and invigorating motivation for research sites to become active participants in NMSU’s goal for carbon neutrality. Recent green power land-leases by the University, for example at the Corona Range and Livestock Research Center with Pattern Energy, are offering the program new insights about how land can be viewed as a multi-faceted resource.



While the Carbon Credits for existing wind-developments belong to third parties, it is recommended that future leases incorporate provisions for the University to share a portion of carbon credits. These future wind and solar projects provide the University with both financial and environmental opportunities.

Future AES projects will begin to review the benefits of net-metering and energy storage, which is becoming a national trend for Agrivoltaic systems. NMSU AES sites do not have either of these configurations, but program directors are looking for ways to benefit financially from renewables, knowing that there is congressional funding for Agrivoltaics research. Any new renewable energy systems need to avoid taking productive land out of operation, until benefits of Agrivoltaics are known.

A detailed site-by-site assessment of renewable energy opportunities at each ACS location can be found in the Solar Photovoltaic Appendix of this report, including aerial images of each site, with Agrivoltaic and ground-mounted solar arrays.

AES Research Focus Areas:

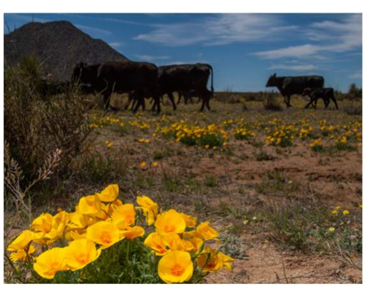
- Digital agriculture
- Precision livestock management
- Agricultural water use efficiency
- Soil health and carbon management
- Reforestation
- Improved crop selection
- Plant breeding
- Dryland cropping systems
- High-value and cover crops
- Renewable energy and agrivoltaics
- Urban horticulture
- Livestock health and productivity
- Sustainable rangeland management

AES ENERGY + WATER + FOOD NEXUS

The following four points summarize lessons learned and recommendations by the Agricultural Experiment Station (AES) program, as they relate to energy and respective carbon emissions. While these sites do not represent a large portion of the University's overall usage, the "Farming Enterprise" side of the AES program experiences high energy costs compared to their overall operating budget, and the department is looking for ways to reduce costs across the spectrum.

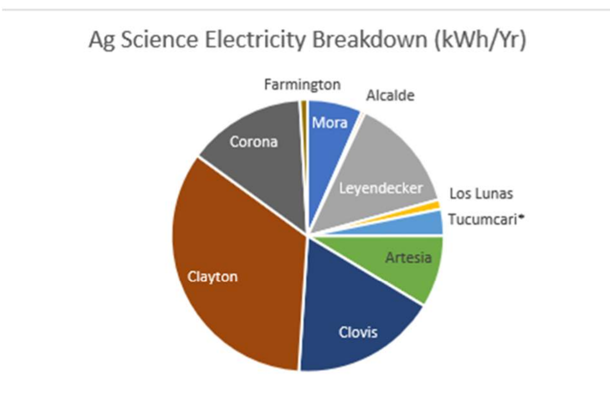
1. Water pumping is extremely energy intensive; it is the biggest expense for agriculture and farming operations and alternative energy sources are currently sought after.
    a. New systems can be used as educational demonstration sites for the University, as well as constituents across the State.
    b. There is a Federal push for **Agrivoltaics** (see following pages), and the program is seeking federal funds for both crops and energy needs. Specifically, the AES program noted that they would like to work with the Governor's Office in this regard.
2. Greenhouses are expensive to operate and are operated seasonally due to energy costs with northern sites being the most expensive to heat.
    a. Mora and Farmington, both northern New Mexico sites, would like to be operated year-round in the future if funding for winter-time heating would be made possible.
    b. Los Lunas, Farmington (crops), & Alcalde (crops/fruit) cold-storage systems are large energy users (keeping seeds, produce, etc.), likely to expand cold-storage at other sites, and will increase energy needs there.
3. Consistent and reliable electricity is needed at ASCs.
    a. The Mora center was closed and evacuated due to recent wildfires in the area, causing seedlings to not be watered, possibly losing years of research data. Two generators will be added to this site to help bolster climate resilience against similar outage events.
4. Some of the sites may be able to take advantage of wastewater and byproduct water from gas and oil, which may help "clean-up" the image of these industries as well as benefit ASCs.

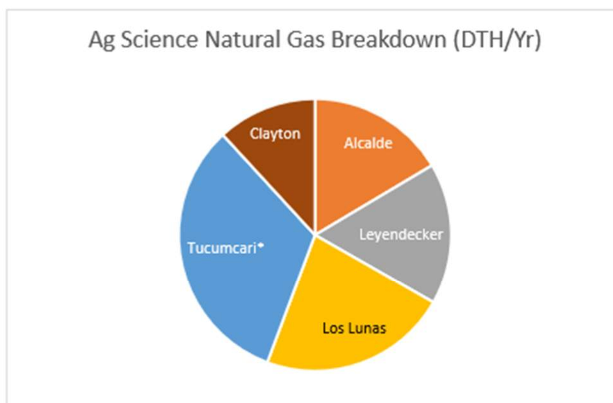
The department believes that funding will be made available through the "Build Back Better" bill and other Federal legislation, and there is a desire among the program to provide a more strategic approach to the associated grants, once facility condition assessments are complete.

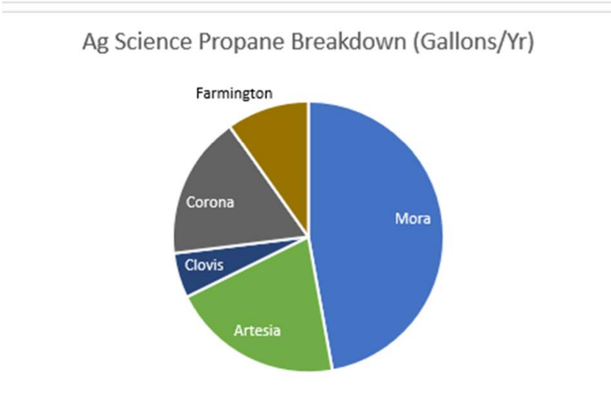


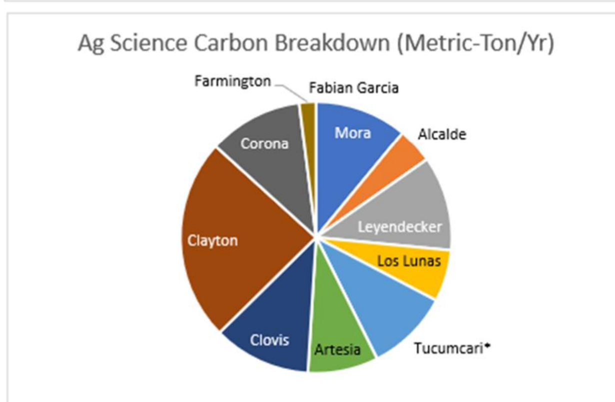

Included in this document is a more detailed sub-report illustrating site-by-site energy consumption and carbon emissions for the Agricultural Science Centers (Appendix D). The summary charts below were obtained from the sub-report and illustrate the following points:

1) Clayton is the largest electricity consumer, followed by Clovis and Corona.
    a. Due to the significant disparity in electricity usage at other sites, these three sites should become priorities when developing renewable energy projects.
    b. Should these sites be slated for load-growth (i.e. facility expansion or equipment expansion), those purchases should be accompanied by solar assets for bundled purchasing.
2) Of the five natural gas using sites, Tucumcari is the largest consumer, followed by Los Lunas
    a. Decarbonization via electrification should begin at these sites.
3) Five sites utilize propane gas and Mora's consumption is nearly half of these sites.
4) When considering all fuels, Clayton's carbon emissions are highest, followed by Clovis.









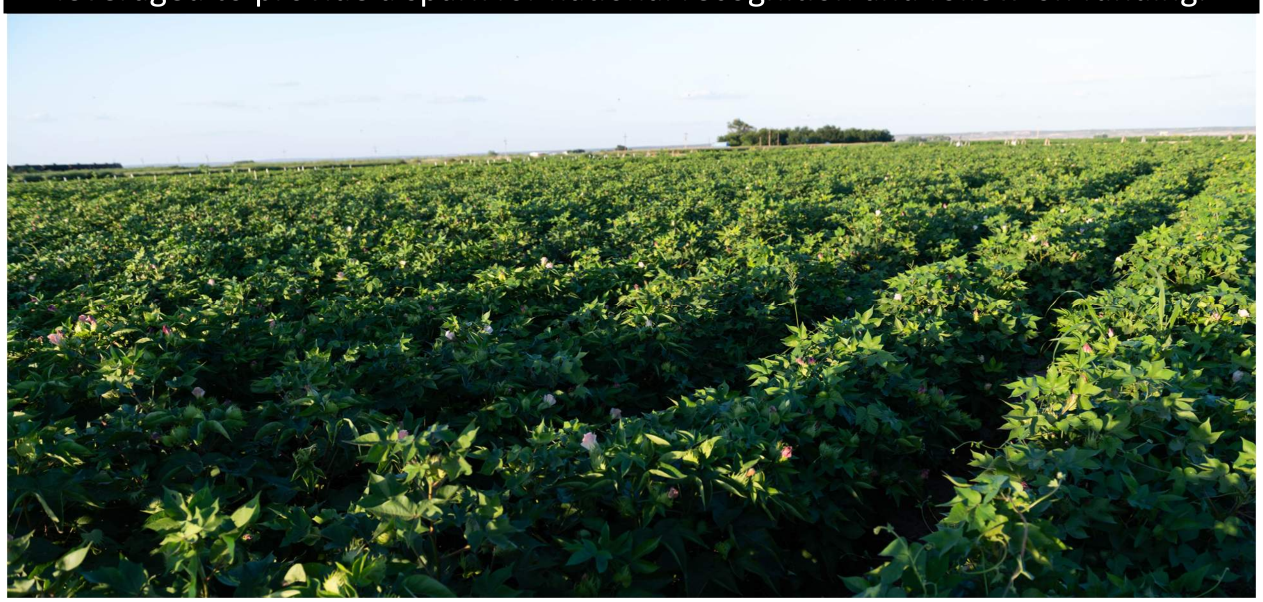
POTENTIAL ENVIRONMENTAL ENGINEERING + AES PROJECTS

The University's Environmental Engineering Department has expressed interest in collaborative research projects with the AES program. These projects should be enacted to help validate new technologies and processes for the Ag-Industry, not necessarily for a move to new technologies across the twelve Agricultural Science Centers:

- Solar and wind for membrane desalinization for agricultural irrigation
- Using bi-products and biochar compost in lieu of fertilizers
- Solar for desalinization for treating water/brine for fresh water supplies
- Chemical and nutrient recovery from wastewater to convert to biomass algae and biofuel oils
- Wastewater to clean hydrogen for energy production
- Wastewater at disposal wells produces contaminants – converting to special purpose applications for mining and agriculture to help with regional water supplies and reducing environmental impact with wastewater disposal.

The Environmental Engineering Department is already working closely with Alamogordo, El Paso Water, and the City of Las Cruces to reduce carbon footprint and integrate renewable energy.

The AES program is challenged when incorporating educational aspects to its research but is interested in developing a **micro-grid demonstration and virtual power plant, using vehicle to grid technology** that is making its way to mainstream markets. This progressive thinking and leadership should be leveraged to provide a spark for national recognition and follow-on funding.



AG SCIENCE RECOMMENDATIONS

It is also understood that energy waste and inefficiencies occur at nearly all ASCs and for this reason these efficiency recommendations are provided in two categories for centers to consider reducing energy costs and planning for decarbonization:

CATEGORY ONE: Low-Cost/No-Cost Options for Energy Savings

- ✓ Exterior Lighting Conversions to LED with appropriate timeclock or photocell controllers
- ✓ Interior Lighting Conversions to LED with appropriate occupant-sensor or timeclock controllers
- ✓ Installation of programmable thermostats for refrigerated-air and furnace-heat HVAC systems
- ✓ HVAC Tune-Up: properly charge refrigerant (where applicable) and aligning fans/motors/belts
- ✓ Window and door weatherization, replacing seals and gaskets

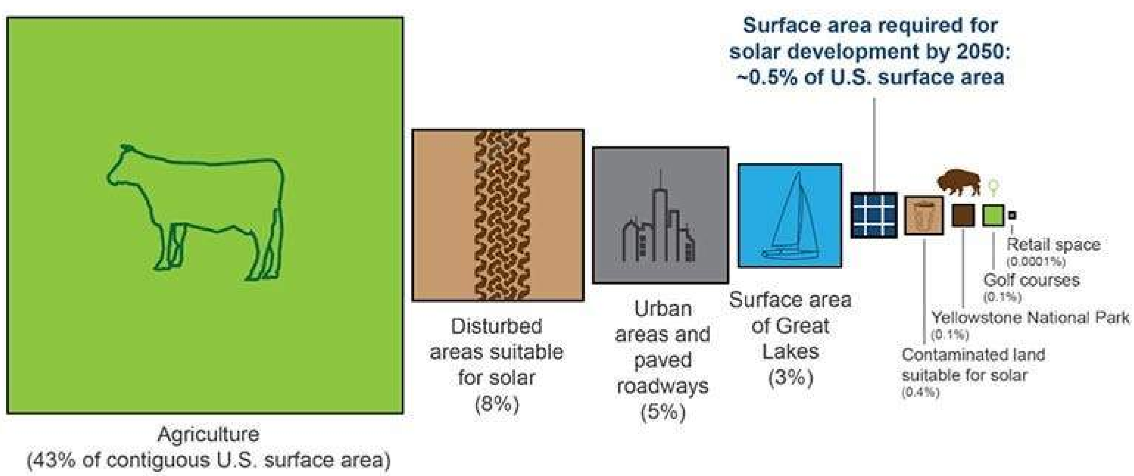
CATEGORY TWO: Capital Investments

- ✓ HVAC Replacement, and gas/propane phase-outs with All-Electric Systems (such as Heat-Pumps)
    - Ground-Coupled Heat-Pumps may be beneficial in areas with good deep-ground properties, which is different from geothermal heat
- ✓ Building Envelope Improvements for researcher comfort and reduction of drafts/dust
    - Window Replacements, especially for single-pane windows
    - Door Replacements, especially for uninsulated and drafty doors
    - Roofing Material improvements, white roofs with better insulation
- ✓ Improving outdoor ambient research areas through Heat-Island Reductions where possible
- ✓ Investment in roof-mounted solar photovoltaics after reducing energy use
- ✓ Investment in solar thermal hot water systems for heating greenhouses

These improvements will reduce operating costs and carbon emissions associated with ASC operations, allowing Agrivoltaic systems to be placed in "highest benefit" locations.

AGRIVOLTAICS (SOLAR PV + AGRICULTURE)

Because the agriculture industry is recognizing the benefits of incorporating solar into existing land-management practices, the "InSPIRE" program was created to provide context for successes in Agrivoltaics. The program is helping create informative fact-based media like this infographic:



Agrivoltaics offers NMSU **one of the most important and relevant cross-disciplinary learning opportunities to integrate Campus as a Living Lab**, via agriculture and electrical engineering department involvement. A December 2022 article by the Institute of Electrical and Electronics Engineers (IEEE) titled “Agrivoltaic Panels Allow Farmers to Harvest Energy: Plant-friendly wavelengths pass right through the translucent arrays” by Peter Fairley, says this about Agrivoltaics.

> *Instead of dedicating land exclusively for solar farms, Abou Najm (UC Davis) is exploring how translucent photovoltaic panels erected over farm fields can be tuned to absorb and transmit optimal bands of sunlight to generate substantial power without stunting the development of crops growing below. In certain cases, the panels might even improve yields.*
>
> *“The U.N. projects that humanity will need on the order of 60 percent more food, 40 percent more water, and 50 percent more energy by 2050. We are at a stage where fixing one issue at a time won’t work. We need to optimize,” says Abou Najm, who is a professor at the UC Davis Department of Land, Air, and Water Resources.*

This is one among a myriad of articles highlighting the ability for solar photovoltaics to help address the water/energy/food nexus, and decarbonize associated agriculture operations. The Ag Science Centers at NMSU have begun exploring Agrivoltaics at remote sites and are interested in placing an array on main campus, in alignment with the “Farm of the Future.”

CASE STUDY EXAMPLE

Jack’s Solar Garden is a partner organization on the InSPIRE project and the largest commercially active Agrivoltaics system in the United States. The 1.2-megawatt array generates enough power for more than 300 homes. Local nonprofits also use the space as pollinator habitat and to train young farmers, such as Brittany Staie, pictured here. Brittany was the farm manager at Jack’s Solar Garden before joining NREL as a research intern. Photo by Werner Slocum, NREL.[7]

The InSPIRE program also provides a free Agrivoltaics Calculator for agricultural sites considering the implementation of Agrivoltaics but needs assistance with the cost/benefit assessment. The calculator can be found here: https://openei.org/wiki/InSPIRE/Financial_Calculator. Additional Federal and Non-Federal resources, recommended when evaluating Agrivoltaics include:

- **Low-Impact Solar Development Basics:**
  https://openei.org/wiki/InSPIRE/Primer
- **Agrivoltaic Success Factors in the United States: Lessons From the InSPIRE Research Study**
  https://openei.org/wiki/InSPIRE/5_Cs
- **Agrivoltaics Map:**
  https://openei.org/wiki/InSPIRE/Agrivoltaics_Map
- **AgriSolar Clearing House:**
  Connecting businesses, land managers, and researchers with trusted resources to support the growth of co-located solar and sustainable agriculture
  https://www.agrisolarclearinghouse.org/

[7] https://cleantechnica.com/2022/08/22/agrivoltaics-growing-plants-power-partnerships/

SECTION FIVE

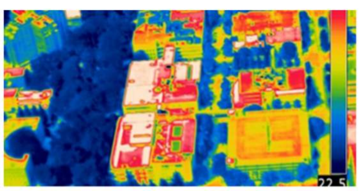
LIVING LAB PROJECTS

Living Lab projects offer students and faculty unique opportunities for hands-on learning, by integrating existing and future Academic Program Areas with existing and future capital projects or assets. Utilizing campus assets and facilities to demonstrate systems and research gives students a chance to inspire learning in a non-traditional manner. This Master Plan seeks dual-purpose Living Lab opportunities, for education and decarbonization. A perfect example of this is associated with the Aggie Power solar array, in which an MOU is in place designed to create a living laboratory with real-time data.

TOP RECOMMENDATION FOR MAIN CAMPUS: Central Plant Equipment as a Living Lab

- ✓ The University Physical Plant Department (PPD) believes this project can be funded through capital project funds, as it will benefit campus assets – it would not be a standalone research project. If planned early enough with faculty, and with semester alignment, students may be able to assist with the design and conduct construction observations. This Living Lab project can be funded through debt service via State funds or Energy Service Performance Contracts (ESPC).
- ✓ Legislators are very excited to do "something" and demonstration projects should align with campus plans/needs. For example, PPD has suggested that New Mexico Senator Martin Heinrich is interested in a Smart-Inverter/Smart-Meter company that adds to, instead of replaces meters, to become "smart."

Arizona State University Climate Lab Examples



Understanding Urban Climate Dynamics

A core focus of the UCRC is on understanding the complex dynamics within the urban climate system. This includes exploring the roles that surface characteristics, land use/land cover, and human activity play in affecting the urban environment. Faculty in the UCRC explore all aspects of the urban climate system, ranging from street-level thermal environments, to boundary-layer processes, air pollution chemistry, and urban-effects on precipitation events.

Exploring Mitigation Strategies

The UCRC is particularly interested in linking scientific understanding of the urban climate system with strategies to mitigate the adverse consequences of urban development. Toward this end, we link geographical scientists with planners, engineers, and designers to develop and evaluate technologies and strategies for sustainable urban designs.

Urban Climate and Human Health & Well Being

The overarching goal of the center is to design and manage sustainable urban climates for improved quality of life in growing cities. This includes research focused on managing urban environmental challenges including extreme heat, poor air quality, and urban hydrology, as well as the urban climate implications for limited energy/food/water resources. The Center also explores the adaptive capacity of at-risk urban populations and relevant policy and planning levers that can address these challenges.

Cooler Phoenix Initiative

Urban climate researchers from ASU have been engaged in studying the urban thermal environment of the greater Phoenix Metro Area for years.

https://sustainability-innovation.asu.edu/urban-climate/

HYDROGEN LIVING LAB PROJECT

While the State of New Mexico and the U.S. Federal government have strong interests in the success of hydrogen projects, for reduction of fossil fuel emissions, it is the opinion of EEA Consulting Engineers that it is not viable for NMSU in the short-term (5-10 years).

The basis for this decision was inclusive of many conversations and was not arrived at lightly. Because of its non-viability, hydrogen should be viewed as a Living Lab project, tied to State or Federal funding associated with R&D or education. The following documents potential avenues and applicability.

On April 10, 2023 the Western Interstate Hydrogen Hub (WISHH) Submits Application for U.S. Department of Energy Funding Grant for a $1.25B grant that will build clean hydrogen hubs across four western states (CO, NM, UT, and WY).

If awarded the Colorado Energy Office says: *WIH2 will bring more than 26,000 jobs, including approximately 7,000 construction-related jobs, across the four states. Getting hydrogen right would mean unlocking a new source of clean, dispatchable power, and a new method of energy storage. It would mean another pathway for decarbonizing heavy industry and transportation. The total funding available for the H2Hubs is $7 billion. Following the DOE's review of the applications, it is anticipated that the DOE will invite applicants to pre-selection interviews this summer (2023) and announce and negotiate awards later in the year.*[8]
https://energyoffice.colorado.gov/climate-energy/western-inter-states-hydrogen-hub

Prior to the April 2023 WISHH application New Mexico Governor Michelle Lujan Grisham signed Executive Order 2022-013, the Hydrogen Hub Development Act, directing collaboration to further clean hydrogen economy. This legislation addresses climate change at every step in the production and use of hydrogen by guiding the industry towards low-carbon methods through impressive tax incentives. Producers who use cleaner methods get larger and larger tax incentives, with those producing hydrogen with a carbon intensity equal to or less than zero receiving the largest incentives, including a 100% gross receipts tax deduction.[9]

[8] https://energyoffice.colorado.gov/sites/energyoffice/files/documents/Control%20Number%202779-1540_WIH2_Concept%20Paper%20redact%20V5.pdf

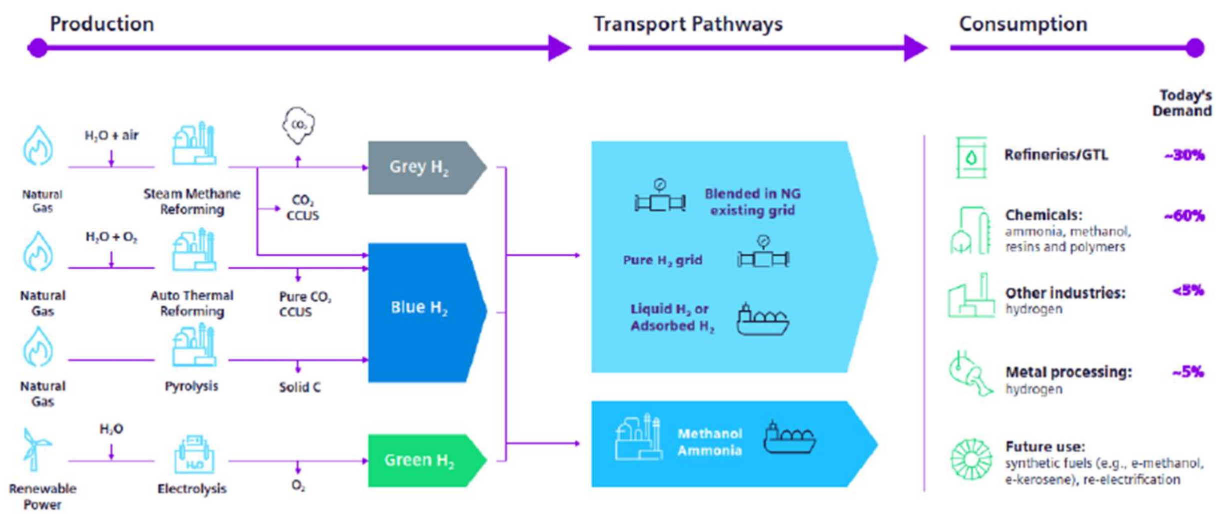
[9] https://www.governor.state.nm.us/2022/01/25/new-mexico-to-boost-clean-energy-economy-with-hydrogen-hub-development-act/

Hydrogen as a Fuel Source

The International Energy Agency (IEA) conducted an assessment for the 2019 G20 Summit in Osaka Japan and published a summary-website, which says "Supplying hydrogen to industrial users is now a major business around the world. Demand for hydrogen, which has grown more than threefold since 1975, continues to rise – almost entirely supplied from fossil fuels, with 6% of global natural gas and 2% of global coal going to hydrogen production. As a consequence, production of hydrogen is responsible for CO2 emissions of around 830 million tonnes of carbon dioxide per year, equivalent to the CO2 emissions of the United Kingdom and Indonesia combined."
https://www.iea.org/reports/the-future-of-hydrogen[10]

The IEA also states, "*Hydrogen can be extracted from fossil fuels and biomass, from water, or from a mix of both. Natural gas is currently the primary source of hydrogen production, accounting for around* ***three quarters of the annual global dedicated hydrogen production of around 70 million tonnes. This accounts for about 6% of global natural gas use.*** *Gas is followed by coal, due to its dominant role in China, and a small fraction is produced from from the use of oil and electricity.*

Should the University be afforded the option for importing or buying hydrogen from external producers it is recommended that only green hydrogen is sourced. The IEA states:



Siemens Energy Hydrogen Paper[11]

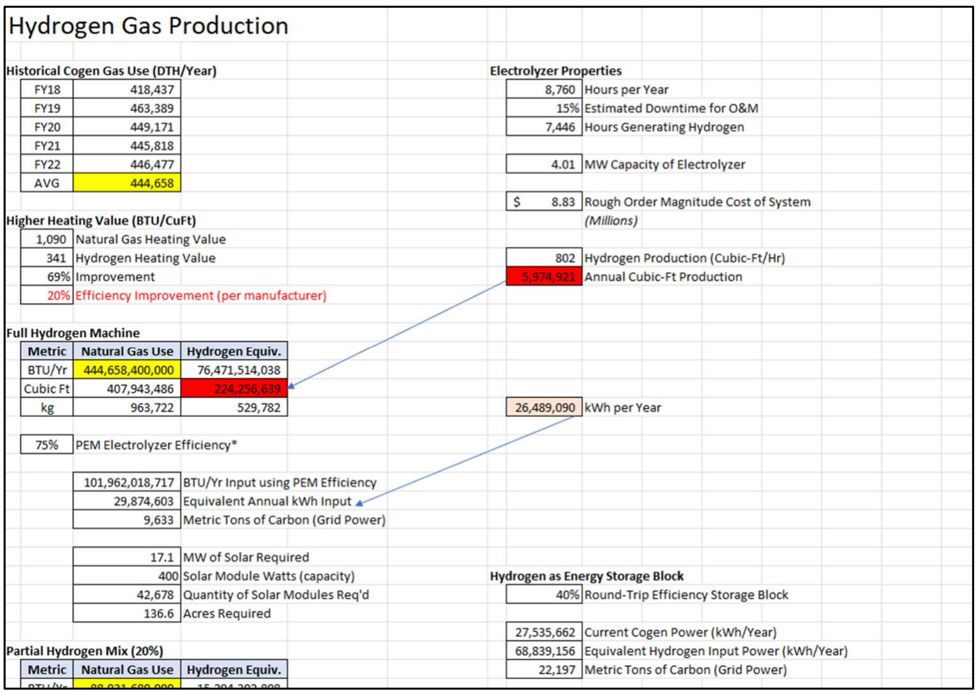
Hydrogen has the highest energy density of all conventional fuels by mass: almost three times as high as that of gasoline or diesel, which is one of the reasons why hydrogen is used as fuel for space travel.

[10] This is a work derived by EEA Consulting Engineers from IEA material and EEA Consulting Engineers is solely liable and responsible for this derived work. The derived work is not endorsed by the IEA in any manner.

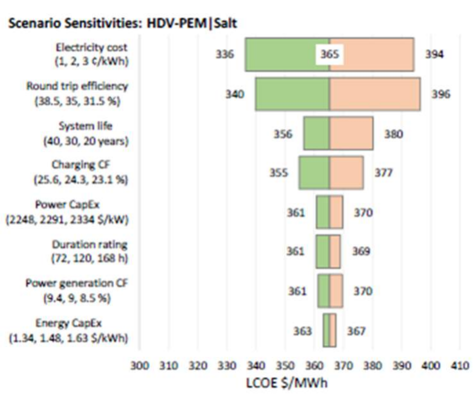
[11] Efficiency – Electrolysis White paper: Siemens-Energy.com/Electrolyzer

Fuel	Density @0°C/32°F, 1 bar		Higher Heating Value (HHV) (Gross Calorific Value - GCV)					Lower Heating Value (LHV) (Net Calorific Value - NCV)				
Gaseous fuels	[kg/m³]	[g/ft³]	[kWh/kg]	[MJ/kg]	[Btu/lb]	[MJ/m³]	[Btu/ft³]	[kWh/kg]	[MJ/kg]	[Btu/lb]	[MJ/m³]	[Btu/ft³]
Acetylene	1.097	31.1	13.9	49.9	21453	54.7	1468					
Ammonia				22.5	9690							
Hydrogen	0.090	2.55	39.4	141.7	60920	12.7	341	33.3	120.0	51591	10.8	290
Methane	0.716	20.3	15.4	55.5	23874	39.8	1069	13.9	50.0	21496	35.8	964
Natural gas (US market)*	0.777	22.0	14.5	52.2	22446	40.6	1090	13.1	47.1	20262	36.6	983

The gross or high heating value is the amount of heat produced by the complete combustion of a unit quantity of fuel. The gross heating value is obtained when all products of the combustion are cooled down to the temperature before the combustion the water vapor formed during combustion is condensed. In thermodynamics, the term standard heat of combustion corresponds to gross heating value. https://www.engineeringtoolbox.com/gross-net-heating-value-d_824.html



Draft Calculations for Las Cruces Hydrogen Hub



Hydrogen power and heat with gas turbines can achieve 80% efficiency to derive hydrogen for industry use.[12] However, NREL models suggest Hydrogen Energy Storage has a 31.5-38.5% Round Trip Efficiency, with most operating costs per MWh represented by Electricity Consumption.
The chart at left was obtained from the DOE paper titled "Long Duration Energy Storage Using Hydrogen and Fuel Cells" (https://www.nrel.gov/storage/storefast.html).

[12] Siemens Energy

HYDROGEN CONCLUSION FOR THIS REPORT

The amount of power required does not justify the capital expenditure, without significant federal subsidies (e.g. the April 2023 WISHH Application to the DOE). Even if the University powered hydrogen electrolyzers with Solar PV and recombined disaggregated molecules with solar as well, 65% of the immense solar energy power would be lost in waste-heat and associated cooling systems.

- ✓ DOE reference documentation does not recommend utilizing existing natural gas pipelines for hydrogen distribution without very specific modifications, as existing lines were not designed for the pressures or molecular mass differences. Considerations include:[13]
    - The potential for hydrogen to embrittle the steel and welds used to fabricate the pipelines.
    - The need to control hydrogen permeation and leaks.
    - The need for lower cost, more reliable, and more durable hydrogen compression technology.
- ✓ This report does not recommend using hydrogen for energy storage, due to the energy intensive splitting and recombining process, which results in a very low round-trip efficiency of 35%.

While these conclusions do not support the adoption of hydrogen infrastructure in the near-term (5-10 years), EEA Consulting Engineers is encouraged by the recent signing of a Memorandum of Understanding between the NM Energy Minerals and Natural resources Department (EMNRD) and New Mexico laboratories for “development of zero-carbon hydrogen.” This January 2022 MOU between EMNRD, Sandia National Labs, and Los Alamos National Labs is an agreement that “leverages national lab expertise with state agencies to deliver economic growth, jobs, and clean energy to New Mexico.”

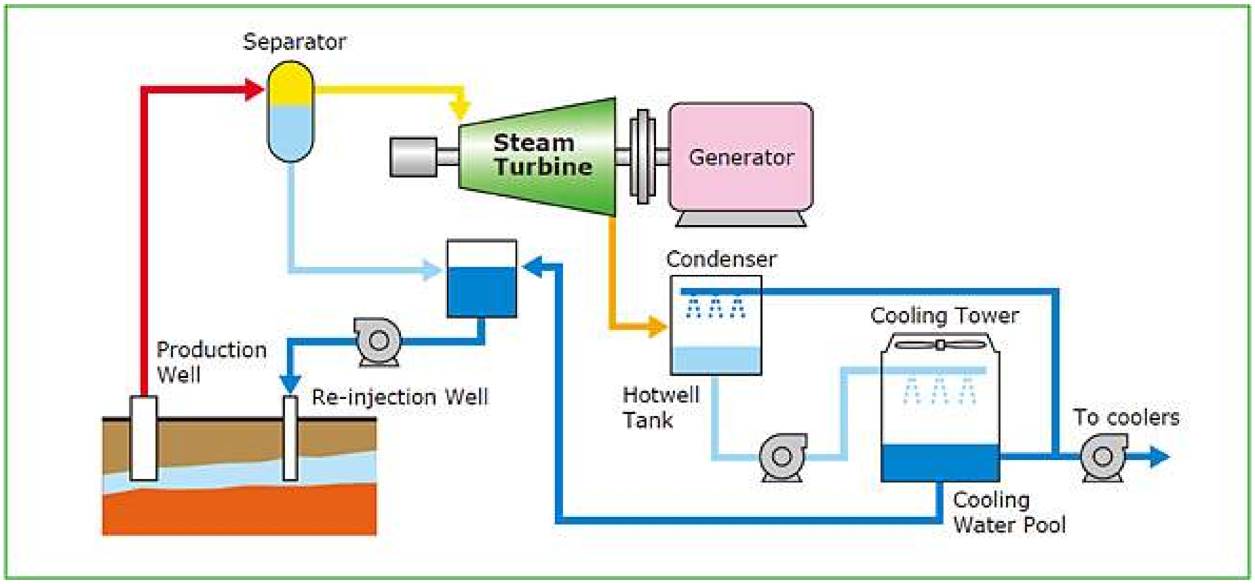
It should be noted that the University was provided with a proposal by SolarTurbines for a low emissions hydrogen package (dated November 2022). This proposal is specifically engineered for the University’s TAURUS 60-7800S natural gas turbine generator. This “Low Nox” upgrade would reduce CO2e emissions from 300 to 10 ppm and will reduce steam output but may allow for a 200 KW extra capacity boost.

Because this Master Plan recommends retirement of the existing steam infrastructure, it is also recommended to retire the existing steam-turbine in lieu of refurbishment or “upgrading” to the Low Nox package. While this upgrade may appear attractive, to reduce emissions by more than 95%, the steam systems maintenance and safety concerns do not warrant further steam investment, in hopes that the University will receive funding for hydrogen to steam production.

[13] https://www.energy.gov/eere/fuelcells/hydrogen-pipelines

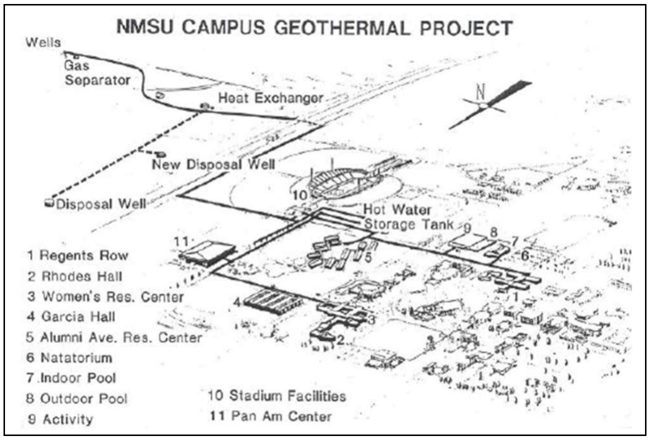
GEOTHERMAL LIVING LAB PROJECT

Unlike ground-source heat-pumps discussed in Section Three of this document, geothermal systems provide high-temperature steam. In some cases, temperatures can reach 400° F. when drilling five miles below the earth's surface, which offers opportunities for power generation or co-generation (heat and power). The image below provides a simplified overview of the system components typical of geothermal power production.



https://global.kawasaki.com/en/energy/equipment/steam_turbines/geothermal_power.html

Due to the complexity and associated maintenance requirements for geothermal systems NMSU has yet to develop a long-lasting system from nearby geological resources. As noted in Section 2 of this document, New Mexico has significant subterranean geothermal potential, especially in the southern part of the state. It should be noted that while the December 2002 report titled "GEOTHERMAL ENERGY AT NEW MEXICO STATE UNIVERSITY IN LAS CRUCES" by James C. Witcher, Rudi Schoenmackers and Ron Polka of the Southwest Technology Development Institute (NMSU, Las Cruces, NM) and Roy A. Cunniff of Lightning Dock Geothermal Inc. (Las Cruces, NM) suggest geothermal is feasible it is recommended that the University explore this technology in a "Living Lab" context only.

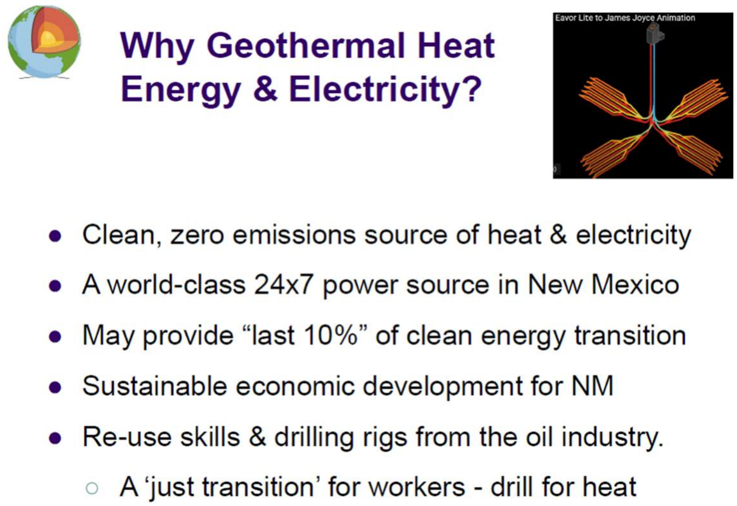


This recommendation was made with considerable discussion and research, to not consider geothermal a primary driver for decarbonization for the University. As stated by Witcher, Schoenmackers, and Polka the two geothermal wells east of Main Campus are "outfitted with submersible pumps and are used alternatively to supply 141 to 148° F water at 250 gpm to supply heat to the NMSU campus district heating system." These temperatures are not highly "useful" in comparison with high temperature resources (+/-400° F.). This out-of-service system is no longer feeding campus utilities, likely due to its maintenance requirements and low temperature heat, as stated in the Witcher, Schoenmackers, and Polka paper "with all heat losses included, 115 to 125° F hot water is supplied to final users on campus." This further suggests that the system was not highly effective, or effective enough to justify its immense infrastructure needs. The following Aquaculture and Greenhouse facilities were the last facilities to receive heating from the geothermal system, but have been demolished (photos courtesy of abovementioned report).

Greenhouse Bench Heating Systems Large

Aquaculture Tanks

The following points were obtained from a 2022 presentation led by New Mexico Senator Ortiz y Pino during a New Mexico Water and Natural Resources Committee (NM-WNRC) meeting. The presentation illustrates that there is renewed geothermal interest in the state, including faculty and stakeholders from New Mexico Tech University in Socorro, NM (https://www.nmlegis.gov/agendas/WNRageAug25.22.pdf).



This renewed New Mexico interest is also evident in the January 2023 Albuquerque Journal *Business Outlook* article titled "On the Cusp of a Geothermal Renaissance." The article highlighted the 18,000-foot bore drilled by Eavor, Inc. in southwest New Mexico, the deepest bore in the state's history.[14] This bore achieved temperatures near 250° C. (480° F.). The same *Business Outlook* highlighted work by Sandia National Labs to examine technology improvements in geothermal drilling.

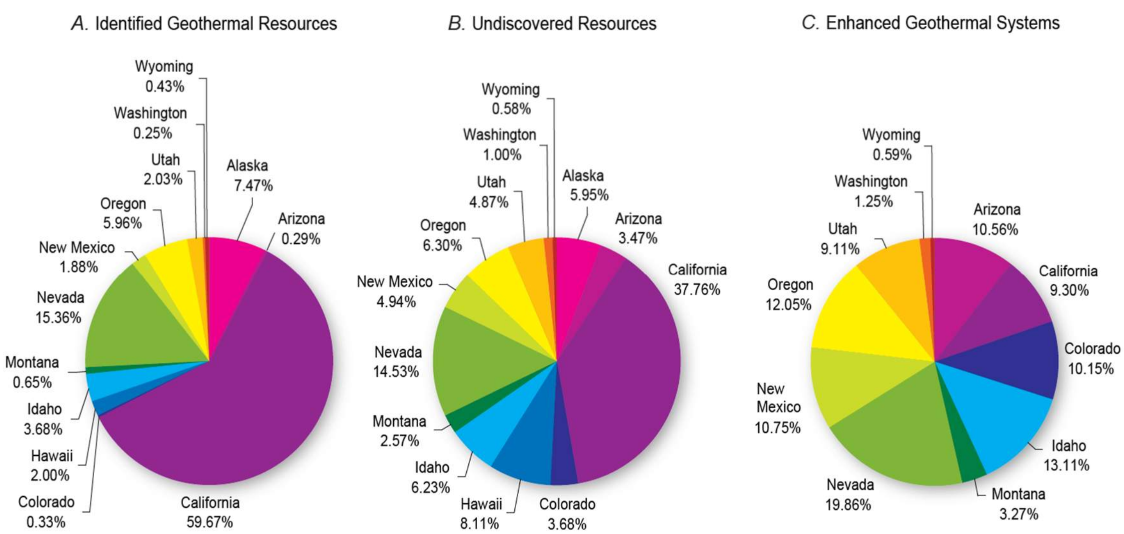
While this technology is not a part of the immediate Energy Transition Plan for NMSU, the level of enthusiasm and interest in the state will help forge a path for deep learning experiences. The following slide from the NM-WNRC presentation includes other examples of demonstrated projects in NM.

[14] https://www.eavor.com/press-releases/success-at-eavors-new-mexico-project-triggers-follow-on-strategic-investments/

FEDERAL SUPPORT OF GEOTHERMAL

In August of 2022 the DOE announced **American-Made Geothermal Manufacturing** Prize winners, awarding teams for developing innovative solutions to harness geothermal energy more easily. The $4.65 million competition incentivized "innovators to use 3D printing, or additive manufacturing, to address the challenges associated with operating sensitive equipment in harsh geothermal environments."

This federal push is a clear indicator that geothermal research funding is available and a likely means for the University to implement new "Living Lab" systems, and this 2008 graphic from the U.S. Geological Survey suggests that New Mexico is among 13 states with significant geothermal potential.



SECTION SIX

FUNDING, FINANCE & PROCUREMENT

The NMSU Facilities & Services Department operates as an internal service center to the University and provides utility services and facilities maintenance. A primary goal of the Department is to keep utility rates on campus consistent and low. This has been challenging under typical conditions due to aging infrastructure, increasing purchased utility costs, and funding restraints. As part of a public institution, the Department is also required to follow federal guidelines in rate development. These guidelines require consideration of the past two years of previous performance, which limits adjustment of rate year over year.

Decarbonization efforts on campus will present additional challenges. Large capital expenses will be required, remaining infrastructure will continue to age, and purchased energy costs are likely to increase as a result. Many of the required and recommended projects will not have a simple financial payback. Because of this, the broader context and purpose of decarbonization must be kept in mind. Examining decarbonization projects through the lens of "proxy carbon prices"[15] and the true social cost of carbon[16] is essential for these reasons.

Alternative funding strategies should be explored for decarbonization efforts, and restructuring of facilities management on campus may even be needed for financial sustainability.

Increasing the space utilization of the campus and reducing footprint where possible through demolition of aging and underutilized facilities and consolidation of programs will further support these efforts. Facility condition assessments of the campus are currently underway to identify potential issues and opportunities.

This section summarizes the current funding systems utilized by the Department and presents several other potential sources that could be used for decarbonization efforts.

[15] https://secondnature.org/wp-content/uploads/Princeton-Case-Study-Rev1.pdf
[16] https://spia.princeton.edu/news/carbon-dioxide-emissions-more-costly-society-previously-thought

CURRENT UTILITIES FUNDING

The State of New Mexico currently funds approximately 60% of the University's Operations & Maintenance (O&M) budget via Instructional & General (I&G) funds. This typically represents between $1-2M annually. The I&G funds are generally not to be utilized for renewal of depreciating assets, which is a major cost for the Facilities department. The funds also cannot not be utilized to build a revolving fund or to pay for energy projects.

The remaining 40% of O&M costs must be recovered by the Facilities & Services department. Operating as an internal service center, the Department develops annual rates according to federal uniform guidelines and after approval, bills campus accordingly for operations and pass-through costs. The Department can retain 15% of operating costs annually if a surplus exists. Prior to 2020 this surplus had been able to support a revolving fund of ~$750,000 annually, however for the past 3 years operations have not resulted in a significant enough surplus to cover a major catastrophic failure should one occur.

Additional funding is provided as programmatic funds for building repair and renewal (BRR). The intent of this funding is to extend the life or increase the value of existing assets. The allocation has remained steady for the past 15 years without adjustments for inflation or other impacts and results in roughly $0.5M annually for the Department's use. The BRR funds cannot be applied specifically to other cost-centers but can be utilized more flexibly with matching funds from Facilities revolving funds.

Several other sources exist and have been utilized for major Facilities capital projects on campus. The ongoing tunnel repairs are a combination of General Obligation (GO) bond and BRR funding. Severance bonds are another alternative and have been sought for steam system repair and remediation funding, for example. These sources of funding typically need to alternate on a 2 year cycle and are traditionally used for smaller projects.

Energy service performance contracts (ESPCs) are another method the Department has utilized for building infrastructure improvements and energy reduction projects. These contracts aim to reduce utility consumption on campus while paying for the upgrades, which are then paid back in time with savings. This avoids debt service in lieu of a contract. While the resulting energy savings are positive to overall campus sustainability efforts, this in effect reduces surplus funding available for the Department's future use by reducing purchased utility costs that can be reimbursed.

Maintaining the current level of operation has proven challenging for the Department with this funding arrangement. Without a strong surplus available to support a revolving fund, opportunities for major system renewal and improvements are limited. Alternative methods of funding will need to be explored to support decarbonization efforts.

POTENTIAL FUNDING SOURCES

The following have been identified as potential funding sources that should be explored further to support decarbonization efforts on campus. Some of these sources are already utilized by the Department for current operations.

- **Federal Partnerships (NREL/DOE/USDA/Sandia Labs, Los Alamos)**
  - *Potential research-based partnerships with regional federal entities*
- **State Officials Special Interest Project Funds**
  - *Support for decarbonization and sustainability efforts from State government*
- **Utilities as 501(c) Business Model**
  - *If arranged as a non-profit, the Department would not be limited to federal rate guidelines*
- **NMSU Departmental Funds (Engineering, Ag, Arts & Science, etc.)**
  - *Potential partnerships with academic departments for joint projects*
- **Clean Energy Revenue Bond (NM Energy, Minerals and Natural Resources Department)**
  - *State program to finance energy efficiency and renewal energy projects*
- **Build Back Better Funds**
  - *Federal funding focused on energy transition*
- **Energy Transition Funds**
  - *Partnerships with private funds focused on decarbonization*
- **Tax Increment Development District/Financing (TIDD/TIF)**
  - *Las Cruces 900-acre campus is in a TIDD zone with a 10-year sliding scale tax bracket which could incentivize commercial development and partnering*
- **Public Private Partnerships (P3)**
  - *Joint projects with commercial entities supporting decarbonization efforts*
- **Endowments**
  - *Partnerships with private endowments focused on decarbonization*
- **NM Severance Tax/GO Bonds**
  - *Currently in use by Department but utilized for repair projects*
- **Energy Performance Contracting**
  - *Currently in use by Department for energy reduction projects*
- **Building Renewal Funds (BRR)**
  - *Currently in use by Department but utilized for minor renewals*
- **Utilities Revolving Funds (URF)**
  - *In past years, surplus funding has been available to support this fund*

TOPICS FOR FURTHER COMMERCIALIZATION RESEARCH

The following climate topics are recommended for continued additional research as opportunities for decarbonization and collaborations among regional and national stakeholders. While none of these topic areas were addressed in detail in this Master Plan, each topic area may provide additional means for decarbonization and/or areas associated with State or Federal funding opportunities.

1. Containerized or vertical indoor agriculture

2. Center for Dryland Resiliency: Food and Water Security

3. Green economy economic development training center

4. Regional training center for net-zero infrastructure and carbon neutrality

5. Regional training center for food and water security

DEFINITIONS

Business As Usual – Continued operation of the natural gas turbine to generate electricity, and continued operation of the campus steam system and natural gas boilers.

Steam System Decommissioning – Partial or full elimination of the campus steam system, potentially including the natural gas boilers, steam distribution piping, and end-use HVAC equipment steam components.

Turbine Upgrades – Modifications to the existing natural gas turbine to improve efficiency, and eventual full replacement of the gas turbine with a modern unit.

Turbine Decommissioning – Elimination of natural gas turbine usage on campus.

Campus Medium Voltage Upgrades – Various upgrades to the campus medium voltage distribution system, potentially including upgrade from 5 kV to 25 kV, installation of a new MV service, installation of new duct-banks and distribution circuits, and installation of new primary switches.

Hydrogen Infrastructure Addition – Implementation of hydrogen storage and distribution system on campus, to serve as replacement for some or all natural gas usage.

Turbine Hydrogen Retrofit – Modification to the existing natural gas turbine to use hydrogen as the primary fuel source. May also include replacement of existing turbine with new.

Building Energy Conservation Projects – Building infrastructure projects (HVAC, lighting, plumbing) aimed at reducing overall power and steam usage by end-use buildings. An example includes the ongoing performance contracting projects on campus.

Steam Distribution Repairs – Repairs to the existing steam distribution system, potentially including elimination of steam leaks, replacement of compromised or missing insulation, and increase of condensate return to the Central Plant. The team's research indicates that approximately 5% of the campus's energy usage currently exists as leaks in the steam system.

Photovoltaic Installations – Installation of photovoltaic panels at various campus locations to generate electricity.

Battery Storage – Installation of battery storage at various campus locations to store generated or consumed electricity for later use.

NMSU Renewable Credits – Usage of carbon offset credits from existing or new large scale photovoltaic or wind turbine facilities on NMSU property.

Purchased Carbon Offset Credits – Usage of carbon offset credits purchased on the open market.

Geothermal Systems – Implementation of either geothermal heating systems or ground coupled heat pump system, which utilize the earth as heat sink or source for direct expansion equipment.

Local District Cooling/Heating Systems – Thermal systems consisting of a central generating plant, distribution piping, and end-use building equipment (the campus's existing chilled water and steam system are examples).

Conversion to Heat Pump Technologies – Implementation of systems utilizing a reversible refrigerant cycle for cooling and heating. Examples include unitary heat pump equipment (rooftop units and split systems), larger direct expansion equipment, variable refrigerant volume systems (which can also include heat recovery), and heat pump chillers.

Thermal Energy Storage – Storage of cooled or heated media (typically water based) in a large volume container intended for later use. TES systems are commonly used to generate chilled or hot water at periods when fuel cost are lower, or when more renewable power options are available. The Central Plant's chilled water TES system and the Satellite Plant's ice TES system are examples.

Utility Provider Carbon Reductions – Reduction of carbon footprint though purchased power from the electrical provider. This would be a result of increased renewables as a percentage of the provider's portfolio (along with an associated reduction in coal, natural gas, and other carbon-based generating plans). The Las Cruces campus's electrical provider (El Paso Electric) for example has a goal of 80% decarbonization by 2035 and 100% decarbonization by 2045.

Green House Gas Emissions – Carbon dioxide, methane, nitrous oxide, and fluorinated gases such as hydrofluorocarbons and halons are the primary greenhouse gases of concern. According to the U.S. Environmental Protection Agency, the three critical measures that determine the harmful impacts of greenhouse gases are the length of time the gas remains in the atmosphere, the atmospheric concentration of the gas, and the amount of energy the gas can absorb (the more energy absorbed, the more detrimental warming effect the gas has). Generally, greenhouse gas emissions are categorized into three "scopes", depending on the source from which they are produced, described below.[17]

- **Scope 1 GHG Emissions:** Direct emissions from sources that are owned or controlled by an organization. These include on-site fossil fuel combustion and fleet fuel consumption.
- **Scope 2 GHG Emissions:** Indirect emissions from sources that are owned or controlled by an organization. These include emissions from the generation of electricity, heat, or steam purchased by an organization from a utility provider.
- **Scope 3 GHG Emissions:** Indirect emissions from sources not owned or directly controlled by an organization, but related to the organization's activities. Scope three emissions include emissions from employee travel, including air travel and daily commuting, as well as waste disposal, wastewater treatment, the embodied GHG emissions of purchased products, and more.

[17] Obtained online from the University of Arizona

2023

APPENDIX A: Energy Data Analysis

EEA CONSULTING ENGINEERS

EXECUTIVE SUMMARY

This appendix includes energy analysis data, charts, and summaries for Main Campus for Fiscal Years 2017 through 2022. The data is presented in a high-level and informative manner in order to remain consistent with the body of the report. While many more analyses are necessary when developing actual building-level decarbonization projects, the data in this appendix should help support the recommendations and assumptions in the report.

Figure A1 below summarizes the six-year utility rates seen by main campus which show an upward trend for Low-Pressure (LP) Natural Gas, Domestic Water, Steam, and Sewer. While this report does not consider water costs or associated conservation measures, it is important to draw a complete picture for cost variability seen by the University. It is important to note that the Steam costs have jumped the most, among other utilities, which is endemic in the spike among natural gas costs.

It should be noted that this report does not focus on costs and paybacks for decarbonization measures, because most projects associated with electrification and reducing carbon emissions do not have traditional paybacks.

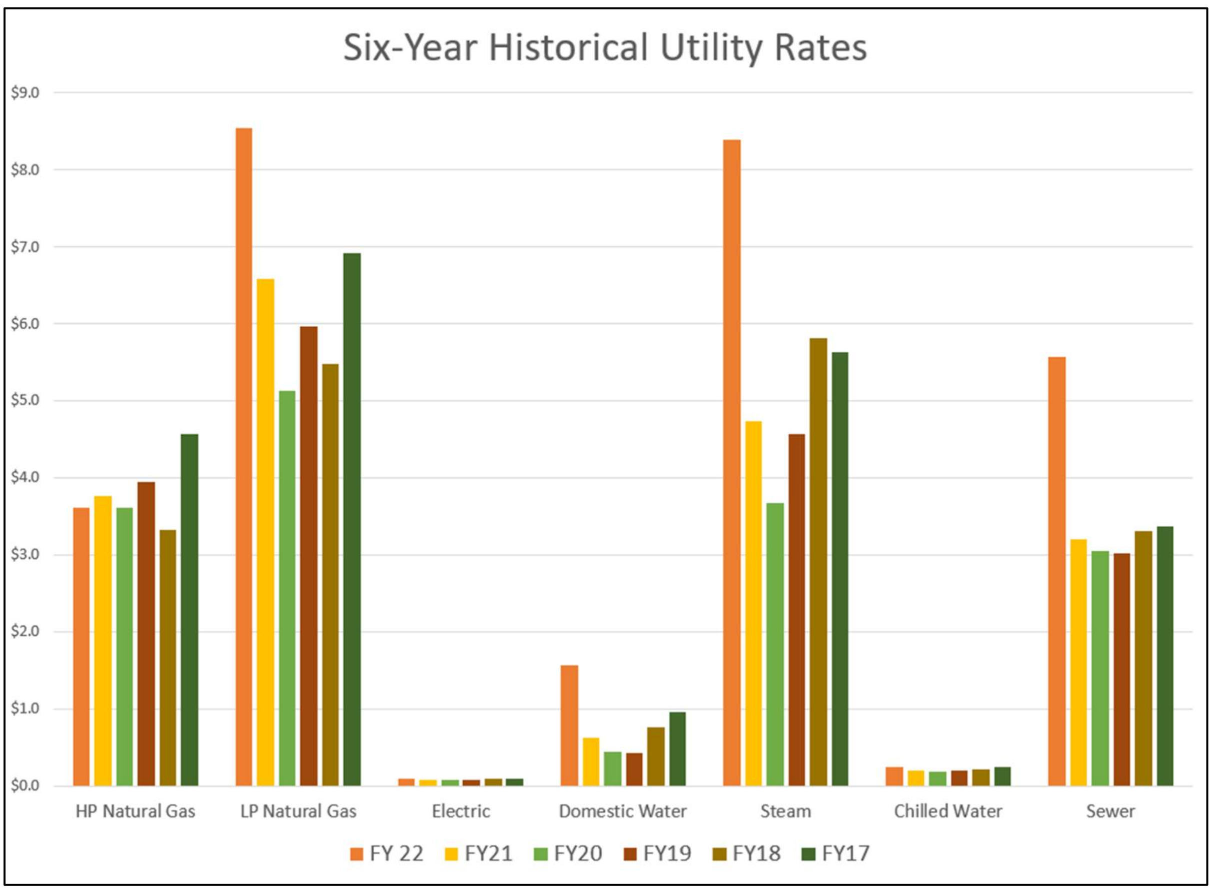


FIGURE A1

Figure A2 below is a summary plot of average On-Peak and average Off-Peak electricity demand for main-campus, with average total demand and demand costs for Main Campus. Considering flat electric rates in Figure A1 above, this figure illustrates that electricity demand is changing. There is a notable downward trend from FY12 to FY17, but average demand has crept or fluctuated since then. FY19 is not concerning due to increased ventilation requirements during the COVID-19 pandemic, but FY20-FY22 are illustrating a slightly concerning upward trend in average demand.

Average peak-demand (blue) follows the total average demand closely, with similar trends, while off-peak is notably different in relation to total average demand. In FY13, FY17, and FY18 off-peak average demand is nearly equal to total average demand, suggesting that most demand is occurring off-peak as suggested. In FY22 data off-peak average demand is greater than total average demand, suggesting that a larger majority of demand is occurring outside of peak-demand windows.

It is also clear that demand costs are steadily increasing since FY16, due to increased on-peak demand, most notably in FY19 due to increased ventilation requirements. However, FY20 through FY22 remain as high or higher than all previous years, likely due to off-peak chilled water storage issues.

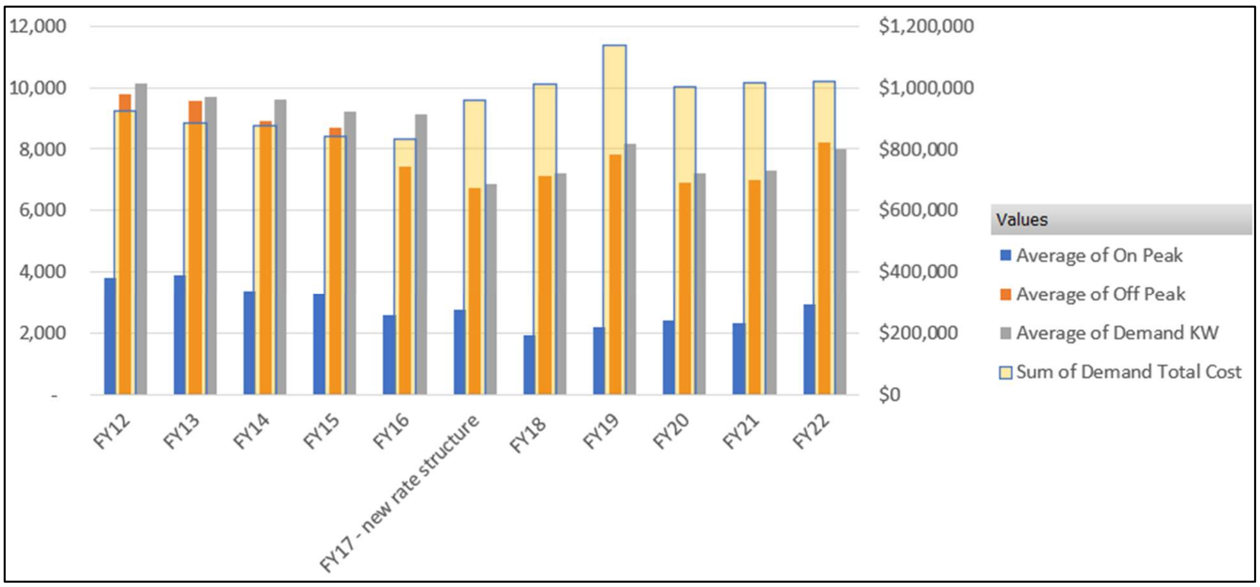


FIGURE A2

ESPINA OVERHEAD ELECTRIC UTILITY LINES

AGGIE POWER (SOLAR PV)

These figures (A3 Battery and A4 PV) are provided simply to verify that the Aggie Power array is performing as intended, and both illustrations confirm that the 3 MW array is performing as intended.

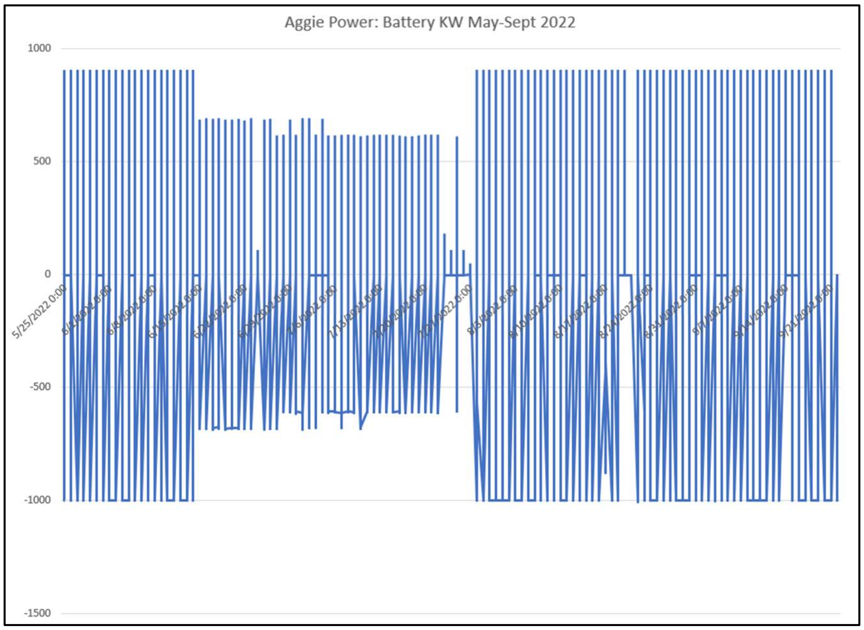


FIGURE A3: MIN = -1,006.7 KW & MAX = 901.6 KW

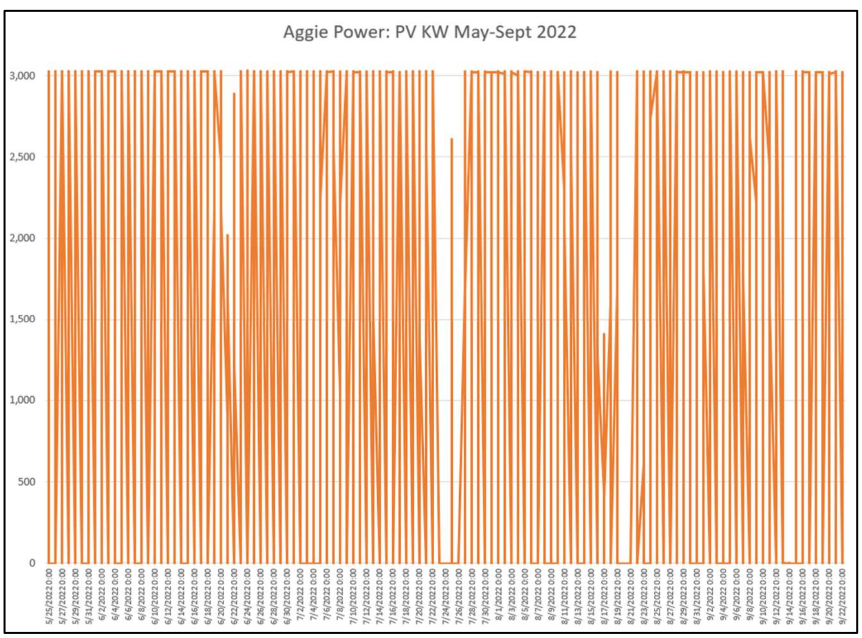


FIGURE A4: MIN = -9.7 KW & MAX = 3,029.2 KW

COGENERATION DATA

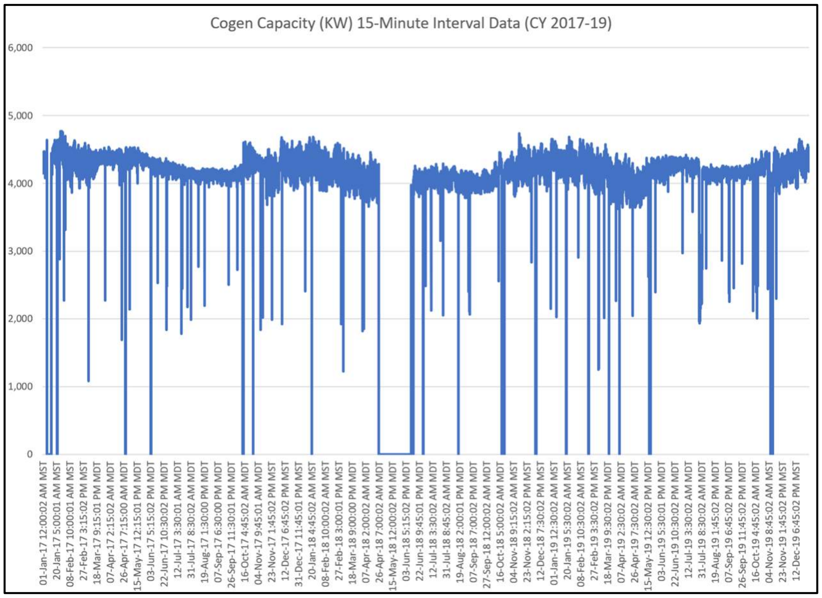


FIGURE A5

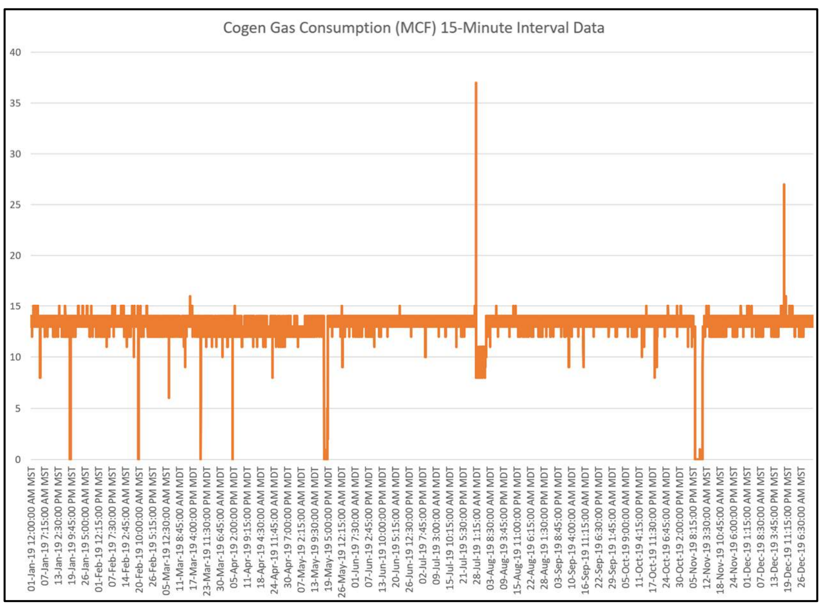


FIGURE A6

Figure A5 and A6 are presented to illustrate how the Main Campus Cogen system is performing over two years of trend-data.

The cogen electrical capacity is clearly maintained throughout the dataset, near 4.5 MW and is confirmed in subsequent figures in this appendix.

Cogen gas data is presented in Figure A6, which illustrates that the campus has a significant baseload throughout the year, confirming the immense impact on current CO2e emissions.

POWER DEMANDS BY CIRCUIT

The data presented in the following pages summarizes peak-demand data for all seven of the Main Campus electricity circuits. This chart (A7) represents all circuit demand, peaking above 10 MW in May/June of 2018, again in November of 2018, and November of 2019. These peaks coincide with the cogen turbine seeing disruptions due to maintenance or otherwise.

While this data does not include FY21 or FY22, there is seasonal variability in electricity usage, with traditional peaks occurring in the Fall – when classes resume. More recent data would illustrate impacts from the Aggie Power Solar PV Array, skewing system-level data (see charts A3 and A4 above).

Valleys in the data occur during winter months as expected, with an average minimum demand near 500 KW, and a baseload near 4 MW is evident. Typical peaks are closer to 6.5 MW when the cogen system is operational, suggesting that future peaks will need energy storage for management, when the cogen system is retired.

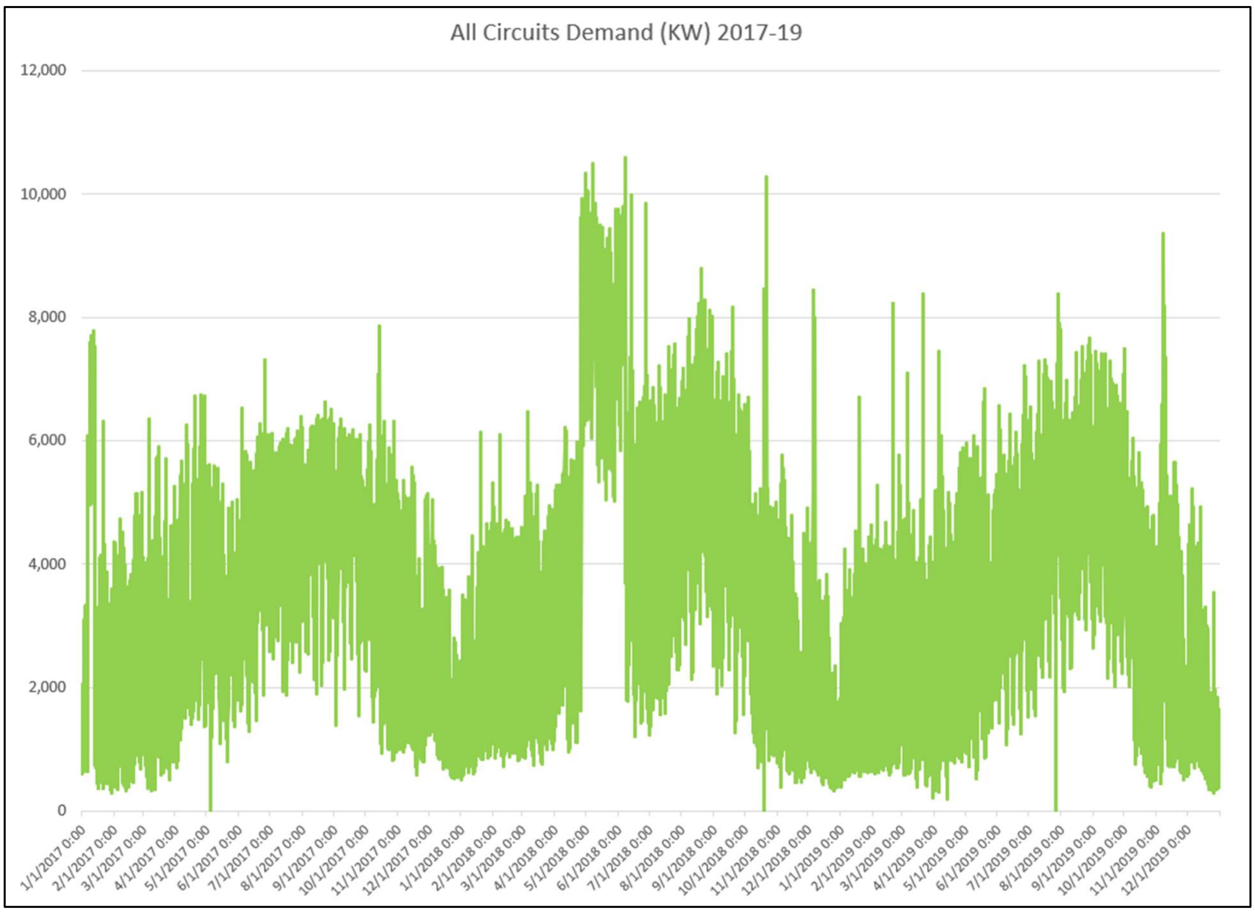


FIGURE A7

Circuit by Circuit Data

These figures illustrate circuit level data to better understand how each circuit behaves in relation to the overall campus grid. In the case of Circuit 7, serving the far northeast side of campus, there are significant and intermittent peaks. This suggests that associated systems are highly variable, with significant room for load management or shaving through energy storage.

As illustrated in Figure A9, Circuit 6 has very little variability and saw a significant drop in demand overtime. This circuit is well managed and an exemplar for other districts/sectors on campus.

Lastly, Circuit 5 saw a significant increase (>200%) at the beginning of 2018, but is otherwise well managed annually (considering peaks).

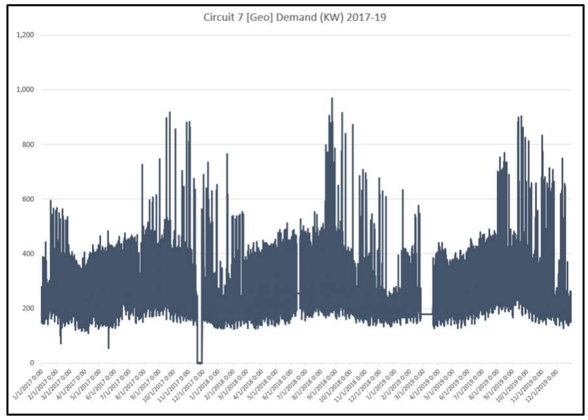


FIGURE A8: #7

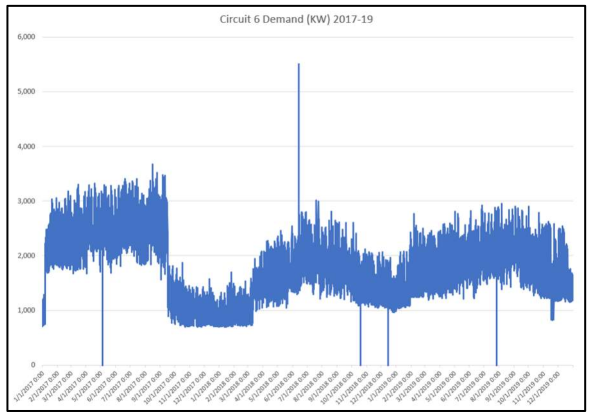


FIGURE A9: #6

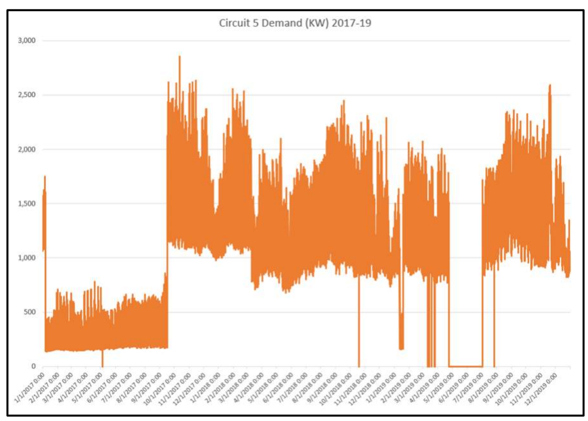


FIGURE A10: #5

Similar to Circuit 6, Circuit 4 has a fairly consistent baseload throughout the year, but is clearly seeing significant peaks. This trend suggests that Circuit 4 has a load-factor that should be addressed, to better match #6.

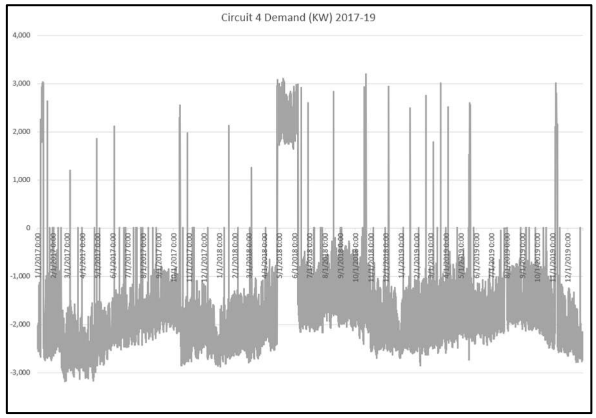


FIGURE A11: #4

Figure A12 illustrates a significant reduction in peak demand overtime for Circuit 3. This >50% reduction is remarkable and appears to remain well-managed, with few peaks/valleys. The most recent peak (2019) occurs in Fall, when classes resumed after summer, as expected.

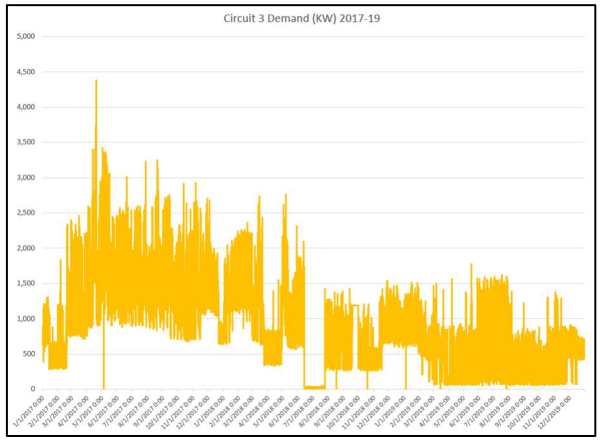


FIGURE A12: #3

Circuit 2 (Figure A13) also appears well managed, with few outlier peaks, though daily demand is highly variable:

- ✓ **Peak = 2,750 KW**
- ✓ **Valley = 400 KW**

This load-factor is also quite high, but peaks occur in the Fall as expected.

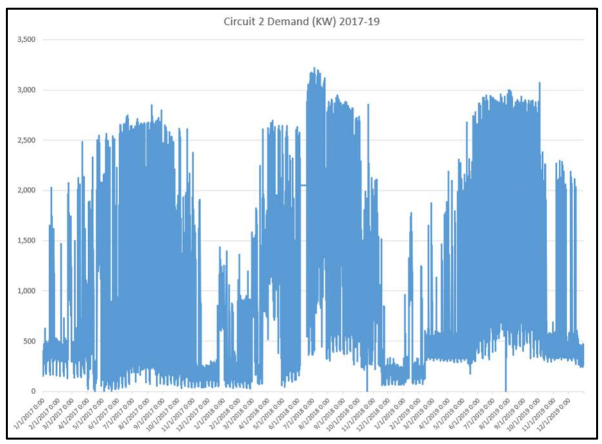


FIGURE A13: #2

Circuit #1, as illustrated in Figure A14 is also an exemplar for load management, with peaks occurring in Fall as expected. Valleys are regularly occurring in Winter/Spring and there is a downward trend in demand, showing that reduction measures are effective.

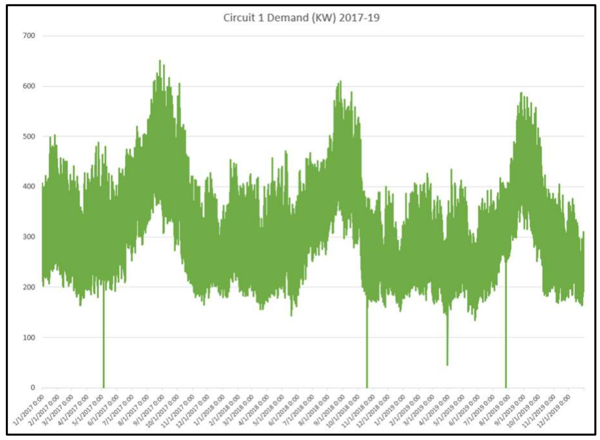


FIGURE A14: #1

THREE-YEAR CIRCUIT BY CIRCUIT DEMAND

This table is provided to highlight summary data for each circuit in relation to others on Main Campus, with Circuit #1 having the lowest Peak and Standard-Deviation. Circuit #4 is an outlier in this table as it is served by the cogen system, which clearly indicates 3.2 MW of capacity. The Circuits with the largest peaks are #3 and #6, and Circuits #2, #3, and #5 have the largest Standard Deviation.

Data	TM	1	2	3	4	5	6	7
Min	-	-	-	-	(3,181.4)	(1.1)	(0.8)	(3.2)
Max	10,598.2	651.0	3,221.3	4,377.1	3,196.7	2,852.7	5,505.7	969.1
Average	3,467.1	308.1	980.2	934.5	(1,622.1)	1,027.4	1,772.5	242.1
St.Dev	1,806.5	79.9	801.3	617.7	1,099.9	607.0	550.7	91.9

**TM – Total Campus Meter*

The following graphs illustrate each circuit as they relate to overall campus demand for summer and winter days, graphing 24-hours of 30-minute interval data; helpful in understanding relationships.

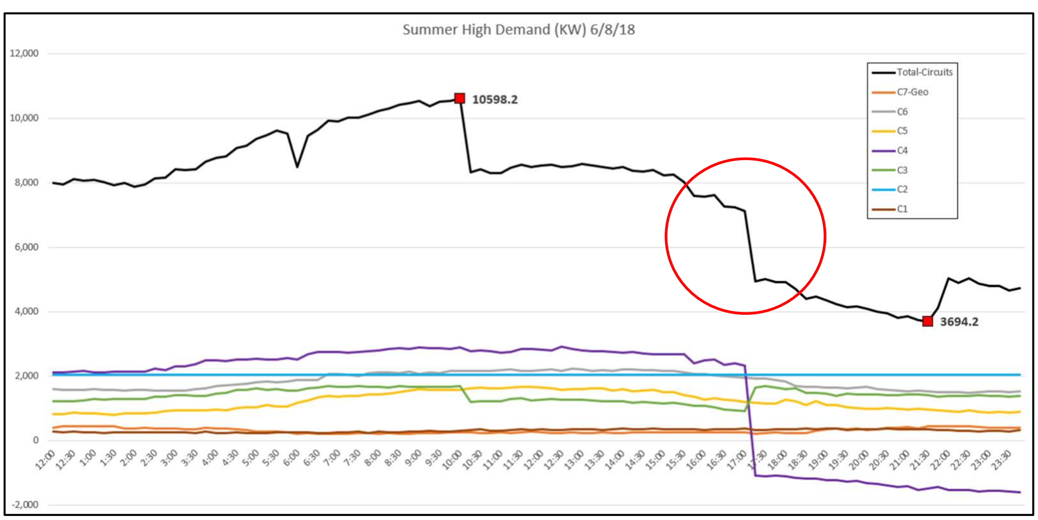


FIGURE A15: Cogen On/Off Circled

Like the Summer-Day graph above (Figure A15), this Winter-Day graph is very helpful in understanding how much the campus varies circuit-to-circuit and as a whole. These two graphs are also important to understand how much of an impact the cogen system has on campus demand, in the case of Circuit #4.

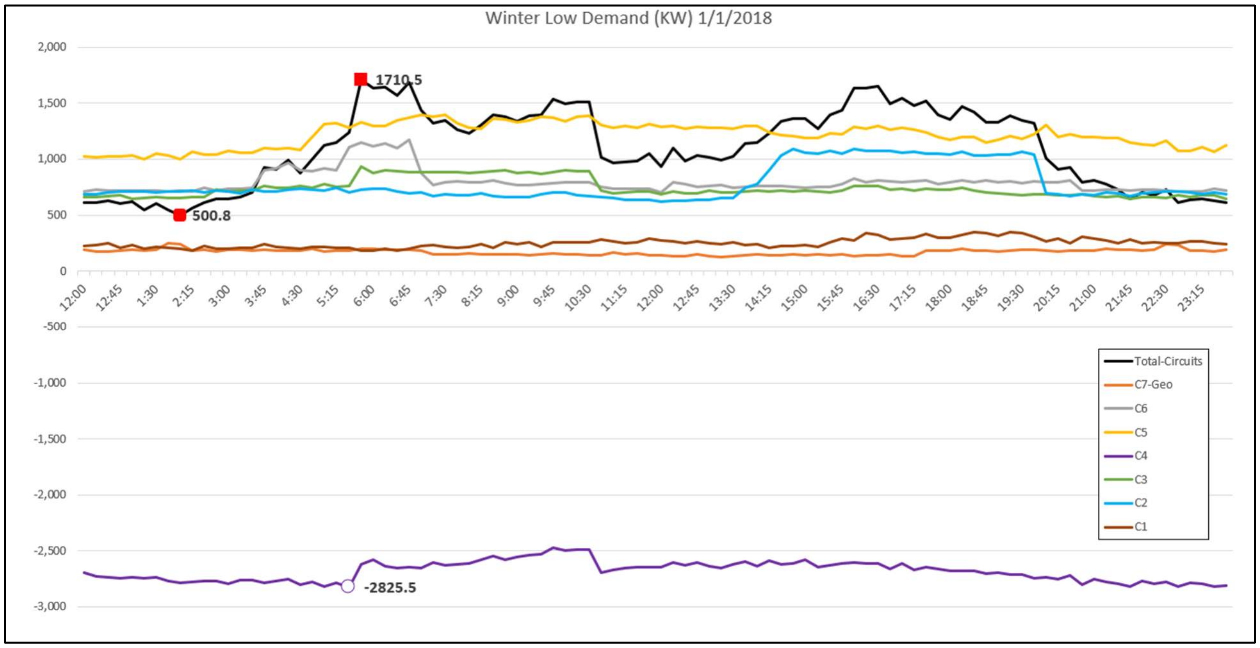


FIGURE A16

ELECTRIFICATION ANALYSIS

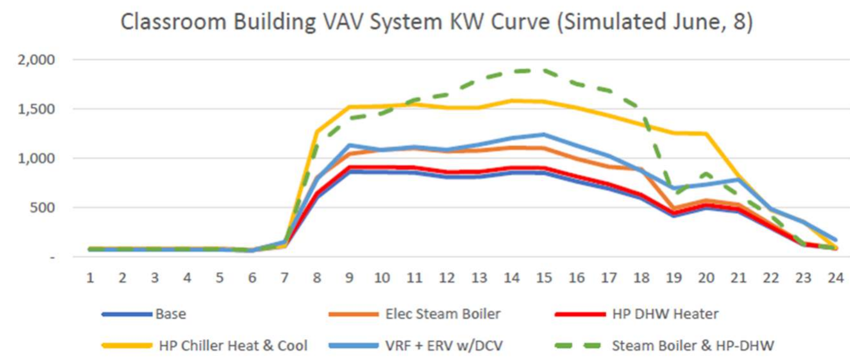


FIGURE A17

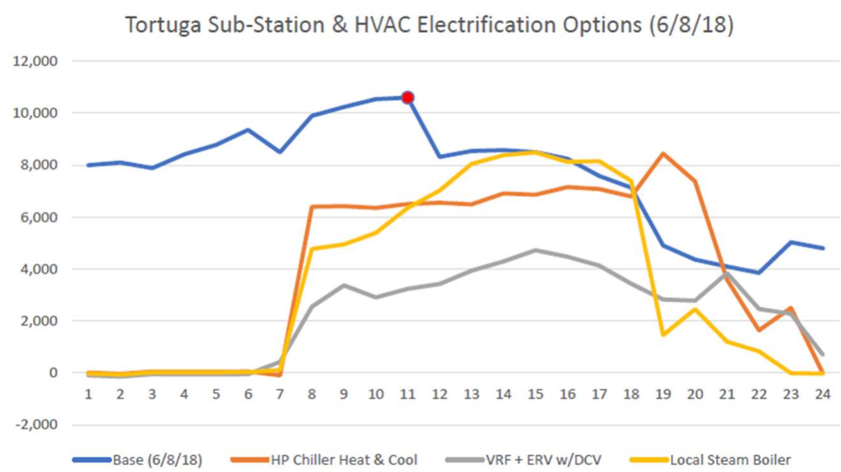


FIGURE A18

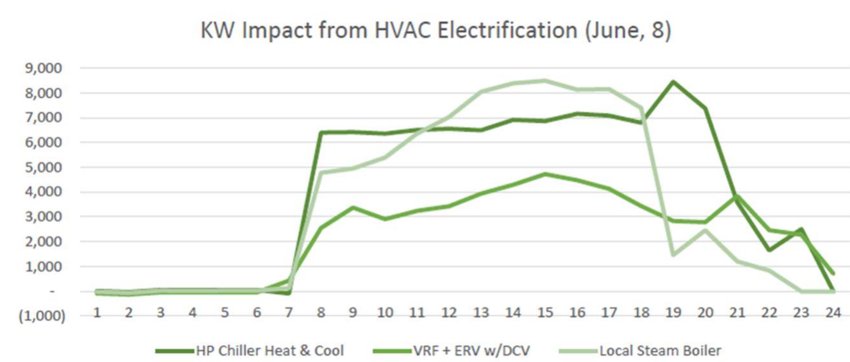


FIGURE A19

Because it is recommended in the body of the report to abandon the natural gas infrastructure on campus for decarbonization, it is important to understand how this impacts peak demand.

The <u>electrical demand increase</u> from HVAC systems that are recommended for decarbonization are plotted on peak days to illustrate their potential impact on campus data. Actual campus metered data is represented by "Base" curves in Figures A17 and A18.

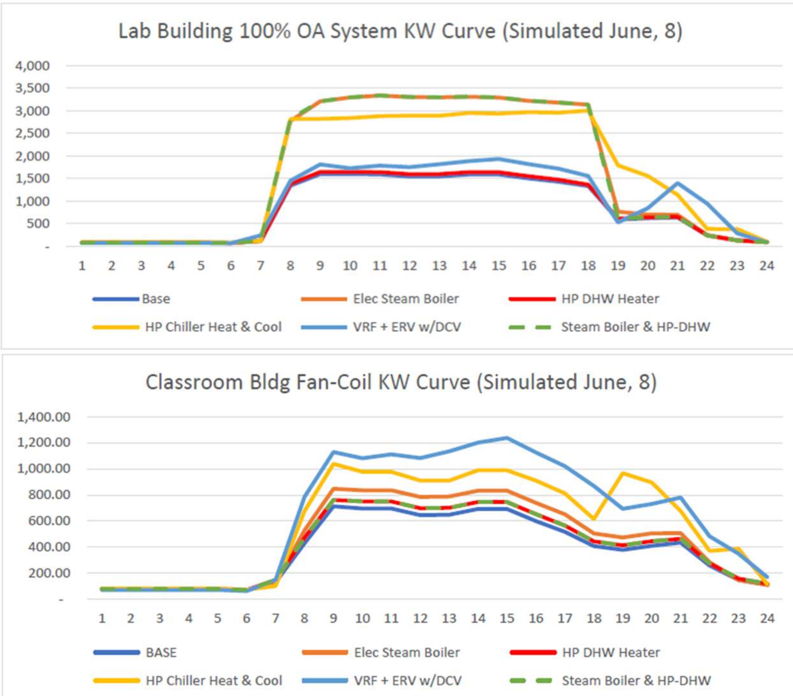


FIGURE A20 and A21

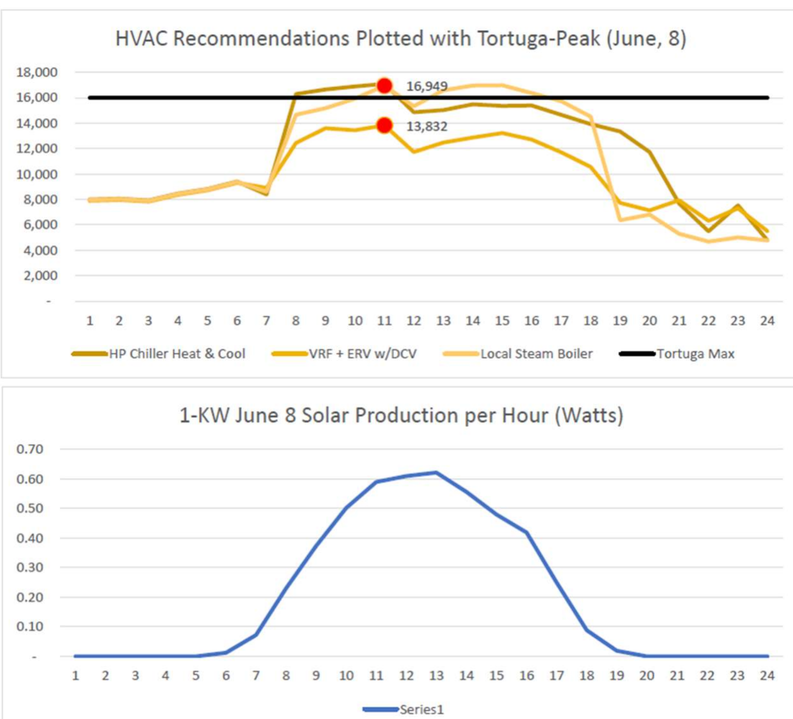
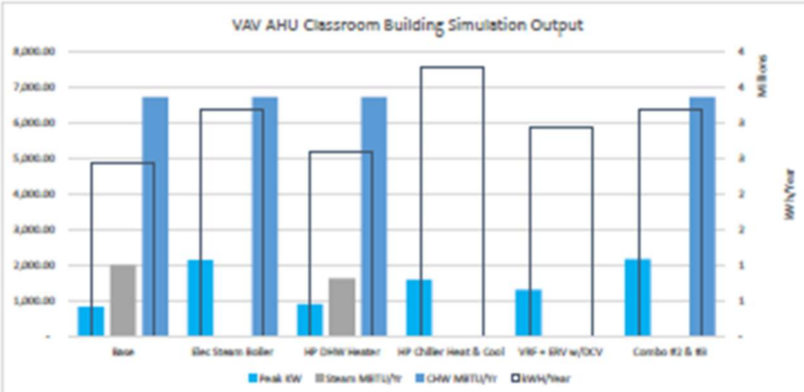
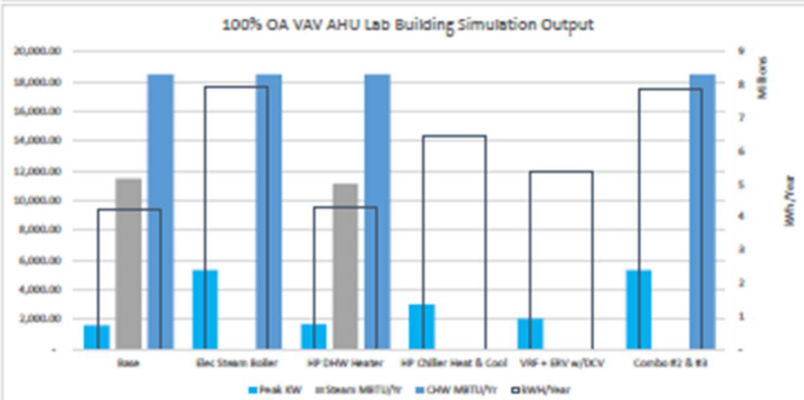


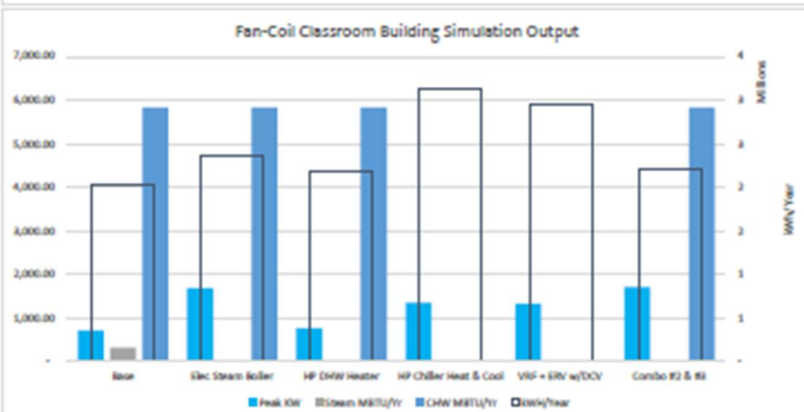
FIGURE A22 and A23

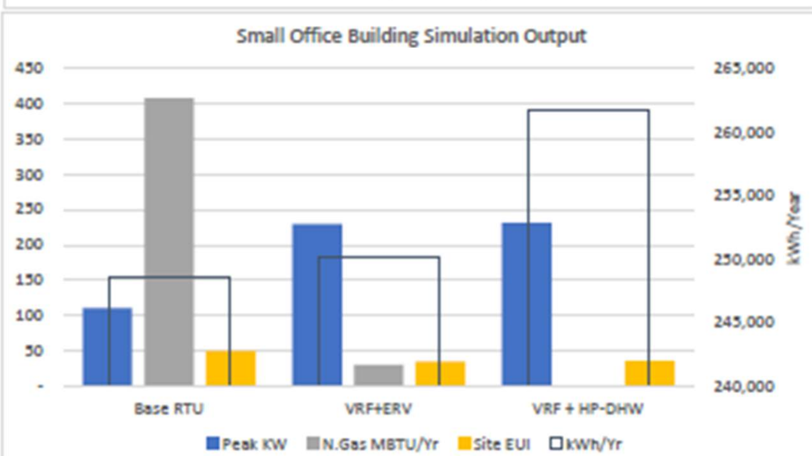
Similar to Figures A17-A19 above, these figures are provided to understand daily electricity demand results from building type simulations and how increases compare to the 16 MW capacity of the Tortuga Sub Station.

Figure A22 (left) suggests that all but the VRF option will exceed the Sub Stations capacity, if one system type were selected campus wide. This data confirms that while electrification is impactful, and solar is a realistic means to achieve decarbonization, Figure A23 clearly illustrates that solar peaks do not align, and energy storage will be necessary.









Corresponding to the HVAC System Type per Building, as seen in the Informative Appendix F, buildings were assigned electrified building profiles from DOE2 (eQuest) simulations.

Simulations were created for each HVAC Option and simulated individually. Results were assigned to buildings and grouped by Option to understand electrical load growth from each.

Data was segregated based on building size as well, utilizing a simulation of a small office building where appropriate.

[FIGURES A24-A27]

BUILDING BY BUILDING DATA

ELECTRICITY

The data in Figure A28 below summarizes FY11 through FY22 electricity consumption at Main Campus, with a clear downward trend. There is a 36% reduction in electricity consumption in this timeframe.

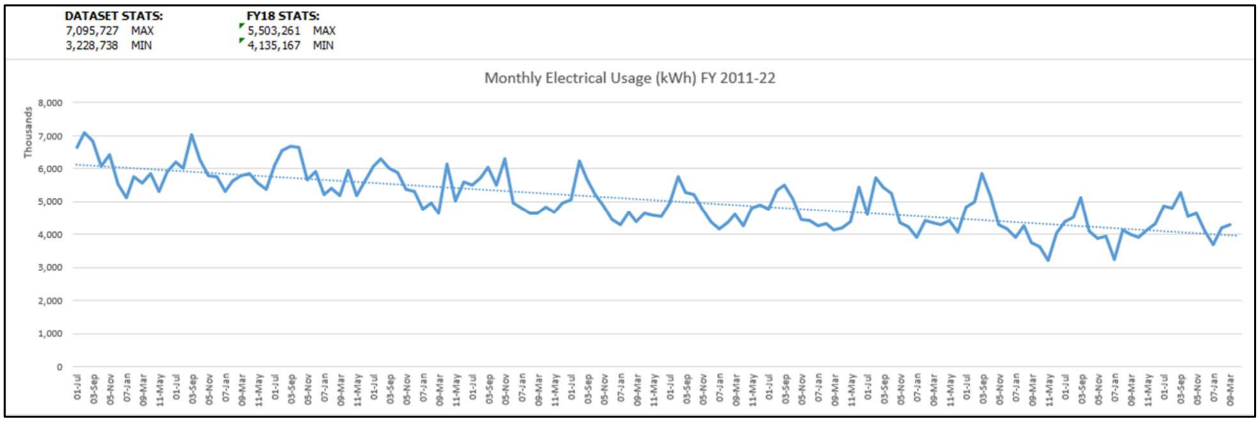
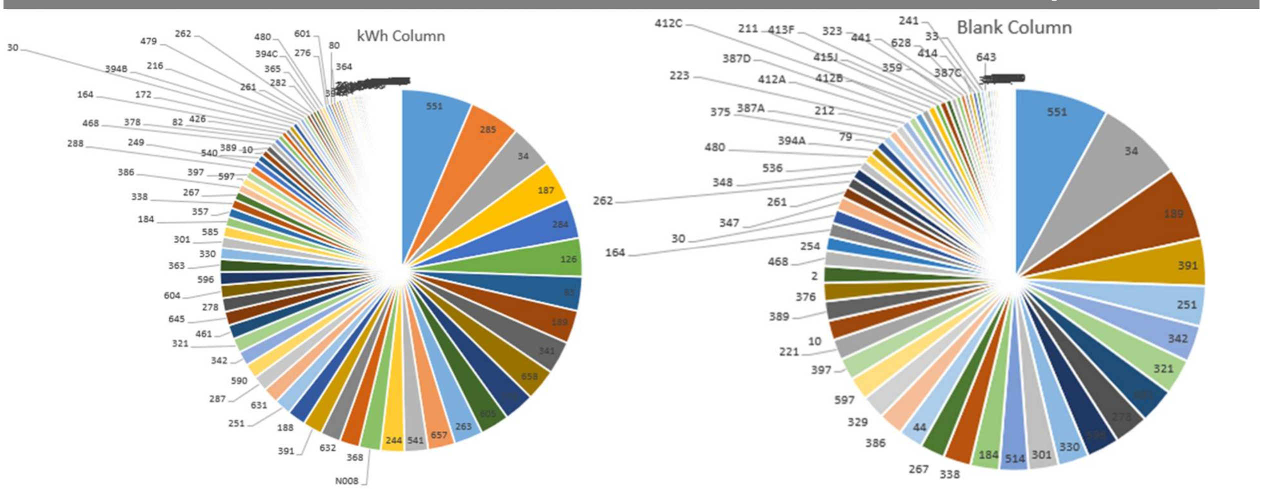


FIGURE A28

TOP-10 FY21-22 ELECTRICITY: 30% of Overall Main Campus Use



Building Name	Bldg #	KWH	% of Total	Grand Total	Observations
SKEEN HALL	551	2,080,680	5.1%	2,080,680	The top electricity consuming facilities on campus are included in this table (apart from the datacenter and Strickland Plant), while pie-charts above summarize each building's contribution to overall electricity use. Of the 211 facilities receiving power from Main Campus these 11 represent 32% of campus use!
CORBETT CENTER	285	1,468,016	3.6%	1,468,016	
FOSTER HALL	34	1,277,961	3.2%	1,277,961	
CHEMISTRY BUILDING	187	1,169,253	2.9%	1,169,253	
PAN AMERICAN CENTER	284	1,151,603	2.8%	1,151,603	
COMPUTER CENTER	126	1,127,121	2.8%	1,127,121	
MILTON HALL	83	983,282	2.4%	983,282	
JETT HALL	189	954,556	2.4%	954,556	
ALEX SANCHEZ HALL	341	951,956	2.4%	951,956	
JUNIPER HALL	658	915,772	2.3%	915,772	
GARCIA RESIDENCE HALL	275	882,334	2.2%	882,334	

TOP-10 FY21-22 ELECTRICITY: kWh per Square-Foot Normalized

Because some facilities are high users due to their purpose or size, the table below illustrates electricity usage normalized for square-footage to help summarize which facilities might be the real "energy hogs."

Building Name	Row Label	Sqft	KWH	(blank)	% of Tota	Grand Tota	Per Sqft
CHARLES STRICKLAN	269	19,449		648,055	1.6%	648,055	33.32
COMPUTER CENTER	126	35,890	1,127,121		2.8%	1,127,121	31.40
SKEEN HALL	551	118,744	2,080,680		5.1%	2,080,680	17.52
JUNIPER HALL	658	59,417	915,772		2.3%	915,772	15.41
FOSTER HALL	34	85,320	1,277,961		3.2%	1,277,961	14.98
MEMORIAL STADIUM	342	27,965	417,199		1.0%	417,199	14.92
NMSU BOOKSTORE	632	42,525	575,388		1.4%	575,388	13.53
DEVASTHALI HALL	657	58,072	782,128		1.9%	782,128	13.47
NEW MEXICO DEPT. (	330	26,125	335,030		0.8%	335,030	12.82
JETT HALL	189	74,643	954,556		2.4%	954,556	12.79

NATURAL GAS

Similar to Figure A28 above, natural gas consumption over 10 years shows a clear downward trend, with a 56% reduction in this timeframe (when considering the peak month of February).

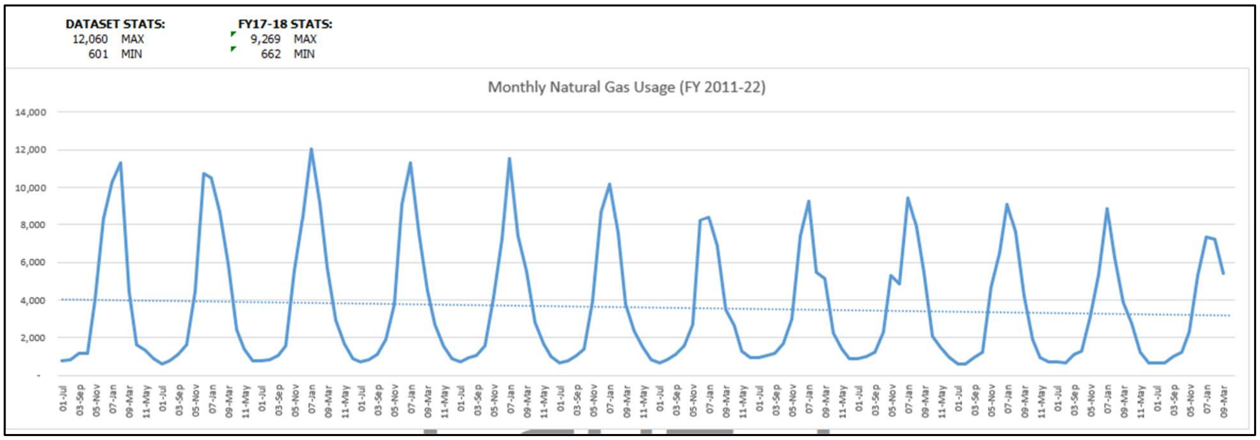
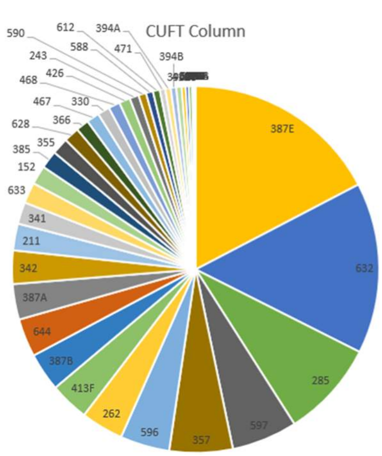
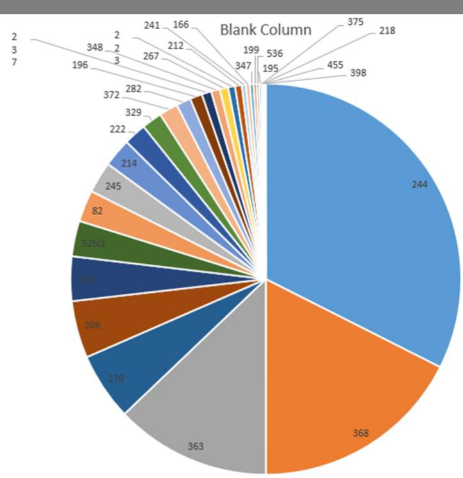


FIGURE A29

TOP-10 FY21-22 NATURAL GAS: 65% of Overall Main Campus Use





LIKE CAMPUSWIDE ELECTRICITY PROFILES, THESE NATURAL GAS PIE-CHARTS ARE GROUPED BY BUILDING NUMBER AND WHETHERE PHYSICAL METERS (LEFT "CUFT") OR CALCULATED EQUIVALENTS (RIGHT "BLANK COLUMN") WERE USED IN DETERMINING ANNUAL USAGE.

Like the top electricity consuming facilities table, this table provides insights into top natural gas consumers, aside from atypical buildings like the Strickland Plant.

Building Name	Bldg #	CUFT	CALC'D	% of Total	Grand Total
GERALD THOMAS HALL	244		6,030	19.4%	6,030
KNOX HALL	368		3,263	10.5%	3,263
ENGINEERING COMPLEX I	363		2,395	7.7%	2,395
CERVANTES VILLAGE APT COMPLEX	387E	2,159		7.0%	2,159
NMSU BOOKSTORE	632	1,880		6.1%	1,880
CORBETT CENTER	285	1,062		3.4%	1,062
COLE VILLAGE	270		1,037	3.3%	1,037
SUTHERLAND VILLAGE	206		879	2.8%	879
GOLF COURSE CLUBHOUSE	597	720		2.3%	720
DACC TECHNICAL STUDIES	357	694		2.2%	694


Gerald Thomas Hall


Knox Hall

TOP-10 FY21-22 NATURAL GAS: Square-Foot Normalized

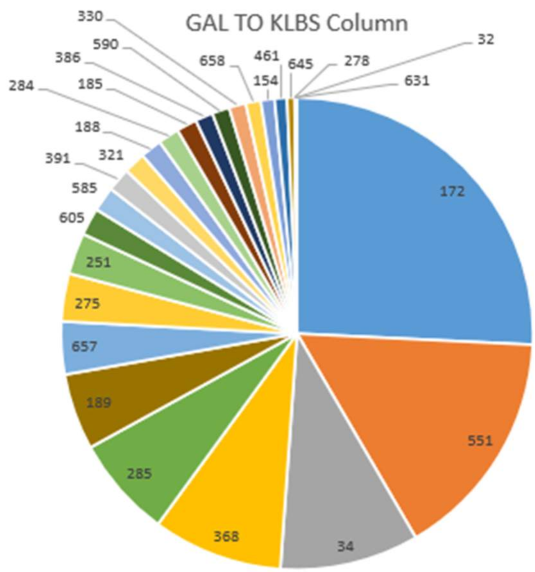
To understand which facilities are possibly using more natural gas than they should, this table lists facility consumption normalized by square-footage. Which illustrates that these 10 facilities represent 50% of campus natural gas use, when considering all educational/office buildings.

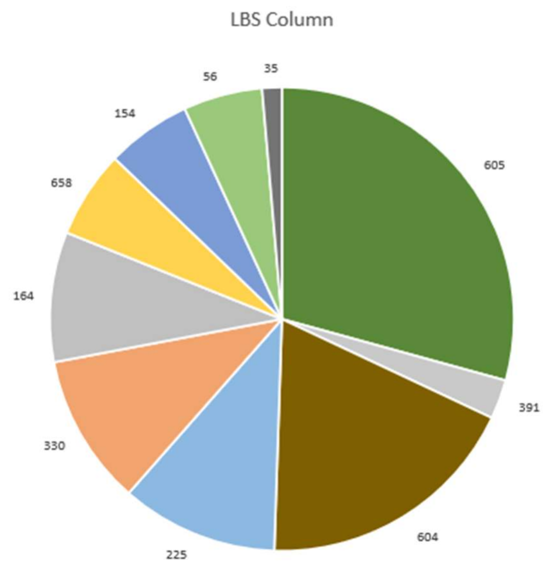
Building Name	Row Label	Sqft	CUFT	(blank	% of To	Grand Tota	Per Sqft
CERVANTES VILLAGE APT	387E	16,236	2,159		7.0%	2,159	0.13
FRENGER FOOD COURT	262	5,670	466		1.5%	466	0.08
VISTA DEL MONTE APT C	526Q	8,192		547	1.8%	547	0.07
PASSIVE SOLAR	348	2,591		135	0.4%	135	0.05
NEALE HALL	164	13,405		684	2.2%	684	0.05
KNOX HALL	368	64,972		3,263	10.5%	3,263	0.05
FARM RESIDENCE	199	915		45	0.1%	45	0.05
ENGINEERING COMPLEX I	363	48,524		2,395	7.7%	2,395	0.05
SUGERMAN SPACE GRAN	212	2,091		103	0.3%	103	0.05
GERALD THOMAS HALL	244	123,574		6,030	19.4%	6,030	0.05

There are 77 facilities that receive natural gas from Main Campus

STEAM USAGE

TOP-10 FY21-22 STEAM: 59% of Overall Main Campus Use






Hadley Hall


Skeen Hall

Building Name	Bldg #	GALTOKLBS	CALC'D	% of Total	Total	Observations
HADLEY HALL	172	32,955		15.4%	32,955	These facilities account for 58.8% of classroom and office building steam usage, and are high-priority for decommissioning. Some facilities require significant use, such as science halls, but Hadley does not.
SKEEN HALL	551	20,292		9.5%	20,292	
FOSTER HALL	34	12,185		5.7%	12,185	
KNOX HALL	368	11,403		5.3%	11,403	
CHEMISTRY BUILDING	187		9,832	4.6%	9,832	
CORBETT CENTER	285	8,899		4.2%	8,899	
MILTON HALL	83		8,425	3.9%	8,425	
BRELAND HALL	184		8,091	3.8%	8,091	
ENGINEERING COMPLEX	541		7,171	3.3%	7,171	
JETT HALL	189	6,686		3.1%	6,686	

TOP-10 FY21-22 STEAM: Pounds per Square-Foot Normalized

Like the top electricity and natural gas users, this table summarizes square-foot normalized steam top users, with Hadley Hall remaining in the group, and unexpectedly at the top of the list. It should be noted that the various column headings for usage are unique to the University's metering and billing database, where some values are from metered data, while others are interpolated or calculated.

Because some values are calculated and/or interpolated it is recommended that additional steam meters be placed at buildings like Hadley to understand whether this data is correct.

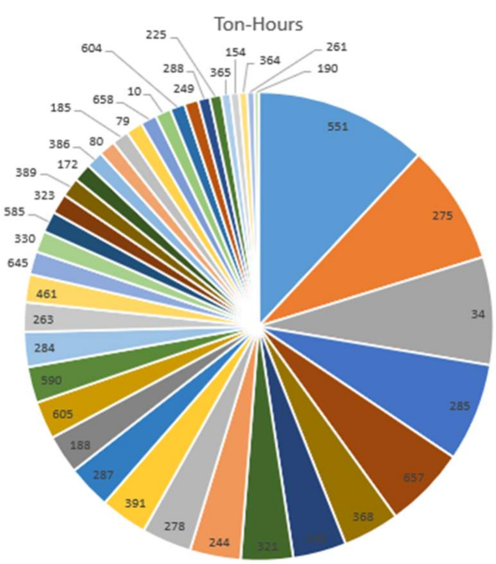
Building Name	Row Label:	Sqft	GALTOKLBS	LBS	(blank)	# PSF	% of Tot	Grand Tota	Per Sqft
HADLEY HALL	172	33,645	32,955				15.4%	32,955	0.98
KNOX HALL	368	64,972	11,403				5.3%	11,403	0.18
SKEEN HALL	551	118,744	20,292				9.5%	20,292	0.17
FOSTER HALL	34	85,320	12,185				5.7%	12,185	0.14
DOVE HALL	56	11,015			1,142		0.5%	1,142	0.10
KENT HALL	33	16,976			1,739		0.8%	1,739	0.10
MUSIC BUILDING	389	46,576			4,765		2.2%	4,765	0.10
WILLIAM B. CONROY HON	35	7,895			806		0.4%	806	0.10
CHEMISTRY BUILDING	187	97,708			9,832		4.6%	9,832	0.10
ED AND HAROLD FOREMA	541	71,352			7,171		3.3%	7,171	0.10
PETE V. DOMENICI HALL	249	35,999			3,617		1.7%	3,617	0.10

There are 56 facilities that receive steam from Main Campus and are grouped for phase-out in Apdx. F

CHILLED WATER USAGE

TOP-10 FY21-22 CHILLED-WATER: Top 55% of Campus (Ton-Hr)

Building Name	Row Label:	Sqft	MBTU	TON-HR	(blank	% of To	Grand Tota
SKEEN HALL	551	118,744		1,007,329		8.1%	1,007,329
GARCIA RESIDENCE HALL	275	187,361		698,845		5.6%	698,845
FOSTER HALL	34	85,320		628,275		5.0%	628,275
CHEMISTRY BUILDING	187	97,708			627,040	5.0%	627,040
CORBETT CENTER	285	186,541		572,188		4.6%	572,188
MILTON HALL	83	86,825			537,521	4.3%	537,521
BRELAND HALL	184	83,177			515,648	4.1%	515,648
DEVASTHALI HALL	657	58,072		476,008		3.8%	476,008
ED AND HAROLD FOREMA	541	71,352			457,318	3.7%	457,318
KNOX HALL	368	64,972		327,788		2.6%	327,788



There are 55 facilities that receive chilled water from Main Campus and the facilities listed above comprise 46.8% of total use.

Like building-level steam usage, the facility data is collected via onsite meters for many facilities, while usage for others are calculated or interpolated.

Skeen Hall is very clearly the largest chilled water user by volume, followed uncharacteristically by the Garcia Residence Hall. It is unexpected to see a dormitory in the top of campus chilled water users and is likely an opportunity for Retro-Commissioning.

TOP-10 FY21-22 Square-Foot Normalized Chilled Water Usage

When normalized for square-footage Garcia Residence Hall is no longer a top user of chilled water, and second place is replaced by the newly constructed Devasthali Hall, which is equally concerning given its new systems and controls.

Building Name	Row Label	Sqft	MBTU	TON-HR	(blank	% of To	Grand Tota	Per Sqft
SKEEN HALL	551	118,744		1,007,329		8.1%	1,007,329	8.48
DEVASTHALI HALL	657	58,072		476,008		3.8%	476,008	8.20
FOSTER HALL	34	85,320		628,275		5.0%	628,275	7.36
DOVE HALL	56	11,015			72,912	0.6%	72,912	6.62
WILLIAM B. CONROY HON	35	7,895			51,443	0.4%	51,443	6.52
KENT HALL	33	16,976			110,583	0.9%	110,583	6.51
CHEMISTRY BUILDING	187	97,708			627,040	5.0%	627,040	6.42
ED AND HAROLD FOREMA	541	71,352			457,318	3.7%	457,318	6.41
YOUNG HALL	32	10,806			68,861	0.6%	68,861	6.37
EDUCATIONAL SERVICES	338	43,192			272,609	2.2%	272,609	6.31

https://nmsuroundup.com/13491/showcase/art-department-claims-new-home-in-devasthali-hall/

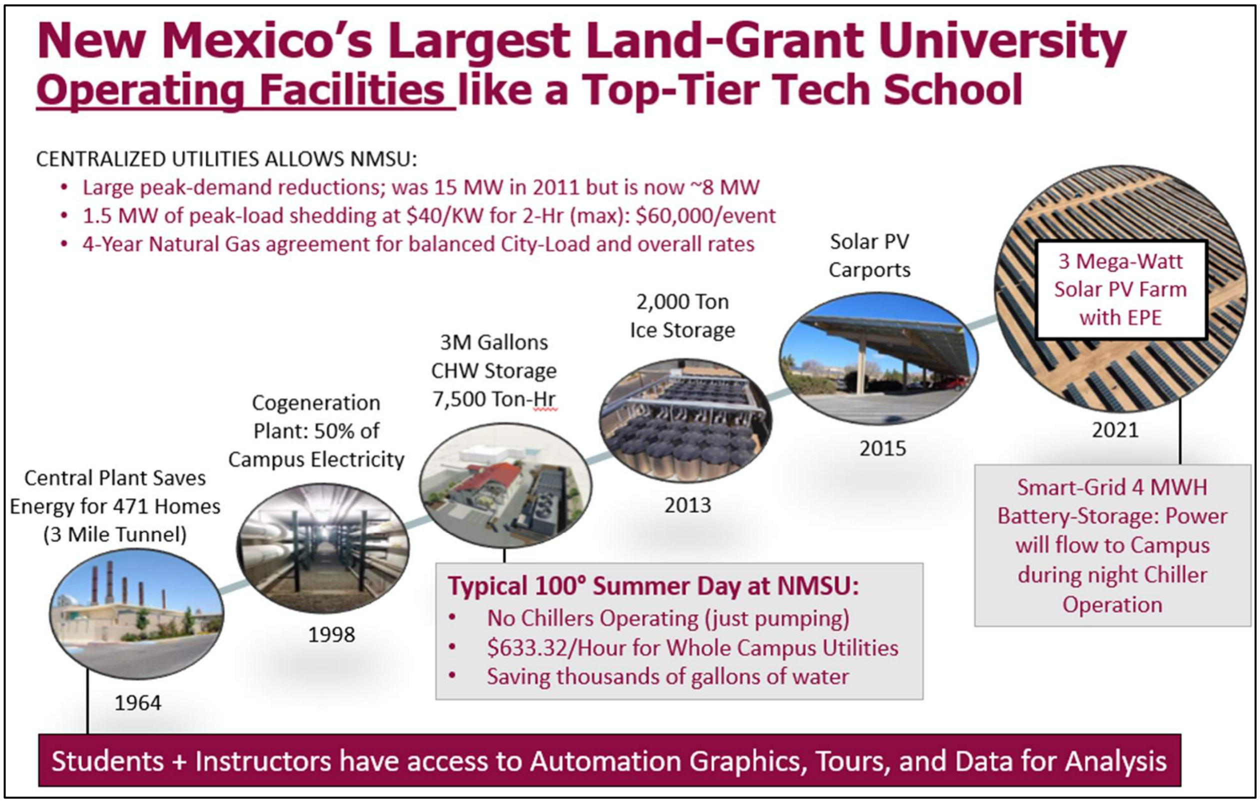
2023

APPENDIX B: Main Campus Infrastructure Review

EEA CONSULTING ENGINEERS

CAMPUS INFRASTRUCTURE REVIEW

NMSU's paths to carbon neutrality are unique to higher education because NMSU is unique:



The following sections summarize Main Campus infrastructure - including associated Carbon Impact, Recommendations, and Operations for:

- ✓ Cogeneration Systems
- ✓ Steam Systems
- ✓ Chilled Water Systems
- ✓ Utility Tunnels
- ✓ Electrical Infrastructure

COGENERATION SYSTEM

Description

The central utility plant houses a natural gas turbine. It is capable of generating 4500 kW for distribution. It can be turned down to 3600 kW (limited by the air permit). The attached heat recovery steam generator can produce up to 22,000 lbs/hr of steam at 100 psi. One half of this steam (11,000 lbs/hr) is fed to a steam turbine chiller, which can provide up to 1250 tons of chilled water. The remaining 11,000 lbs/hr is piped to the campus.

The peak campus electrical demand is 10.5 MW. In the winter, the peak campus steam demand is 66,000 lbs/hr. In the summer, the peak campus chilled water demand is 6,600 tons.

Presently, the gas turbine operates continuously. And the steam generator and the steam turbine chiller are both base loaded. In the summer, the steam generator provides all of the needed steam for the campus. In the winter, the steam turbine chiller provides all of the needed chilled water to the campus.

The cogeneration system serves to provide additional resiliency to the electrical system. With the existing parallel switchgear and synchronous controls, a seamless switchover from EPE to the cogeneration power is possible.

IMAGE 1 – COGEN TURBINE

Existing Report Findings

GLHN (Tucson, AR) was hired by the University to study the cogeneration system. Their findings were assembled in a report, titled COGENERATION SYSTEM, dated June 16, 2009. The basics of the system have not changed since then, so the findings of the study are appropriate today.

One third of the energy put into the system in the form of natural gas comes out in the form of electric power. One third of the energy input is lost through system inefficiencies. The remaining one third of energy input is exhausted in the form of very hot air.

Economics: The cogeneration system potentially provides utility cost savings, depending on the costs of natural gas and electricity. The report states that when electricity costs $0.12/kWh, it is cost effective to run the turbine, as long as the cost of gas is less than $9.25/Dth.

Impact on Carbon

When compared to a generic electrical utility company that generates electricity by burning 100% natural gas and distributes the electricity over long distance transmission lines, the University cogeneration system is theoretically about 33% more efficient. It gets this efficiency advantage because the campus does not have long distance transmission lines. In this simple comparison, the cogeneration system would also generate 33% less carbon.

However, a carbon comparison with the electricity from El Paso Electric is a bit more complex. The electricity that comes from EPE includes two sources. The main source is from the main EPE distribution system, and it includes about 25% from nuclear and the rest from natural gas. The other source is the PV farm that sits adjacent to the campus.

Presently, about 70% of the campus EPE electricity usage is from EPE transmission lines and about 30% is from the Aggie Power PV farm.

Carbon conclusions: Based on our analysis of current electricity usage, carbon production would be reduced by 57% if the gas turbine was turned off.

IMAGE 2 – COGEN STEAM BYPASS

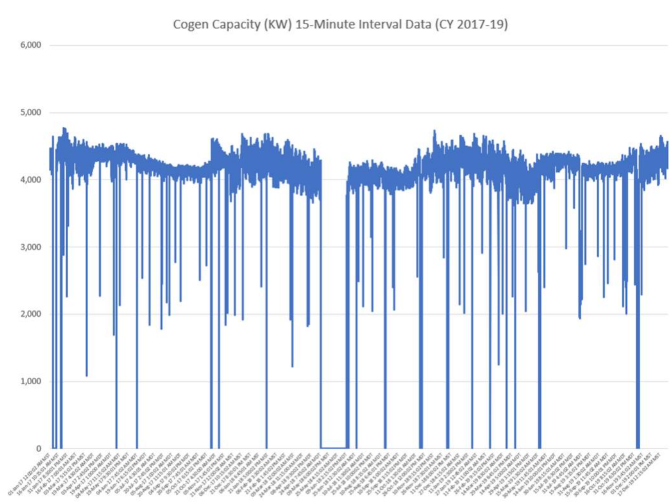
Recommendations

As explained elsewhere in this report, the mandate of 50% carbon reduction by 2030 can be achieved while continuing to operate the existing cogeneration system. To achieve the mandate of carbon neutrality by 2045, the operation of the cogeneration system will need to be dramatically changed before 2045. One of the following will be required:

- Turn the gas turbine off (and associated steam chiller).
- Operate the gas turbine with hydrogen.
- Provide very large amounts of carbon offsets.

Our recommendation is to plan to decommission the cogeneration system before 2045, and to do so in a time frame that is most advantageous for the University. With that in mind, we recommend that no more updates to the system be performed, unless and until the use of hydrogen as the source of energy becomes a reality.

IMAGE 3 – STEAM CHILLER



GRAPH 1 – COGEN POWER CAPACITY

The power capacity plotted above represents an average of 3,835 KW (3.84 MW) with a maximum output of 4,766 KW (4.77 MW). When running at capacity the cogeneration system is able to provide nearly 50% of the campus' peak electrical demand, and if running all year with 6%[1] of hours under maintenance.

STEAM SYSTEMS

Description

Most campus buildings are provided steam from the central campus steam system. Most of the existing steam distribution piping is routed inside of tunnels. However, there are some direct-bury steam and condensate lines, as well. These direct-bury lines have proven to be especially problematic, due to steam leaks. Within individual buildings, steam is used as a source of heat for space heating, domestic water heating, food preparation, swimming pool heating, and some autoclaves.

Equipment: The central utility plant (CUP) houses four pieces of steam generating equipment. The 22,000 lbs/hr Nebraska heat recovery steam generator, which is connected to the gas turbine, is presently base loaded. The other three more traditional boilers are operated on an as-needed basis. There are two 44,000 lbs/hr Keeler water tube boilers and one 15,000 lbs/hr Cleaver Brooks fire tube boiler.

Load: In the winter, the peak campus steam demand is 66,000 lbs/hr. In the summer, the peak demand is less than 11,000 lbs/hr. Presently, the N+1 arrangement of boilers allows the campus load to be easily addressed, even if one of the boilers is down.

Steam leaks are an ongoing problem. Fixing these leaks will be an important early step.

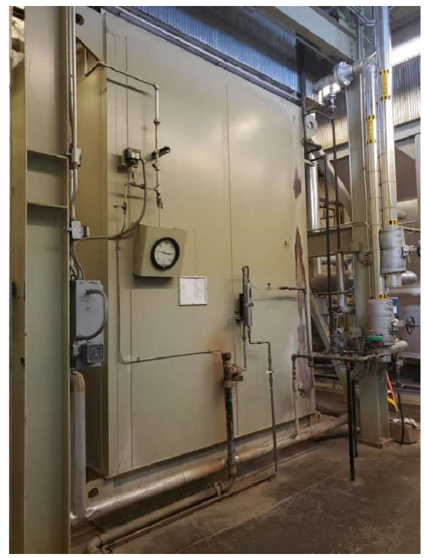


IMAGE 4 – COGEN BOILER

Existing Report Findings

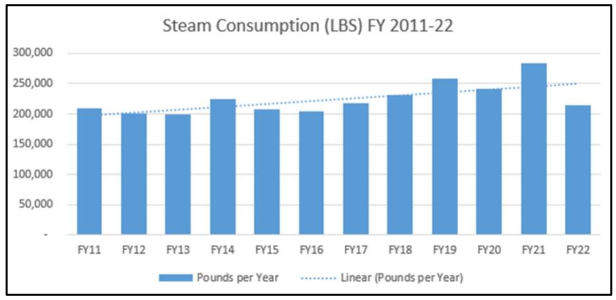
GLHN (Tucson, AR) was hired by the University to study the campus steam system. Their findings were assembled in a report, titled STEAM SYSTEM, dated June 16, 2009. The basics of the system have not changed since then, except for the replacement of the steam absorption chiller with a steam turbine chiller, and most of the findings of the study are still appropriate today.

GLHN produced an abridged update to their 2009 report in 2022. This update focused specifically on needed steam and condensate repairs that reside in the utility tunnel system and in building mechanical rooms. The estimated costs to address these repairs is very significant and are copied from that report:

[1] CY 2017-2019 Data

"The cost to repair/replace all deficient, inoperable, and damaged equipment is approximately ***$35,000,000****."*

"The annualized cost for the same repair/replacement scope spread over a 10-year timeframe is approximately ***$4,000,000****."*



Graph 2

These costs are very significant because of their magnitude. And because the steam system will need to function properly for many years to come. **We do not see a path to carbon neutrality that avoids maintaining the integrity of the campus steam system.** Steam repairs must be made a priority. If the chosen path to carbon neutrality includes the decommissioning of the steam system, this will need to be phased and will take many years to accomplish. If hydrogen becomes a reality and the chosen path includes operating the gas turbine with hydrogen as fuel, and the steam system is preserved, then its proper operation into the future must be insured. See recommendations below.

The 2022 update report also defined additional ongoing costs due to steam system deficiencies. These conclusions are copied from the report:

Steam piping system *"deficiencies leading to tunnel structure failures due to steam induced corrosion resulting in* ***$800,000 annually*** *for the last 5 years."*

"Current steam production costs attributed to lost steam and condensate is estimated at ***$300,000 annually*** *(additional natural gas, chemical treatment, and domestic water usage)."*

IMAGE 5 – TYPICAL TUNNEL PIPING

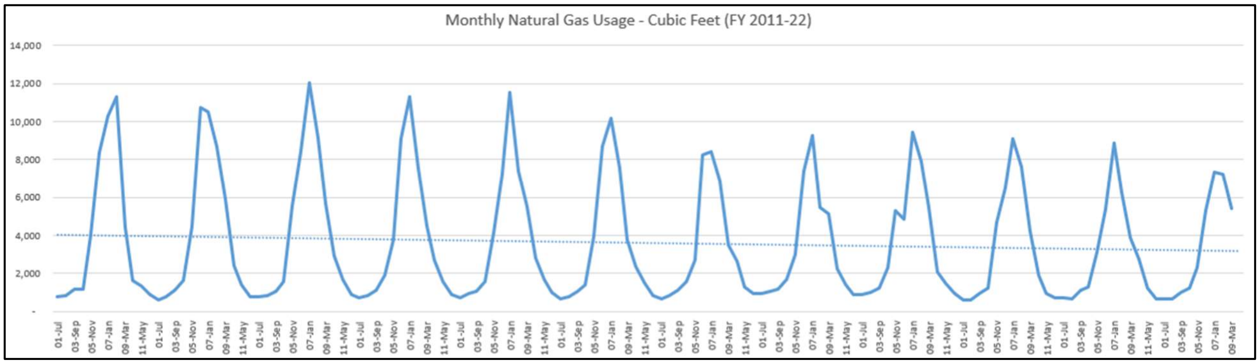
Note: The present increased cost of natural gas has served to increase this estimate of $300,000 to probably at least $400,000.

Impact on Carbon

Presently, all generated steam is produced by burning natural gas. Natural gas usage comprises 77% of the campus total carbon footprint. And much of the 77% can be directly and indirectly attributed to the burning of gas (by the steam boilers and the gas turbine) to produce steam. It follows easily that the contribution to the campus carbon footprint by the production of steam is very significant. It will need to be mitigated to meet the 2045 mandate.

IMAGE 6 – TYPICAL TUNNEL PIPING

Boilers gas consumption is approximately 22% of the campus gas usage.



GRAPH 3

The gas turbine uses 73% of the campus natural gas. The portion of natural gas consumption by the turbine that can be indirectly attributed to the heat recovery steam generator is approximately 16% of the turbine usage, or about 12% of the campus gas usage.

The total of cogen and boiler use is about 95% of campus gas usage.

Gas usage is 77% of campus total carbon.

Therefore, the calculated contribution from steam to the campus total carbon is about 74%.

UTILITY CONSUMPTION

Dataset	Main Campus	Alamogordo	Grants	Ag Science*	Total
kWh Electricity (2022)	30,728,880	2,353,903	1,092,522	1,824,359	35,999,664
Net Electricity Use kWh	23,728,880	2,353,903	1,092,522	1,824,359	28,999,664
DTH Natural Gas (2022)	611,936	4,592	44,667	4,986	666,181
Therms Natural Gas (22)	6,119,360	45,921	446,667	49,862	6,661,810

CARBON EMISSIONS

Dataset	Main Campus	Alamogordo	Grants	Ag Science*	Total
Electricity Carbon	9,150	907.66	421.28	687.63	11,166
Natural Gas Carbon	33,718	253.02	2,461.13	440.23	36,872
Total Carbon	42,868	1,160.69	2,882.41	1,127.86	48,038
Percent of Total	89%	2%	6%	2%	

**Ag Gas Emissions includes Propane and Natural Gas*

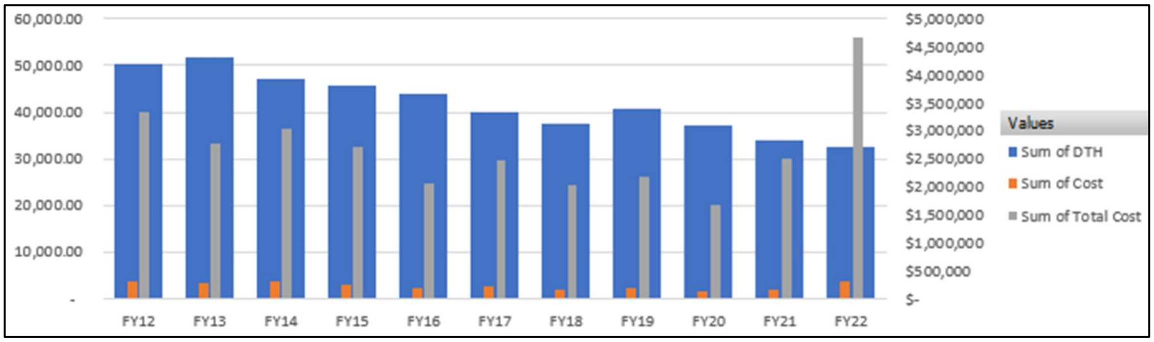
Alamogordo & Grants: Energy Star emissions factors 0.0003856 MT/kWh (both PNM and Continental Divide)

MAIN CAMPUS UTILITIES

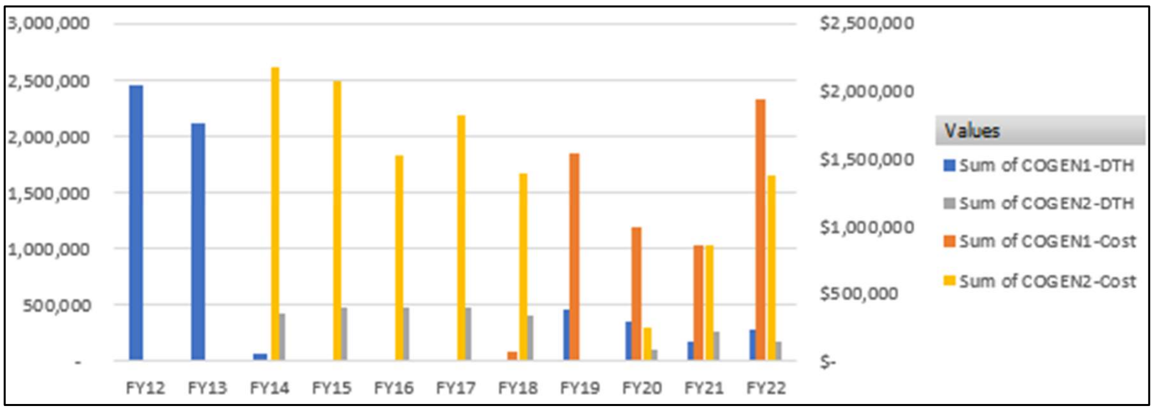
					% of Total on Main Campus	
Dataset	DTH	LBS	TON-HR	Emissions*	% of Gas Use	% of Emissions
Chilled Water						
Steam						
Gas Turbine	446,477			24,601	73%	57%
Boilers	133,034			7,330	22%	17%
Low Pressure Gas	32,425			1,787	5%	4%

*0.0551 metric tons CO2/Mcf or DTH

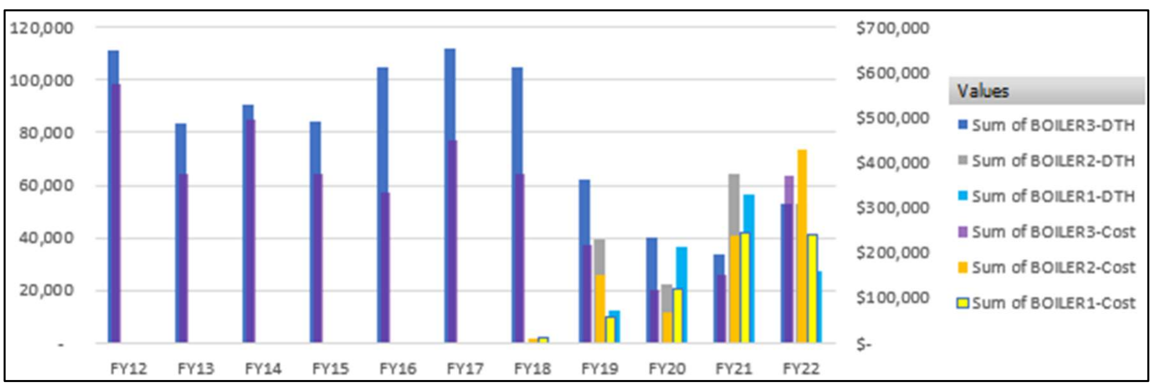
GRAPH 4



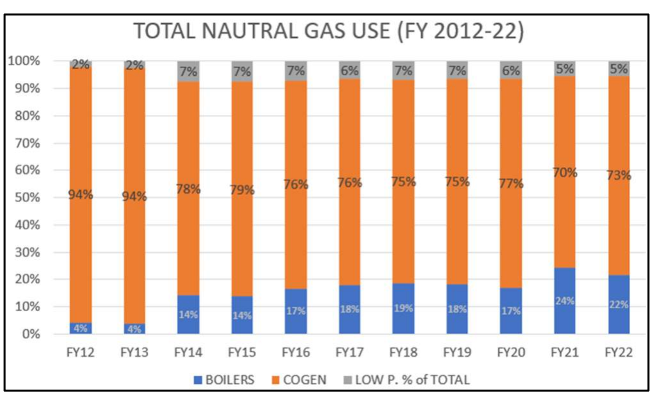
GRAPH 5: TEN-YEAR TOTAL CAMPUS GAS CONSUMPTION & COSTS



GRAPH 6: TEN-YEAR COGEN GAS CONSUMPTION & COSTS



GRAPH 7: TEN-YEAR BOILER GAS CONSUMPTION & COSTS



GRAPH 8

The graphs presented on this page are used to illustrate reductions in natural gas use campuswide (Graph 5), whereas individual natural gas consumption at the equipment level was largely elevated between FY12-18.

Graph 8 illustrates that boiler consumption, as a percentage of total Main Campus usage is increasing over time, while low-pressure natural gas is becoming a smaller portion. Cogen has remained consistent from FY14.

Recommendations

The mandate of 50% carbon reduction by 2030 can be achieved while continuing to operate the existing steam system as is. To achieve the mandate of carbon neutrality by 2045, the operation of the steam system will need to be dramatically changed before 2045. One of the following will be required:

- ✓ Provide very large amounts of carbon offsets.
- ✓ Perpetuate the campus steam distribution system and replace the central plant gas-fired boilers with electric boilers.
- ✓ Operate the gas turbine with hydrogen and perpetuate the campus steam system.
- ✓ Decommission the campus central steam system.

Our recommendation is to plan to decommission the steam system before 2045, and to start immediately. This will require an enormous amount of complicated work, and it will be costly. With that in mind, we recommend five 5-year phases of implementation. We recommend that the University continue to implement this plan, unless and until the use of hydrogen as a viable source of fuel for the turbine becomes a reality. At that time, the University can re-evaluate.

Recommendations:

The campus steam system will need to remain in operation for many years, regardless of which of the Options are chosen for implementation.

We recommend that the following items be implemented as soon as possible:

- ✓ Develop a workable plan to repair steam leaks. Commence with the plan immediately. Every leak that is repaired will immediately help to reduce the carbon footprint, and it will save money by reducing natural gas usage. Start with the leaks that are easiest to fix.
- ✓ Replace steam-powered domestic water heaters in individual buildings with electric water heaters or, even better, solar domestic water heaters.
- ✓ One of the Options is to replace the existing gas-fired steam boilers with electric boilers.
- ✓ Phase 1 of this plan could add electric boilers inside the existing Satellite Chilled Water Plant. This is recommended as a first step because there is potentially as much as 9 MW of 24kV power available at this location. The new boilers should be sized to correspond to the size of the existing steam main located in the tunnel adjacent to the Satellite Plant.
- ✓ Additional Phases would add electric boilers in the Central Utility Plant to replace the existing gas-fired boilers.

Another Option includes the decommissioning of the entire Central Campus Steam System, including the boilers and the piping distribution systems. As presented above, decommissioning the entire steam system would potentially have a tremendous impact on reducing carbon. In effect, all of the natural gas that is presently used to generate steam would no longer be needed. Rather than replacing the steam generating sources, as presented above, this Option would replace the steam in individual buildings with more carbon-friendly sources of heat.

IMAGE 7 – BOLILER #2

Examples of how this could be done include:

- ✓ Replace steam-powered domestic water heaters in individual buildings with electric water heaters or, even better, solar domestic water heaters.
- ✓ Add electric steam boilers to individual buildings. This would allow existing mechanical systems to otherwise remain as is. Note that this option may require an upgrade of the electrical power system in the building.

Upgrade HVAC systems to all-electric systems that do not use gas as a source of heat. Examples include variable flow refrigerant systems, heat pump systems, smaller regional district energy systems, heat pump chillers, etc.

Install solar PV and battery systems strategically on campus.

It would be a very large and complicated endeavor to decommission the entire campus steam system. We recommend doing this over a duration of 25 years. We have defined five separate 5-year phases. The phases are illustrated on the enclosed steam map and include the following:

- Phase 1a: Steam line south of Knox Hall, including DACC
- Phase 1b: Skeen, Gerald Thomas, and Knox
- Phase 1c: Jett, Engineering Complex, Goddard, Thomas & Brown
- Phase 2: Branson Library and buildings to the north
- Phase 3: Walden Hall to Pan American Center
- Phase 4: Anderson Hall to Chamisa Village
- Phase 5: Central Utility Plant

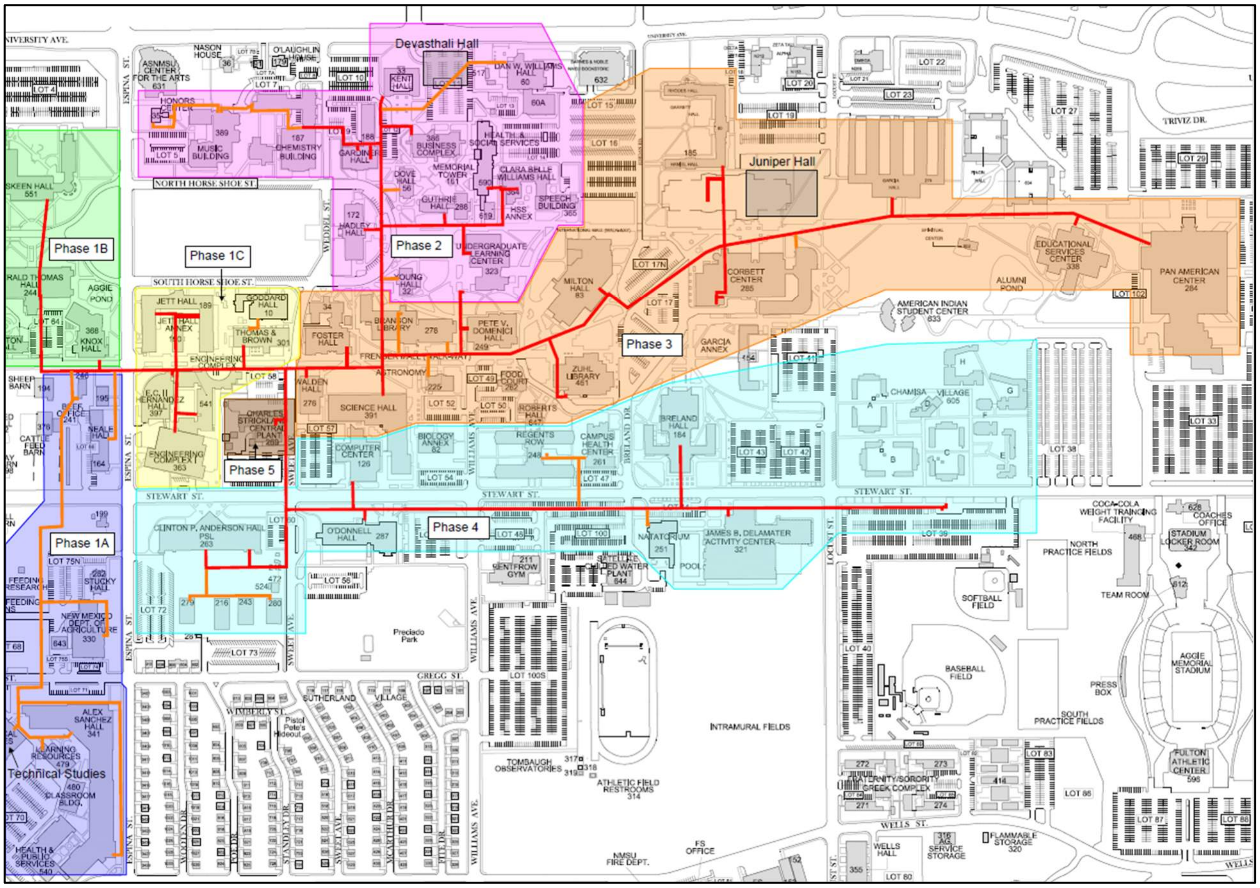
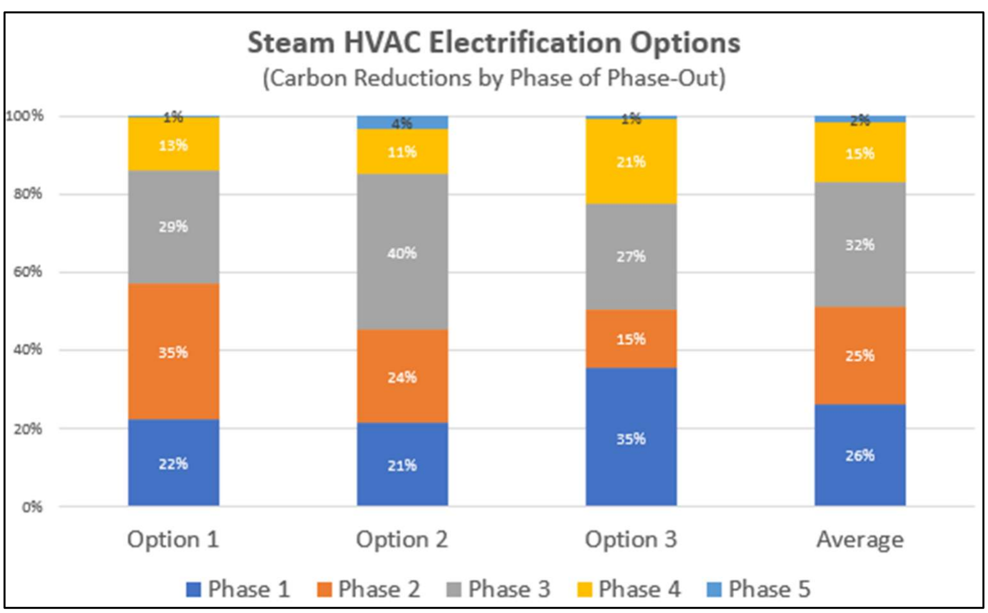


IMAGE 8 – STEAM PHASE-OUT MAP

These phases were discussed with the NMSU facilities team to determine where "low-hanging" fruit exists, as means to begin phase-out, which is Phase 1A and DACC. The chart below illustrates carbon reductions associated with each phase, with three options for decarbonization of HVAC systems.



GRAPH 9

The three Options evaluated for steam-related HVAC electrification are:

1) Electric Steam Boilers are localized to individual buildings or clusters of buildings.

2) Variable Refrigerant Flow (VRF) Heat-Pumps and removal of Steam and Chilled-Water at each building, using energy recovery ventilators for fresh-air.

3) Heat-Pump Chillers used for heating and cooling at individual buildings or in clusters of buildings.

CAMPUS CHILLED WATER SYSTEM

Description

Most campus buildings are provided chilled water from the central campus chilled water system. Most of the existing chilled water distribution piping is routed inside of tunnels. However, there are also some direct-bury lines. Within most individual buildings, chilled water is used as the source of cooling.

Equipment at the Central Utility Plant:
Chilled water is produced by three (3) 1500 ton electrically driven centrifugal chillers, one (1) 1100 ton absorption chiller (which is inactive), and one (1) 1250 ton steam turbine driven centrifugal chiller. The four active chillers have a total capacity of 5,750 tons. The adjacent thermal storage facility of 3 million gallons is capable of storing up to 25,000 ton-hrs of chilled water.

IMAGE 9 – MAIN CHILLER PLANT

Equipment at the Satellite Plant:
Chilled water is produced by one (1) 2500 ton electrically driven centrifugal chiller. A low temperature 877 ton electrically driven centrifugal chiller is used to charge the adjacent 24 Calmac ice storage tanks, which provide chilled water to campus through a plate and frame heat exchanger.

IMAGE 10 – SATELLITE PLANT ICE EXCHANGER

Load and Operation:

In the summer, the peak campus chilled water demand is 6,600 tons. Presently, the steam turbine chiller (1250 tons) is base loaded and operates continuously throughout the year.

During the electricity demand on-peak hours (3-7 pm, Monday through Friday, June through September), the two thermal storage systems complement the turbine chiller and provide chilled water to the campus so the electric chillers can be off during these on-peak hours.

IMAGE 11 – SATELLITE PLANT ICE STORAGE TANKS

During the off-peak hours, the electric machines are used to charge the two thermal storage systems and to complement the turbine chiller to provide the needed capacity to the campus. It is noted that the tanks for the thermal storage system at the CUP are open to atmosphere. As a result, operation of this system has been problematic and a bit inefficient.

Existing Report Findings

GLHN (Tucson, AR) was hired by the University to study the campus chilled water system. Their findings were assembled in a report, titled CHILLED WATER SYSTEM, dated June 16, 2009. Several upgrades to the system have been incorporated that have resulted in a system that still has the basics of the 2009 system, but it has been changed significantly.

One of the steam absorption chillers in the CUP was replaced by a steam turbine driven centrifugal chiller.

The report recommend that additional capacity would be needed in the future to address the anticipated campus growth. The addition of a satellite plant was recommended. The satellite plant was constructed in 2011.

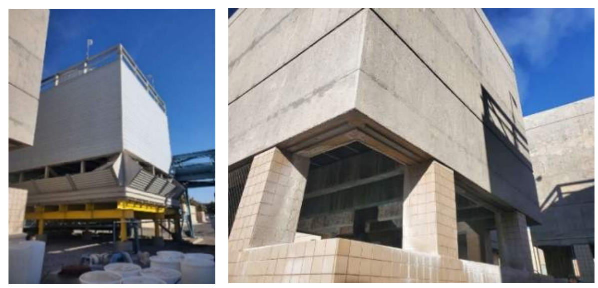


IMAGE 12 – CENTRAL PLANT COOLING TOWERS
(New Unit Left & Original Tower Right)

The report stated a peak campus demand in 2009 of 6,600 tons. Interestingly, the peak demand in 2022 is still 6,600 tons. The fact that the peak has not grown since 2009 can be attributed to the following: the campus has not grown as anticipated, many successful energy conservation measures have reduced the chilled water load, and several improvements to the operation of the chilled water system have effectively reduced the overall demand.

Impact on Carbon

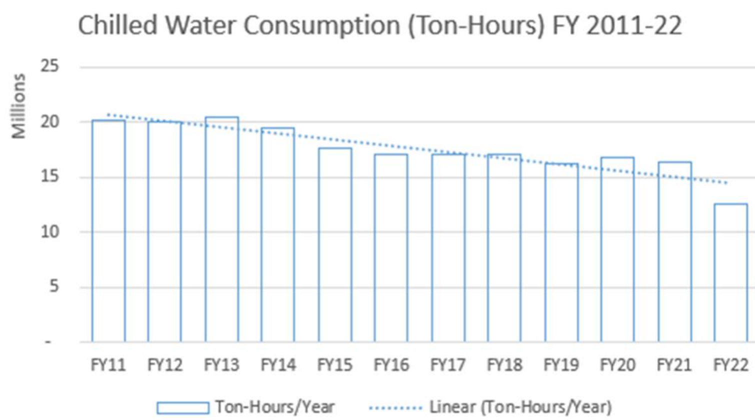
One of the possible paths to carbon neutrality includes decommissioning the cogeneration system. If this path is followed, the steam turbine chiller would also be decommissioned. The result would be a system that is powered completely by electricity. Operation of this system would be very different. Decisions would need to be made regarding preferences of operation. That is, the system could be operated to optimize the carbon footprint or to optimize the electricity costs.


IMAGE 13 – SATELLITE PLANT CHILLER

Another of the optional paths to carbon neutrality contemplates the addition of stand-alone heating and cooling systems to individual buildings. These upgrades would serve to reduce the load on the central chilled water system.

Recommendations

The central chilled water system will be around for many years. It is anticipated that the campus peak chilled water demand will not increase in the future, it may decrease. This would occur as changes to campus infrastructure are implemented that do not need central chilled water.



GRAPH 10

Upgrades and operation changes to the central system should be made to reduce the system carbon footprint. It must be noted that these upgrades may have the effect of increasing future electricity costs.

Graph 10 (left) clearly illustrates that campuswide chilled water usage is exhibiting a downward trend over the last 10 years.

The data suggests that chilled water consumption as dropped 38% in this timeframe

CAMPUS ELECTRICAL DISTRIBUTION

Description

Selected highlights of the electrical distribution system include the following:

The University is served by El Paso Electric Company (EPE). EPE serves the NMSU campus through two separate campus substations, Tortugas and Geothermal. Tortugas is fed 25kV from EPE and serves most of the campus with 6 circuits. Geothermal is fed 25kV from EPE and serves mostly east of the interstate at 5 kV.

The campus medium voltage distribution contains two voltages, 5kV and 25 kV. The legacy campus is 5kV. Most of the housing and newer/remodeled buildings and facilities are using 25kV. There are many 25kV – 5kV bi-directional transformers.

- Cogeneration: A single 5 MW natural gas-driven turbine generates about 4.3 MW of capacity. It feeds circuits 3 and 4 and is providing redundancy for the EPE Tortugas Substation loads connected to these circuits. It operates at 5 kV and primarily serves loads at this voltage.
- Cogeneration operation: Presently the cogeneration system operates continuously, except for scheduled downtimes for maintenance.
- Cogeneration resiliency: It operates in parallel with EPE for some circuits and provides a seamless transfer of power for those circuits when the EPE power is lost.

Existing Report Findings

In February of 2011, Las Cruces experienced a sustained power outage that essentially shut down the campus until normal power was restored. NMSU decided to hire a consultant to review the campus electrical infrastructure. Bohannan Huston and Spectrum Engineers were hired by the University to study the campus electrical infrastructure and to make recommendations. Their findings were assembled in a report, titled SITE ELECTRICAL INFRASTRUCTURE MASTER PLAN, dated August 29, 2014.

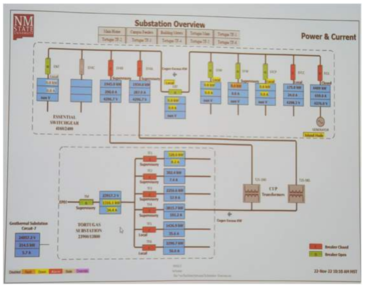


IMAGE 14 – POWER MONITORING DASHBOARD OVERVIEW

The main objectives of the master plan effort included the following:

- ✓ Increase reliability
- ✓ Explore the gas turbine generator as a reliable, alternative source
- ✓ Phase out 5kV and convert to all 25kV
- ✓ Plan for future growth and flexibility

The basics of the system have not significantly changed since then, so most of the findings of the study are still appropriate today. However, if the study were to be updated today, the mandate to achieve carbon neutrality would add the follow objectives:

- ✓ Plan for a future that will increasingly rely on a more robust electrical distribution system to support needed changes to the campus to embrace carbon neutrality
- ✓ Increase resiliency

- ✓ The report recommended upgrades that were estimated in 2014 to cost over $28M to accomplish.

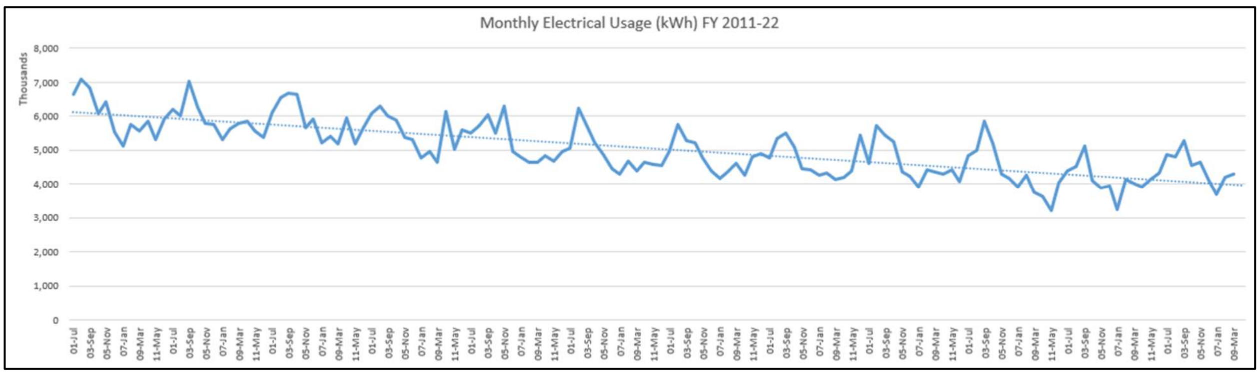
Impact on Carbon

Many future campus upgrades that are made to reduce the carbon footprint will need a more robust electrical distribution system

What has changed since the master plan report was completed in 2014 is the mandate to proceed to carbon neutrality. This mandate will be accomplished by moving away from fossil fuels. A more reliable and robust electrical distribution system is a must. Needed updates to the campus electrical distribution system will absolutely have to be done. An upgraded system will be the heart and soul of a carbon neutral campus infrastructure. The required changes will not be possible without these electrical upgrades. This should be at the top of the list of priorities.

Recommendations

The University has defined an estimated cost of $60M to accomplish the needed electrical distribution system upgrades. This $60M reflects an escalation of the 2014 estimate of $28M, and it also reflects an increased scope of work needed to add robustness to the system. This cost reflects the work that is needed to support a carbon neutral campus and to provide increased resiliency. **Implementing this is most important!**



GRAPH 11

Regarding the cogeneration system: There are two options that keep the cogeneration system. There are two options that decommission the cogeneration system. All these options require a more robust electrical distribution system.

Recommended system upgrades:

- ✓ The legacy 5 kV system is old and increasingly unreliable. It should be phased out in favor of a new and more robust 25kV system.
- ✓ Replace the legacy 5kV system and upgrade the existing 25kV system. The upgraded 25kV system needs to be more robust to support future carbon neutral campus upgrades.
- ✓ To enhance resiliency, provide a second and separate EPE feed to the campus. Also provide a new substation.
- ✓ To enhance resiliency, future 25kV circuits should be looped rather than radial.

IMAGE 15 – SATTELITE PLANT GEAR

IMAGE 16 – CENTRAL PLANT GEAR

COMPLETING THE PRIMARY ELECTRICAL LOOP

Tortuga Sub-Station & Electrical Loop Review

The Tortuga Sub-Station is located on largely undeveloped the south end of campus and it is a recommendation of this report to complete an actual electrical "loop," with a sub-station at Espina.

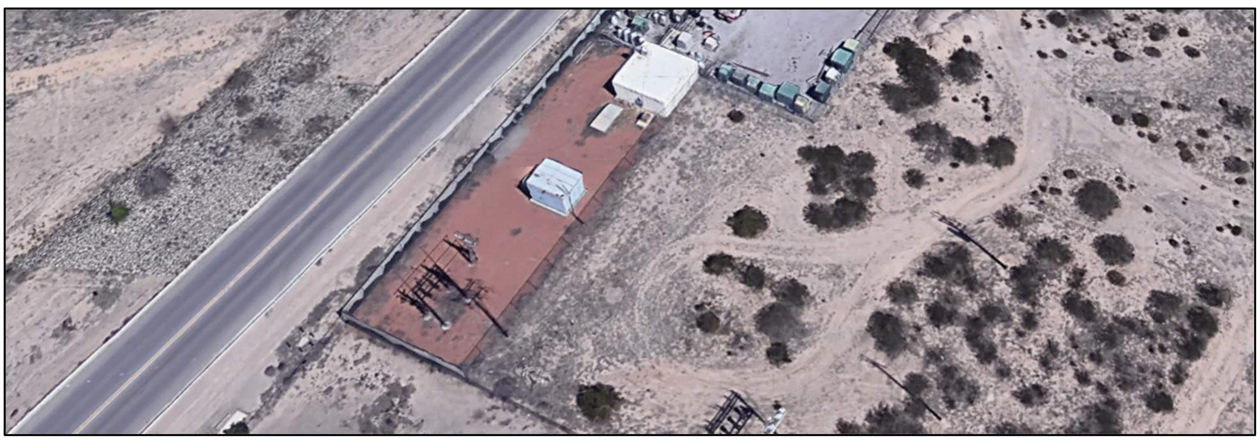


IMAGE 17 – AERIAL VIEW OF TORTUGA

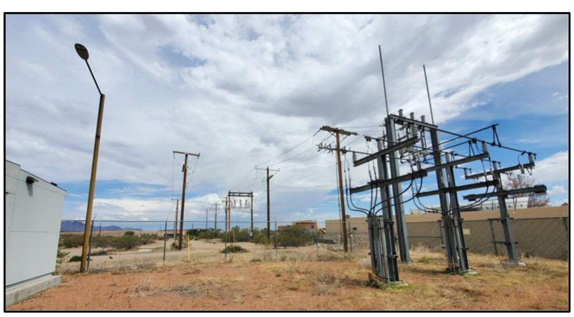


IMAGE 18 – TORTUGA POLES

IMAGE 19 – TORTUGA SWITCHING VAULT

It is recommended that the University construct a new sub-station located at the Campus' South Espina Street Campus Entrance (below). This will complete an electrical loop with the ability to leverage existing high-voltage lines in that location, as well as create a second El Paso Electric tie-in location.

IMAGE 20

It is important that this new sub-station be co-located and planned with Electric-HVAC upgrades, NMSU owned Solar PV projects, and near-term Electric Vehicle capacity needs. Critical electrical tie to EPE and critical systems are physically located next to the cogeneration system.

The University needs a strategy for failures, quick connecting temp backup systems with failures, including power

SYSTEM OF TUNNELS

Description

Approximately 15,000 linear feet of utility tunnels lie underneath the campus. Most of the campus utilities distribution is routed inside these tunnels. The tunnels contain steam, chilled water, domestic water, gas, and electric lines. These lines serve the majority of buildings on campus. The tunnels were built in phases since the 1950's. The structural condition of the tunnels vary widely across the campus.

Existing Report Findings

In 2011 and 2012, partial failures of tunnel sections led NMSU to obtain a full investigation of the structural integrity of the tunnels.

Bohannan Huston was hired to perform this study. The findings of their study were documented in a report, entitled STRUCTURAL INTEGRITY STUDY FOR NEW MEXICO STATE UNIVERSITY UTILITY TUNNEL, dated October 10, 2013.

The report listed the deficiencies and organized/prioritized them into 5 categories. Category A contained the highest priority deficiencies. The total estimated cost to repair the deficiencies was over $2.7M.


IMAGE 21 – 2022 TUNNEL REPAIR

Impact on Carbon

Most of the campus steam and chilled water distribution piping is routed in the tunnels. We have concluded that the steam and chilled water systems will need to continue to be viable for many years. For that reason, it is important for the tunnels to likewise continue to be viable.

Recommendations

The University has been working to repair tunnel sections that are deficient. We recommend that this systematic repair of the tunnels continue, as the tunnels will be needed for many years in the future.

Also, it is vitally important for the steam piping leaks and deficiencies that are inside the tunnels to be addressed. These steam leaks are having a seriously negative effect on the integrity of the tunnels. See the section on CAMPUS STEAM SYSTEM for additional comments.


IMAGE 22 – TUNNEL EXAMPLE

2023

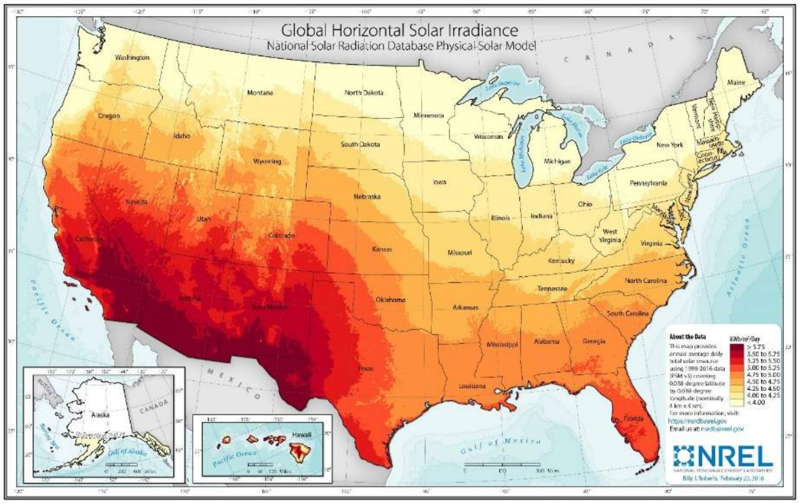
APPENDIX C: Possible PV + Storage Sites

EEA CONSULTING ENGINEERS

EXECUTIVE SUMMARY

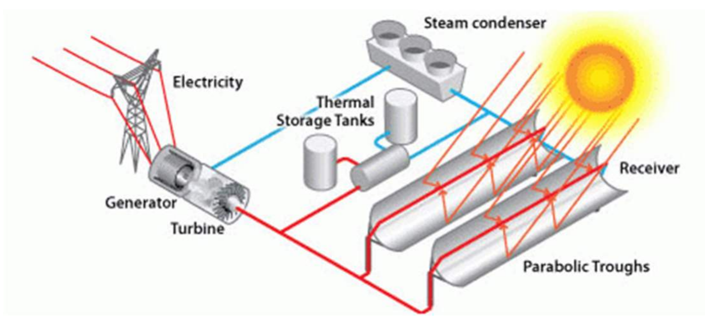
Main Campus Summary

This appendix provides an analysis of potential solar photovoltaic (PV) locations on Main Campus, as well as Branch Campuses, Dona Ana Community College (DACC) sites, and Ag Science Centers. Each site is addressed separately considering potential array size and/or layout, energy savings, cost savings, and carbon reductions.



It is no mystery that New Mexico is in the center of the U.S. "Sun Belt" and Las Cruces is seated in the highest solar irradiance concentration (per NREL).

This unique advantage allows NMSU for superior solar photovoltaic and solar thermal performance and associated return on investment. The irradiance levels in Las Cruces, and much of the locations where Branch Campuses and Ag Science Centers are located, make investing in solar technologies a no brainer across the state.



For this reason EEA Consulting Engineers highly recommends solar technologies as the primary decarbonizatoin mechanisms for all sites. While traditional solar photovoltaic systems (PV) are analyzed and recommended herein, there are other commercially viable solar technologies – like concentrating solar – that are not evaluated but deserve consideration.

It is recommended to pursue the walkway and parking-lot sites with priority, as these sites are in visible locations that will help with recruiting and visibility of cleantech adoption for existing faculty, staff, and students. While many rooftop sites were identified by universities participating in the DOE/NREL Solar Cup, it is unclear as to whether the age of roofs and structural capacity would allow for cost-competitive placement (compared to ground-mount). It is also unclear as to whether re-roofing intervals and warranties will allow for rooftop placement. In total, 34 Sites were identified and are grouped in three categories:

1) NREL Collegiate Solar Cup Sites – 18 Locations
2) Parking Lot Sites identified by EEA – 11 Locations
3) Highly Visible Walkway Sites identified by EEA – 5 Locations

Metric	NREL Sites	Parking Lots	Walkways	Total
Capital Cost	$59.9M	$56.9M	$2.9M	$119.7M
Solar PV MW Capacity	12.19	8.42	0.57	21.18
Cost Savings/Year**	$1.7M	$1.1M	$80,360	$2.86M
Met. Ton Carbon Saved	6,877	4,345	324	11,546

**Does not include parking lot trenching, concrete, paving, or re-striping*

***Considers savings at $0.08/kWh based on current solar PV rate with El Paso Electric*

The tables below summarize the Solar PV opportunity associated with Ag-Science Centers and branch campuses, with energy consumption information (kWh Usage) for comparison to Solar production (Solar kWh). This comparison (Solar Fraction) for each location reflects the percentage of usage offset by solar.

Ag Science Center Summary

Site / Location	Solar PV (KW)	Electricity Use (kWh/Yr)	Solar kWh/Yr	Solar Fraction	4-Hr Battery KW
Leyendecker	381	119,662	666,400	266%	456.44
Los Lunas	Not Available for Solar PV	7,076	Not Available for Solar per Ag Science Leadership		
Alcalde		250,818			
Farmington	1,280	20,579	2,240,000	13,720%	1,534.25
Mora	32	57,706	56,000	47%	38.36
Fabian Garcia	112	157,598	196,000	-	134.25
Corona	9,757	317,502	17,075,520	6,650%	11,695.56
Clayton	256	620,310	448,000	72%	306.85
Clovis	620	256,781	1,085,000	342%	743.15
Artesia	1,120	16,326	1,960,000	1,244%	1,342.47
Tucumcari	1,716	532,069	3,003,000	5,204%	2,056.85
Total	15,274	1,824,359	26,729,920	1,465%	18,308.16

**Energy data was not available for the Fabian Garcia Center therefore it is excluded in the above*

It should be noted that Ag Science Centers have the potential to increase electricity use by 227% if natural gas and propane equipment are electrified. Should this occur, the overall solar fraction is reduced to 646%, meaning that with additional electrical consumption the proposed solar sites will generate an excess of 22,594 MWh per year. This excess should be considered for exporting potential, public-private partnerships, or community solar arrays. In the table below Ag Science Center solar PV production matches current usage, with no excess production; but battery storage capacity is equal to the total potential storage capacity to illustrate how impactful Ag sites could be for community resiliency.

Total NMSU Solar Photovoltaic Opportunity (CO2e MT. – Metric Tons of Carbon Saved)

Site / Location	Capacity (MW)	kWh Usage/Yr	Solar kWh/Yr	Solar Fraction	4-Hr Battery KW	CO2e MT.
Main Campus*	21.2	23,728,880	35,806,630	151%	8,430	11,546
Grants Campus	0.8	1,070,590	1,388,333	130%	950	448
Alamogordo	1.0	1,964,835	1,741,950	89%	1,193	562
DACC (Main)	1.3	473,038	2,222,485	470%	1,522	717
Ag Science	15.27	1,824,359	1,824,359	100%	18,308	588
Total	39.57	29,061,702	42,983,757	148%	30,403	13,860

**Energy use is "net" usage considering the contribution by the Aggie Power solar array*

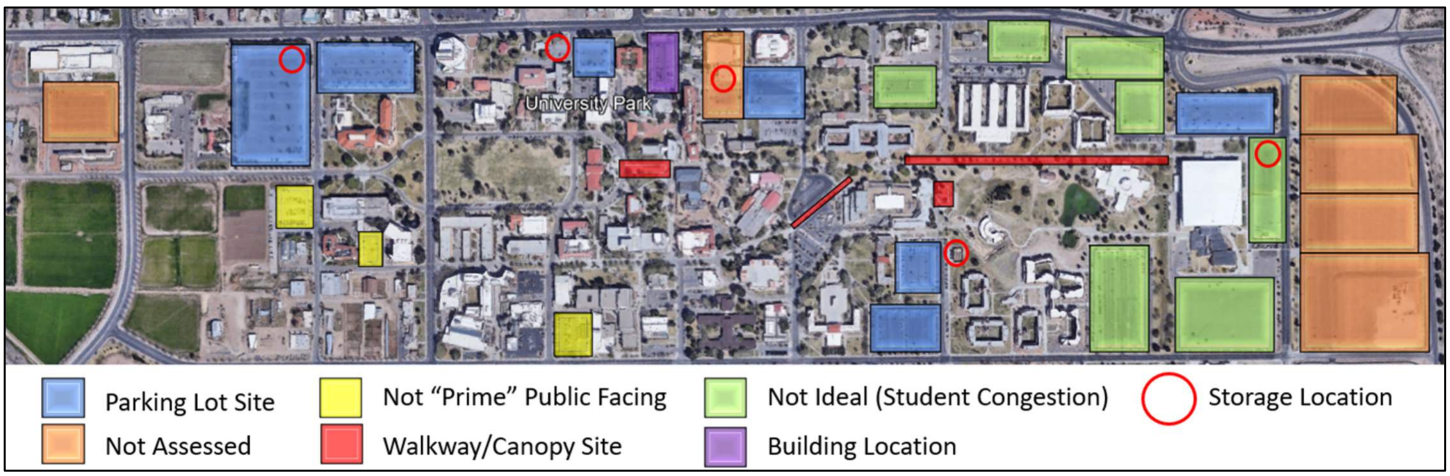
Satellite Plant PV Array Main Campus

Satellite Plate Switchgear

BATTERY STORAGE LOCATIONS

7 Battery Storage Locations

1) Skeen Hall Parking
2) Chemistry Parking
3) Bookstore Parking
4) Corbett South Parking
5) Pan Am East Parking
6) Softball Parking
7) Track & Field Parking



These seven sites were identified for **4-hour discharge** solar energy storage locations, for decentralized placement, for back-feed into more than one medium-voltage circuit. While lithium-ion battery energy storage systems (Li-BESS) is the most likely technology for storage implementation on campus, additional technologies are under development and should become economically viable in 5-10 years.

Li-BESS are currently priced near $400 per kWh and have an energy density equivalent to 1 MWh in the footprint of a 50-foot shipping container. For planning purposes, the University can assume "Qty. Units" below are representative of the number of 50-foot shipping containers required in the associated location.

Location	Size MWh	Qty. Units	Associated PV Capacity and Array(s)	
			MW	Identified Solar Array Location
1) Skeen Hall Parking	3.189	3	2.91	Skeen North (0.91 MW) and Skeen West (2 MW)
2) Chemistry Parking	0.296	1	0.27	Gardiner/Kent (0.27 MW)
3) Bookstore Parking	0.982	1	0.90	Bookstore (0.896 MW)
4) Corbett South Parking	1.280	1	1.17	Corbet Small (0.49 MW) & Corbet Large (0.68 MW)
5) Pan Am East Parking	1.062	1	1.0	Pan Am Center Parking (0.969 MW)
6) Softball Parking	0.810	1	0.74	Softball Parking Lot (0.739 MW)
7) Track & Field Parking	1.578	2	1.44	Track & Field Parking Lot (1.44 MW)
TOTAL Li-BESS	9.196	10	8.43	All Li-BESS Identified Above – Est. $3.68M Capex

NOTE: Should the University implement these energy storage projects, retiring the Cogen system will not be an issue

MAIN CAMPUS STORAGE/BATTERY LOCATIONS

The newly constructed Aggie-Power solar farm located on the south end of NMSU's Main Campus utilizes single-axis tracking solar photovoltaic systems and a 1-Megawatt Tesla battery "Mega-Pack." This battery technology utilizes Lithium-Ion battery cells stacked in parallel racks in a modular housing, like a shipping container.

Because the University has experience with this technology, and has regional precedent, it is recommended that new energy storage systems installed in the next 5 years incorporate the same technology. Vendors such as Powin and Sungrow offer similar modular storage technologies and are considered equivalent products to the Mega-Pack.

Aggie Power Installation
https://engr.nmsu.edu/news-events/2022/05/epe-solar.html

1 MW battery pack made by Tesla
https://www.tesla.com/en_eu/megapack

While 9.196 MWh of storage was identified on the previous page, for four-hour discharge, additional sites could be identified to allow for staged discharge on a larger scale. For context, the electrification of HVAC systems is likely to add **26.5 GWh of usage**, much of which will be "On-Peak" and very costly with increases to demand charges. Pictured below are example systems from two of the other leading BESS manufacturers.

POWIN GRID-SCALE ENERGY STORAGE SYSTEM
https://www.energy-storage.news/powin-energy-supplies-battery-storage-for-microgrid-in-israel-frequency-regulation-in-taiwan/

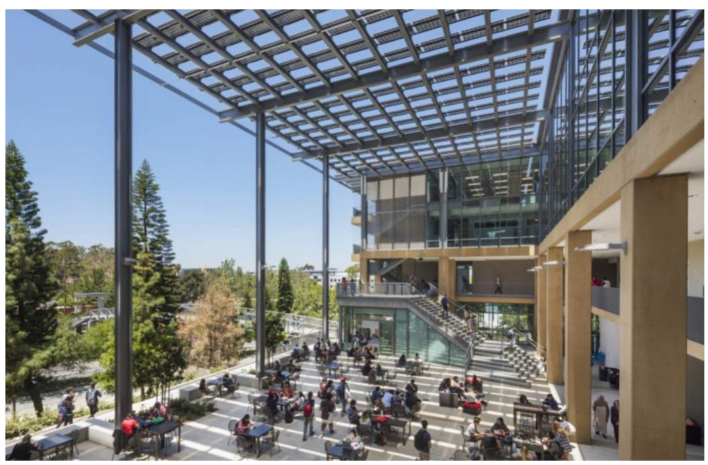
SUNGROW GRID-SCALE ENERGY STORAGE SYSTEM
https://www.pv-magazine.com/2022/01/03/massive-deal-in-israels-growing-energy-storage-market/

SOLAR PV ARCHITECTURAL INTEGRATION

The following renderings were obtained by DLR Group for presentation to the Office of the University Architect, each of which represents an elegant solution for integrating solar PV systems into architecture.

Arizona State University Parasol Structure (AZ Big Media)

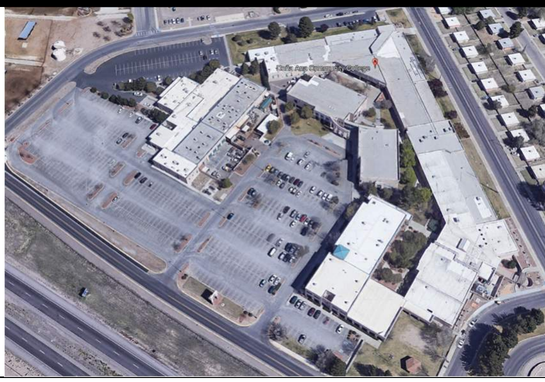
San Diego State University



UC Irvine

BRANCH CAMPUS BREAKDOWNS

DACC Main Campus



If implementing Solar Carports in Parking Lots:

- 10 Carport Groupings = 51,000 square-feet
- 2,125 Modules = 850 KW

If adding Solar PV to available Rooftops:

- 14 Roof Sections/Segments
- 1,050 Modules = 420 KW

Total Solar Potential:

- 1.27 MW Capacity
- 6,089 kWh/Day → 1,522 KW Battery (4 Hr.)

DACC Electricity Use (kWh/Year):

108,999	Learning Resources
94,054	General Classrooms
269,985	Technical Studies
473,038	Total Annual kWh

If this usage represents 70% of energy used onsite, electrifying the remaining 30% (converting steam/gas systems to electric), usage could increase to 660,000 kWh/year. Because this does not match the total solar potential of 2,222,500 kWh/year, additional load growth and electrification opportunities could be afforded.

Solar PV Potential Breakdown:

- Parking = 1,487,500 kWh/Yr
  - $104,000 Savings/Yr
- Roofs = 735,000 kWh/Yr
  - $51,000 Savings/Yr

Potential Storage Opportunity:

- Parking Arrays = 4,075 kWh/Day
  - 1,018 KW Capacity (4 Hr.)
  - $176,000 Savings/Year
- Rooftop Arrays = 2,013 kWh/Day
  - 503 KW Capacity (4 Hr.)
  - $87,000 Savings/Year

Solar PV Savings are based on $0.07/kWh and Storage Savings are based on $0.12/kWh

Potential Rooftop Solar PV Array Locations

Example Carport Courtesy of GoEnergyLink.com

Grants Branch Campus

The existing solar photovoltaic array (below left) is not operational per discussions with facility management. The array was not reviewed in person by EEA Consulting Engineers but appears to be soiled and degraded. Should the University desire to fill existing parking spaces with new carport arrays, the following data may be helpful in sizing.

Potential Parking Lot Solar Carports

- 10 Carport Groupings = 47,600 square-feet
- 1983 Modules = 793 KW

Grants Campus 3-Year Average Electricity Usage:
1,070,590 kWh/Year (FY 2019-2020 through FY 2021-2022)

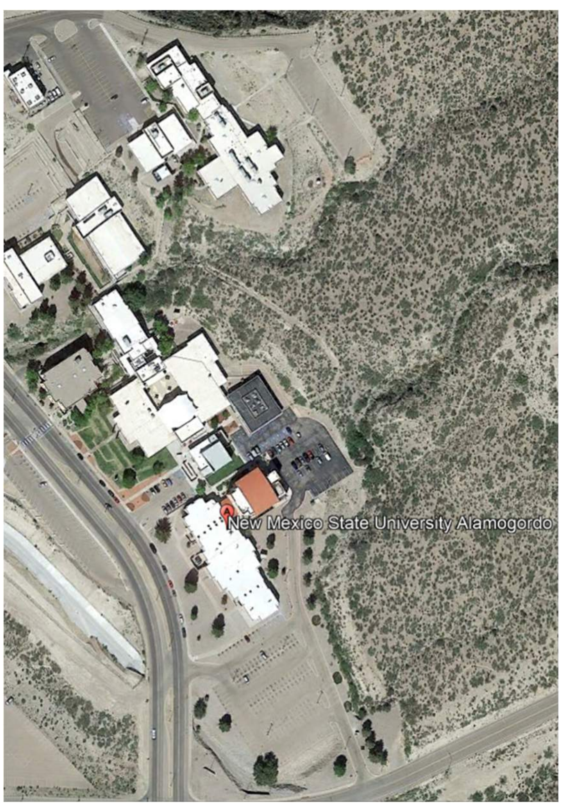
Solar PV Potential:

- 1,388,333 kWh/Year
- $97,000 Savings per Year

Solar Fraction = 130% → *This leaves room for electrification!*

Battery Energy Storage Potential:
3,803 kWh/Day → 950 KW Capacity (4 Hr.)
$164,000 Savings/Year (*360 Days per Year Discharge*)

Alamogordo Branch Campus



Should the University place Solar PV Arrays on Available Rooftops:

- 8 Rooftop Areas = 25,200 square-feet
- 525 Modules = 210 KW

Should existing Parking Lots be covered with Solar Carports:

- 11 Carport Groupings = 47,124 square-feet
- 1,963 Modules = 785 KW

Alamogordo Electricity Usage:
1,964,835 kWh (CY 2021)

Solar PV Potential:

- 995.4 KW → 1,741,950 kWh/Year
- Rooftop = 367,500 kWh/Year
- Parking = 1,374,450 kWh/Year
- $122,000 Savings/Year

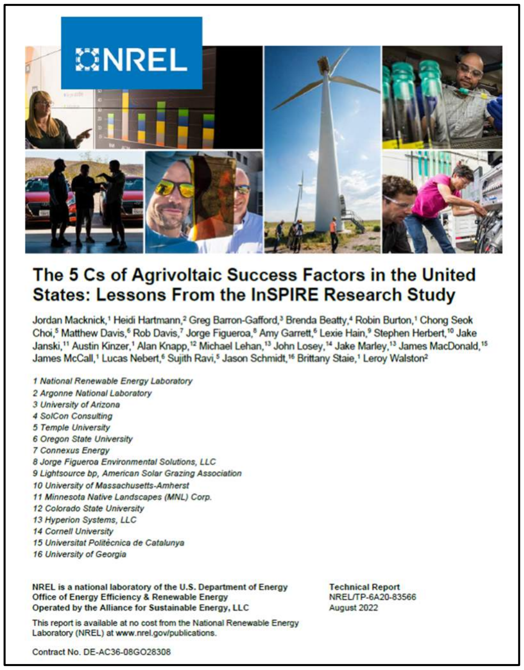
Solar Fraction = 87% Coverage of Annual Electricity Usage

Battery Energy Storage Potential:

- 4,772 kWh/Day → 1,193 KW Total Battery Capacity
- Rooftop = 1,006 kWh/Day → 251 KW Battery (4 Hr.)
- Parking = 3,765 kWh/Day → 941 KW Capacity (4 Hr.)
- $206,000 Savings/Year

AG SCIENCE CENTERS & AGRIVOLTAICS

NREL - The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons From the InSPIRE Research Study



The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons From the InSPIRE Research Study

Jordan Macknick,[1] Heidi Hartmann,[2] Greg Barron-Gafford,[3] Brenda Beatty,[4] Robin Burton,[1] Chong Seok Choi,[5] Matthew Davis,[6] Rob Davis,[7] Jorge Figueroa,[8] Amy Garrett,[6] Lexie Hain,[9] Stephen Herbert,[10] Jake Janski,[11] Austin Kinzer,[1] Alan Knapp,[12] Michael Lehan,[13] John Losey,[14] Jake Marley,[13] James MacDonald,[15] James McCall,[1] Lucas Nebert,[6] Sujith Ravi,[5] Jason Schmidt,[16] Brittany Staie,[1] Leroy Walston[2]

1 National Renewable Energy Laboratory
2 Argonne National Laboratory
3 University of Arizona
4 SolCon Consulting
5 Temple University
6 Oregon State University
7 Connexus Energy
8 Jorge Figueroa Environmental Solutions, LLC
9 Lightsource bp, American Solar Grazing Association
10 University of Massachusetts-Amherst
11 Minnesota Native Landscapes (MNL) Corp.
12 Colorado State University
13 Hyperion Systems, LLC
14 Cornell University
15 Universitat Politècnica de Catalunya
16 University of Georgia

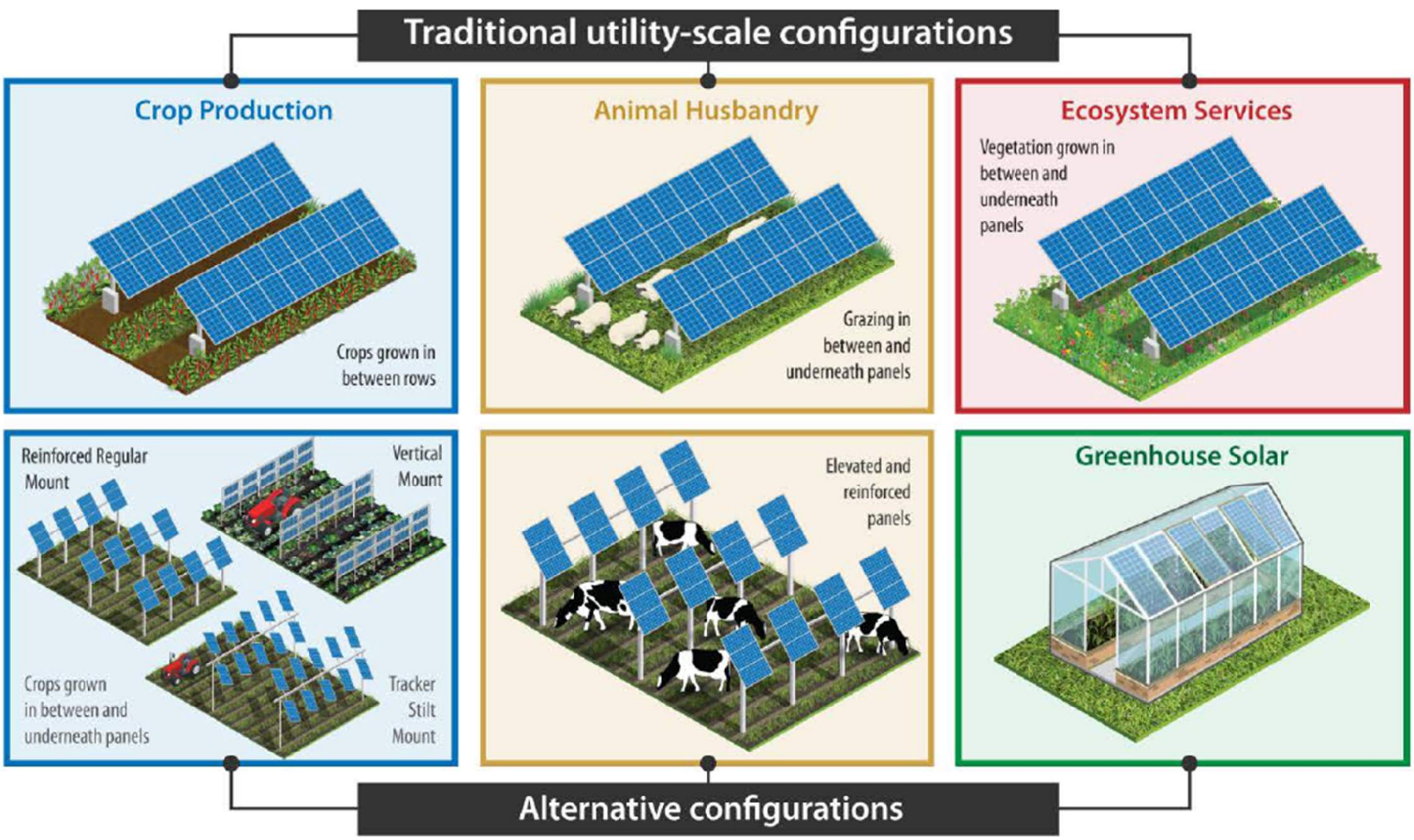
NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

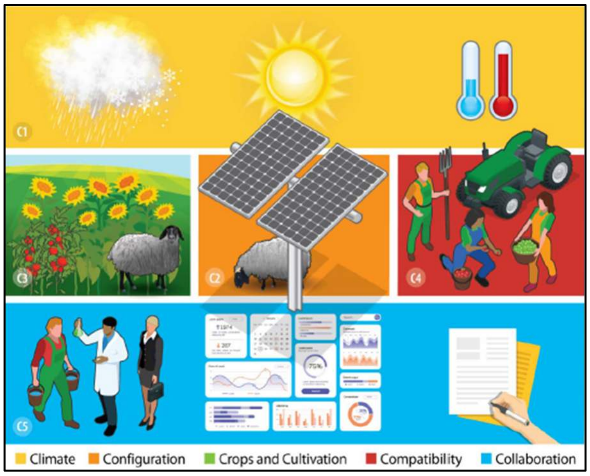
Technical Report
NREL/TP-6A20-83566
August 2022

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Utility scale PV installations are expected to require a minimum of 4 million acres, and up to 11 million acres of land, by 2050 based on solar deployment scenarios (U.S. Department of Energy 2021). Agricultural lands coincide with areas favorable to solar energy deployment; the available solar insolation and stable soil conditions on agricultural lands reduce project risks (Adeh et al. 2019). Farmlands have many characteristics that make them desirable from a solar development perspective, including having existing connections to the electric grid, access roads, and relatively flat ground. These characteristics, combined with the growing economic challenges of traditional farming, have led to solar projects being developed on agricultural lands (Walston et al. 2021). Deployment of solar technologies in rural landscapes has led to community resistance to solar development, similar to the resistance to cellular tower development, wind energy development and oil and gas development (Wilke 2020; Petrova 2013; Thomas et al. 2017; Moore et al. 2021) in some locations throughout the United States.

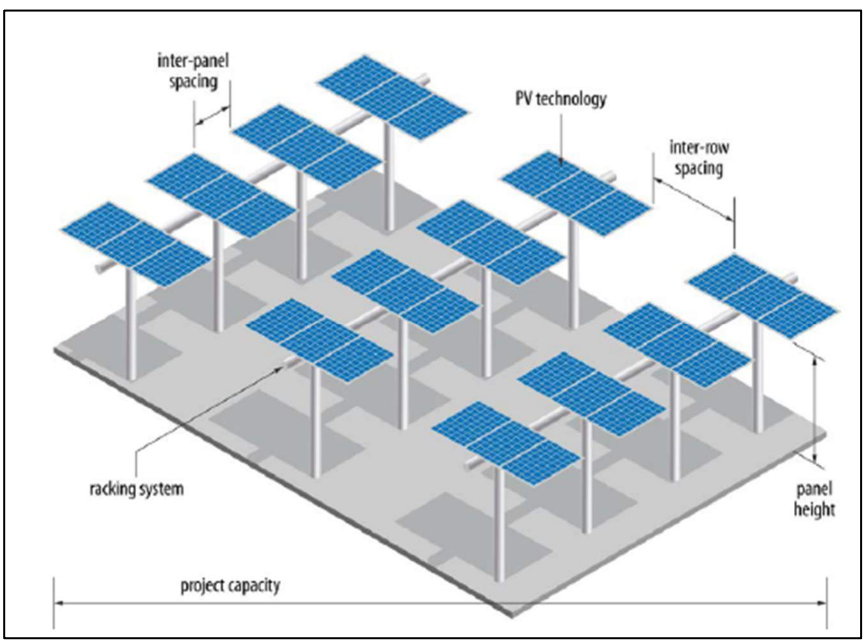




NREL Agrivoltaics Report: 5 C's of Project Success

Lessons learned are categorized into five primary themes, termed "The 5 Cs" (Figure 3):

- **Climate**, Soil, and Environmental Conditions (C1): *The ambient conditions and factors of the specific location that are beyond the control of the solar owners, solar operators, agrivoltaic practitioners, and researchers.*
- **Configurations**, Solar Technologies and Designs (C2): *The choice of solar technology, the site layout, and other infrastructure that can affect light availability and solar generation.*
- **Crop Selection and Cultivation** Methods, Seed and Vegetation Designs, and Management Approaches (C3): *The methods, vegetation, and agricultural approaches used for agrivoltaic activities and research.*
- **Compatibility** and Flexibility (C4): *The compatibility of the solar technology design and configuration with the competing needs of the solar owners, solar operators, agricultural practitioners, and researchers.*
- **Collaboration** and Partnerships (C5): *Understandings and agreements made across stakeholders and sectors to support agrivoltaic installations and research, including community engagement, permitting, and legal agreements.*



Example Configuration from the NREL InSPIRE Research Study

It should be noted that there is significant competitive grant based federal funding for solar photovoltaics, and specifically, the DOE's Foundational Agrivoltaic Research for Megawatt Scale (FARMS) Funding Program awarded funding for projects in 2022 to the following universities and researchers:

- Iowa State University
- Ohio State University
- Rutgers University
- Solar and Storage Industries Inst.
- University of Alaska Fairbanks
- University of Arizona

POTENTIAL AGRICULTURAL SCIENCE / RESEARCH CENTER SOLAR ARRAYS

Leyendecker Agricultural Science Center

The ASC has allocated 47,600 square-feet to solar energy systems.

This area could be allocated as indicated at left, representing 1.09 acres, which could house 952 solar PV modules, or 381 KW (dc).

This array would cost roughly $1.14M and would produce roughly 666,400 kWh per Year.

This size of array could generate $46,648 in cost savings per year and offset 214.88 Metric Tons of Carbon (CO2e).

Based on the sites annual usage of 250,818 kWh, this array would represent 266% of annual usage, which allows for electrification and/or electrical load-growth.

Farmington

The ASC has allocated 160,000 square-feet to solar energy systems.
This area could be allocated as indicated at left, representing 3.67 acres, which could house 3,200 solar PV modules, or 1,280 KW (dc).
This array would cost roughly $3.84M and would produce roughly 2,240,000 kWh per Year. Note: This land is not currently owned by the ASC and approval from NAPI would be required.

This size of array could generate $156,800 in cost savings per year and offset 722.29 Metric Tons of Carbon (CO2e).

Based on the site's annual usage of 16,326 kWh, this array would represent 13,720% of annual usage, which allows for electrification and **significant** electrical load-growth.

Mora

The ASCh has allocated 4,000 square-feet to solar energy systems.

This array could be suspended above plant-benches (as indicated at bottom left), which could house 80 solar PV modules, or 32 KW (dc).

This array would cost roughly $96,000 and would produce roughly 56,000 kWh per Year.

https://www.pv-magazine.com/2022/12/13/novel-agrivoltaic-array-tech-for-greenhouses/

This size of array could generate $3,920 in cost savings per year and offset 18.06 Metric Tons of Carbon (CO2e).

Based on the site's annual usage of 119,662 kWh, this array would represent 47% of annual usage, which does not allow for electrification or electrical load-growth. If a second, similarly sized system were implemented atop a second greenhouse, the total production would likely offset all energy use.

Fabian Garcia

The ASC has allocated 14,000 square-feet to solar energy systems.

This area could be allocated as indicated at left, which could house 280 solar PV modules, or 112 KW (dc).

This array would cost roughly $336,000 and would produce roughly 196,000 kWh per Year.

This size of array could generate $13,720 in cost savings per year and offset 63.2 Metric Tons of Carbon (CO2e).

Annual electricity usage was not provided for this site, but based on an average site's annual usage of 182,436 kWh, this array would represent 107% of annual usage, which allows for electrification and **some** electrical load-growth.

Usage figures must be confirmed prior to acting.

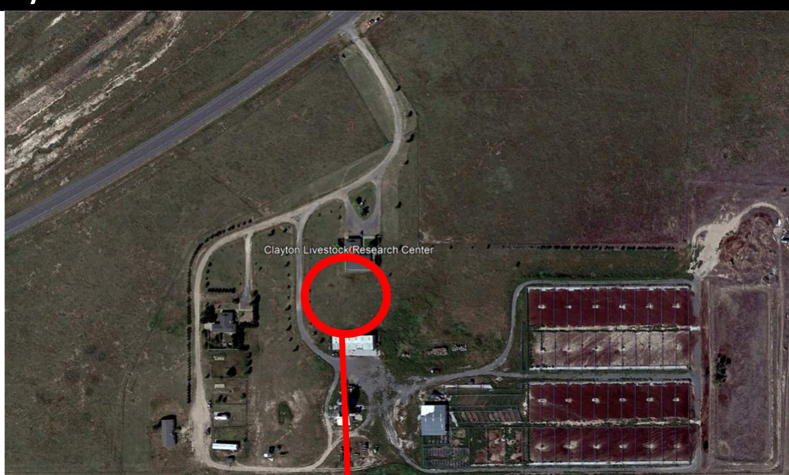
Corona

The ASC has allocated 1.22M square-feet to solar energy systems. This area could be allocated as indicated at left, representing 28 acres, which could house 24,000 solar PV modules, or 9.76 MW (dc). This array would cost roughly $29.27M and would produce roughly 17,075 MWh per Year.

This size of array could generate $1.195M in cost savings per year and offset 5,506 Metric Tons of Carbon (CO2e). This is a high level estimate, as are sizing figures above, and should be verified further.

Based on the site's annual usage of 256,781 kWh, this array would represent much more power than the site's annual usage, which allows for consideration as a P3 or Community-Solar site with the electric utility.

Clayton



The ASC has allocated 32,000 square-feet to solar energy systems. This area could be allocated as indicated at left, representing 0.73 acres, which could house 640 solar PV modules, or 256 KW (dc). This array would cost roughly $1M and would produce roughly 448,000 kWh per Year.

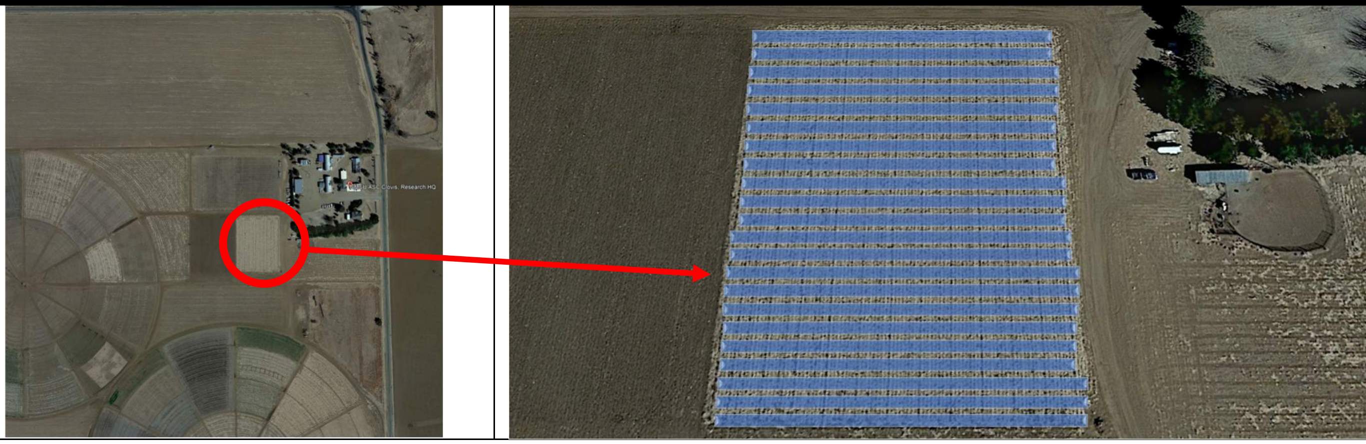
<u>Note</u>: This land is not currently owned by the ASC and approval from NAPI would be required.

This size of array could generate $31,360 in cost savings per year and offset 144.46 Metric Tons of Carbon (CO2e).

Based on the site's annual usage of 620,310 kWh, this array would represent 72% of annual usage, which does not allow for electrification or electrical load-growth.

Should a similarly sized system be planned, doubling the array capacity to 500 KW, there would be significant excess power for electrification and/or load growth.

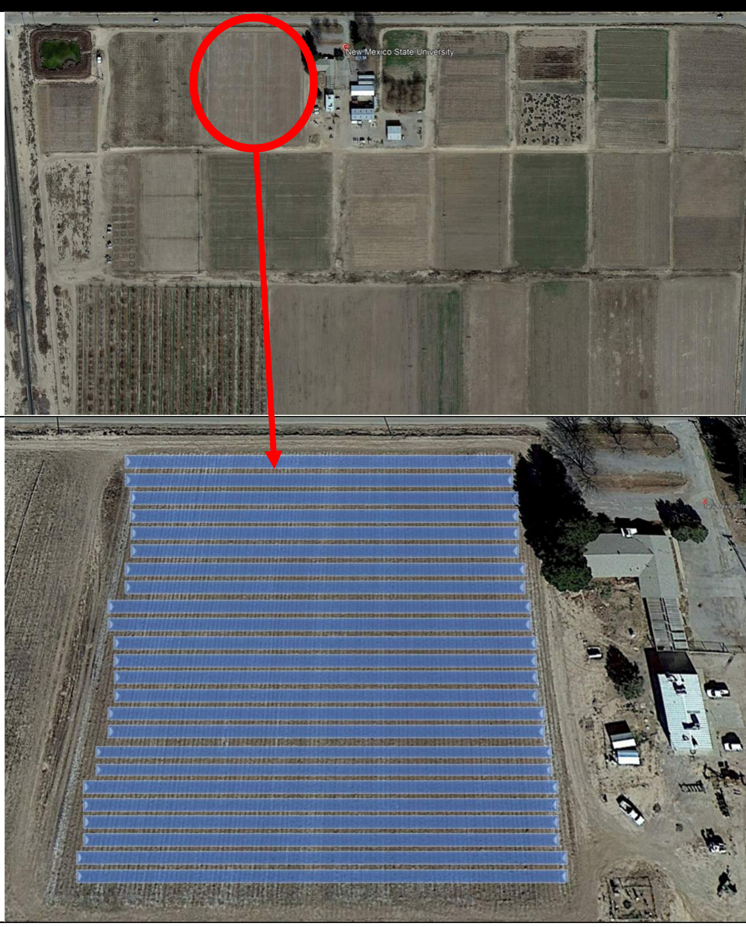
Clovis



The ASC has allocated 77,500 square-feet to solar energy systems, representing 1.78 acres. This area could be allocated as indicated above, which could house 1,550 solar PV modules, or 620 KW (dc).

This array would cost roughly $1.86M and would produce roughly 1,085,000 kWh per Year. This size of array could generate $75,950 in cost savings per year and offset 349.86 Metric Tons of Carbon (CO2e). Based on the site's annual usage of 317,502 kWh, this array would represent 342% of annual usage, which allows for **significant** electrification and/or electrical load-growth.

Artesia



The ASC has allocated 140,000 square-feet to solar energy systems, representing 3.21 acres.

This area could be allocated as indicated at left, which could house 2,800 solar PV modules, or 1.12 MW (dc). Alternately, currently unused land to the south could be utilized.

This array would cost roughly $3.36M and would produce roughly 1,960,000 kWh per Year.

This size of array could generate $137,200 in cost savings per year and offset 632.0 Metric Tons of Carbon (CO2e).

Based on the site's annual usage of 157,598 kWh, this array would represent 1,244% of annual usage, which allows for **significant** electrification and/or electrical load-growth.

Tucumcari

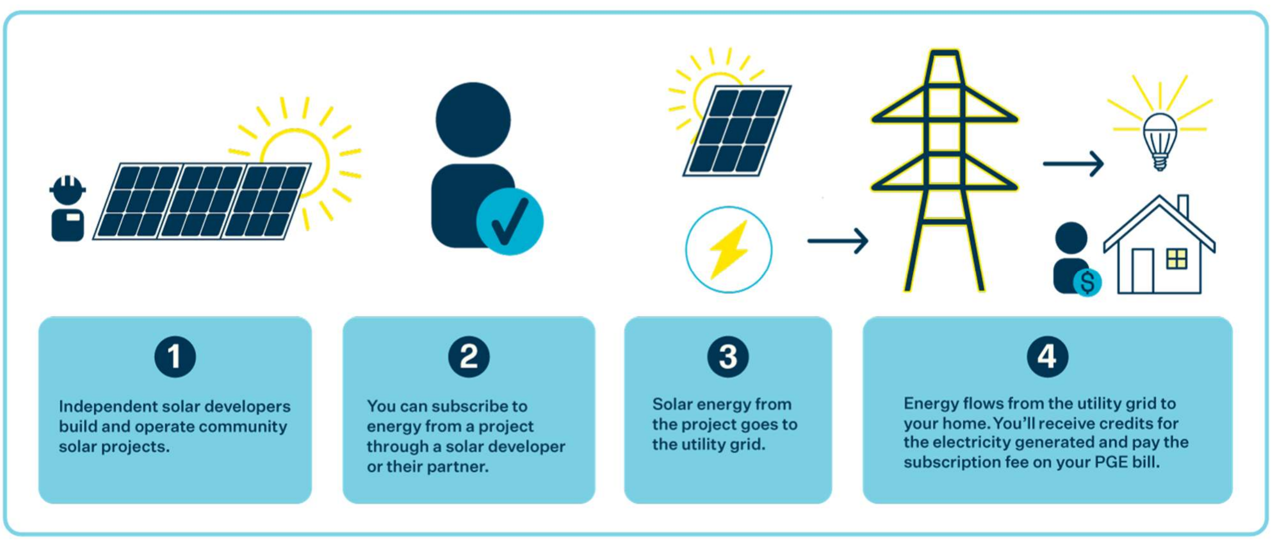
The ASC has allocated 214,500 square-feet to solar energy systems, representing 4.91 acres.

This area could be allocated as indicated at left, which could house 4,290 solar PV modules, or 1.72 MW (dc). This array would cost roughly $5.15M and would produce roughly 3,003,000 kWh per Year.

This size of array could generate $210,210 in cost savings per year and offset 968.32 Metric Tons of Carbon (CO2e).

Based on the site's annual usage of 57,706 kWh, this array would represent 5,204% of annual usage, which allows for **significant** electrification and/or electrical load-growth. This may be a candidate for a P3 solar development agreement or community solar project with the utility company.

EXAMPLE COMMUNITY SOLAR PROCESS



https://portlandgeneral.com/energy-choices/renewable-power/community-solar

Locations Not Considered

The following three locations were not reviewed as part of this study due to their land-ownership (in the case of the Convention Center), and inability to safeguard from vandalism and/or theft (Pan Am Parking).

The open field west of the bookstore was also removed from consideration in this assessment due to the "prime" nature of street-front land and potential architectural master plan growth.

While these three sites would offer tremendous opportunity for both energy generation and the ability to widely showcase NMSU's commitment to Green-Energy, future considerations may make these sites ideal for PV.

Should facilities be constructed west of the bookstore, it is recommended that the building incorporate stree-facing solar photovoltaic canopies (assuming they will have clear access to solar radiation, without shading from associated structures).

Las Cruces Convention Center

Open Field West of the Bookstore

Pan Am Center Far Northeast Parking Lot

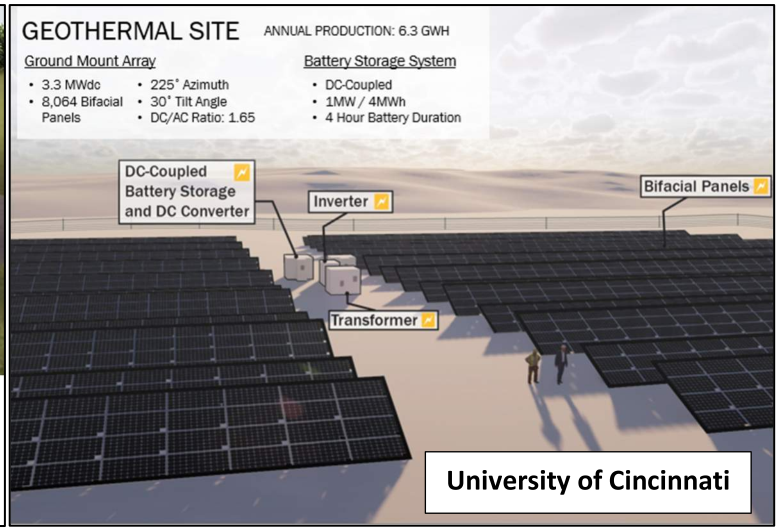
Summary of Rooftop & Strategic Arrays

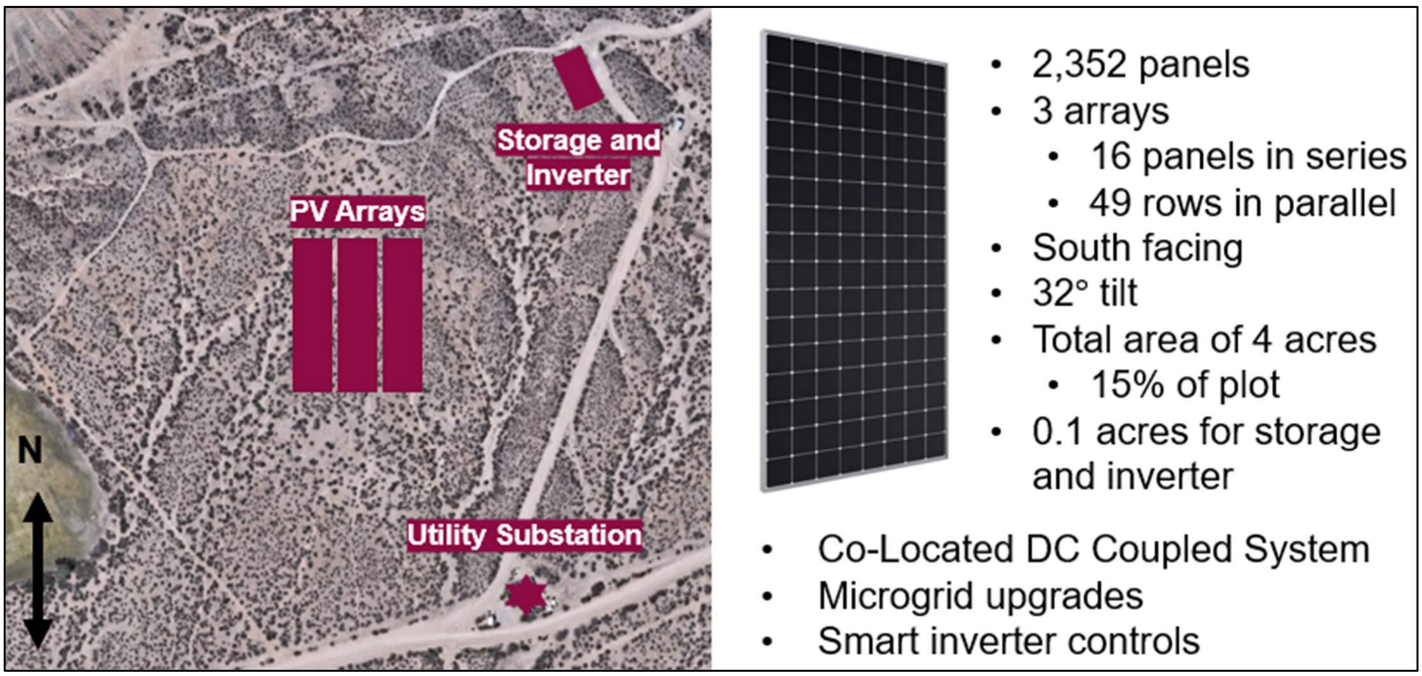
Presented by the NREL/DOE U.S. Department of Energy Solar District Cup Collegiate Design Competition… many teams recommended an array at the Geothermal Circuit-7 location, and for this report two are illustrated below for comparison. Arrays were not selected from respective universities with any ranking and only system size (KW) was obtained from associated presentations, with storage, cost, and savings data performed by EEA.

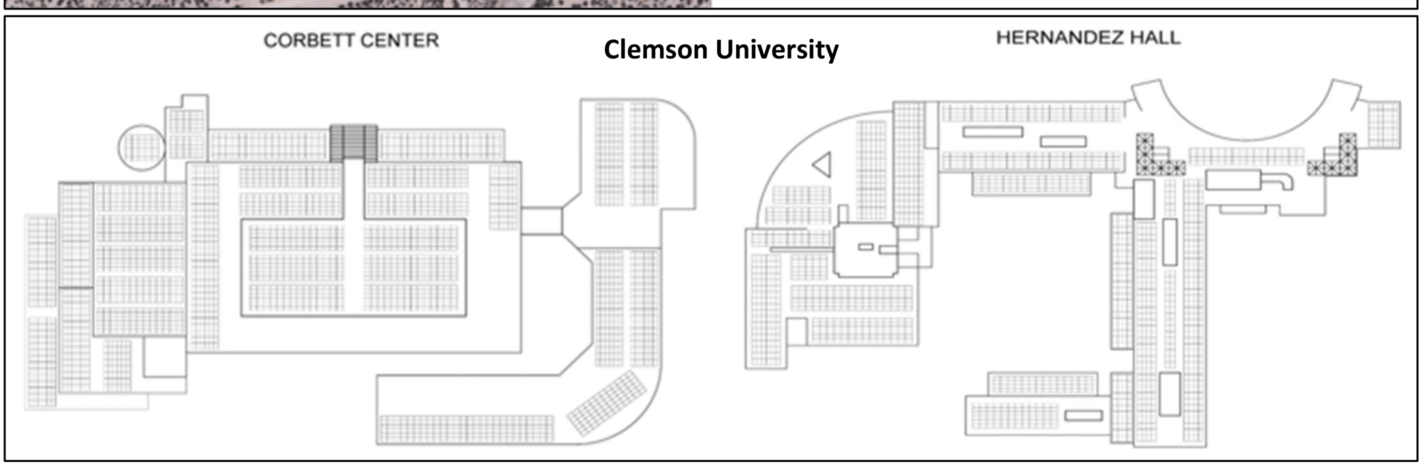
#	SITE	ARRAY SIZE	STORAGE SIZE kWh	ARRAY COST	STORAGE COST	TOTAL COST	ANNUAL SAVINGS	CARBON REDUCTION
1	Geothermal Site[1]	1.1	1,318	$3,300,000	$2,109,589	$5,409,589	$154,000	621
2	Geothermal Site[2]	3.3	3,955	$9,900,000	$6,328,767	$16,228,767	$462,000	1,862
3	Hernandez+Corbett[3]	4.3	5,154	$12,900,000	$8,246,575	$21,146,575	$602,000	2,426
4	Jett Hall[4]	0.282	338	$ 846,000	$540,822	$1,386,822	$39,480	159
5	Goddard Hall[4]	0.105	126	$ 315,000	$201,370	$516,370	$14,700	59
6	Thomas & Brown[4]	0.122	146	$ 366,000	$233,973	$599,973	$17,080	69
7	Branson[4]	0.287	344	$ 861,000	$550,411	$1,411,411	$40,180	162
8	Science[4]	0.380	455	$ 1,140,000	$728,767	$1,868,767	$53,200	214
9	Computer[4]	0.124	149	$ 372,000	$237,808	$609,808	$17,360	70
10	Breland[4]	0.297	356	$ 891,000	$569,589	$1,460,589	$41,580	168
11	Pan Am[5]	0.792	949	$ 2,376,000	$1,518,904	$3,894,904	$110,880	447
12	Engineering[5]	0.137	164	$ 411,000	$262,740	$673,740	$19,180	77
13	Zuhl Library[6]	0.203	243	$ 609,000	$389,315	$998,315	$28,420	115
14	Chamisa[6]	0.223	267	$ 669,000	$427,671	$1,096,671	$31,220	126
15	Financial Services[6]	0.241	289	$ 723,000	$462,192	$1,185,192	$33,740	136
16	Corbett Center[7]	0.278	333	$ 834,000	$533,151	$1,367,151	$38,920	157
17	Hadley Pergola[7]	0.016	19	$ 48,000	$30,685	$78,685	$ 2,240	9
18	Total	12.1	14607.71	$36,561,000	$23,372,329	$59,933,329	$1,706,180	6,877

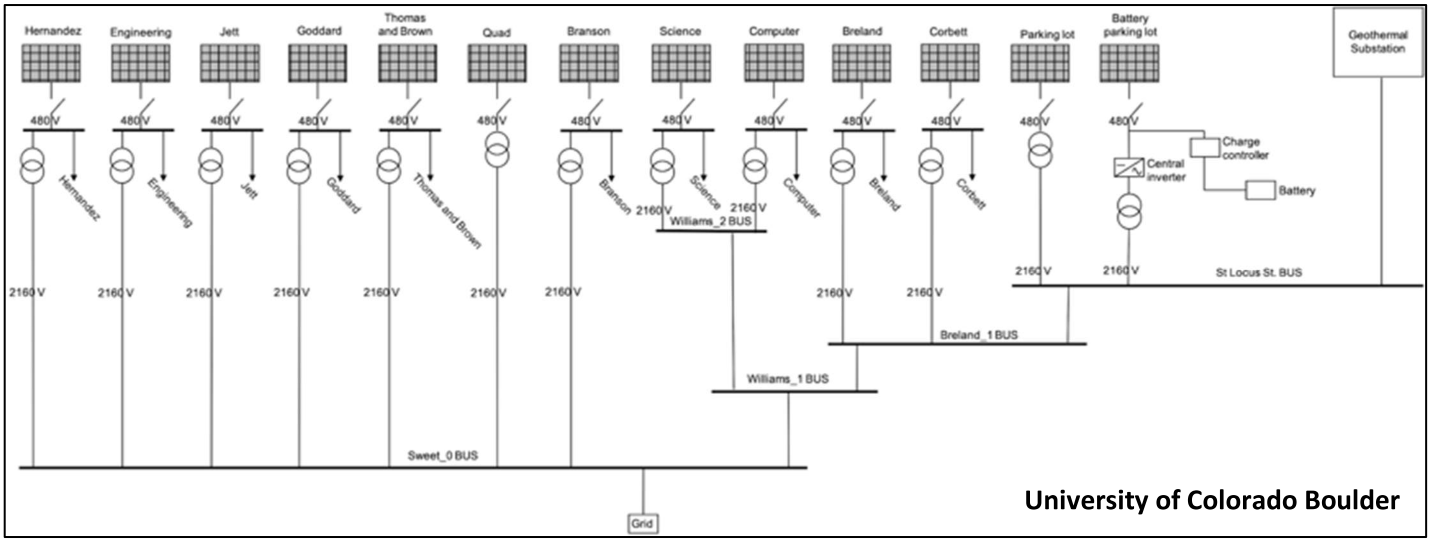
[1] Brown University Site
[2] University of Cincinnati Site
[3] Clemson University Site
[4] CU Boulder Site
[5] Embry Riddle Site
[6] Marquette University Site
[7] West Virginia University Site

DIAGRAMS FROM NREL UNIVERSITY COMPETITIION

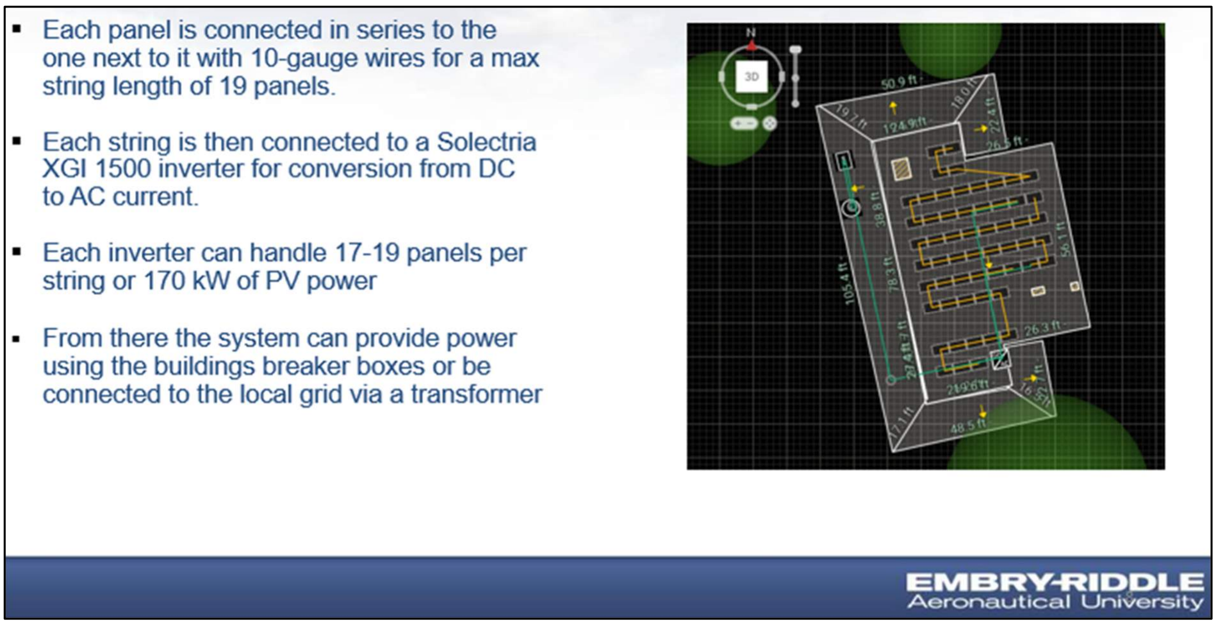




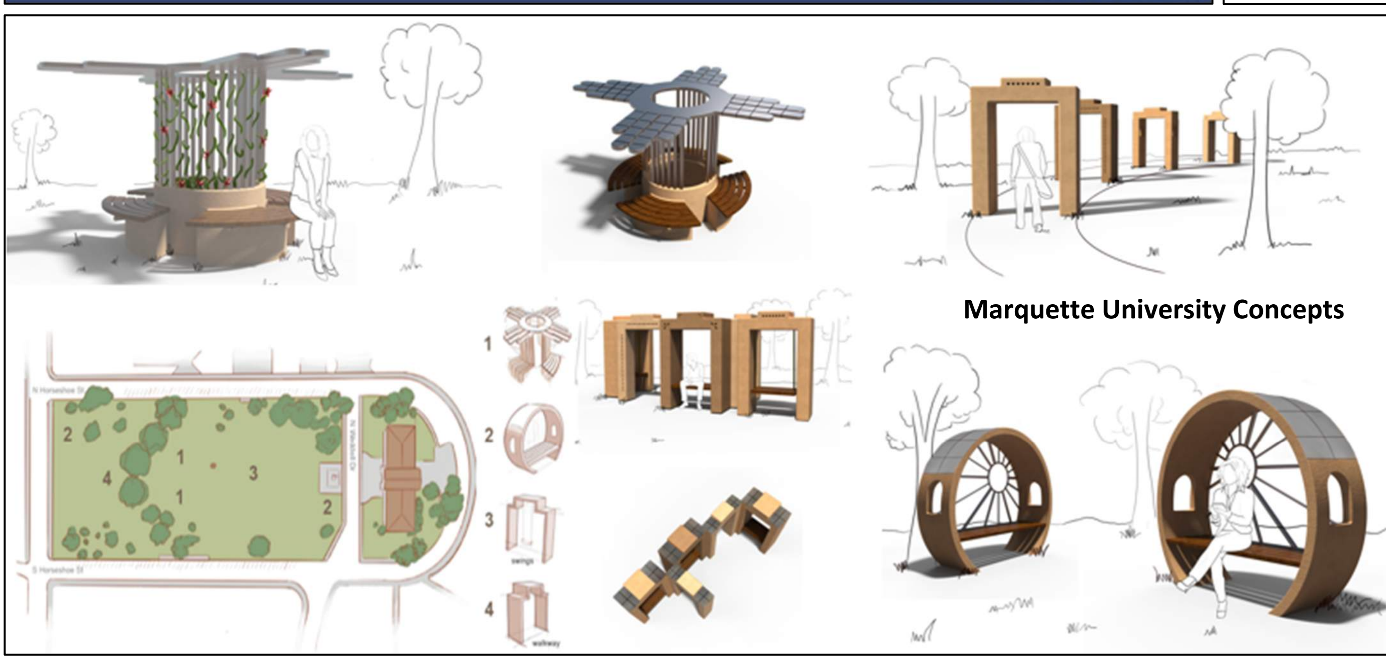




University of Colorado Boulder



Marquette University



Marquette University Concepts

Summary of Potential Parking Arrays

#	SITE	ARRAY SIZE MW	STORAGE SIZE kWh	ARRAY COST	STORAGE COST	TOTAL COST	ANNUAL SAVINGS	CARBON REDUCTION
19	Pan Am Center	0.97	1,062	$4,845,000	$1,699,068	$6,544,068	$124,032	500
20	Skeen North	0.91	997	$4,550,000	$1,595,616	$6,145,616	$116,480	469
21	Gardiner/Kent	0.27	296	$1,350,000	$473,425	$1,823,425	$34,560	139
22	Recycling	0.03	N/A	$150,000	$ 52,603	$202,603	$ 3,840	15
23	Track & Field	1.44	1,578	$7,200,000	$2,524,932	$9,724,932	$184,320	743
24	Softball Parking	0.74	810	$3,695,000	$1,295,781	$4,990,781	$94,592	381
25	Corbet Small	0.49	532	$2,426,500	$850,937	$3,277,437	$62,118	250
26	Corbet Large	0.68	748	$3,412,500	$1,196,712	$4,609,212	$87,360	352
27	Bookstore	0.90	982	$4,480,000	$1,571,068	$6,051,068	$114,688	462
28	Skeen West	2.0	2,192	$10,000,000	$3,506,849	$13,506,849	$256,000	1,032
29	Total	8.42	9,229	$42,109,000	$14,766,992	$56,875,992	$1,077,990	4,345

Summary of Potential Walkway Arrays

#	SITE	ARRAY SIZE KW	ARRAY COST	ANNUAL SAVINGS	CARBON REDUCTION
30	Corbet West	62	$310,000	$ 8,680	35
31	Corbet East	32	$160,000	$ 4,480	18
32	Horseshoe East	167	$835,000	$ 23,380	94
33	Pan Am Walkway	313	$1,565,000	$ 43,820	177
34	Total	574	$2,870,000	$ 80,360	324

POTENTIAL MAIN CAMPUS ARRAYS

Pan Am Center Main Parking Lot

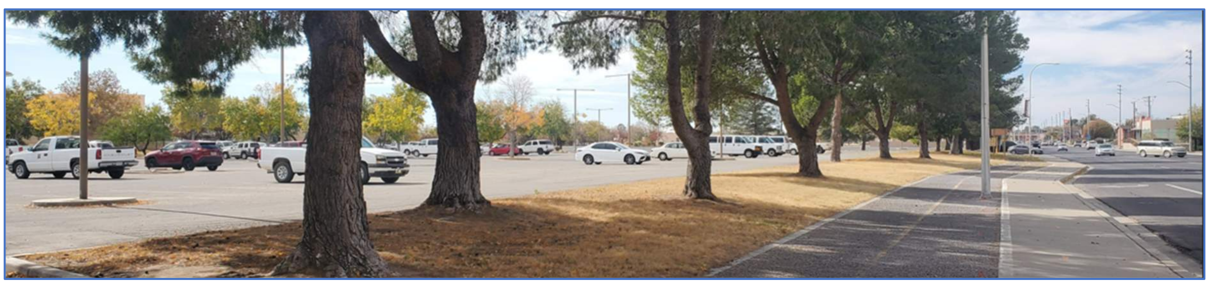
NOTE: Parking lot lighting will need to be removed and relocated within carport structures

- Parking Lot Size: (170-Width x 38-Length) x 9-Rows North/South = 58,140 Sqft
- 2,423 Modules = 969 KW

(There appears to be multiple interconnection locations on each side of the parking lot)

Skeen Hall Parking North

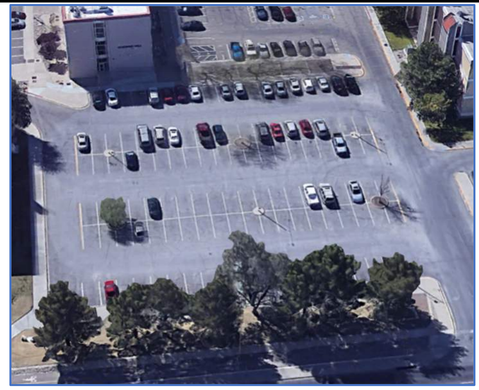
NOTE: Trees are in place within parking barriers and will reduce the overall array size



NOTE: Modules will be highly visible and are not recommended to be installed in the above landscaping barrier, to preserve established trees, though tree roots may be impacted in other locations

- Parking Lot Size: (390-Width x 20-Length) x 7 Rows East/West = 54,600 Sqft
- 2,275 Modules = 910 KW
  *Transformer at northeast corner of the lot

Gardiner & Kent Hall Parking Lot



- Parking Lot Size: (36-Length x 180-Width) x 2.5 Rows East/West = 16,200 Sqft → 675 Modules = 270 KW
    - *1 Row is shaded by trees and the Gardiner Hall*
    - *Transformer is in the Chemistry Building parking lot*

Aggie Recycling Facility

- Estimated Load: 50 HP x 4-Hours/Day x 30-Days/Month = 53,712 kWh/Year (unconfirmed estimate)
- At 1,750 kWh/KW → Roughly 30 KW Array & 77 Modules

Track & Field Parking

Example from PV Magazine

Parking Lot Size:
(495-Width x 35-Length) x 5-Rows North/South = 86,625 Sqft → 3,600 Modules = 1.44 MW

*Vault highlighted at southwest corner of the lot (left)

Softball Field Parking

Parking Lot Size:

- (211-Width x 35-Length) x 6-Groups East/West = 44,310 Sqft
- 1,847 Modules = 739 KW

*Electrical vault clouded at left

Corbet Center South Parking Lots

Small Lot:

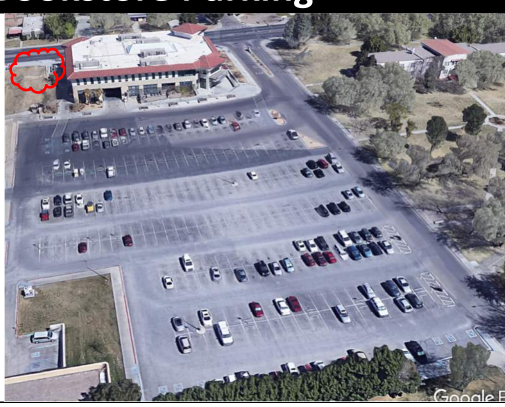
- Parking Size: (208-Width x 35-Length) x 4-Groups North/South = 29,120 Sqft

Large Lot:

- Parking Size: (195-Width x 35-Length) x 6-Groups North/South = 40,950 Sqft

*Switch-gear in electrical yard, clouded at left

Bookstore Parking



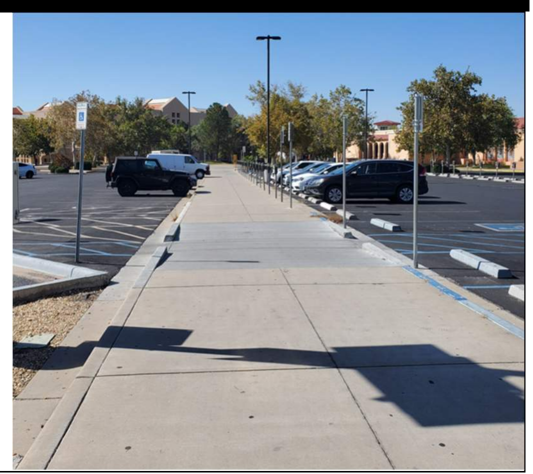
Parking Size:
(256-Width x 35-Length) x 6-Groups North/South = 53,760 Sqft

Transformer located at the northwest corner of the bookstore (cloud at left)

Images from Business Insider and Electric & Hybrid Vehicle Technology International (respectively)

Skeen West

Corbet Center West Promenade/Walkway



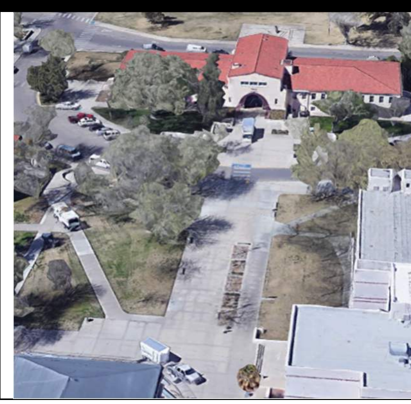
- Creates a shaded walkway and a very visible, dimensions below if just shading the walkway

Corbet Center East Plaza



- Creates a shaded walkway and a very visible – possible location for displays, signage, etc.

Horseshoe East


Examples by Lumos Solar - https://lumossolar.com

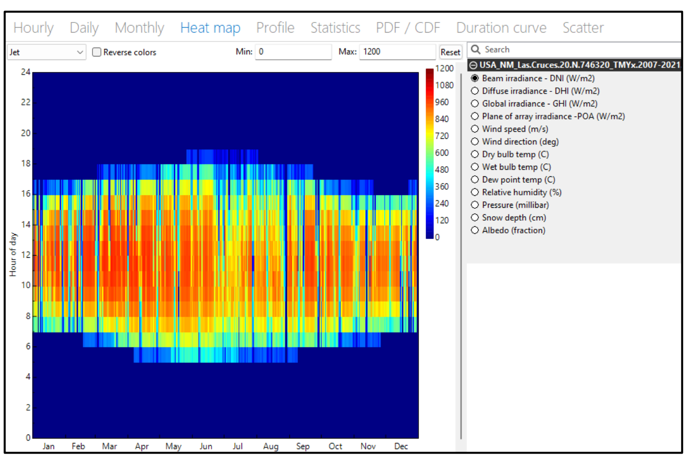
- Creates a shaded walkway and a very visible – possible location for displays, signage, etc.

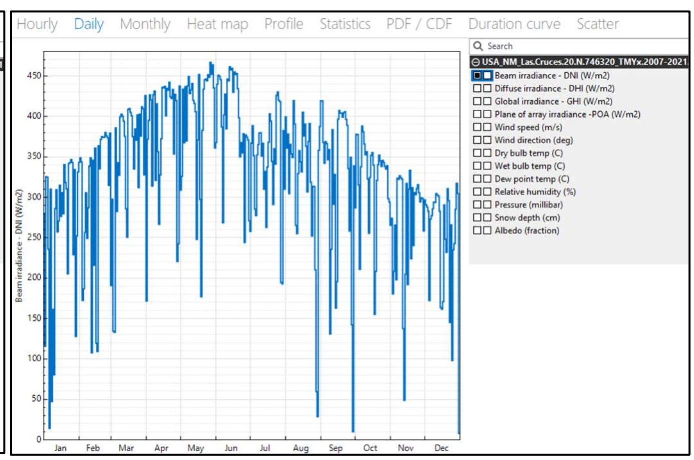
Walkway to Pan Am

- Creates a shaded walkway and a very visible – possible location for displays, signage, etc.

CALCULATION ASSUMPTIONS

- All systems are fixed tilt with an azimuth of 180° (directly south), and a tilt-angle of 32°
- $5/Watt for Modules, Racking, & Structure for Trellis Systems
- $3/Watt for Modules and Racking on Roof-Mount Systems
- $400/kWh for Lithium-Ion Battery Storage (includes soft-costs)
- 1,750 kWh/KW Solar Irradiance Efficiency for Walkway Systems and 1,600 kWh/KW for Parking Structure Systems
- 400 Watts per Module (for EEA PV Locations), DOE/NREL Competition modules vary per site
- 4-Hour Storage Capacity for Batteries (deployed during El Paso Electric Peak)
- 24 Square-Feet per Module when sizing parking-lot systems (racked with no inter-module spacing)
- Carbon Reductions based on EPA Energy Star Target Finder 0.000322 Metric-Tons/kWh for El Paso Electric





2023

APPENDIX D: Agricultural Science Center Energy Data Analysis

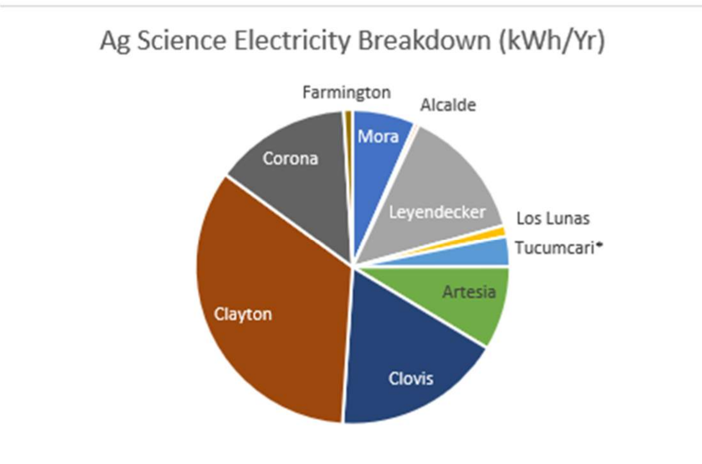
EEA CONSULTING ENGINEERS

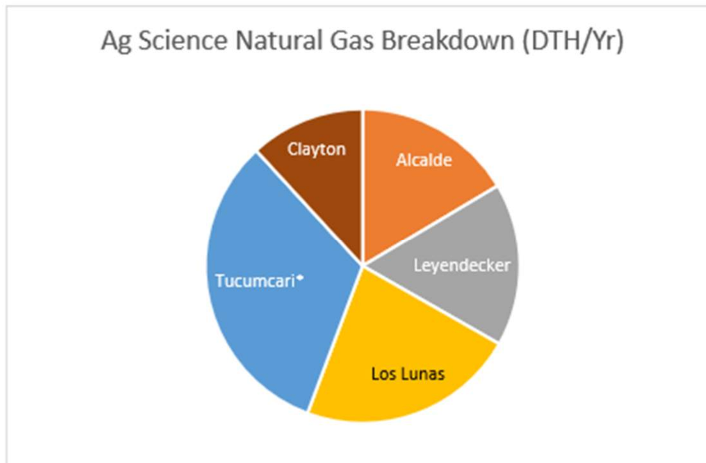
SUMMARY

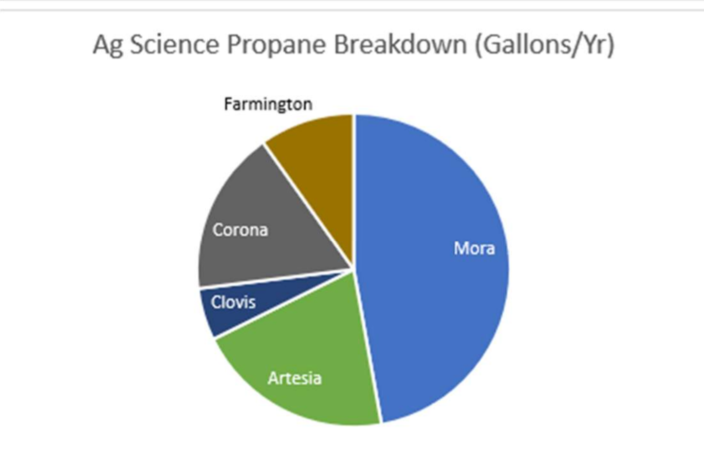
The Ag Science Centers across the NMSU program are statewide centers of excellence in agriculture research and experimentation, offering the University as well as the State of New Mexico a diverse and unique testbed for climate technologies. The twelve locations are not only geographically diverse, representing three of the most abundant climate zones in the United States, but each location conducts research different from one another.

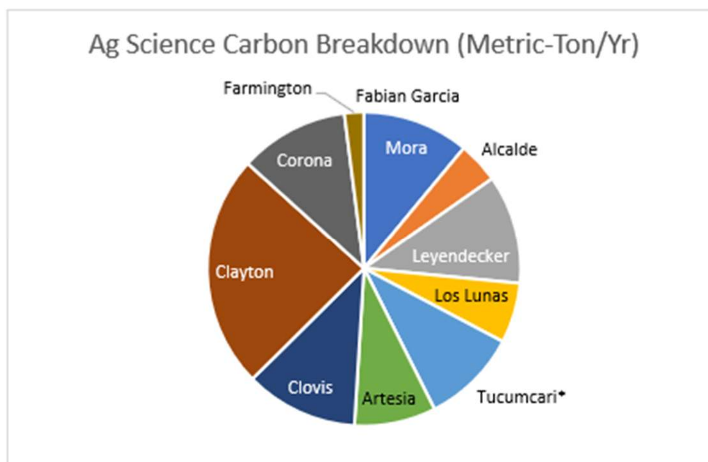
The twelve NMSU Ag Science Centers should leverage the University's ability to educate students and community stakeholders about climate-tech and low-energy agriculture.

To better understand energy consumption and carbon emissions by the Ag-Science Centers, as they relate to overall University contributions, each center's data was assembled and aggregated. The charts below represent Electricity, Natural Gas, and Propane consumption per site as well as associated carbon emissions from consumption.









These graphs indicate that each fuel consumption category is dominated by one or two ASCs, which correspond to higher levels of activity, based on conversations with Agricultural Experiment Station leadership. While this data is helpful to understand relationships among centers, the following page compares this data to NMSU overall.

This table summarizes fuel consumption at each science center, as well as electricity equivalents where natural gas and propane are used, to approximate load-growth should centers abandon fossil fuel heating. As illustrated in Table-2 below, ASCs have a fraction of the overall NMSU carbon emissions, making it difficult to prioritize associated decarbonization efforts.

TABLE-1: AG-SCIENCE CENTERS ENERGY CONSUMPTION COMPARISON

				Electrification						
	Electricity Consumption			Nat. Gas Use			Propane Use			All Electric
Site	Cost	kWh	CO2 MT	DTH	BTU's	kWh Equiv	Gallons	BTU's	kWh Equiv	Total kWh/Yr
Mora	$ 19,827	119,662	46	-	-	-	14,956	1,368,496,875	400,966	520,628
Alcalde	$ 72,283	7,076	3	820	820,427,320	240,383	-	-	-	247,460
Leyendecker	$ 212,335	250,818	81	838	837,688,600	245,441	-	-	-	496,259
Los Lunas	$ 144,120	20,579	8	1,119	1,119,224,000	327,930	-	-	-	348,509
Tucumcari*	$ 7,534	57,706	22	1,619	1,619,000,000	474,363	-	-	-	532,069
Artesia	$ 15,315	157,598	61	-	-	-	6,515	596,110,558	174,659	332,257
Clovis	$ 36,929	317,502	122	-	-	-	1,700	155,550,000	45,576	363,078
Clayton	$ 68,662	620,310	239	590	589,883,256	172,834	-	-	-	793,145
Corona	$ 27,912	256,781	99	-	-	-	5,424	496,329,750	145,423	402,204
Farmington	$ 3,217	16,326	6	-	-	-	3,123	285,745,350	83,723	100,049
Fabian Garcia			-	-	-	-	-	-	-	-
Total	$ 608,135	1,824,359	688	4,986	4,986,223,176	1,460,950	31,718	2,902,232,533	850,346	4,135,656

TABLE-2: NMSU MAIN CAMPUS COMPARISON

DATASET	ELECTRICITY USE	ELECTRICITY CO2e	GAS USE	GAS CO2e	TOTAL CO2e
Main Campus	30,729 MWh/Yr	9,150 Met. Tons	611,936 MBTU/Yr	33,718 M.Ton	42,868 MT
% of University	85%	19%	92%	70%	89%
Ag-Science Centers	1,824 MWh/Yr	688 Met. Tons	7,888 MBTU/Yr	440 Met. Tons	1,128 M.Ton
% of University	5.1%	1.4%	0.7%	0.9%	2.3%

While it is difficult to prioritize decarbonization at ASCs at this point, the following “broad-strokes” recommendations should be enacted to help further the case for funding carbon emission mitigation strategies. These actions will help the Agricultural Experiment Station program provide a stronger business case for additional funding and support, and more importantly, bridge the gap with other NMSU constituents that are unaware of the amazing ASC work. Additionally, further study on the potential cost of electrification at each ASC is recommended for future budgeting purposes.

- All Sites should use a common tracking platform for logging and comparing energy consumption data, adding sub-meters at each site, and tying to the Main-Campus analytics system would simplify this greatly.
- Propose a bi-annual or quarterly energy and carbon committee for sharing research and accomplishments with Branch Campuses and Main Campus stakeholders, helping illustrate how effectively the AES program integrates carbon reduction measures. Involving AS-NMSU in this endeavor would likely prove beneficial.
- Continue working with outside entities for Agrivoltaics research and deployment, creating a center of expertise in high-desert and dry-climate carbon reductions. The findings associated with climate zone specific research around Agrivoltaics can be shared globally, closing the divide in the energy, water, and food nexus.
- Advocate to create a link on the NMSU “Research” area on the University website’s homepage related to “Carbon & Climate Initiatives” underway (e.g. carbon capture, Tucumacari’s reclaimed water-tech, etc.).

In support of the advancement of Agrivoltaics, the following section provides a site-by-site data assessment of each ASC, as it relates to available land, existing energy use, and solar photovoltaic potential. The availability of land was obtained from AES leadership and is provided for context such that useful and arable land must be balanced with future energy project footprint(s) to ensure that land management remains a central focus.

AGRIVOLTAICS

The tables below summarize data in Appendix C (Solar Energy Analysis) and compare available land, as well as annual energy use per site. Table-3 summarizes available land and energy consumption at each site (kWh/Year), whereas Table-4 compares available land to solar photovoltaic (PV) capability for cost savings and carbon reductions (Metric-Tons per Year). As illustrated by "Solar Fraction" in Table-4 the proposed PV electricity production far exceeds the energy consumption at most centers, aside from Mora and Clayton. Should all centers remove natural gas and propane using equipment and "electrify" all energy using assets, Table-5 summarizes associated new "Solar Fractions."

TABLE-3 COMPARISION OF AVAILABLE LAND VS. PROPOSED LAND FOR RENEWABLES

Science Center	Total Acreage	Sq Feet Proposed	Converted to Acreage	Proposed % Acreage	Qty of Solar Modules	Elec. Use/Yr
Leyendecker	203.00	47,600	1.09	0.54%	952	250,818
Los Lunas	210.00	-	0	0.00%	-	20,579
Alcalde	61.00	-	0	0.00%	-	7,076
Farmington	253.00	160,000	3.67	1.45%	3,200	16,326
Mora	118.00	4,000	0.09	0.08%	80	119,662
Fabian Garcia	47.00	14,000	0.32	0.68%	280	-
Corona	27,886.00	1,219,680	28	0.10%	24,394	256,781
Clayton	320.00	32,000	0.73	0.23%	640	620,310
Clovis	160.00	77,500	1.78	1.11%	1,550	317,502
Artesia	160.00	140,000	3.21	2.01%	2,800	157,598
Tucumcari	465.00	214,500	4.91	1.06%	4,290	57,706
Total	29,883.00	1,909,280	43.8	0.15%	38,186	

TABLE-4 AGRIVOLTAICS POTENTIAL

Science Center	PV Wattage	PV KW Capacity	Est. Cost of Array	kWh/Yr Production	Cost Savings/Year	Carbon Savings	Solar Fraction
Leyendecker	380,800	381	$ 1,142,400	666,400	$ 46,648	214.88	266%
Los Lunas	-	-	-	-	$ -	-	-
Alclade	-	-	-	-	$ -	-	-
Farmington	1,280,000	1,280	$ 3,840,000	2,240,000	$ 156,800	722.29	13720%
Mora	32,000	32	$ 96,000	56,000	$ 3,920	18.06	47%
Fabian Garcia	112,000	112	$ 336,000	196,000	$ 13,720	63.20	107%
Corona	9,757,440	9,757	$ 29,272,320	17,075,520	$ 1,195,286	5,506.00	6650%
Clayton	256,000	256	$ 768,000	448,000	$ 31,360	144.46	72%
Clovis	620,000	620	$ 1,860,000	1,085,000	$ 75,950	349.86	342%
Artesia	1,120,000	1,120	$ 3,360,000	1,960,000	$ 137,200	632.00	1244%
Tucumcari	1,716,000	1,716	$ 5,148,000	3,003,000	$ 210,210	968.32	5204%
Total	15,274,240	15,274	$ 45,822,720	26,729,920	$ 1,871,094	8,619.06	1465%

TABLE-5 POTENTIAL SOLAR FRACTION WITH ELECTRIFICATION

Science Center	Proposed Usage	Electrical Increase	New Solar Fraction
Leyendecker	496,259	198%	134%
Los Lunas	348,509	1694%	0%
Alcalde	247,460	3497%	0%
Farmington	100,049	613%	2239%
Mora	520,628	435%	11%
Fabian Garcia	-	0%	-
Corona	402,204	157%	4245%
Clayton	793,145	128%	56%
Clovis	363,078	114%	299%
Artesia	332,257	211%	590%
Tucumcari	532,069	922%	564%
Total	4,135,656	227%	646%

Should ASCs decarbonize through electrification of existing gas appliances/systems, the solar fraction better aligns with the "Electrical Increase" in this Table-5.

This table also illustrates that "load-growth" can occur at most sites, through the addition of electric vehicles and farming equipment. Should sites such as Mora and Clayton see significant load growth, the "Sq Feet Proposed" in Table-3 should be increased, to allow for more solar production.

Important to Note:

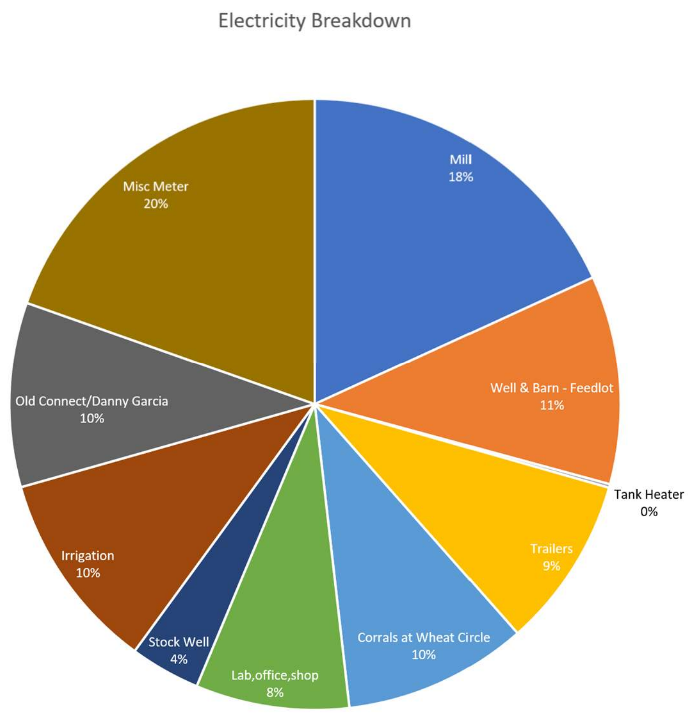
- Clayton experiences high electrical consumption due to industrial energy use from mill and irrigation equipment
- Leyendecker houses a small proof-of-concept Agrivoltaics array
- Corona has eight electricity meters and would benefit from a phased approach to solar, though 24/7 reliability would be key for human and lifestock life safety

EXAMPLE ELECTRICITY END-USE BREAKDOWN

This "end-use" Electricity Breakdown Data from the **Clayton Ag Science Center** illustrates where energy is used. Based on these allocations the following Solar PV arrays could be sized to meet the associated meter/load:

TABLE-6 SOLAR OFFSET OF SPECIFIC END-USES

	Potential Solar PV Arrays		
Meter	KW Capacity	# Modules	First Cost
Mill	52.99	132	$ 158,977
Well & Barn - Feedlot	32.20	80	$ 96,586
Trailers	26.43	66	$ 79,275
Corrals at Wheat Circle	28.31	71	$ 84,917
Lab,office,shop	23.71	59	$ 71,117
Stock Well	10.85	27	$ 32,561
Irrigation	30.84	77	$ 92,512
Old Connect/Danny Garcia	28.49	71	$ 85,471
Misc Meter	57.17	143	$ 171,501
Whole Site	290.41	726	$ 871,235

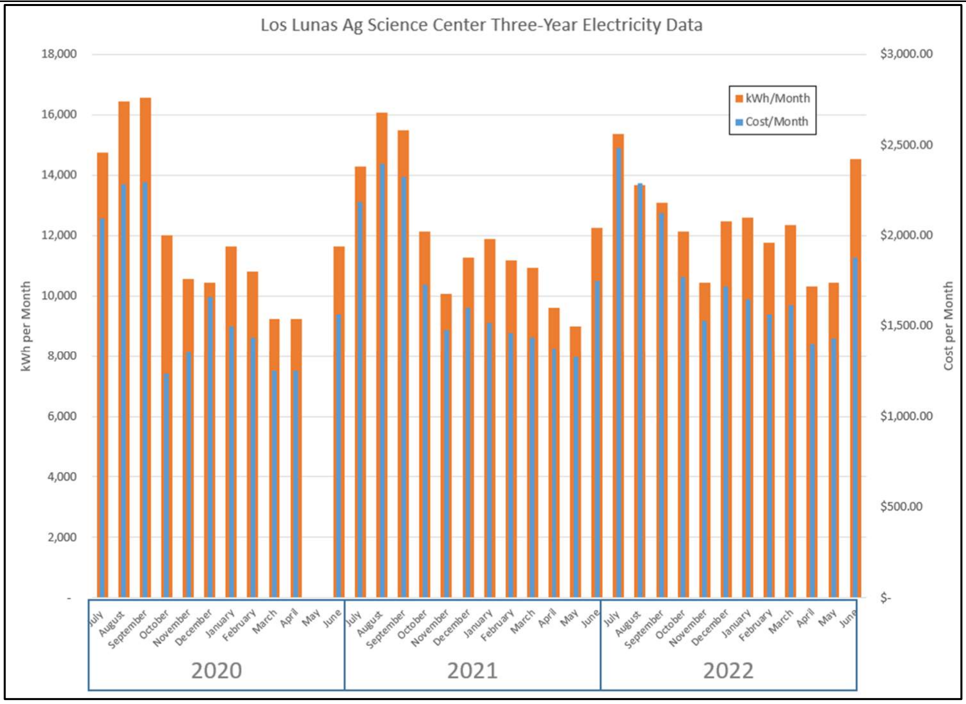


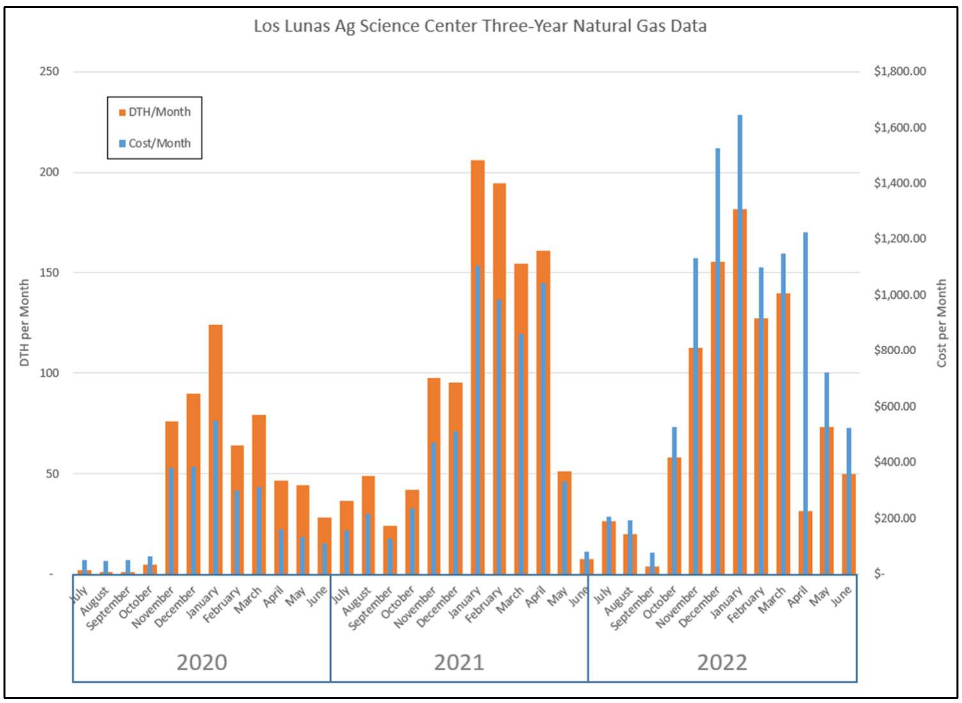
NOTE: While this data may not be representative of other sites, the data above can be interpolated for offsetting specific end-uses at other Ag-Science Centers.

Pilot plant at Heggelbach Farm in Germany, where different crops are grown under PV modules
https://commons.wikimedia.org/wiki/User:Tobi_Kellner

The following pages provide site-by-site summaries of energy consumption data for this assessment. Data was provided by AES leadership and accounts for more than one calendar year to ensure data relevancy. In each case, data that is used for analysis is highlighted green for easy identification.

Los Lunas Center Energy Data





ELECTRICITY

Year	Cost	kWh
2019-20	$17,932.71	133,320
2020-21	$20,579.03	144,120
2021-22	$21,455.94	149,160

NATURAL GAS

Year	Cost	kWh
2019-20	$ 2,549.16	562
2020-21	$ 6,126.30	1,119
2021-22	$10,028.56	979

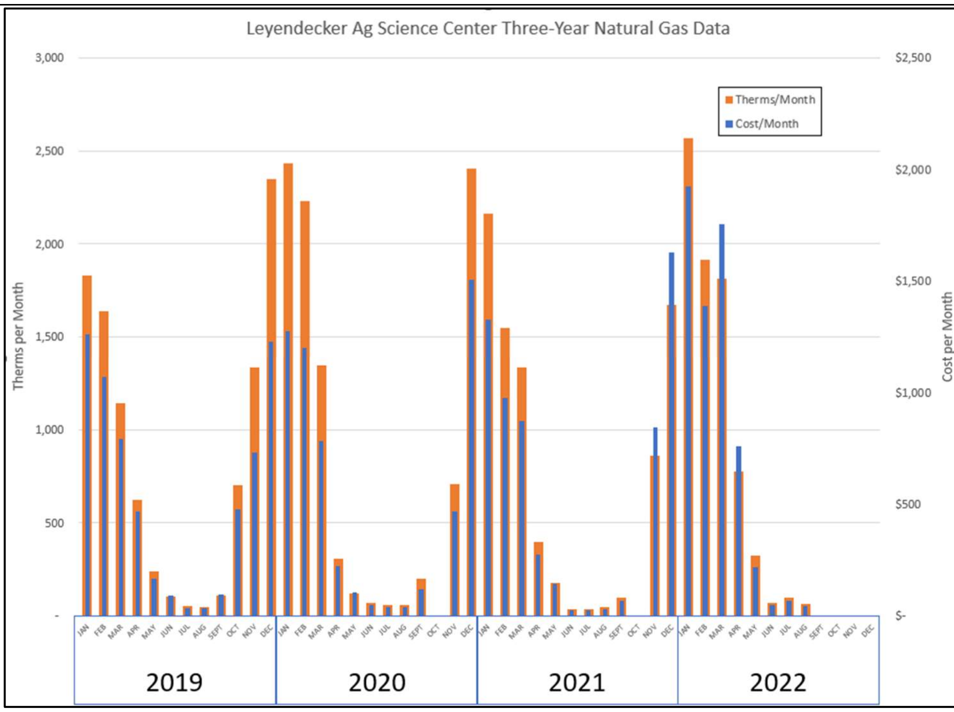
ELECTRICITY OBSERVATIONS:

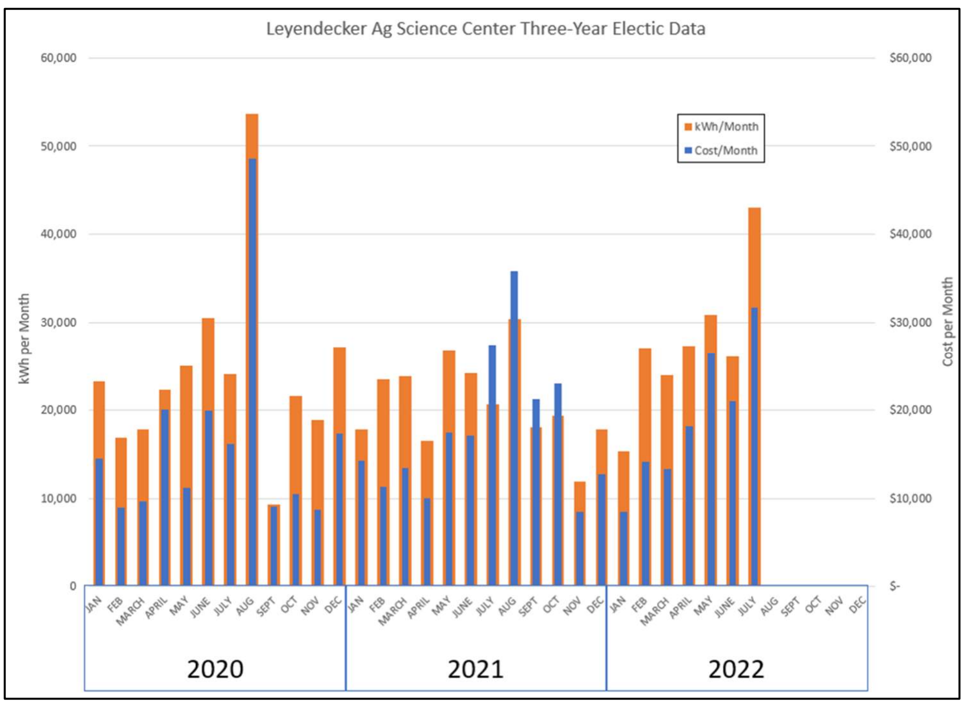
1) Clear Summer Peaking
2) Peak usage is above 16,000 kWh per month
3) Peaks occur in July
4) Summer use is trending downward
5) Base-Load (lowest use) is near 9,000 kWh per month
6) Lowest use occurs in April

NATURAL GAS OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is near 200 DTH
3) Peaks occur in January
4) Winter use is trending down but cost is trending upward
5) Base-Load (lowest use) is near 5 DTH per Month
6) Lowest use occurs in August

Leyendecker Center Energy Data





NATURAL GAS

Year	DTH	Cost
2020	994.69	$ 5,816
2021	837.69	$ 6,221
2022	763.02	$ 6,203

ELECTRICITY

Year	kWh	Cost
2020	290,447	$194,603
2021	250,818	$212,335
2022	193,646	$133,182

(2022 Represents Partial Year)

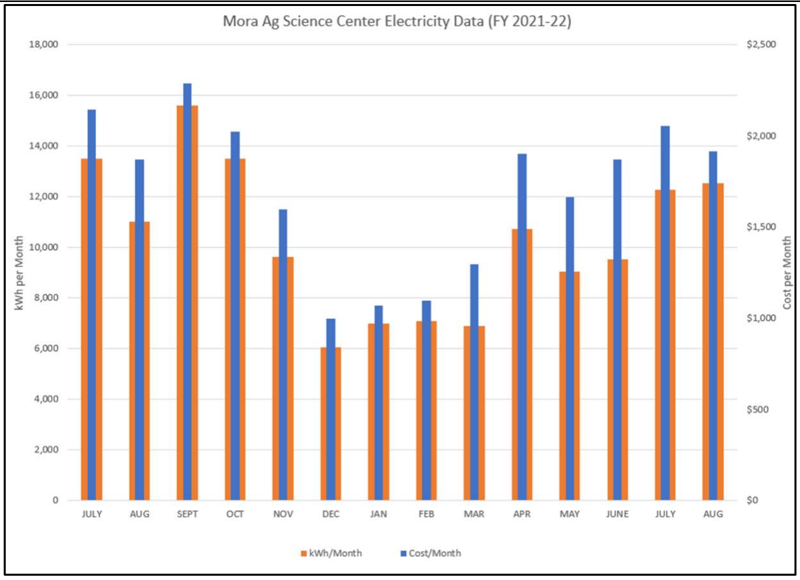
ELECTRICITY OBSERVATIONS:

1) Clear Summer Peaking
2) Peak usage is above 50,000 kWh per month
3) Peaks occur in July
4) Summer use is trending downward
5) Base-Load (lowest use) is near 9,000 kWh per month
6) Lowest use occurs in Sept.

NATURAL GAS OBSERVATIONS:

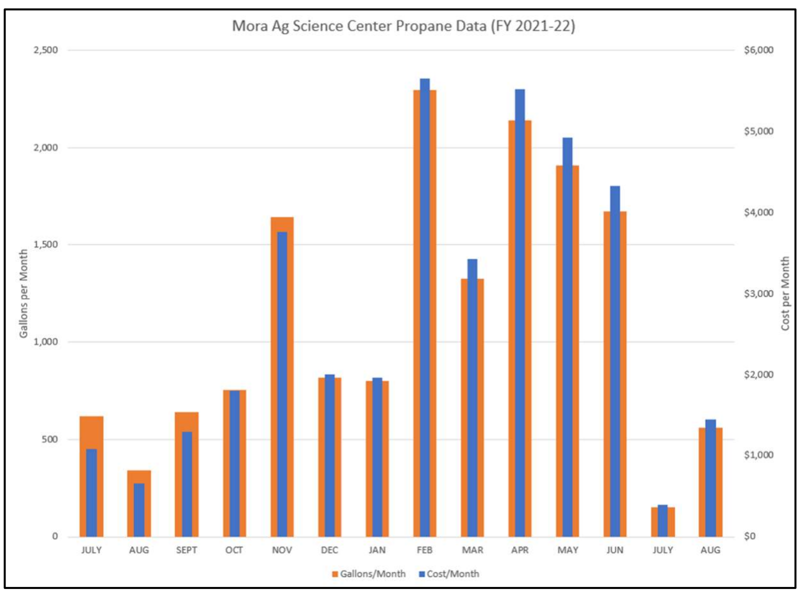
1) Clear Winter Peaking
2) Peak usage is near 2,600 Therms per Month
3) Peaks occur in January
4) Winter use is trending up and so is cost
5) Base-Load (lowest use) is near 100 Therms per Month
6) Lowest use occurs in June

Mora Center Energy Data



ELECTRICITY OBSERVATIONS:

1) Clear Fall Peaking
2) Peak usage is above 15,000 kWh per month
3) Peak occurs in September
4) Summer trending is not discernable
5) Base-Load (lowest use) is near 6,000 kWh per month
6) Lowest use occurs in December



PROPANE OBSERVATIONS:

1) Clear Winter Peaking, but unexpectedly high use in Spring
2) Peak usage is near 2,250 Gallons per Month
3) Peaks occur in September
4) Winter trending is not discernable
5) Base-Load (lowest use) is near 200 Gallons per Month
6) Lowest use occurs in July

ELECTRICITY

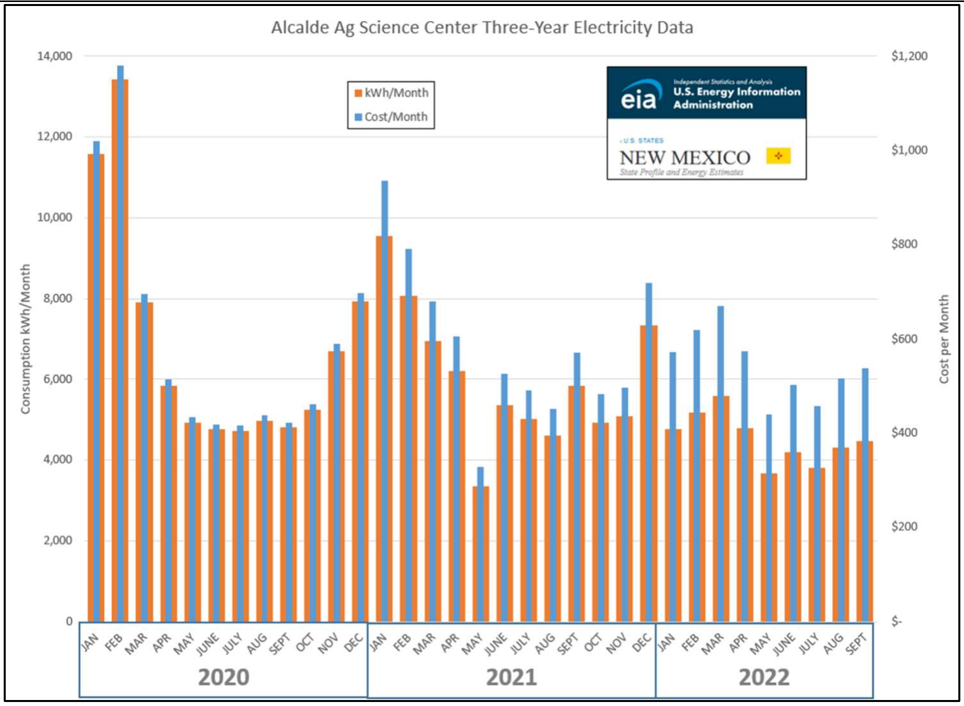
	Month	Amount	KWH
2021	JAN	-	0
	FEB	-	0
	MAR	-	0
	APR	-	0
	MAY	-	0
	JUNE	-	0
	JULY	2,146	13520
	AUG	1,871	11023
	SEPT	2,288	15610
	OCT	2,027	13525
	NOV	1,598	9627
	DEC	996	6060
2022	JAN	1,071	6975
	FEB	1,098	7089
	MAR	1,296	6897
	APR	1,902	10751
	MAY	1,664	9042
	JUNE	1,871	9543
	JULY	2,055	12292
	AUG	1,916	12546
	SEPT	-	0
	OCT	-	0
	NOV	-	0
	DEC	-	0

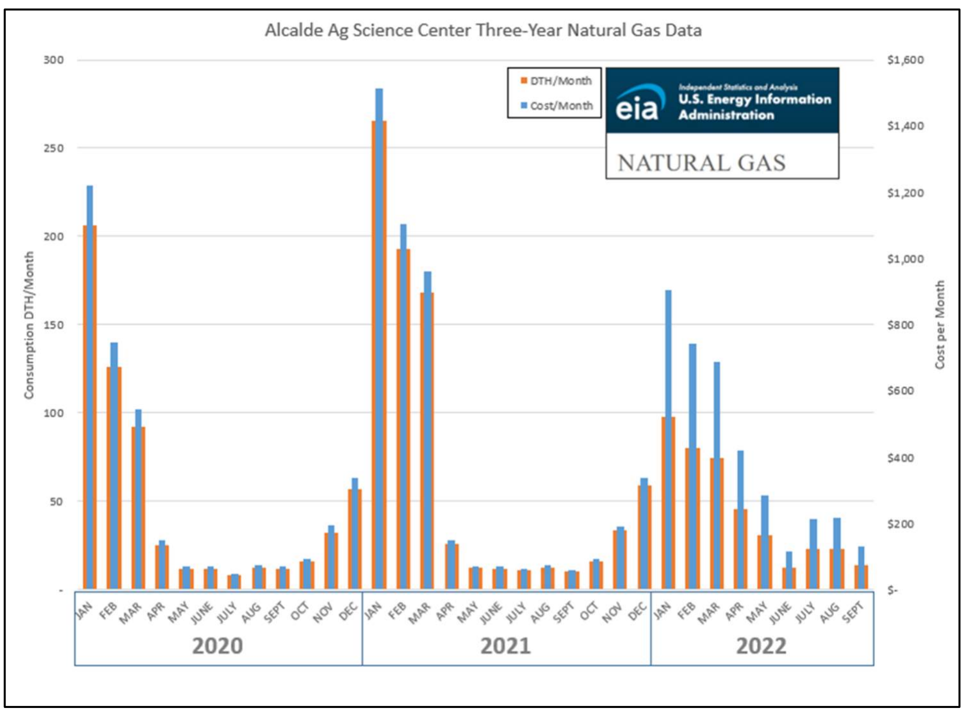
PROPANE

	Month	Amount	Gallons
2021	JAN	$ -	0
	FEB	$ -	0
	MAR	$ -	0
	APR	$ -	0
	MAY	$ -	0
	JUN	$ -	0
	JULY	$ 1,086.40	620.8
	AUG	$ 658.44	339.4
	SEPT	$ 1,298.68	639.3
	OCT	$ 1,804.62	753.8
	NOV	$ 3,758.06	1643.2
	DEC	$ 1,998.47	815.7
2022	JAN	$ 1,965.64	802.3
	FEB	$ 5,652.29	2294.9
	MAR	$ 3,421.86	1326.3
	APR	$ 5,517.59	2140.4
	MAY	$ 4,923.80	1,907
	JUN	$ 4,330.01	1673.3
	JULY	$ 391.13	151.6
	AUG	$ 1,449.69	561.9
	SEPT	$ -	0
	OCT	$ -	0
	NOV	$ -	0
	DEC	$ -	0

(Partial Data was Provided)

Alcalde Center Energy Data





ELECTRICITY

Year	Amount	kWh
2020	$ 7,286	82,799
2021	$ 7,076	72,283
2022	$ 4,888	40,767

(2022 represents partial data)

NATURAL GAS

Year	Amount	DTH
2020	$ 6,102	610
2021	$ 8,204	820
2022	$ 4,014	401

(2022 represents partial data)

ELECTRICITY OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is above 14,000 kWh per month
3) Peaks occur in February
4) Summer use is flat
5) Base-Load (lowest use) is near 3,500 kWh per month
6) Lowest use occurs in May

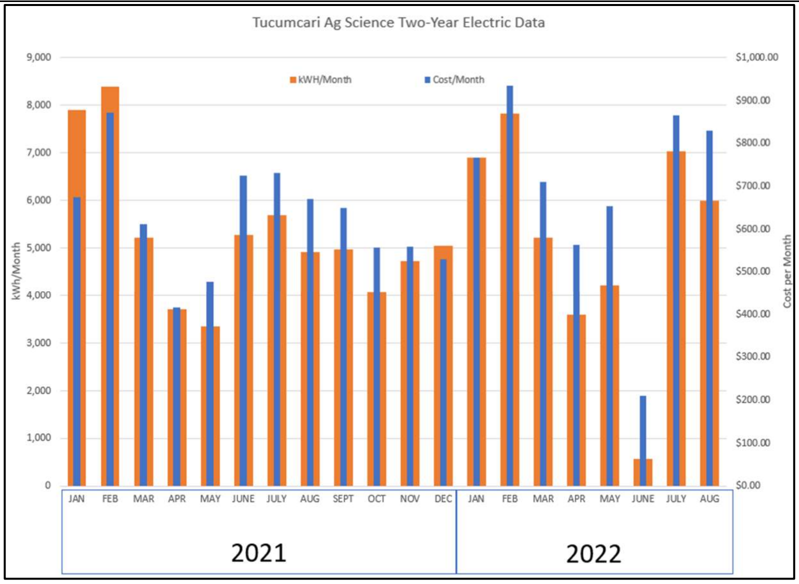
NATURAL GAS OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is near 270 DTH per Month
3) Peaks occur in January
4) Winter use is trending down but cost is trending upward
5) Base-Load (lowest use) is near 20 DTH per Month
6) Lowest use occurs in July

NOTE: *EIA State Energy Costs were used for this site as cost data was not provided.* https://www.eia.gov/totalenergy/data/annual/

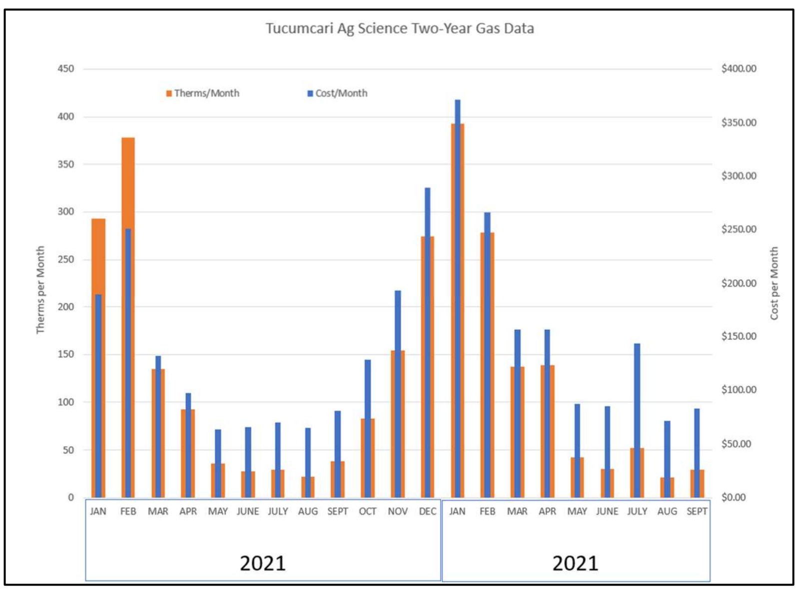
EIA Cost Data for New Mexico		
2020	$	0.09 / kWh
2021	$	0.10 / kWh
2022	$	0.12 / kWh

Tucumcari Center Energy Data



ELECTRICITY OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is above 8,000 kWh per month
3) Peak occurs in February
4) Summer trending is not discernable
5) Base-Load (lowest use) is near 600 kWh per month
6) Lowest use occurs in June



NATURAL GAS OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is near 400 Therms per Month
3) Peaks occur in January
4) Winter trending is not discernable
5) Base-Load (lowest use) is near 25 Therms per Month
6) Lowest use occurs in August

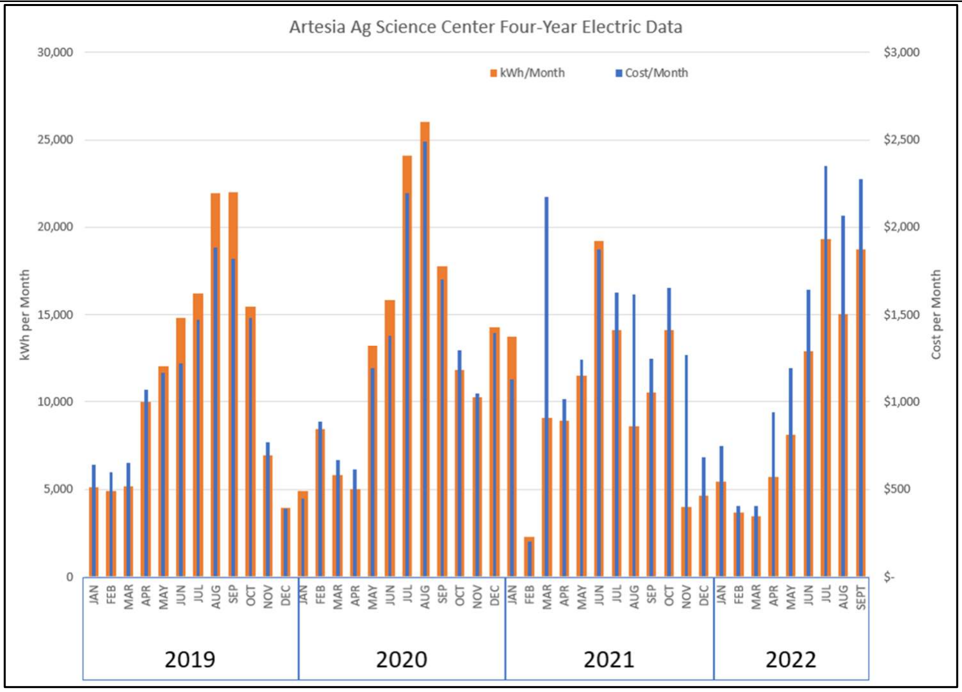
ELECTRICITY

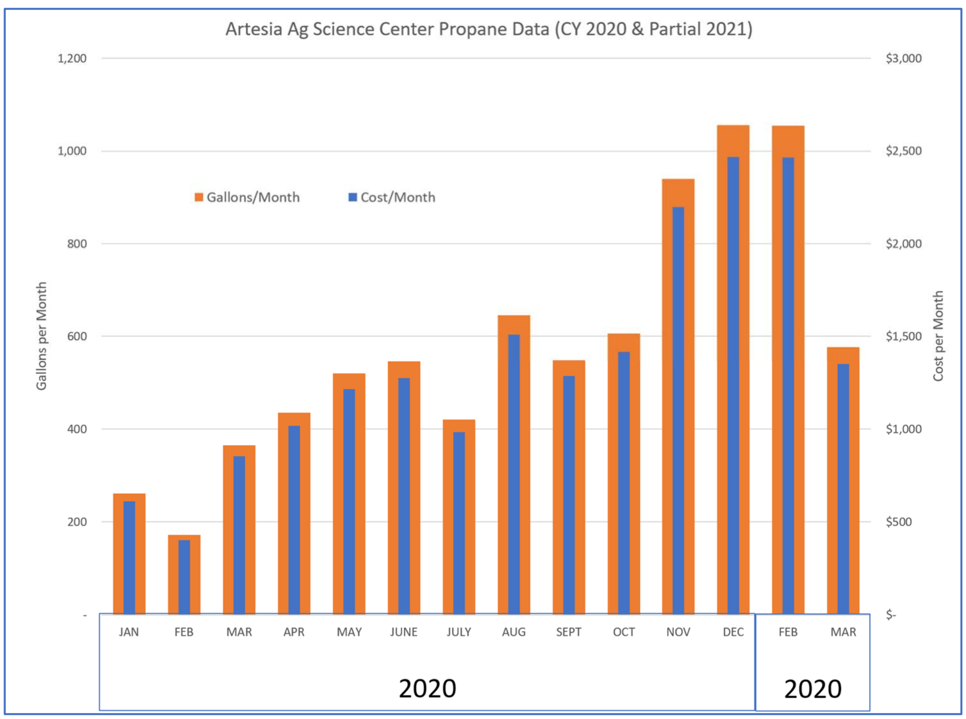
	Month	Cost	kWh
2021	JAN	$ 674.99	7906
	FEB	$ 872.06	8393
	MAR	$ 611.81	5224
	APR	$ 416.50	3697
	MAY	$ 477.07	3342
	JUNE	$ 725.41	5282
	JULY	$ 731.95	5687
	AUG	$ 669.84	4906
	SEPT	$ 649.07	4973
	OCT	$ 556.14	4062
	NOV	$ 559.13	4722
	DEC	$ 529.88	5039
2022	JAN	$ 767.37	6900
	FEB	$ 934.58	7827
	MAR	$ 710.84	5215
	APR	$ 561.90	3588
	MAY	$ 652.75	4222
	JUNE	$ 210.65	565
	JULY	$ 865.04	7028
	AUG	$ 829.10	5991
	SEPT	$ -	0
	OCT	$ -	0
	NOV	$ -	0
	DEC	$ 65.99	226

NATURAL GAS

	Month	COST	THERMS
2021	JAN	$ 189.71	293
	FEB	$ 250.74	378
	MAR	$ 132.05	135
	APR	$ 97.34	93
	MAY	$ 63.82	36
	JUNE	$ 65.63	28
	JULY	$ 69.94	29
	AUG	$ 65.18	22
	SEPT	$ 80.74	38
	OCT	$ 128.70	83
	NOV	$ 193.64	154
	DEC	$ 288.97	274
2022	JAN	$ 371.80	393
	FEB	$ 266.48	278
	MAR	$ 156.61	137
	APR	$ 156.61	139
	MAY	$ 87.73	42
	JUNE	$ 85.21	30
	JULY	$ 143.63	52
	AUG	$ 71.51	21
	SEPT	$ 82.81	29
	OCT	$ -	0
	NOV	$ -	0
	DEC	$ -	0

Artesia Center Energy Data





ELECTRICITY

Year	Cost	kWh
2019	$ 13,155	138,501
2020	$ 15,315	157,598
2021	$ 15,731	120,743
2022	$ 12,032	92,449

PROPANE

Invoice date	Amount Due	Gallons
2/5/2019	$ 610.00	261.02
2/5/2019	$ 402.84	172.37
3/22/2019	$ 854.00	365.43
12/10/2019	$ 1,015.75	434.64
1/30/2020	$ 1,214.12	519.52
4/13/2020	$ 1,273.24	544.82
11/10/2020	$ 983.30	420.75
1/8/2021	$ 1,508.94	645.67
2/4/2021	$ 1,283.45	549.19
3/19/2021	$ 1,415.92	605.87
12/2/2021	$ 2,196.24	939.77
1/18/2022	$ 2,467.45	1,055.82
3/17/2022	$ 2,465.28	1,054.89
3/30/2022	$ 1,348.01	576.81

NOTE: NM Commodity Rate Used to derive usage, at $2.337/Gallon

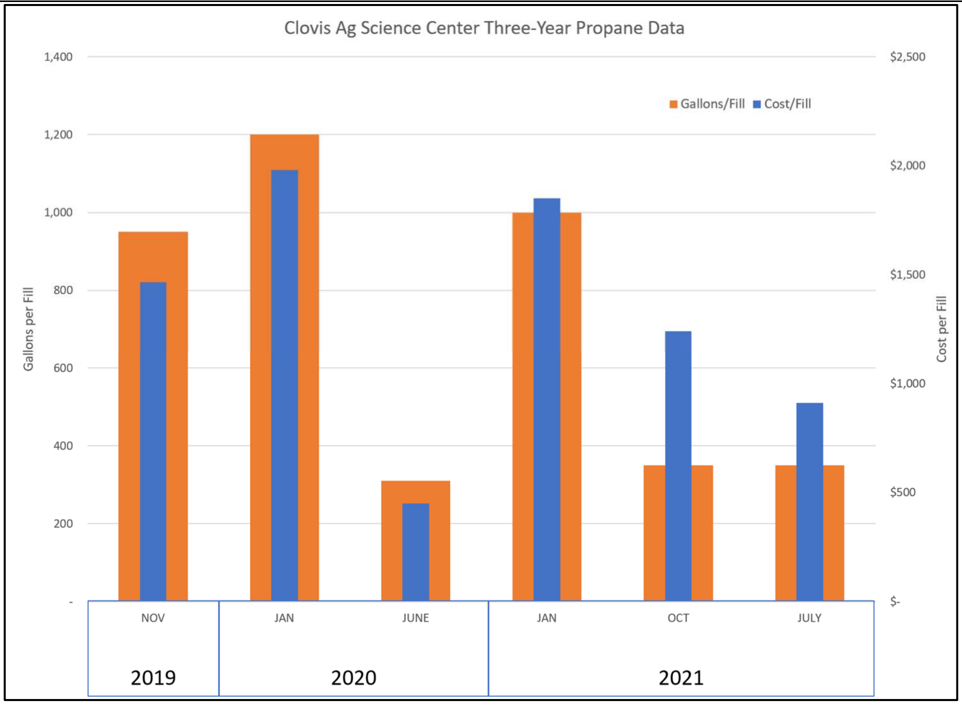
ELECTRICITY OBSERVATIONS:

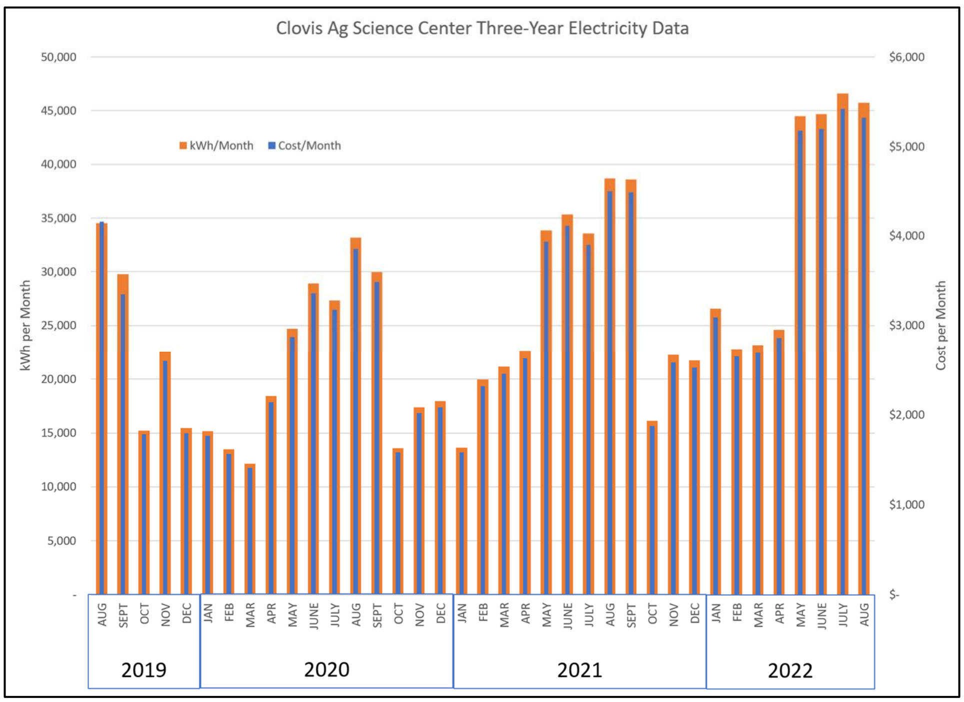
1) Clear Summer Peaking
2) Peak usage is above 25,000 kWh per month
3) Peaks occur in August
4) Summer use is trending downward
5) Base-Load (lowest use) is near 3,500 kWh per month
6) Lowest use occurs in Feb.

PROPANE OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is near 1,050 Gallons per Month
3) Peaks occur in December
4) Winter trend is not discernable
5) Base-Load (lowest use) is near 175 Gallons per Month
6) Lowest use occurs in Feb.

Clovis Center Energy Data





PROPANE

YEAR	MONTH	COST	GAL	RATE
2019	NOV	$1,465.00	950.00	$ 1.34
2020	JAN	$1,980.00	1,200.00	$ 1.65
2020	JUNE	$ 449.50	310.00	$ 1.45
2021	JAN	$1,850.00	1,000.00	$ 1.85
2021	OCT	$1,242.50	350.00	$ 3.55
2022	JULY	$ 910.00	350.00	$ 2.60

JAN/OCT/JULY TOTAL:

Cost	Gallons
$4,002.50	1,700.00

ELECTRICITY

Year	Cost	kWh
2019	$13,690.88	117,562
2020	$29,340.66	252,259
2021	$36,929.14	317,502
2022	$32,415.20	278,693

(2019 & 2022 Partial Years)

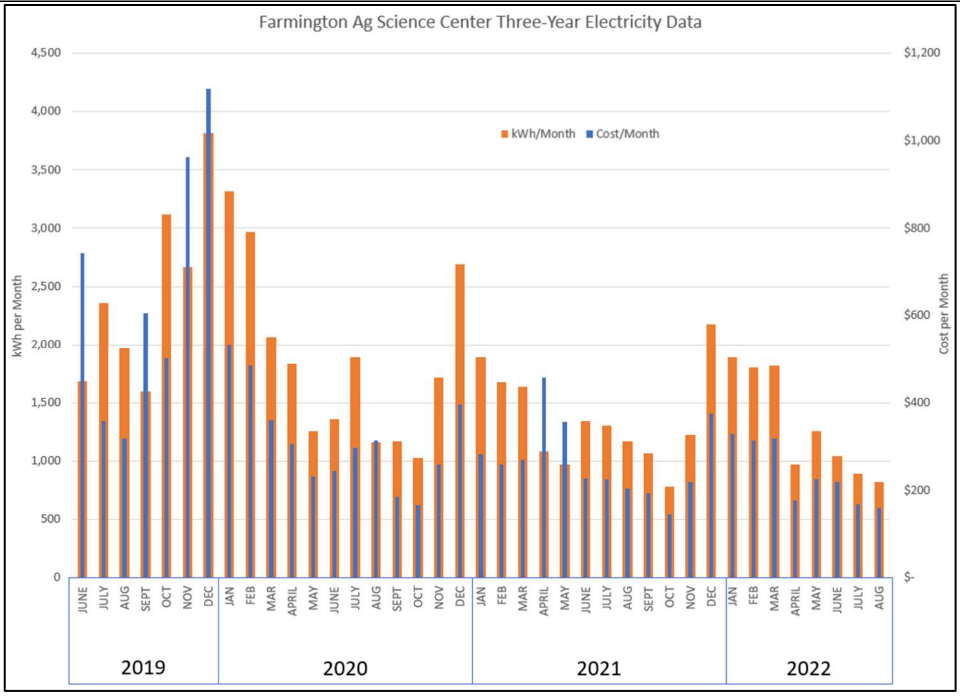
PROPANE OBSERVATIONS:

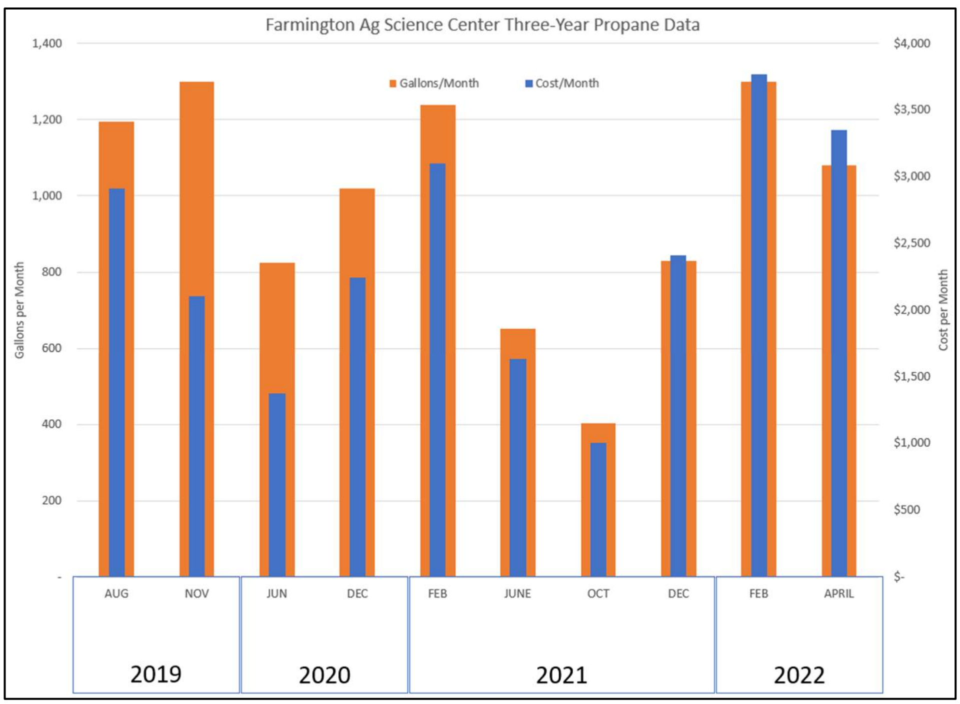
1) Clear Winter Peaking
2) Peak usage is near 1,200 Gallons per Month
3) Peaks occur in January
4) Winter trend is not discernable
5) Base-Load (lowest use) is near 300 Gallons per Month
6) Lowest use occurs in June

ELECTRICITY OBSERVATIONS:

1) Clear Summer Peaking
2) Peak usage is above 45,000 kWh per month
3) Peaks occur in July
4) Summer use is trending up
5) Base-Load (lowest use) is near 14,000 kWh per month
6) Lowest use occurs in March

Farmington Center Energy Data





ELECTRICITY

Year	Cost	kWh
2019	$4,606.64	17,205
2020	$3,780.56	22,459
2021	$ 3,217	16,326
2022	$1,910.84	19,748

(2019 & 2022 Partial Years)

PROPANE

Year	#	Month	Cost	Gallons	Rate
2019	1	AUG	$2,909.72	1,196.00	
2019	2	NOV	$2,106.00	1,300.00	$ 1.62
2020	3	JUN	$1,376.75	824.00	$ 1.67
2020	4	DEC	$2,244.00	1,020.00	$ 2.20
2021	5	FEB	$3,100.00	1,240.00	$ 2.50
2021	6	JUNE	$1,629.00	651.00	$ 2.50
2021	7	OCT	$1,004.75	401.90	$ 2.50
2021	8	DEC	$2,408.45	830.00	$ 2.90
2022	9	FEB	$3,770.58	1,300.00	$ 2.90
2022	10	APRIL	$3,348.62	1,080.00	$ 3.10

	Cost	Gallons
2021 data	$8,142.20	3,122.90

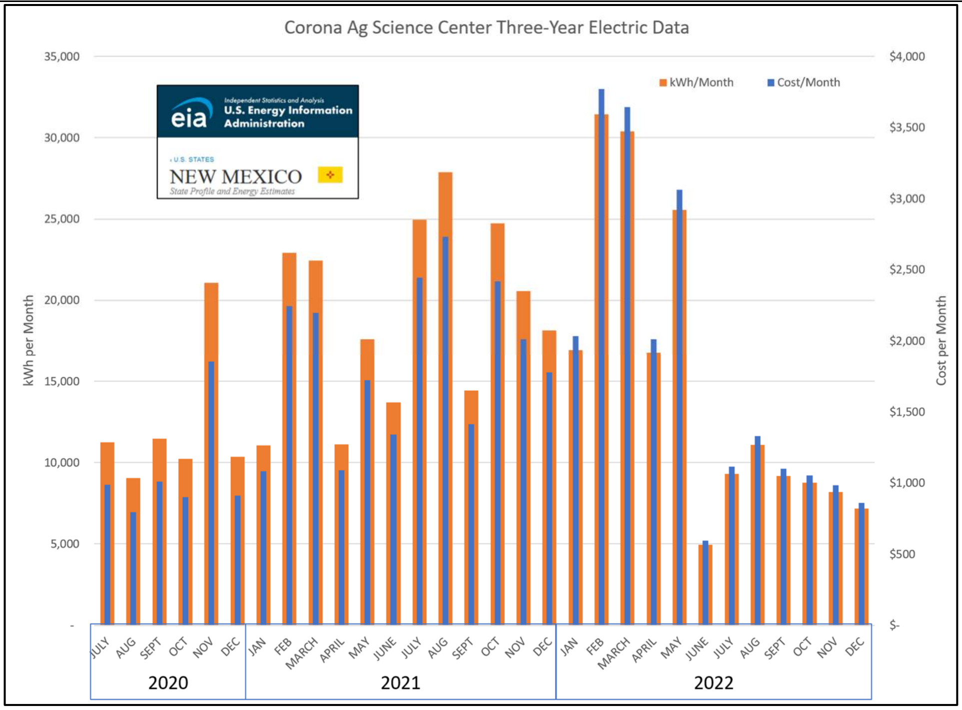
ELECTRICITY OBSERVATIONS:

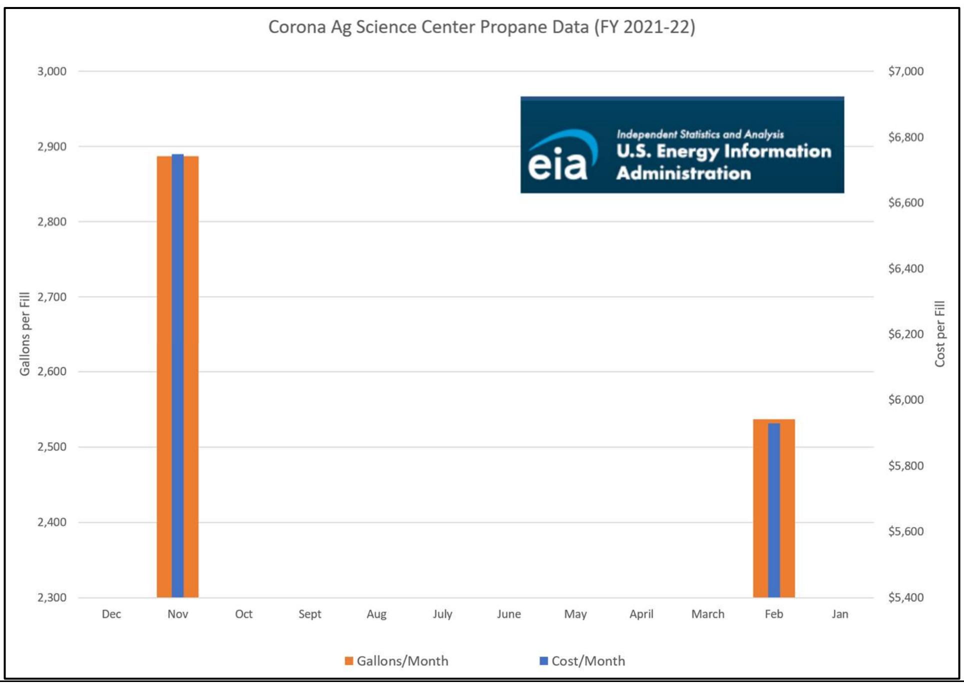
1) Clear Winter Peaking
2) Peak usage is above 3,500 kWh per month
3) Peaks occur in December
4) Summer use is trending down
5) Base-Load (lowest use) is near 800 kWh per month
6) Lowest use occurs in October

PROPANE OBSERVATIONS:

1) Clear Winter Peaking
2) Peak usage is near 1,300 Gallons per Month
3) Peaks occur in November
4) Winter trend is not discernable
5) Base-Load (lowest use) is near 400 Gallons per Month
6) Lowest use occurs in October

Corona Center Energy Data





ELECTRICITY

EIA NM Elec Rates	
2020	$ 0.09
2021	$ 0.10
2022	$ 0.12

	Cost	kWh
FY 2021-22	$ 27,912	256,781

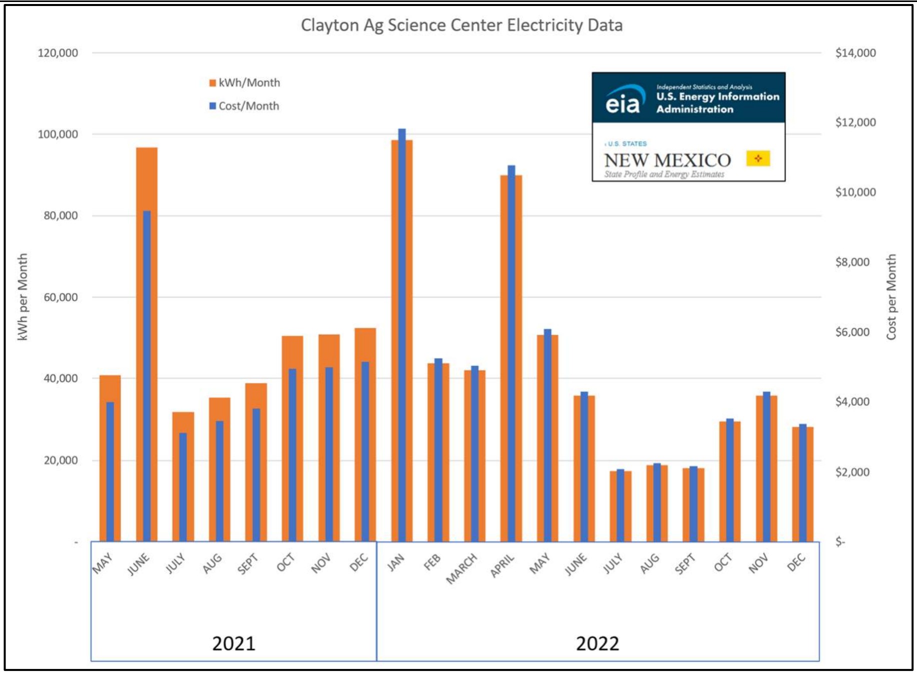
PROPANE

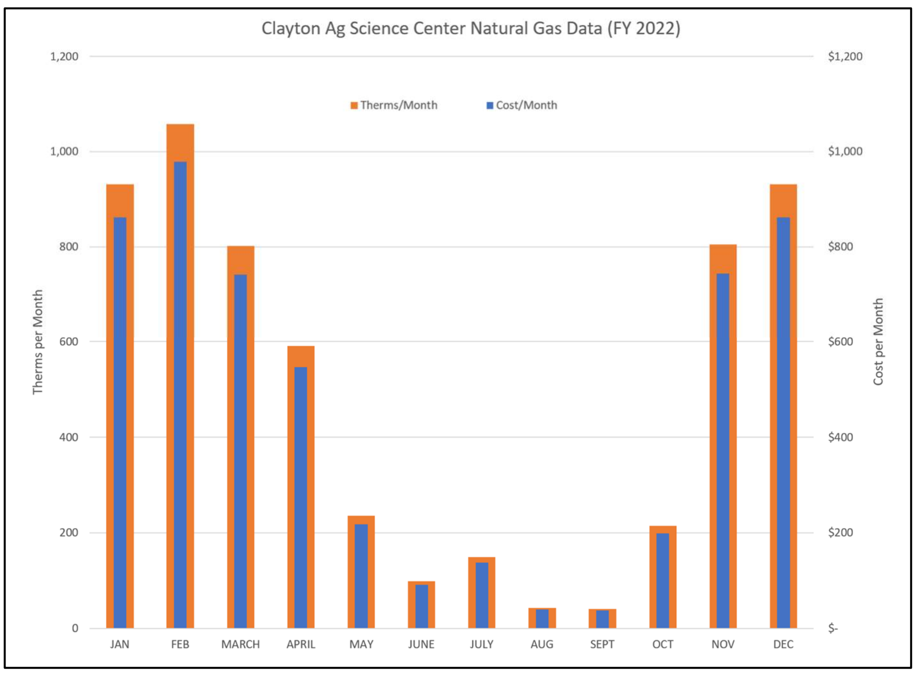
	Cost	Gallons
CY 2022	$12,676.75	5,424.37

NOTE: NM Commodity Rate Used to derive usage, at $2.337/Gallon

NEW MEXICO EIA PROPANE & ELECTRICITY DATA USED:
https://www.eia.gov/dnav/pet/pet_pri_wfr_a_EPLLPA_PRS_dpgal_w.htm

Clayton Center Energy Data





ELECTRICITY

	Month	Cost	kWh
2021	MAY	$ 3,987	$ 40,723
	JUNE	$ 9,468	$ 96,712
	JULY	$ 3,106	$ 31,729
	AUG	$ 3,453	$ 35,270
	SEPT	$ 3,800	$ 38,812
	OCT	$ 4,946	$ 50,525
	NOV	$ 4,985	$ 50,921
	DEC	$ 5,134	$ 52,445
2022	JAN	$ 11,825	$ 98,621
	FEB	$ 5,235	$ 43,659
	MARCH	$ 5,029	$ 41,943
	APRIL	$ 10,778	$ 89,893
	MAY	$ 6,084	$ 50,746
	JUNE	$ 4,286	$ 35,747
	JULY	$ 2,088	$ 17,411
	AUG	$ 2,257	$ 18,826
	SEPT	$ 2,173	$ 18,125
	OCT	$ 3,524	$ 29,387
	NOV	$ 4,293	$ 35,806
	DEC	$ 3,364	$ 28,057

NATURAL GAS

CY 2022 Data		
Month	Therms	Cost
JAN	931	$ 861
FEB	1,058	$ 978
MARCH	802	$ 742
APRIL	591	$ 546
MAY	236	$ 218
JUNE	99	$ 92
JULY	149	$ 138
AUG	43	$ 40
SEPT	41	$ 38
OCT	215	$ 199
NOV	805	$ 744
DEC	931	$ 861

NOTE: *EIA State Energy Costs were used for this site as cost data was not provided.*
https://www.eia.gov/totalenergy/data/annual/

2023

APPENDIX E: Higher Education State of the Industry

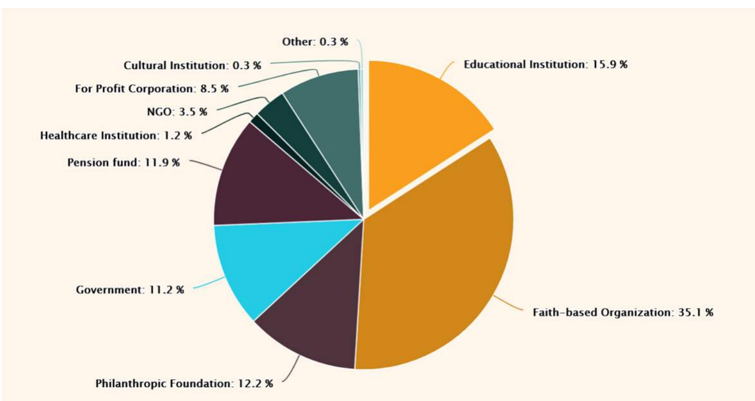
EEA CONSULTING ENGINEERS

HIGHER EDUCATION (STATE OF THE INDUSTRY)

This Appendix is provides a glimpse of what Regional University Sustainability Programs are doing in the Southwestern U.S. to address climate change through facilities projects and instruction. The universities selected for this report include the following five institutions, presented in order:

- University of New Mexico (Albuquerque, NM)
- University of Texas El Paso (El Paso, TX)
- University of Arizona (Tucson, AZ)
- Arizona State University (Phoenix, AZ)
- Colorado State University (Ft. Colins, CO)

According to an April 2022 New York Times **Climate Forward** newsletter article By Hiroko Tabuchi titled "Kicking Oil Companies out of School" reinforced the fact that "Over the past decade, students around the world have successfully pressed many universities to sell off their fossil fuel investments." Tabuchi provides reference to the Global Fossil Fuel Commitments Database which lists fossil fuel divestment commitments made by institutions worldwide, in which 15.9% of global divestments are represented by Educational Institutions.



The full list of U.S. Educational Institutions can be found at the following link, but include the likes of Yale University, Vassar College, Wellesley College, USC, the University of Michigan, Syracuse University, Stanford University, Princeton University, John Hopkins University, Harvard University, Georgetown University, Cornell University, and California State.

https://divestmentdatabase.org/?campaign_id=54&emc=edit_clim_20220816&instance_id=69457&nl=climate-forward&regi_id=89866805&segment_id=101533&te=1&user_id=d56d92ff02fdd9a47445b4df110d94a4

Of note is the stark correlation among divested educational institutions and Carnegie Classifications for R1 Doctoral Research Universities, of which there are 146 institutions (2021).

The Times article highlights the example by faculty and senior staff at the University of Cambridge, whom "are poised to vote on a measure that would require the university to stop accepting funding from coal, oil and gas companies. It would be the first leading university to do so, and a vote could happen as early as this autumn."

While NMSU is not yet in a position to make this type of statement, divestment can be achieved in other ways, some of which are provided herein.

Regional University Sustainability Programs

University of New Mexico (UNM)

District Energy System at Ford Utilities

UNM Facilities Management (FM) has one of the most sophisticated utility plants of all the universities in the country. The Ford Utilities Center can generate 219,000 pounds per hour of steam, 4,000 tons of chilled water, 14 megawatts of electricity, and enough compressed air for the campus. The FM Utilities Division also operates two remote chilled water plants - the Lomas Chilled Water Plant and the HSC Chilled Water Plant. These facilities have a combined chilled water capacity of 8,300 tons.

The fourth location is the Campus Utility Plant, which can generate 24,000 pounds per hour of steam, and 1,000 tons of chilled water. The upgrades save students and taxpayers approximately $2.5 million annually and reduces UNM's direct carbon footprint by 39% annually as compared to staying with the municipal power provider (PNM).

Cogeneration

In the early 2000s, UNM FM Utilities conducted a massive upgrade to the Ford Utilities Center. The project included installation of natural gas cogeneration units to become more energy independent and accommodate the inevitable campus growth in a cost effective and energy efficient manner. UNM now has its own District Energy System and produces most of the power needed on campus.

The upgrades save students and taxpayers approximately $2.5 million annually and reduces UNM's direct carbon footprint by 39% annually as compared to staying with the municipal power provider (PNM).

This project earned UNM a 2008 Energy Star Award from the EPA. This award is given to projects for "efficiency and fuel savings and making outstanding contributions to reducing greenhouse gas emissions from energy generation."

Ford Utilities Center has two cogeneration units (combined heat and power) that help produce 12 megawatts of electricity. Then the wasted heat gets captured and repurposed for heating the main and north campus buildings.

UNM Green Fund - Application for University of New Mexico Green Fund

The University of New Mexico (UNM) Green Fund is a collection of resources meant to be used in pursuance of sustainability at UNM. This fund's establishment is to promote all types of sustainability: environmental, social, and economic. The Green Fund as an operable tool should function to assist UNM and subsidiaries in accomplishing long term viability via providing opportunities and initiatives that would otherwise go unfunded.

The Green Fund is supported by student fees and can be used to fund projects or initiatives, both educational and infrastructural, for The University of New Mexico campus and community. This funding is meant to encourage and foster long term sustainability of The University of New Mexico as both a physical place and as an intellectual community.

Evaluation criteria for proposed projects:

- Impact on carbon footprint, including use of energy efficiencies or renewable energy.
- Increasing students' awareness of environmental issues.
- Educating and engaging students, staff, and faculty in "green" behaviors.
- Highly visible, conspicuous and noticeable projects.
- Use of matching funds from other organizations.

- Partnership with UNM department or organization, which can ensure successful completion of proposed project or initiative.
- Specific in scope of work and expected outcomes.

The UNM Sustainability Council was created to assist the Office of Sustainability in enhancing awareness about sustainability both within and outside of the UNM community.

University of Texas El Paso (UTEP)

Project MOVE 2022

During the past 12 years, The University of Texas at El Paso (UTEP) has hosted an annual day of community service called Project MOVE (Miner Opportunities for Volunteer Experiences). Campus leaders created this event so UTEP students, faculty, staff, and alumni could give back to the community, which has given so much to the University, and to provide opportunities for volunteers to learn more about the community, its residents, and their needs.

https://www.utep.edu/student-affairs/projectmove/#.Xq-XPC-z3UI

Center for Community Engagement

The mission of the Center for Community Engagement is to enhance higher education and contribute to the public good through community-based teaching and learning initiatives that enrich student education, promote civic engagement, and improve the community while capitalizing on the region's and UTEP's social and intellectual capital.

https://www.utep.edu/cce/

The Green Fund is a student-approved fee referendum that will assess $3 per student per semester, raising up to $200,000 per year for campus sustainability projects. These projects will help UTEP's sustainability initiatives and the environment* by:

- Investing in renewable energy
- Promoting environmental sustainability on campus
- Providing educational opportunities such as student internships
- Increasing energy efficiency
- Conserving water and other resources

*Green Fund will NOT fund anything the university is already required to do by law or policy.

Green Idea

You can be part of a great successful change on campus and in your community. But first, all things start with a bright Green Idea, and we would love to hear yours. Fill out our idea form here and a Green Fund member will personally reach out to you.

https://www.utep.edu/student-affairs/greenfund/ (email to greenfund@utep.edu)

How are projects reviewed and funded?

The Green Fund Committee will oversee the funds. It will consist of five students, two administrators and one faculty member. Proposals for funding may be submitted for consideration by students, faculty or staff. Each proposal is reviewed by the Green Fund Committee and those with a majority vote of the Committee will be recommended to the University President for final decision.

How will I know where my money goes?

The Green Fund Committee records all funding allocations and provides an annual report to the Student Government Association and the University President.

University of Arizona

Sustainability & Climate Action Plan

The Office of Sustainability is currently developing the University's first-ever institutional Sustainability & Climate Action Plan, which will be released in 2023. When paired with the University's Strategic Plan and Campus Master Plan, the Sustainability & Climate Action Plan will work synergistically to enhance the operational sustainability of the University, while also fostering a culture of environmental awareness and appreciation. The Plan will align with the United Nations' Sustainable Development Goals and will integrate metrics from the Association for the Advancement of Sustainability in Higher Education's (AASHE) Sustainability Tracking, Assessment and Rating System (STARS) framework. The Sustainable Development Goals provide a path forward for addressing global and local challenges such as poverty, inequality, climate change and environmental degradation, with the goal of making significant progress toward all goals by 2030. The STARS framework is a methodology that colleges and universities around the world can use to capture the full spectrum of their sustainability activities and measure advancements over time and across institutions. Beyond integrating with the SDGs and STARS, two very valuable and widely recognized international efforts, the Plan will also include comprehensive internal initiatives across the University's research, academic, and operational sectors.

What is Climate Neutrality, and What Are Scope Emissions?

The University of Arizona monitors both its carbon and climate footprints as we work toward our neutrality goals. One way we track the increases and decreases in campus energy and resource use over time is through the University's Greenhouse Gas Inventory. Greenhouse gases are gases that trap heat in the atmosphere, thus contributing to global warming and, as a result, climate change.

Many large corporations and institutions of higher education now track and report transparently on the emissions generated from their direct operations, and most are beginning to now account for scope three emissions as well. The University's Facilities Management department leads the development and publication of the institution's full inventory of greenhouse gases, in close partnership with the Office of Sustainability, Financial Services, Parking & Transportation Services, and other departments on campus. These departments participate in a collaborative effort to aggregate and analyze all of the necessary data for the Greenhouse Gas Report, which is published annually. Reports for FY2019, FY2020, and FY2021 are available below. Each report includes historical emissions inventories dating back to FY2015.

Second Nature and Our Commitment to Climate Neutrality

Second Nature is a non-profit institution committed to advancing climate action in, and through, higher education. The organization offers a wealth of resources for colleges and universities, including information on carbon offsets and tools for climate action planning. One of Second Nature's central goals is to achieve a 50% decarbonization of the U.S. economy by the year 2030, primarily through the activation of more colleges and universities as climate leaders.

The University of Arizona has been working extensively with Second Nature to advance its climate adaptation and mitigation efforts. In 2018, under the University Strategic Plan, the University moved up its climate neutrality goal date from 2050 to 2040, understanding the need to lead in the promotion of a climate neutral economy. The University also set a goal of reducing its scope two emissions by 100% by 2025, a goal that will be achieved on January 1, 2021 through the large-scale renewable energy agreement with Tucson Electric Power.

The University has a long history of engagement in sustainability initiatives, and first demonstrated its commitment to building a more sustainable future by becoming one of the charter signatories of the American College and University Presidents Climate Commitment (ACUPCC) in 2007. In 2015, Second Nature launched a new set of Presidents' Climate Leadership Commitments for higher education institutions, offering the Carbon Commitment (formerly the ACUPCC), the Resilience Commitment, and the Climate Commitment, a combination of the former two commitments. Maintaining and expanding upon our original commitment, the University of Arizona became one of 93 charter signatories of those new commitments by then signing Second Nature's Climate Commitment, pledging that the University would not only reduce its greenhouse gas emissions to zero by 2050, but also would integrate climate resiliency in partnership with the Tucson community, positioning the University to be a profound and dynamic force in southern Arizona with relation to climate change education, research, and preparedness. Under the 2018 Strategic Plan, the University of Arizona moved its climate neutrality goal date up from 2050 to 2040.

In tandem with the University's recent UC3 efforts, President Robert Robbins also joined Second Nature's President's Climate Leadership Steering Committee. The Committee is composed of high-level university and college administrators, including chancellors, presidents, provosts, and CFOs, and is the chief oversight body of the Presidents' Climate Leadership Commitments, responsible for advising on its policy and direction. In this capacity, Dr. Robbins represents and elevates the voice of the University of Arizona, while providing leadership and advocacy to address the global climate crisis.

Arizona State University (ASU)

Climate positive

Since fiscal year 2019, ASU has been carbon neutral for scope 1 and 2 emissions. ASU has achieved this through Energy Efficiency, Green Construction, Offsetting, and Renewable Energy acquisition. ASU will work to reduce the need for offsets through its efforts to decarbonize over the next several years.

Achieving Carbon Neutrality at ASU Case Study

Commitments:

- Achieve carbon neutrality for Scope 1 and 2 emissions by FY 2025.
- Update: achieved carbon neutrality for Scope 1 and 2 emissions in FY 2019.
- Achieve carbon neutrality for Scope 3 emissions by FY 2035.
- Update: in progress, reduced 49% since FY 2007.
- Energy efficiency and conservation
- Low-carbon energy use
- Purchasing measures: energy-related
- Transportation measures

Energy monitoring

ASU has installed additional meters to monitor ASU's energy use since 2007. Energy monitoring is essential to identifying energy efficiency opportunities in locating wasteful practices and inefficient operations and determining progress. In addition, ASU implemented Campus Metabolism, an interactive web tool that displays historical and real-time energy use and generation on campus, informing and educating the ASU community through dashboards, graphics and simulations.

Identifying energy waste

ASU uses data from building-level energy monitors to identify energy waste. Two forms of analysis are used: year-on-year energy data is compared for each building to identify increases in energy use and energy use intensity is compared across buildings by class to identify outliers with excessively high use. The results are used to guide energy efficiency and conservation efforts.

ASU Solar

For more information on ASU's solar power generation, check out the ASU solar website.

Launched in June 2018, the ASU Carbon Project purchases and generates offsets for difficult to mitigate ASU carbon emissions. The ASU Carbon Project is funded, in part, by the price on carbon for all ASU-sponsored air travel.

The project objectives are:

- Reduce ASU's greenhouse gas emissions.
- Reduce the need to purchase offsets in the future.
- Tell ASU's story and connect to local communities while supporting academics and research.

ASU Carbon Project Solutions

Carbon Sink at ASU West: The Carbon Sink and Learning Forest mitigates ASU's carbon emissions while providing a living laboratory for ASU faculty and students. The forest consists of 1,000 trees on 10.5 acres at ASU West. As a living laboratory, faculty and staff have access to investigate a wide range of research questions while the trees mature and sequester carbon.

University Sustainability Practices.

Urban Forestry: ASU has worked with the cities of Phoenix, Scottsdale, and Tempe to plant trees with the help of many volunteers. As they grow, the trees will sequester carbon to reduce ASU's carbon emissions. During their life, the trees reduce the heat island effect, beautify the community, and provide shade.

Colorado State University (CSU) - Ft. Collins, CO

In 2008, CSU became a signatory of the American College & University Presidents' Climate Commitment (ACUPCC). The goal of this effort is for university campuses to reduce Greenhouse Gas (GHG) emissions to the point of carbon neutrality. In short, the commitment requires participating campuses to take the following steps in pursuit of climate neutrality:

- Develop a comprehensive plan (a Climate Action Plan) to achieve climate neutrality
- Make the action plan, inventory, and periodic progress reports publicly available

CSU Climate Action Plan

CSU completed their first Climate Action Plan (CAP) in September 2010. The Climate Action Plan outlines how and when CSU will achieve climate neutrality. The CAP is considered a "living document" and is reviewed and updated every few years by a sub-committee of the CSU Presidents Sustainability Commission.

CSU STARS Reports

In 2015, CSU became the first university in the world to earn a Platinum rating in STARS. CSU received a Platinum rating again in 2017. STARS is considered the most comprehensive and well-respected sustainability assessment for colleges and universities with 700 institutions taking part on 6 continents. STARS is provided by AASHE (Association for the Advancement of Sustainability in Higher Education).

Here are just a few of the things that helped CSU earn this landmark score.

CSU is an EPA Green Power Partner

Since 2006 CSU has participated as an EPA Green Power Partner helping to promote and advance the use of renewable electricity through this voluntary program.

2023

APPENDIX F: Informative Appendix

EEA CONSULTING ENGINEERS

EPA CARBON EQUIVALENCY CALCULATOR DATA

Net Electricty Consumption Main-Campus: 25,628,880 kWh (FY 2022 Est.)

11,087 Metric Tons **of Carbon Dioxide (CO_2) equivalent**

This is equivalent to greenhouse gas emissions from:

- **2,389** gasoline-powered passenger vehicles driven for one year
- **27,519,983** miles driven by an average gasoline-powered passenger vehicle

This is equivalent to CO_2 emissions from:

- **1,247,542** gallons of gasoline consumed
- **1,089,087** gallons of diesel consumed
- **12,266,657** pounds of coal burned
- **147** tanker trucks' worth of gasoline
- **1,397** homes' energy use for one year
- **2,157** homes' electricity use for one year
- **61.2** railcars' worth of coal burned
- **25,669** barrels of oil consumed
- **452,731** propane cylinders used for home barbeques
- **0.003** coal-fired power plants in one year
- **0.028** natural gas-fired power plants in one year
- **1,348,640,765** number of smartphones charged

This is equivalent to greenhouse gas emissions avoided by:

- **3,836** tons of waste recycled instead of landfilled
- **548** garbage trucks of waste recycled instead of landfilled
- **479,904** trash bags of waste recycled instead of landfilled
- **3** wind turbines running for a year
- **420,205** incandescent lamps switched to LEDs

This is equivalent to carbon sequestered by:

- **183,323** tree seedlings grown for 10 years
- **13,121** acres of U.S. forests in one year
- **74.8** acres of U.S. forests preserved from conversion to cropland in one year

Natural Gas Consumption Main-Campus: 6,119,360 Therms (FY 2022)

32,378 Metric Tons **of Carbon Dioxide (CO_2) equivalent**

This is equivalent to greenhouse gas emissions from:

6,976 gasoline-powered passenger vehicles driven for one year	**80,367,694** miles driven by an average gasoline-powered passenger vehicle

This is equivalent to CO_2 emissions from:

3,643,247 gallons of gasoline consumed	**3,180,504** gallons of diesel consumed
35,822,802 pounds of coal burned	**429** tanker trucks' worth of gasoline
4,078 homes' energy use for one year	**6,300** homes' electricity use for one year
179 railcars' worth of coal burned	**74,961** barrels of oil consumed
1,322,128 propane cylinders used for home barbeques	**0.009** coal-fired power plants in one year
0.081 natural gas-fired power plants in one year	**3,938,488,887** number of smartphones charged

This is equivalent to greenhouse gas emissions avoided by:

11,203 tons of waste recycled instead of landfilled	**1,600** garbage trucks of waste recycled instead of landfilled
1,401,482 trash bags of waste recycled instead of landfilled	**8.8** wind turbines running for a year
1,227,141 incandescent lamps switched to LEDs	

This is equivalent to carbon sequestered by:

535,365 tree seedlings grown for 10 years	**38,317** acres of U.S. forests in one year
218 acres of U.S. forests preserved from conversion to cropland in one year	

BUILDING BY BUILDING STEAM PHASE OUT

PHASE ONE: YEARS 2023 to 2028

Building Name	Bldg #	Phase	KW Increase	kWh Increase
ALEX SANCHEZ HALL	341	1A		
NEW MEXICO DEPT. OF AGRICULTURE	330	1A		
DACC TECHNICAL STUDIES	357	1A		
NEALE HALL	164	1A		
DACC, LEARNING RESOURCES	479	1A		
URBAN ENTOMOLOGY RESEARCH CENTER	246	1A		
SKEEN HALL	551	1B		
GERALD THOMAS HALL	244	1B		
KNOX HALL	368	1B		
JETT HALL	189	1C		
ED AND HAROLD FOREMAN ENGINEERING COMPLEX	541	1C		
ENGINEERING COMPLEX I	363	1C		
THOMAS & BROWN HALL	301	1C		
JOHN WHITLOCK HERNANDEZ HALL	397	1C		
GODDARD HALL	10	1C		

PHASE TWO: YEARS 2028 to 2033

Building Name	Bldg #	Phase	KW Increase	kWh Increase
CHEMISTRY BUILDING	187	2		
DEVASTHALI HALL	657	2		
GARDINER HALL	188	2		
HEALTH AND SOCIAL SERVICES BUILDING	590	2		
BUSINESS COMPLEX BUILDING	386	2		
GUTHRIE HALL	288	2		
MUSIC BUILDING	389	2		
HADLEY HALL	172	2		
CLARA BELLE WILLIAMS HALL	364	2		
YOUNG HALL	32	2		
DOVE HALL	56	2		
HARDMAN & JACOBS UNDERGRAD LEARNING CTR	323	2		
KENT HALL	33	2		
WILLIAM B. CONROY HONORS CENTER	35	2		

PHASE THREE: YEARS 2033 to 2038

Building Name	Bldg #	Phase	KW Increase	kWh Increase
CORBETT CENTER	285	3		
FOSTER HALL	34	3		
PAN AMERICAN CENTER	284	3		
MILTON HALL	83	3		
JUNIPER HALL	658	3		
GARCIA RESIDENCE HALL	275	3		
SCIENCE HALL	391	3		
ZUHL LIBRARY	461	3		
BRANSON LIBRARY	278	3		
EDUCATIONAL SERVICES CENTER	338	3		
PETE V. DOMENICI HALL	249	3		
WALDEN HALL	276	3		
RHODES-GARRETT-HAMIEL RES HALL	80	3		
ASTRONOMY BUILDING	225	3		

PHASE FOUR: YEARS 2038 to 2040

Building Name	Bldg #	Phase	KW Increase	kWh Increase
COMPUTER CENTER	126	4		
CHAMISA VILLAGE	605	4		
PSL, CLINTON P. ANDERSON HALL	263	4		
AQUATICS CENTER	251	4		
O'DONNELL HALL	287	4		
JAMES B. DELAMATER ACTIVITY CENTER	321	4		
BRELAND HALL	184	4		
AGGIE HEALTH & WELLNESS CENTER	261	4		

PHASE FIVE in 2040

Building Name	Bldg #	Phase	KW Increase	kWh Increase
CHARLES STRICKLAND CENTRAL PLANT	269	5		

HVAC SYSTEM TYPE PER BUILDING

USED WHEN ASSIGNING SIMULATED ELECTRIFICATION ENERGY PROFILES PER BUILDING

Building Name	Primary System Type
GODDARD HALL	Single Duct w/ Mixed Air
GORDON WATTS	Packaged RTU
GUTHRIE HALL	2-Pipe Fancoil
HADLEY HALL	4 Pipe Fancoil
HARDMAN AND JACOBS UNDERGRADUATE LEARNING CENTER	Single Path Mixed Air
HEALTH AND SOCIAL SERVICES BUILDING	Single Path Mixed Air
HSS ANNEX	Single Duct w/ Mixed Air
JAMES B. DELAMATER ACTIVITY CENTER	Single Duct w/ Mixed Air
JETT ANNEX	Single Duct w/ Mixed Air
JETT HALL	Single Duct w/ Mixed Air
JOHN WHITLOCK HERNANDEZ HALL	Single Duct w/ Mixed Air
JORNADA USDA EXP. RANGE HQ (WOOTON HALL)	Single Duct w/ Mixed Air
JUNIPER HALL	Water Source Heat Pump
KNOX HALL	Single Duct w/o Mixed Air
MILTON HALL	Multizone w/ Mixed Air
MUSIC BUILDING	4-Pipe Fancoil
NASON HOUSE	Packaged RTU
NATATORIUM	Single Duct w/ Mixed Air
NEMATOLOGY	Packaged RTU
NEW MEXICO DEPT. OF AGRICULTURE	Dual Duct w/ Mixed Air
NMDA ADDITION	Single Duct w/ Mixed Air
O'DONNELL HALL	Dual Duct w/ Mixed Air
PAN AMERICAN CENTER	Dual Duct w/ Mixed Air
PETE V. DOMENICI HALL	Single Duct w/ Mixed Air
PGEL	Packaged RTU
POLICE STATION	Packaged RTU
RENTFROW HALL	Packaged RTU
RHODES, GARRETT, HAMIEL	4 Pipe Fancoil
SCIENCE HALL	Dual Duct w/ Mixed Air
SKEEN HALL	Single Duct w/ Mixed Air
SUGERMAN SPACE GRANT BUILDING	Packaged RTU
SUTHERLAND VILLAGE	Residential Furnace
TEJADA BUILDING, EXTENSION ANNEX	Packaged RTU
THOMAS & BROWN HALL	Dual Duct w/ Mixed Air
TOM FORT	Residential Furnace
WEIGHT CENTER	Packaged RTU
WILLIAM B. CONROY HONORS CENTER	Single Duct w/o Mixed Air
YOUNG HALL	Single Duct w/ Mixed Air
ZUHL LIBRARY	Dual Duct w/ Mixed Air

Building Name	Primary System Type
ACADEMIC RESEARCH A	Packaged RTU
ACADEMIC RESEARCH B	Packaged RTU
ACADEMIC RESEARCH C	Packaged RTU
AGGIE EXPRESS CONVENIENCE STORE	Packaged RTU
AGGIE HEALTH & WELLNESS CENTER	4-Pipe Fancoil
ALUMNI VISITORS CENTER	Packaged RTU
AMERICAN INDIAN STUDENT CENTER	Single Duct w/ Mixed Air
ANIMAL CARE FAMILY	Packaged RTU
ASTRONOMY BUILDING	Dual Duct w/ Mixed Air
BARNES & NOBLE NMSU BOOKSTORE	Single Duct w/ Mixed Air
BIOLOGY ANNEX	Packaged RTU
BRANSON LIBRARY	Dual Duct w/ Mixed Air
BRELAND HALL	4-Pipe Fancoil
BUSINESS COMPLEX BUILDING	Single Duct w/ Mixed Air
CAMPUS POLICE/AG INSTITUTE	Packaged RTU
CENTER FOR THE ARTS	Single Duct w/ Mixed Air
CERVANTES COMPLEX	Residential Furnace
CHAMISA COMPLEX	Water Source Heat Pump
CHEMISTRY BUILDING	Single Duct w/ Mixed Air
CLARA BELLE WILLIAMS HALL	Single Duct w/ Mixed Air
COACHES COMPLEX	Packaged RTU
COMMUNICATION SCIENCES BUILDING	Dual Duct w/ Mixed Air
COMPUTER CENTER	Single Duct w/o Mixed Air
CORBETT CENTER	Single Duct w/ Mixed Air
DEVASTHALI HALL	Single Duct w/ Mixed Air
DOVE HALL	Single Duct w/o Mixed Air
ED AND HAROLD FOREMAN ENGINEERING COMPLEX	4-Pipe Fancoil
EDUCATIONAL SERVICES CENTER	Dual Duct w/ Mixed Air
FACILITES AND SERVICES	Multizone w/ Mixed Air
FIRE STATION	Packaged RTU
FOSTER HALL	Single Duct w/ Mixed Air
FRENGER FOOD COURT	Packaged RTU
FS ACCESS CONTROL	Packaged RTU
FS ALARM SHOP	Packaged RTU
FS CARPENTER SHOP	Evaportive Cooling
FS CUSTODIAL	Packaged RTU
FS ELECTRIC SHOP	Packaged RTU
FS F.A.T.E.	Evaportive Cooling
FS FACILITY MAINTENANCE	Packaged RTU
FS GROUNDS	DX Split System w/o Mixed Air
FS LARGE CONFERENCE ROOM	Heatpump w/Fixed Min Air
FS MECHANICAL SHOP	Packaged RTU
FS OFFICE	Packaged RTU
FS PAINT AND MOVERS	Evaportive Cooling
FS RECYCLING	Evaportive Cooling
FS SIGN SHOP	Packaged RTU
FS STRUCTURAL SHOP	Evaportive Cooling
FS VEHICLE MAINTENANCE	Packaged RTU
FS WAREHOUSE	Packaged RTU
FULTON ATHLETIC CENTER (STADIUM ANNEX)	Single Duct w/ Mixed Air
GARCIA CENTER	Packaged RTU
GARCIA HALL	4 Pipe Fancoil
GARCIA RESIDENCE HALL	Multizone w/ Mixed Air
GARDINER HALL	Single Duct w/o Mixed Air
GENESIS CENTER A	Packaged RTU
GENESIS CENTER B	Packaged RTU
GENESIS CENTER C	Packaged RTU
GERALD THOMAS HALL	Dual Duct w/ Mixed Air

NEW MEXICO CLEAN ENERGY INCENTIVES

(FOR REVIEW DURING PROJECT DEVELOPMENT FOR TRANSFERABILITY AND/OR SALE)

Name	State/ Territory	Category	Policy/Incentive Type	Created	Last Updated
Business Energy Investment Tax Credit (ITC)	US	Financial Incentive	Corporate Tax Credit	03/15/2002	12/09/2022
Solar Energy Gross Receipts Tax Deduction	NM	Financial Incentive	Sales Tax Incentive	05/25/2007	11/08/2022
Renewable Electricity Production Tax Credit (PTC)	US	Financial Incentive	Corporate Tax Credit	03/11/2002	09/09/2022
U.S. Department of Energy - Loan Guarantee Program	US	Financial Incentive	Loan Program	09/12/2008	09/08/2022
Plug-In Electric Drive Vehicle Tax Credit	US	Financial Incentive	Personal Tax Credit	08/18/2021	08/29/2022
Qualified Commercial Clean Vehicle Tax Credit	US	Financial Incentive	Corporate Tax Credit	08/18/2022	08/18/2022
Alternative Fuel Vehicle Refueling Property Tax Credit (Corporate)	US	Financial Incentive	Corporate Tax Credit	08/18/2022	08/18/2022
Energy-Efficient Commercial Buildings Tax Deduction	US	Financial Incentive	Corporate Tax Deduction	01/10/2006	08/16/2022
2021 Sustainable Building Tax Credit (Corporate)	NM	Financial Incentive	Corporate Tax Credit	12/08/2021	08/16/2022
2021 Sustainable Building Tax Credit (Personal)	NM	Financial Incentive	Personal Tax Credit	12/08/2021	08/16/2022
New Solar Market Development Tax Credit	NM	Financial Incentive	Personal Tax Credit	08/16/2022	08/16/2022
USDA - High Energy Cost Grant Program	US	Financial Incentive	Grant Program	09/27/2010	07/20/2022
Community Solar Program	NM	Regulatory Policy	Community Solar Rules	12/09/2021	06/14/2022
Alternative Fuel Vehicle Loan Program	NM	Financial Incentive	Loan Program	06/10/2021	12/10/2021
Advanced Energy Gross Receipts Tax Deduction	NM	Financial Incentive	Sales Tax Incentive	03/19/2010	09/21/2021

Name	State/ Territory	Category	Policy/Incentive Type	Created	Last Updated
Gross Receipts Tax Exemption for Sales of Wind and Solar Systems to Government Entities	NM	Financial Incentive	Sales Tax Incentive	02/16/2010	09/21/2021
Net Metering	NM	Regulatory Policy	Net Metering	01/01/2000	09/21/2021
Green Power Purchasing Goal for Federal Government	US	Regulatory Policy	Green Power Purchasing	02/19/2004	08/27/2021
City of Albuquerque - Solar Easements and Rights Laws	NM	Regulatory Policy	Solar/Wind Access Policy	11/13/2014	08/09/2021
New Mexico Solar Easements & Rights Laws	NM	Regulatory Policy	Solar/Wind Access Policy	01/01/2000	08/03/2021
Efficient Use of Energy Act	NM	Regulatory Policy	Public Benefits Fund	04/24/2006	07/28/2021
Alternative Energy Product Manufacturers Tax Credit	NM	Financial Incentive	Industry Recruitment/Support	05/25/2007	07/18/2021
Energy-Efficient Appliance Manufacturing Tax Credit	US	Financial Incentive	Industry Recruitment/Support	01/10/2006	07/14/2021
Federal Appliance Standards	US	Regulatory Policy	Appliance/Equipment Efficiency Standards	06/30/2006	07/07/2021
Geothermal Heat Pump Tax Credit (Personal)	NM	Financial Incentive	Personal Tax Credit	12/21/2009	06/04/2021
Geothermal Heat Pump Tax Credit (Corporate)	NM	Financial Incentive	Corporate Tax Credit	12/21/2009	06/04/2021
New Mexico Gas Company - Commercial Efficiency Programs	NM	Financial Incentive	Rebate Program	02/09/2011	02/05/2021
Biomass Equipment & Materials Compensating Tax Deduction	NM	Financial Incentive	Sales Tax Incentive	04/29/2005	07/31/2020

Name	State/ Territory	Category	Policy/Incentive Type	Created	Last Updated
Albuquerque City - Green Path Program	NM	Regulatory Policy	Building Energy Code	10/28/2016	06/16/2020
Building Energy Code	NM	Regulatory Policy	Building Energy Code	07/31/2006	06/16/2020
USDA - Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program	US	Financial Incentive	Loan Program	10/04/2012	02/25/2020
PNM - Commercial Energy Efficiency Rebate Program	NM	Financial Incentive	Rebate Program	08/11/2009	07/08/2019
PNM - Performance-Based Solar Program	NM	Financial Incentive	Performance-Based Incentive	01/17/2006	11/29/2018
El Paso Electric Company - Commercial Efficiency Program	NM	Financial Incentive	Rebate Program	12/15/2009	11/29/2018
Xcel Energy (Electric) - Commercial Energy Efficiency Rebate Program	NM	Financial Incentive	Rebate Program	07/05/2012	11/29/2018
Qualified Energy Conservation Bonds (QECBs)	US	Financial Incentive	Loan Program	10/23/2008	08/22/2018
USDA - Rural Energy for America Program (REAP) Loan Guarantees	US	Financial Incentive	Loan Program	04/09/2003	08/21/2018
USDA - Rural Energy for America Program (REAP) Grants	US	Financial Incentive	Grant Program	04/09/2003	08/21/2018
USDA - Rural Energy for America Program (REAP) Energy Audit and Renewable Energy Development Assistance (EA/REDA) Program	US	Financial Incentive	Grant Program	02/18/2015	08/21/2018

Name	State/ Territory	Category	Policy/Incentive Type	Created	Last Updated
Modified Accelerated Cost-Recovery System (MACRS)	US	Financial Incentive	Corporate Depreciation	03/15/2002	08/21/2018
Energy Goals and Standards for Federal Government	US	Regulatory Policy	Energy Standards for Public Buildings	06/19/2006	08/21/2018
Clean Renewable Energy Bonds (CREBs)	US	Financial Incentive	Loan Program	05/02/2006	08/15/2018
Interconnection Standards	NM	Regulatory Policy	Interconnection	08/15/2008	08/24/2017
Solar/Wind Construction Permitting Standards	NM	Regulatory Policy	Solar/Wind Permitting Standards	09/16/2014	08/24/2017
Clean Energy Revenue Bond Program	NM	Financial Incentive	Bond Program	04/29/2005	05/25/2017
Local Option - Renewable Energy Financing District/Solar Energy Improvement Special Assessments	NM	Financial Incentive	PACE Financing	07/15/2009	05/25/2017
Drinking Water State Revolving Loan Fund	NM	Financial Incentive	Loan Program	04/24/2012	03/22/2017
Agricultural Biomass Income Tax Credit (Personal)	NM	Financial Incentive	Personal Tax Credit	12/14/2010	03/22/2017
Agricultural Biomass Income Tax Credit (Corporate)	NM	Financial Incentive	Corporate Tax Credit	12/14/2010	03/22/2017
Interconnection Standards for Small Generators	US	Regulatory Policy	Interconnection	10/30/2007	07/27/2016