7

ENVIRONMENTAL STEWARDSHIP

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The University of California boasts a robust sustainability program driven by a nationally-recognized comprehensive sustainability policy and leading-edge presidential initiatives. Its sustainability policy positions the system campuses as leaders in environmentally sound operations. As of 2007, all of the 10 chancellors are also signatories to the American College & University Presidents' Climate Commitment.

Overwhelming scientific consensus points to climate change being driven by the release of carbon dioxide into the atmosphere, primarily from the burning of fossil fuels. UC is responding to this growing environmental crisis with direct action by committing to emit zero greenhouse gases on a net annual basis from its buildings and vehicle fleet by 2025.

Glossary of Terms

Degree-Day (Heating / Cooling) - a measurement of heating or cooling load relative to a base temperature. It is the product of the number of days during the year and the degrees above (cooling) or below (heating) the base temperature each day.

Emissions Factor - a value expressing the relationship between a pollutant released into the atmosphere and the activity associated with that release

Energy Use Intensity (EUI) - an expression of annual energy consumed per square foot, expressed as kBtu/sf/yr

kBtu/sf/yr - one thousand British Thermal Units per square foot, per year

$MtCO_2e$ - Metric tonnes of carbon dioxide equivalents

STRATEGIC PRIORITIES

- Implement high-performance retrofits of existing buildings that meet recommended EUI targets.
- Design future new buildings to high-performance standards that meet recommended EUI targets.
- Install solar photovoltaic panels on all campus non-residential buildings.
- Install solar hot water heaters on all campus residential buildings and solar photovoltaic panels on all campus non-residential buildings to reduce carbon emissions from electricity use.
- Install solar photovoltaic panels above parking lots, walkways, and other available open spaces.
- Partner with Riverside Public Utilities or third-party renewable energy developers to install significant off-site solar photovoltaic or wind energy generation capacity.

Stewardship of the natural environment is a core value of UC Riverside that shapes policy decisions, inspires daily action and presents pertinent learning opportunities. In planning for campus growth to accommodate increases in enrollment, the Master Plan Study balances opportunities to protect, enhance, or restore natural systems; promote alternative transportation options; introduce greater efficiencies in campus infrastructure and resource use; and, most importantly, envision a roadmap to carbon neutrality.

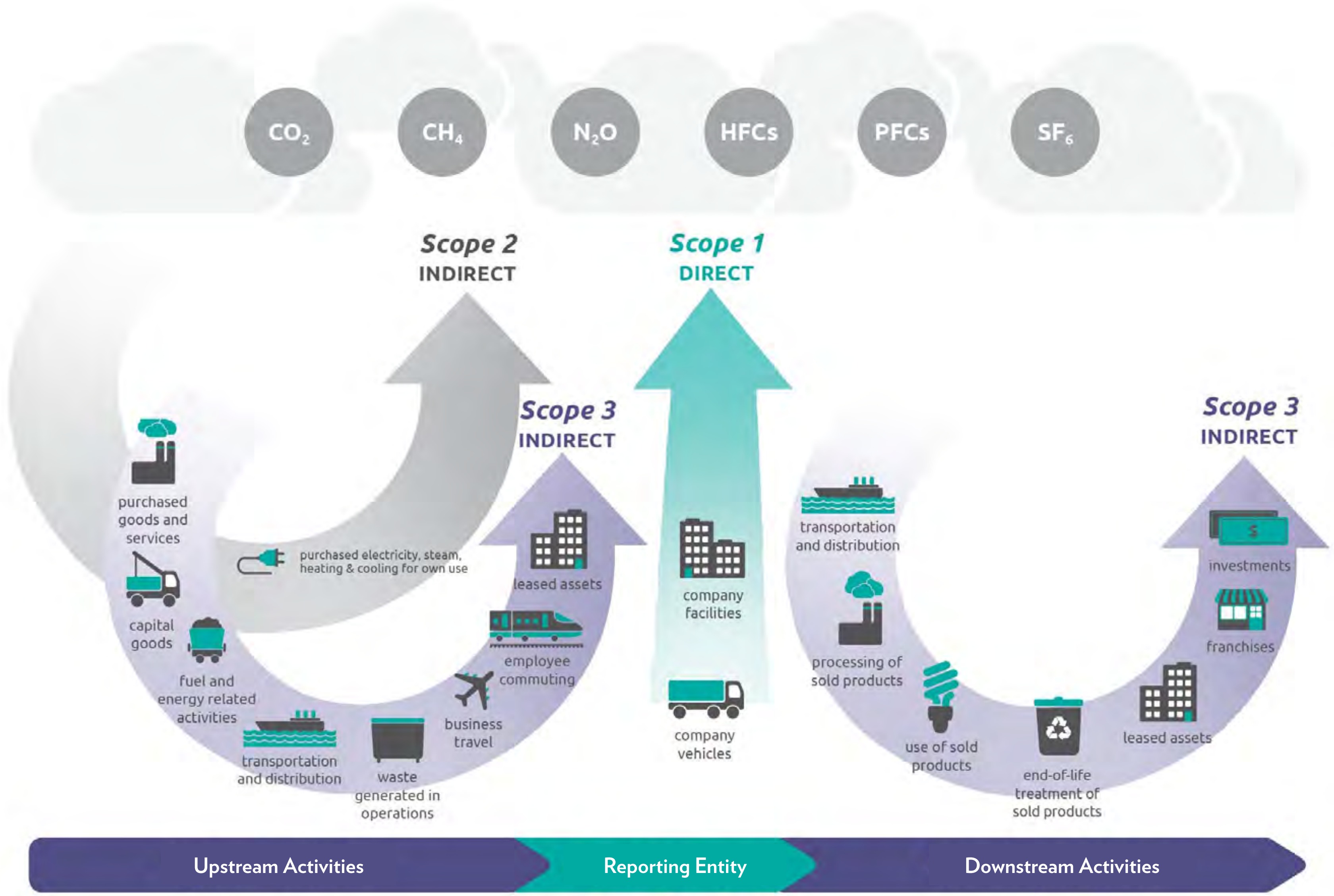
Future growth of the campus will need to enhance this commitment to environmental stewardship to account for the impacts of development and expansion of campus infrastructure. The goal of carbon neutrality is a key commitment that the Planning Team studied. The results are detailed in this chapter. Environmental stewardship involves many other considerations, some of which are addressed in Chapter 4, Landscape & Open Space; Chapter 5, Circulation & Transportation; and Chapter 6, Infrastructure & Utilities.

CARBON NEUTRALITY 2025

UC Riverside has implemented a variety of stewardship programs on campus. In this Master Plan Study, the Planning Team focused on strategies for achieving the University of California's Carbon Neutrality 2025 Initiative, announced in November 2013 by President Janet Napolitano. This initiative commits the University of California system to emitting zero net greenhouse gases from all of its campuses and vehicle fleets by 2025, something no other major university system has accomplished.

The University will need to take bold steps to achieve carbon neutrality by 2025. The Master Plan Study provides a foundational analysis and identifies strategies for meeting the Carbon Neutrality 2025 challenge.

Figure 7.1 GREENHOUSE GAS PROTOCOL (GGP) SCOPES & EMISSIONS SOURCES



Source: Greenhouse Gas Protocol

7.1 Assessment

UNDERSTANDING GREENHOUSE GAS (GHG) EMISSIONS

Greenhouse gas (GHG) emissions come in multiple types and from multiple sources, making analysis complex. The Greenhouse Gas Protocol (GGP), developed by the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD), standardizes a method for measuring, managing, and reporting greenhouse gas emissions. The Greenhouse Gas Protocol has been adopted by The Climate Registry (TCR), which runs voluntary compliance reporting in the State of California. In particular, the Greenhouse Gas Protocol divides the auditing and analysis of greenhouse gas emissions into three main "scopes," as follows:

- **Scope 1: Direct GHG Emissions** comprises greenhouse gas emissions that occur from sources owned or controlled by the University. These emissions include on-site combustion or other types of release (such as chemical production) from owned assets such as boilers, company vehicles, and other process equipment. UC Riverside reports its complete Scope 1 emissions to The Climate Registry, the UC Office of the President, and the American University Presidents' Climate Commitment.
- **Scope 2: Indirect GHG Emissions** accounts for emissions from the generation of electricity (or heat or steam) purchased from another party. UC Riverside reports its complete Scope 2 emissions to The Climate Registry, the UC Office of the President, and the American University Presidents' Climate Commitment.
- **Scope 3: Other Indirect GHG Emissions** accounts for all other indirect emissions. These emissions result from the activities of a subject entity but occur from sources not owned or controlled by the University. Examples include emissions resulting from services or materials purchased by the University, employee commuting activities, and business air travel, among others. UC Riverside currently reports Scope 3 emissions to the UC Office of the President and the American University Presidents' Climate Commitment, with the following exclusions: waste, water, and purchasing.

UC RIVERSIDE'S CARBON FOOTPRINT

According to the UC Riverside Office of Sustainability, in 2014 (the year to which emissions data in the Master Plan Study are benchmarked), UC Riverside emitted 108,924 metric tons of carbon dioxide equivalents ($MtCO_2e$) Buildings are the single greatest contributor to these emissions. in 2014, UC Riverside's approximately 6,900,000 square feet of facilities produced 70,021 $MtCO_2e$, or 64 percent of the total. Of this 64 percent of emissions from UC Riverside buildings, 68 percent resulted from electricity generated to supply campus demand, while 32 percent resulted from natural gas combustion. Remaining campus emissions resulted from fleet vehicles, refrigerant leakage and other minor sources.

Figure 7.2 CAMPUS CARBON EMISSIONS BY SCOPE (IN $MtCO_2e$)

Scope 1	
Direct Emissions	22,535 (20.7%)
Scope 2	
Indirect Emissions (Electricity)	47,486 (43.6%)
Scope 3	
Indirect Emissions (Other)	38,903 (35.7%)
TOTAL	
	108,924 (100%)

Figure 7.3 Source: The Climate Registry and UC Riverside Office of Sustainability

FACTORS IN UC RIVERSIDE'S GHG EMISSIONS

The analyses performed for the Physical Master Plan Study revealed valuable information about factors contributing to UC Riversides' GHG emissions and the interactions between these factors. UC Riverside's current GHG footprint results from a complex interaction of the following factors:

- Regional climate
- Existing building stock
- Types and energy intensities of existing campus buildings
- Fuel source & carbon intensity
- Renewable energy
- Carbon offsets

UC Riverside's future emissions will result from a complex interaction of the foregoing factors, along with building types and energy intensities of planned new buildings.

Regional climate

Riverside, California, is located in Climate Type 3B (Warm, Dry) with 2,430 Cooling Degree-Days and 1,779 Heating Degree-Days per year. (A technical measurement in climate analysis, the units Cooling Degree Days and Heating Degree Days are not intended to add up to 365). Annual precipitation totals 10.4 inches occurring mostly in the winter and early spring. Riverside experiences extreme heat and cold nights during the summer and moderate temperatures during the winter. Buildings in Riverside typically use more energy than buildings in more moderate climates. Buildings located in more temperate climates can achieve a lower energy intensity since they have lower heating and cooling requirements throughout the year.

Building stock

The University projects that its enrollment will grow to 25,000 students by 2020 and 30,000 students by 2025. To accommodate this projected growth, the Planning Team has modeled the addition of up to 2.9 million gross square feet (GSF) to the campus's existing inventory of 6.4 million GSF of space. Complete details of the program used for the Master Plan Study are included in Chapter 1, *Building On The Path To Preeminence.*

Types and energy intensities of existing campus buildings

Many variables determine the annual energy use of a building, which in turn largely determines its carbon impact. These variables include the surrounding climate, the efficiency and operation of building systems, and building function. Because no two buildings are exactly alike in their use, design, and operation, building performance assessments normalize energy use by establishing a common metric. This metric is Energy Use Intensity, or EUI. EUI is an expression of annual energy consumed per square foot (kBtu/sf/yr). At the time of this writing, the average EUI for all UC Riverside buildings is 130 kBtu/sf/yr.

As detailed in Chapter 6, *Infrastructure & Utilities,* the Planning Team conducted an in-depth assessment of age, condition, and performance of existing campus buildings during the Master Plan Study to understand the EUIs of different groups of buildings on campus.

Figure 7.3 RIVERSIDE HEATING AND COOLING DEGREE-DAYS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEV
AVERAGE HIGH (°F)	68	68	71	76	80	87	94	95	91	83	74	67
AVERAGE LOW (°F)	43	44	46	49	54	57	62	62	59	53	46	42
PRECIPITATION (INCHES)	2.32	2.4	1.69	0.67	0.2	0.08	0.04	0.08	0.16	0.47	0.83	1.38

Source: http://www.usclimatedata.com/climate/riverside/california/united-states/usca1695

Riverside's climate is semi-arid, with highs in summer often well over 100 degrees Fahrenheit.

Types and energy intensities of planned new buildings

A study for the UC system by the University of California and the California Institute for Energy and Environment grouped UC buildings into three general building types and provided EUI baselines and targets for each (see Figure 7.4).

Using this work as a model, the Planning Team reviewed UC Riverside's building inventory and grouped campus buildings into the following four types:

- Instruction, Institutional and Campus Support
- Research
- Housing and Dining
- Student Support

To establish benchmarks for comparing and evaluating the actual and potential energy performance of these building types, the Planning Team first referenced the U.S. Environmental Protection Agency's (EPA) Target Finder tool. Column 1 in Figure 7.5 shows the median EUI for a selection of building types represented on the UC Riverside campus. The Planning Team also referenced three additional standards recognized in the building industry. Each standard – California Title 24, 30% better than Title 24, and Architecture 2030 – represents a increasingly higher level of energy performance than the median shown in column 1.

Fuel source & carbon intensity

UC Riverside obtains most of its electric power from Riverside Public Utilities (RPU). It also operates a central utility plant. Chapter 6, *Infrastructure & Utilities,* provides more in-depth information on existing energy infrastructure.

The carbon content of energy is expressed in pounds of carbon dioxide (CO_2) per megawatt hour, calculated using an emissions factor. In the context of UC Riverside's carbon neutrality plan, the emissions associated with electricity generated for the campus is expressed in pounds of carbon dioxide (C02) per megawatt hour (MWH) of electricity.

The carbon intensity of electricity sourced from the grid varies widely. Today, Riverside Public Utilities generates 36 percent of its electricity from coal. RPU has been reducing the carbon content of its electricity

Figure 7.4 EUI TARGETS BY BUILDING TYPE

	Baseline	Target
Academic/Administrative Non-Complex Space (Instruction, Institutional and Campus Support)	65	33
Housing Non-complex Space (Housing and Dining)	59	29
Lab/Complex Space (Research)	310	158

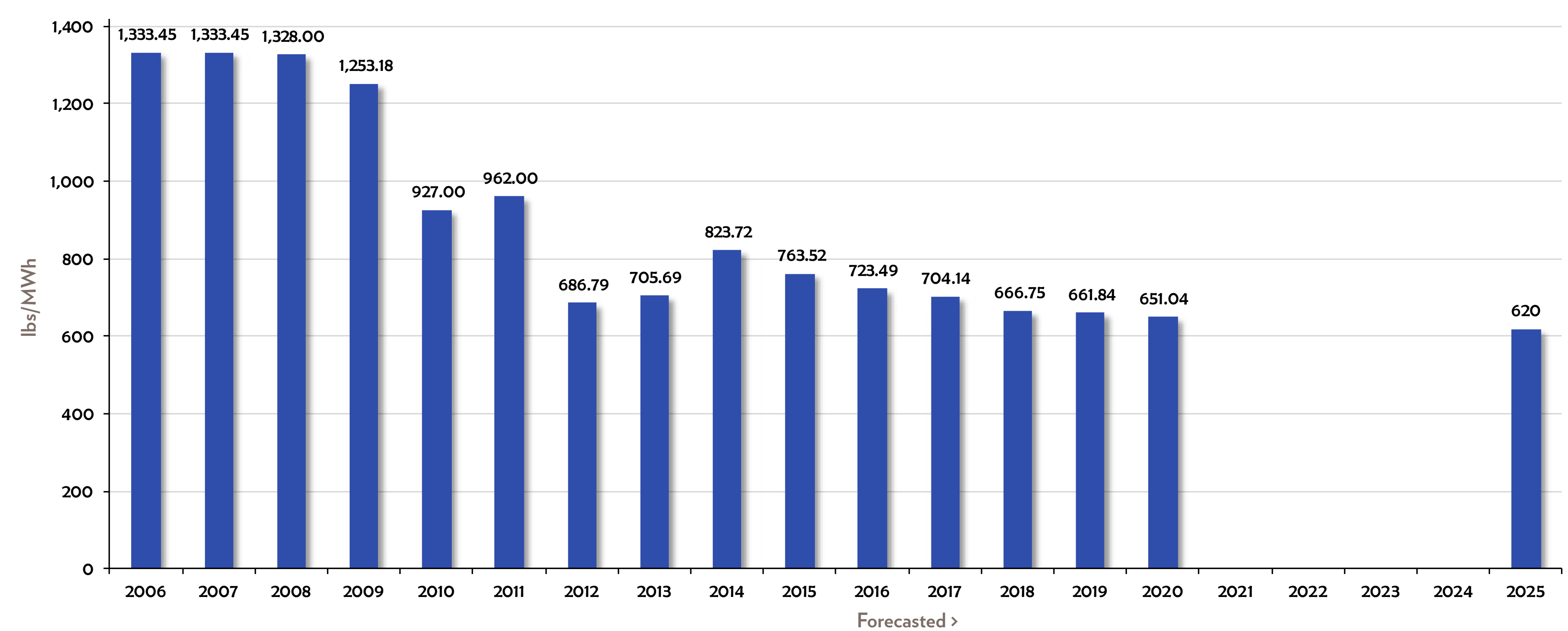
Source: University of California and California Institute for Energy and Environment

Figure 7.5 EUI BENCHMARKS BY BUILDING TYPE

	Median EUI (EPA[1])	Title 24[2]	30% Better Than Title 24	Architecture 2030[3]
Laboratory	274[4]	219	153	82
Restaurant/Cafeteria	224	179	125	67
College/University	132	106	74	40
Library	92	74	52	28
Office	87	70	49	26
Housing	66	53	37	20
Fitness Center	43	34	24	13
Performing Arts	37	30	21	11
Storage/Warehouse	29	23	16	9

[1]Except for lab buildings, which are not included in EPA's TargetFinder
[2]Demonstration Only, Title 24 is prescriptive, not EUI-based
[3]2030 Challenge Target for 2015 [4]Since EPA's TargetFinder does not include lab buildings, this value was derived from the Labs21 database by climate zone and UC EUI targets. The resulting value reflects Average EUI for All Labs in Climate Zone 3B

Figure 7.6 TREND IN CARBON CONTENT OF RIVERSIDE PUBLIC UTILITIES ELECTRICITY



over time. As shown in Figure 7.6, the carbon intensity of RPU electricity has been declining, from 1,333.45 pounds CO_2 per MWH in 2006 to 823.72 in 2014, a reduction of approximately 40%. At the time of the Master Plan Study, RPU projected an additional 11% reduction by 2020, for a total reduction in carbon intensity of approximately 52% between 2006 and 2020. With various state and federal policies currently in place or likely to be enacted, the carbon content of RPU electricity likely will reduce further.

To conservatively estimate the carbon intensity of RPU electricity in the 2025, when UC Riverside must achieve the Carbon Neutrality 2025 Initiative, the planning team calculated a linear and logarithmic trend in the 2006-2020 data and added approximately 10% back, for a projected value of 620 pounds CO_2 per MWH for RPU electricity in 2025.

Renewable energy

Although limited in output, UC Riverside has begun on-campus production of renewable energy. As of the Master Plan Study, a 3.0 MW ground-mounted photovoltaic installation produces electricity for the campus. The campus also produces solar hot water on the rooftops of the Glen Mor student housing facility.

Annual carbon offsets

The California Air Resources Board (CARB) established a GHG cap-and-trade program starting in 2013 as required by Assembly Bill 32 (AB32), the California Global Warming Solutions Act. Emitters of greater than 25,000 $MtCO_2e$ must purchase an allowance for each ton of GHG they emit above this threshold. Many California universities including UC Riverside are near or above this cap and must participate in the purchase of carbon offsets. UC Riverside's Scope 1 emissions currently fall below this threshold and are expected to remain as such. However, the purchase of carbon offsets may still be required to meet the UC Carbon Neutrality 2025 goal, even if CARB's GHG cap-and-trade program does not require the University to do so.

In April 2014, CARB approved the allocation of free allowances to the University of California system for the 2013-2020 period. Starting in 2014, UC campuses received 98 percent of the allowances needed for their annual compliance. Every year after 2014, the allowance amount will decrease in line with the reduction in the cap-and-trade program's overall emissions cap reduction, or about 2 percent per year. The program also requires reporting of investments in energy efficiency and other projects consistent with the goals of AB 32, the total amount of which should equate to the total value of the free allowances. When the UC carbon neutrality commitment goes into effect in 2025, UC Riverside will need to purchase carbon offsets for any emissions not already eliminated through investments in energy efficiency and renewable energy.

UC Riverside is currently expected to purchase third-party carbon-credits (valued at $12.70 per $MtCO_2e$ at the time of the Master Plan Study) to offset emissions that exceed each year's emissions cap. At 2015 and estimated future emissions levels, these are real and significant costs that must be factored into planning for future physical improvements.

The Planning Team's analysis demonstrates the annual cost of carbon offsets would be over $1 million per year starting in 2025 for business-as-usual. Offset costs will be approximately $500,000 per year if all energy efficiency and renewable energy opportunities are implemented on campus. These costs would be less than $200,000 per year with offsite renewable energy to account for campus electricity use. Carbon offsets could theoretically be zero if all of these strategies were pursued in combination with switching all natural gas, hot water and domestic heating to heat pumps powered by electricity.

7.2 Methodology for Developing Carbon Neutrality Scenarios and Strategies

DESIGNING A CARBON NEUTRALITY STRATEGY FOR UC RIVERSIDE

The Planning Team quantified the key factors in current building-related emissions using inputs from on-site building assessments and from research and calculations developed as part of the Master Plan Study. The Planning Team then developed scenarios that vary these key factors to achieve carbon neutrality. For reference, see Fig. 7.8.

High performance targets for existing and new buildings

To guide future retrofits of existing facilities and the design of new facilities, the Planning Team developed recommended EUI targets for existing and new facilities, shown in Fig. 7.7, representing ambitious but feasible performance targets for UC Riverside's buildings.

Figure 7.7 PROPOSED HIGH-PERFORMANCE EUI TARGETS

	Existing Building Retrofits	New Construction
Instruction, Institutional and Campus Support	45	39
Research (Complex Space)	155	136
Housing and Dining	43	34
Student Support	100	88

Figure 7.8 KEY FACTORS IN CARBON EMISSIONS AND INPUTS TO UC RIVERSIDE CARBON ANALYSIS

KEY FACTORS IN CARBON EMISSIONS	INPUTS TO CARBON MODEL
Riverside climate	• N/A (Reflected in building energy use data and EUI targets)
Building stock	• Total square footage of buildings (new and existing) • List of demolished buildings (name, square footage, and type) • Planned new buildings (type, square footage) • Building type (Instruction, Institutional and Campus Support; Research; Housing and Dining; Student Support)
Types and energy intensities of existing campus buildings	• Existing building energy use data
Types and energy intensities of planned new buildings	• Planned building EUI targets
Fuel source and carbon intensity	• Carbon intensity of electricity and natural gas
Renewable energy	• Existing solar photovoltaic and hot water generation • Solar resource availability • Area available for rooftop installation • Solar hot water resource fraction • Opportunity sites for buildings and ground-mount solar
Carbon offsets	• Carbon offset price per metric ton

To estimate future energy consumption and associated carbon emissions, the Planning Team then applied the targeted EUIs to the different types of new buildings envisioned in the Master Plan Study. These EUI targets were also modeled using sophisticated energy analysis software. The results of this analysis are presented and discussed further in Chapter 6, *Infrastructure & Utilities*.

Fuel source and anticipated carbon intensity

Most energy serving UC Riverside buildings comes from Riverside Public Utilities. RPU's portfolio is shifting from fossil fuels to renewable sources, such as solar and wind. After reviewing past and forecasted carbon content of RPU energy, the Planning Team assumed a fuel source carbon intensity of 620 pounds of greenhouse gas emissions per megawatt hour of production for 2025, a reduction of 4.7% beyond the forecast level shown in Figure 7.6 for 2020.

Renewable energy

The Planning Team evaluated on-campus and off-campus renewable energy options that can replace carbon-intensive and non-renewable fossil fuel-based energy sources. In particular, the following were evaluated:

- Solar photovoltaics for electricity production
- Solar hot water production for domestic uses
- Wind energy for electricity production
- Biogas for both electricity and heat production (cogeneration)

Offsets

For any carbon offsets included in UC Riverside's carbon neutrality strategy, the analysis assumed a price of $12.70 per $MtCO_2e$.

DEVELOPING CARBON NEUTRALITY SCENARIOS

After characterizing and quantifying existing conditions and planned campus growth, the Planning Team developed scenarios illustrating the effects of implementing the Master Plan Study, drawn from the key factors in the carbon neutrality analysis.

Building efficiency

The scenarios update the campus building stock by removing the carbon impacts from buildings slated for demolition and replacement. For existing buildings that will remain in operation, the scenarios assume energy efficiency improvements from high-performance upgrades that target recommended EUIs. Scenarios assume that new buildings will incorporate high-performance energy efficiency strategies to achieve the recommended EUI targets for their respective types.

On-campus renewable energy

- **Ground-mount solar**
  All scenarios envision on-campus solar generation from ground-mount photovoltaic installations above parking lots, walkways, and other available open spaces.

- **Rooftop solar photovoltaics**
  One scenario envisions an option for on-campus solar photovoltaic electricity generation from the rooftops of all non-residential campus buildings, including existing buildings to remain and new buildings to be built.

- **Canopy solar photovoltaics**
  Two scenarios envision on-campus solar photovoltaic electricity generation from canopy solar above building rooftops, which offers increased area for production and thus generation capacity.

- **Solar hot water for residential buildings**
  Three scenarios envision solar hot water production on the rooftops of all existing residential buildings and all planned new residential buildings.

- **Electrified infrastructure**
  One scenario envisions replacement of natural gas with electric heat pumps for the campus's steam plant.

Off-campus renewable energy

After maximizing on-campus rooftop and ground-mount generation potential, the scenarios calculate the amount of off-campus renewable energy, in the form of solar and wind generation, required to achieve carbon neutrality from all facility operations except the campus steam plant.

Carbon offsets

The scenarios estimate the annual cost of any offsets needed to achieve carbon neutrality after the implementation of the strategies selected for each scenario.

7.3 Pathways Toward Carbon Neutrality

UC RIVERSIDE'S CARBON NEUTRALITY SCENARIOS

The Planning Team's scenarios illustrate pathways for UC Riverside to achieve carbon neutrality. The scenarios are not exhaustive—the University could implement a preferred scenario representing a combination of the measures shown. For example, some rooftops could have direct-mount solar while others could have canopies; off-campus solar and wind energy could be pursued along with carbon offsets.

In realizing any of the scenarios, UC Riverside will need to:

- Retrofit existing buildings and design new buildings to meet aggressive EUI targets
- Install solar generation directly on building rooftops or on canopies above rooftops
- Develop off-campus renewable energy capacity or purchase carbon offsets
- Choose wind or solar energy for off-campus renewable energy production

Fig 7.9 provides a comprehensive view of the five scenarios.

Scenario 0: Baseline

Reflected in the first column of Fig. 7.9, existing campus conditions (2014) provide a baseline benchmark for the five carbon neutrality scenarios. The campus's 6.4 million square feet of buildings have an average EUI of 130 kBtu/sf/yr. On-campus solar generation is limited to 3 MW from the existing ground-mount photovoltaic array, and on-campus solar hot water is limited to the existing system on Glen Mor.

Scenario 1: High-performance buildings

Scenario 1 demonstrates the effects of energy efficiency modernizations for existing buildings and aggressive EUI targets for new buildings, averaging 80 kBtu/sf/year across campus, at the full campus build-out of 8.9 million square feet. As this scenario reveals, energy efficiency alone cannot neutralize current and projected additional campus GHG emissions.

Scenarios 2-5: High-performance buildings with four renewable energy alternatives

After high-performance strategies are implemented for all existing and new buildings in a fully built-out campus of 8.9 million square feet, renewable energy must replace fossil fuels. If renewable energy cannot entirely replace fossil fuels, carbon offsets must be purchased to achieve carbon neutrality. Scenarios 2-5 demonstrate the effects of four alternative renewable energy scenarios for UC Riverside:

Scenario 2 adds 8 MW of ground-mount solar generation to UC Riverside's current on-campus renewable energy generation. This scenario envisions new ground-mount solar covering about 25 acres of walkways, parking lots, and other open spaces. All remaining scenarios include this new, 8-MW, ground-mount solar installation..

Scenario 3 adds 9.7 MW of new rooftop solar energy production to the increased on-campus renewable energy generation shown in Scenario 2. This scenario assumes 50% coverage (maximum practical) of all campus non-residential buildings with photovoltaic panels. In addition, this scenario reflects the addition of either 53 MW of off-campus solar energy production or 43 MW of off-campus wind energy production to UC Riverside's energy supply.

Scenario 4 adds 41 MW of new canopy solar energy production to the increased on-campus renewable energy generation shown in scenario 2. Solar canopies offer more area for generation and thus more production capacity. By generating more energy on-campus from canopy solar arrays, this scenario reduces the capacity needed from off-site generation to 32 MW of solar energy or 23 MW of wind energy.

Scenario 5 also adds 41 MW of new canopy solar energy production to current on-campus renewable energy generation (in addition to Scenario 2's new, 8-MW ground-mount production). In this scenario, campus infrastructure is also updated by decommissioning campus natural gas steam generation and introducing electric heat pumps instead. To offset this increased electrical load, off-campus renewable energy generation must increase to either 63 MW of solar energy production or 45 MW of wind energy production.

DISCUSSION AND RECOMMENDATIONS

Energy efficiency

UC Riverside's carbon neutrality scenarios require campus building energy efficiency to improve from the current campus average EUI of 130 kBtu/sf/yr to 80 kBtu/sf/yr. This is a significant undertaking that translates to upgrades throughout existing campus buildings and high performance construction for all new facilities.

Energy efficiency is not an ultimate solution for neutralizing the campus's carbon footprint. While energy efficiency reduces energy consumption and associated GHG emissions, it does not eliminate them. For example, UC Riverside's central plant burns natural gas, a fossil fuel. While the efficiency of the plant may be increased, it will always produce some GHG emissions by virtue of its fuel source.

Energy efficiency recommendations

- Eliminate buildings that have exceeded their useful life and perform poorly.
- Develop a long-term strategy to inform short-term and project-by-project decisions about heating, cooling and energy distribution with carbon neutrality as a priority.
- Investments in infrastructure should give preference to renewable and low-carbon fuel sources to ensure systematic reductions in GHG emissions are achieved over time.
- Upgrade existing buildings that will remain in service, at least to current energy code minimums.
- Design and construct all new buildings for high performance and energy efficiency.
- Target net-zero capable EUIs for Instruction, Institutional and Campus Support and Housing and Dining building types. (This may not be possible for Research and Student Support.) See Chapter 6 recommendations for meeting EUI targets for existing and new buildings.

Renewable energy

After implementing energy efficiency measures, UC Riverside will need to pursue on-campus and/or off-campus solar generation in order to achieve carbon neutrality. After increasing the energy efficiency of existing and new buildings to an average campus EUI of 80 kBtu/sf/yr and optimizing campus steam and cooling infrastructure, 129 million kWh of annual electrical demand and 269 million kBtu of annual thermal energy demand remain. This demand must be supplied with carbon-free energy to avoid the significant ongoing operational costs of carbon offsets.

Riverside has excellent solar resources available throughout the year. The average annual solar insolation is equal to 1,900 kilowatt-hours per square meter. (The US national range is 1,000-2,100 kilowatt-hours per square meter.)

Multiple factors affect the efficiency of solar generation. Current solar photovoltaic technology can only capture about 20 percent of incident solar radiation. Additional losses result from conversion to alternating current (AC) and other factors. Solar arrays must also consider solar panel tilt, spacing for access, and other factors.

After considering these variables, an area of 240 acres would be required to construct a large enough solar array to produce 100 percent of the current UC Riverside electricity usage.

(Land resources of the existing campus are too valuable to devote to a single use such as ground mounted solar.)

If there were technology that could capture 100 percent of this solar radiation, UC Riverside would require 16 acres of solar panels to supply its current demand of 123,900 Megawatt-hours.

UC Riverside currently operates a 3-MW ground-mount solar installation. The Master Plan Study demonstrates that the University can increase its on-campus solar generation from ground-mount installations by 8 MW, to 11 MW total, by installing ground-mount solar over parking lots and walkways and on suitable unused open space.

Two options exist for rooftop solar electricity production. Photovoltaic panels mounted on building rooftops can be maximized at 9.7 MW of installed capacity. This assumes a utilization of 50 percent of total rooftop area, the maximum practical. Alternatively, the University may install solar canopies above existing or new rooftops. This would allow for up to 41 MW of solar electricity production. Campus solar is a significant undertaking that would likely require partnering with a third-party solar provider in a power purchase agreement (PPA).

In addition to solar electricity, UC Riverside can implement solar hot water on campus, similar to that already in place on Glen Mor. Using the sun's rays to heat water for domestic uses is a proven technology widely used in many parts of the world. When installed on appropriate buildings, solar hot water is more cost-effective than solar photovoltaic. Solar hot water is best suited to buildings with large hot water demand, such as residential buildings, rather than academic buildings.

On an annual basis, at least 50 percent of the daily hot water demand in UC Riverside's residential buildings can be served by solar hot water.

Glen Mor residential housing includes the installation of a domestic solar hot water system that offsets 45 percent of the natural gas demand of the building.

Photovoltaic electricity production can be distributed, so it is broadly applicable to any building rooftop, or to ground installation. The Master Plan Study targets solar photovoltaics for all non-residential building rooftops, and for selective ground installations. On-campus generation should directly serve adjacent building loads, providing so-called "microgrid" benefits. These benefits include minimizing transmission losses and avoiding constraints in the campus's utility distribution ("pinch points" in the campus grid) when managed on the campus side of utility sub-stations.

Although solar hot water is more cost-effective than solar photovoltaic, it requires large and consistent domestic hot water demand within a short distance to take advantage of hot water output. For this reason, the Planning Team targeted solar hot water installations for residential building rooftops only, since they have large and consistent domestic hot water demand throughout the year.

In 2015, electricity supply to UC Riverside came primarily from large, remote generation facilities. No dedicated off-campus renewable energy is serving the campus. After maximizing on-campus solar electricity and on-campus solar hot water, UC Riverside will still need large off-campus renewable energy installations to avoid expensive carbon offsets. As expressed in the scenarios, these installations would need to produce anywhere from 32 MW to 63 MW of solar electricity offsite to avoid carbon offsets. This assumes that all campus natural gas uses are converted to use electricity and that solar canopies (rather than rooftop-mounted solar panels) are installed.

Alternatively, wind farms producing between 23 MW and 45 MW could be installed instead of solar fields. Wind and solar have different production characteristics, accounting for the differing capacities of wind and solar. Compared to off-campus wind energy, off-campus solar energy generation would require much less land area, would be quicker and easier to permit and install, and could be installed on any site with unobstructed solar access.

San Gorgonio Pass near Riverside is one of the windiest places in Southern California. For this reason, it has over 600MW of installed wind power generation in operation. Although wind energy is widely deployed in Riverside County, it is not well suited to the steep and urbanized landscape of the UC Riverside campus. When implemented at a utility scale in locations with strong, consistent wind, wind power can be highly cost-effective. Wind energy from one or more off-campus utility-scale wind farms would reduce the need to develop on-campus solar, which is inherently more expensive and complicated. This strategy is highly dependent on finding a viable site. At 2 MW per turbine, generation capacity of 25 to 50 MW of off-site wind energy would require 13 to 25 wind turbines. At 85 acres per MW, generation of 25 MW to 50 MW would require 2,100 to 4,500 acres. Such a site would need to offer strong winds and adjacent high voltage transmission lines. Identifying and permitting a viable site for wind energy will take at least 3-5 years.

Long term, as utility-scale electricity generation converts from fossil fuel sources to renewable sources, such as solar and wind, electricity has the potential to become completely carbon neutral. For this reason, renewable energy production is a critical component of any carbon neutrality strategy. Additionally, renewable energy is free after the initial investment, perpetually boosting returns with no additional carbon-related costs.

Figure 7.9 SCENARIOS FOR CARBON NEUTRALITY

0 — 2015 Baseline

Existing campus conditions provide a starting-point for evaluating the impacts of planning variables, including future campus building growth, the efficiency of those buildings and the kinds of fuel sources supplying energy to those buildings.

1 — High-Performance Buildings
With Existing Ground-Mount Solar

With energy efficiency modernizations for existing buildings and aggressive EUI targets for new, the campus will emit significantly less carbon-dioxide. The campus would still be far from achieving carbon-neutrality, however, so credit offsets will need to be purchased annually.

	0 — 2015 Baseline	1 — High-Performance Buildings
SQUARE FOOTAGE (BUILDINGS)	6,400,000 square feet	8,900,000 square feet (full build-out)
AVERAGE BUILDING EUI	130 kBtu/sf/yr	80 kBtu/sf/yr
CARBON NEUTRALITY STRATEGIES	Increased shade indicates changes from previous scenario	Increased shade indicates changes from previous scenario
High Performance Buildings		See Chapter 6 for specific energy efficiency measures
On-Campus Solar		
Existing Ground-Mount Capacity	3.0 MW	3.0 MW
New Rooftop Capacity	None	None
New Ground-Mount Capacity	None	None
New Canopies Capacity	None	None
Solar Hot Water	Existing Only (Glen Mor)	Existing Only (Glen Mor)
Off-Campus Utility Generation	None	None
Specifications for Solar Option	N/A	N/A
Specifications for Wind Option	None	None
Campus Infrastructure Upgrades	N/A	N/A
Specifications	None	None
RESULTS		
Solar as % of Total Electricity	2.1%	2.2%
Avoided Offset Costs from Solar	$17,000 (from existing on-site solar)	$47,000 annually
REMAINING EMISSION SOURCES	Utility electricity supply; on-site natural gas combustion	Utility electricity supply; on-site natural gas combustion
EMISSIONS / OFFSETS NEEDED	73,000 $MtCO_2e$	46,000 $MtCO_2e$
Potential Cost (Annual)	$925,000	$583,000

2

High-Performance Buildings
With Existing Ground-Mount Solar

New Renewable Energy
New Ground-Mount Solar

In addition to high-performance buildings, if renewable energy in the form of new ground-mount solar is pursued, the cost for carbon offsets can be reduced significantly.

3

High-Performance Buildings
With Existing Ground-Mount Solar

New Renewable Energy
New Ground-Mount Solar
Rooftop Solar Electric & Hot Water
Off-Campus Utility-Scale Solar (Option A)
OR
Off-Campus Utility-Scale Wind (Option A)

Further expanding the production of renewable energy for the campus can reduce the costs for offsets even more. Aggressive rooftop solar or generating utility-scale solar electricity off-campus are alternative options described in this scenario.

4

High-Performance Buildings
With Existing Ground-Mount Solar

New Renewable Energy
New Ground-Mount Solar
Rooftop Solar Electric & Hot Water
Off-Campus Utility-Scale Solar (Option B)
OR
Off-Campus Utility-Scale Wind (Option B)

It is possible to supply 100% of all electricity demand on campus with renewable carbon-free energy, but carbon offsets would still need to be purchased annually to offset the remaining consumption of fossil fuels (natural gas).

5

High-Performance Buildings
With Existing Ground-Mount Solar

New Renewable Energy
New Ground-Mount Solar
Rooftop Solar Electric & Hot Water
Off-Campus Utility-Scale Solar (Option C)
OR
Off-Campus Utility-Scale Wind (Option C)

Electrified Infrastructure
Both Option 1 and Option 2 contribute enough carbon-neutral electricity to meet 100% of site electric demand, including new additional load from electric heat pumps replacing on-site, natural gas-powered steam (so there is no on-site combustion). Campus infrastructure energy efficiency upgrades are implemented to achieve across-the board emissions reductions not captured in EUI, including upgrade of chillers.

All-electric infrastructure eliminates natural gas on campus. Off-campus utility-scale renewable energy supplies 100% of campus electricity from carbon-free sources or generates enough surplus carbon-free electricity to offset emissions from natural gas.

2	3	4	5
8,900,000 square feet (full build-out)	8,900,000 square feet (full build-out)	8,900,000 square feet (full build-out)	8,900,000 square feet (full build-out)
80 kBtu/sf/yr	80 kBtu/sf/yr	80 kBtu/sf/yr	80 kBtu/sf/yr
Increased shade indicates changes from previous scenario	Increased shade indicates changes from previous scenario	Increased shade indicates changes from previous scenario	Increased shade indicates changes from previous scenario
3.0 MW	3.0 MW	3.0 MW	3.0 MW
None	9.7 MW (50% coverage of all non-residential buildings)	None (See New Canopies Output Below)	None (See New Canopies Output Below)
8 MW (Coverage of walkways and parking areas; about 25 acres)	8 MW (Coverage of walkways and parking areas; about 25 acres)	8 MW (Coverage of walkways and parking areas; about 25 acres)	8 MW (Coverage of walkways and parking areas; about 25 acres)
None	None	41 MW (100% coverage)	41 MW (100% coverage)
Existing Only (Glen Mor)	All Residential Rooftops (including Glen Mor)	All Residential Rooftops (including Glen Mor)	All Residential Rooftops (including Glen Mor)
None	**53 MW Solar OR 43 MW Wind**	**32 MW Solar OR 23 MW Wind**	**63 MW Solar OR 45 MW Wind**
N/A	181-acre site for 100% of campus electricity	99-acre site for 100% of campus electricity	100-acre site for 100% of campus electricity
None	43 MW on 3,690-acre site to provide 100% of campus electricity	1955-acre site for 100% of campus electricity	1955-acre site for 100% of campus electricity
N/A	None	None	
None			Campus steam decommissioned; electric heat pumps replace campus steam
15%	100% (25.9% from on-campus sources)	100%	100%
$64,000 annually	$423,000 annually	$423,000 annually	$600,000 annually
Utility electricity supply; on-site natural gas combustion	On-site natural gas combustion	On-site natural gas combustion	0
39,000 $MtCO_2e$	14,000 $MtCO_2e$	14,000 $MtCO_2e$	0
$498,000 annually	$177,000 annually	$177,000 annually	0

NOTE Scenarios 2-5 explore combinations of on-site and off-site renewable energy installation scenarios to achieve carbon neutrality building on the fundamental assumptions about energy efficient buildings and infrastructure in Scenario 1.

Solar photovoltaic farms would provide the most straightforward and dependable carbon neutral energy production to help eliminate or offset campus GHG emissions. Power Purchase Agreements (PPAs) with Riverside Public Utilities as a third-party solar provider could potentially be negotiated to supply carbon neutral electricity instead of electricity generated with fossil fuels. Solar-generated electricity from remote facilities that have inexpensive land costs, ideal solar exposures and sufficient utility grid access can benefit the UC Riverside campus by preserving campus land for academic uses.

Biogas

For the purpose of the Master Plan Study, biogas is defined as the process of collecting agricultural and food waste and converting it to electricity by reducing the feedstock through bio-digesters, creating methane as a result, and burning that methane to drive steam-powered electric generators. Biomass recovery systems are capable of reducing food and agricultural waste by converting it to energy. Waste heat is also collected and used. Biogas use offers the secondary benefit of waste reduction, diverting waste from a landfill where methane (a powerful greenhouse gas) might be released into the atmosphere uncontrolled.

UC Davis uses anaerobic digesters to produce biogas for combustion for cogeneration (heat and power) and for use in vehicles that run on natural gas. Fuel cells were also considered as a technology to produce renewable energy from biogas, however the success at UC Davis using combustion of biogas was deemed most appropriate. Since there were no other renewable energy feedstocks for fuel cells, they were not further considered (fuel cells can also run on natural gas, however that is a fossil fuel with greenhouse gas emissions and inherently not carbon neutral).

Based on production and feedstock numbers from the UC Davis biogas system, UC Riverside could likely produce approximately 2 million kWh per year (1.5 percent of total energy demand in 2025) from 10,000 tons of organic food and agricultural waste. This is about half of the waste input and energy production associated with the UC Davis system, which has 50 percent more students to generate waste and greater agriculture sources for feedstock.

A biogas system would have an upfront cost of $4.2 million. Relative to the energy production, a biogas system is not a cost efficient strategy. Biogas presents several other challenges. A great volume of reliable feedstock must be collected and transported to the processing site, creating cost, imposing logistical coordination needs, and requiring energy input and associated greenhouse gas emissions. As a new technology, biogas may pose higher costs with uncertain reliability of meeting predicted energy production performance.

Energy expended to collect and deliver feedstock must be considered. Overall, the cost of a biogas system for the amount of energy it produces it not cost effective, however it may be worthwhile when waste elimination and treatment is considered, or as a research opportunity.

Biogas purchased from a third party source should be considered as a carbon offset, not an energy resource for the purpose of on-campus energy supply. (See "Off-Site Biogas Offset Purchase.") The purchase of off-site biogas carbon offsets are one specific type of carbon offset. They represent purchasing the right to claim the carbon reductions from the biogas project elsewhere, but not the actual use and substitution of biogas for natural gas use on the UC Riverside campus. In 2014, UC Riverside purchased 20,000 MMBTU of biogas carbon offsets.

Renewable energy recommendations:

- Install solar thermal generation on all residential building rooftops.
- Install solar energy generation capacity on all other building rooftops.
- Partner with utilities to develop off-site utility-scale solar and/or wind power to fulfill campus energy needs

Carbon Offsets

After energy efficiency and renewable energy strategies are implemented, any remaining carbon footprint will need to be accounted for by purchasing carbon offsets.

Carbon offsets have limitations. They do not always result in additional greenhouse gas reductions (the concept of "additionality" is a fundamental and contentious issue with carbon offsets). This should be seen as a last resort, as carbon offsets are annual payments with no payback and only include the benefit of carbon reduction, so grid generation is still required for power.

KEY FINDINGS

To achieve carbon neutrality per the space need projected in the Master Plan Study, UC Riverside must:

- Reduce existing building energy use by 49%.
- Achieve performance 36% better than California energy code for new buildings.
- Install 10 MW of solar photovoltaic capacity on all non-residential building rooftops.
- Install 16 Billion Btu/yr of solar hot water on all residential building rooftops.
- Install 8 MW of solar on 25 acres of campus open space and above parking lots and walkways.
- Install 53 MW of off-campus solar on 162 acres of land or 43 MW of off-campus wind on 3,690 acres of land.
- Purchase $175,000 per year of carbon offsets to account for natural gas combustion or convert all remaining natural gas infrastructure to electric and install additional 15 MW of solar or 12 MW of wind energy to account for this increased load.
- Purchase offsets for Scope 3 Emissions (resulting mostly from transportation).