VANDERBILT UNIVERSITY

BLUESKY ENERGY VISION

FINAL REPORT DECEMBER 2018

BlueSkyVision

In support of FUTUREVU

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Foreword

FutureVU, Vanderbilt University's vision for the future of our campus, focuses on the importance of collaboration and shared purpose. Collaboration among the Vanderbilt community, including students, faculty and staff and with the vibrant city of Nashville that surrounds our beautiful campus. We must also hold a shared purpose of enhancing and promoting sustainable behaviors and practices in our community.

FutureVU is guided by core principles, including an adherence to sustainable practices, to ensure changes made to the campus environment are in support of Vanderbilt's Academic Strategic Plan. To ensure the long-term success of FutureVU, Vanderbilt must strive to achieve the highest standards of sustainability with a focus on environmental, social and economic responsibility.

The early planning process of FutureVU included initial recommendations to promote sustainability. In November 2017, the leaders of FutureVU, including the Division of Administration, decided to take these guidelines a step further and introduced the BlueSky Energy Vision Study. BlueSky is a bold goal for Vanderbilt to reduce its carbon footprint by bringing together diverse campus partners to address a complex set of issues with big ideas and out-of-the-box thinking. The shared vision and collaborative approach are what will drive BlueSky toward its goal of making Vanderbilt's energy consumption more efficient.

As a top research university, we have a responsibility to model sustainable energy consumption. Vanderbilt is committed to being a leader in how we contribute positively to our environment. That commitment is reflected in the BlueSky effort. FutureVU and BlueSky are examples of what Vanderbilt does best: bringing together students, faculty and staff to consider distinct solutions to a complex set of topics. Those collaborative efforts are why Vanderbilt will achieve the BlueSky vision.

Sincerely,

Nicholas S. Zeppos
Chancellor

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Table of Contents

Executive Summary

BlueSky Energy Vision Background

Sustainability has been an issue of increasing importance at Vanderbilt University throughout its recent history. Starting with the establishment of the Vanderbilt Environmental Advisory Committee in 2000, a variety of stakeholders have been involved in and pushed for actions on this important front as demonstrated in Figure 2. With the completion of FutureVU,[1] initiated in 2017, FutureVU calls for leadership in reducing greenhouse gas emissions to zero while creating a walkable, sustainable campus. FutureVU is driven by a core set of principles, defined with significant input from the Vanderbilt community, that recognizes the need for Vanderbilt to continue to lead on issues of sustainability. FutureVU launched the BlueSky Energy Vision Study (BlueSky Vision) in January 2018 to re-envision the campus energy infrastructure and to identify effective strategies for reducing carbon emissions on campus from the 2016 Greenhouse Gas (GHG) Emissions Baseline, Figure 1.

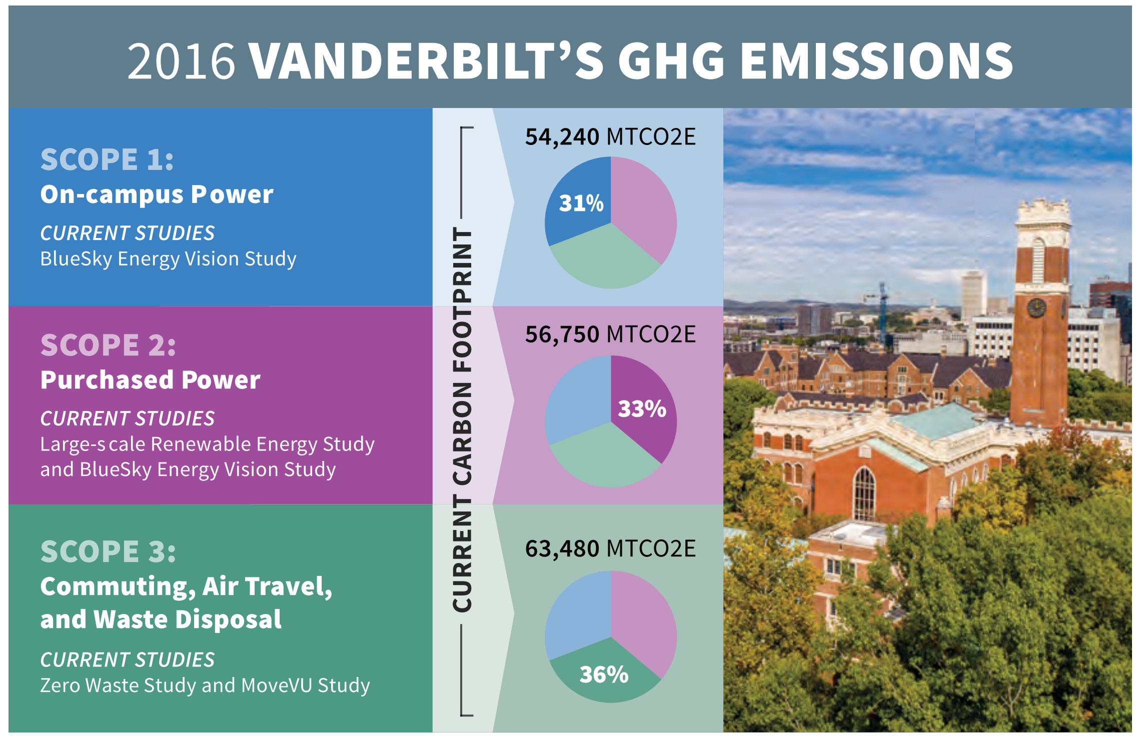


Figure 1. Vanderbilt's 2016 Greenhouse Gas Emissions Baseline

1 FutureVU Executive Summary summarizes the planning process, provides a brief overview of the information gathering phase and campus analysis, and emphasizes the guiding principles.

Vanderbilt University Sustainable Action Timeline

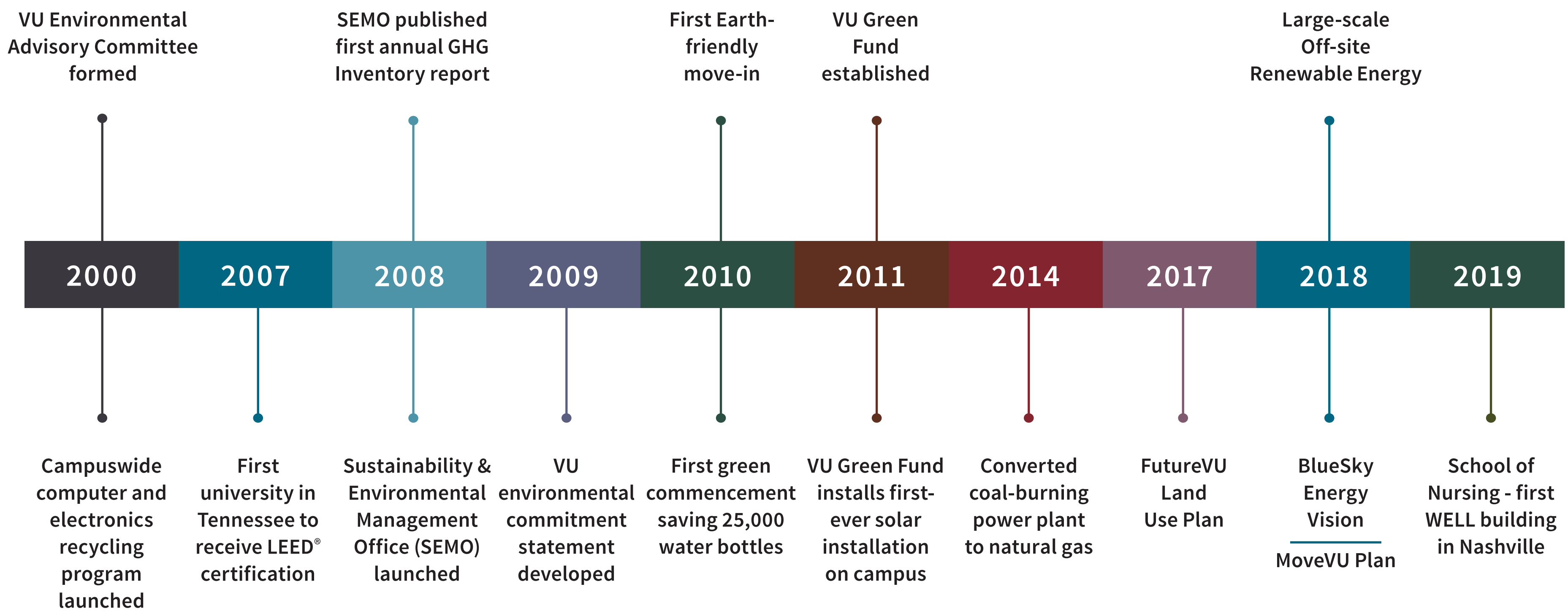


Figure 2. Vanderbilt Leadership Major Sustainable Action Timeline

A VIBRANT, CONNECTED & PEOPLE-CENTERED VANDERBILT

FutureVU Principles: Vanderbilt University

- Is an internationally recognized research university with strong partnerships among its schools
- Believes diversity and inclusion are integral to its mission
- Is a community of neighborhoods
- Is a historic, multilayered and vigorous campus
- Is a university that resides in a unique and distinctive park setting
- Is a walkable and sustainable campus
- Is a citizen of Nashville and the region

Total Campus

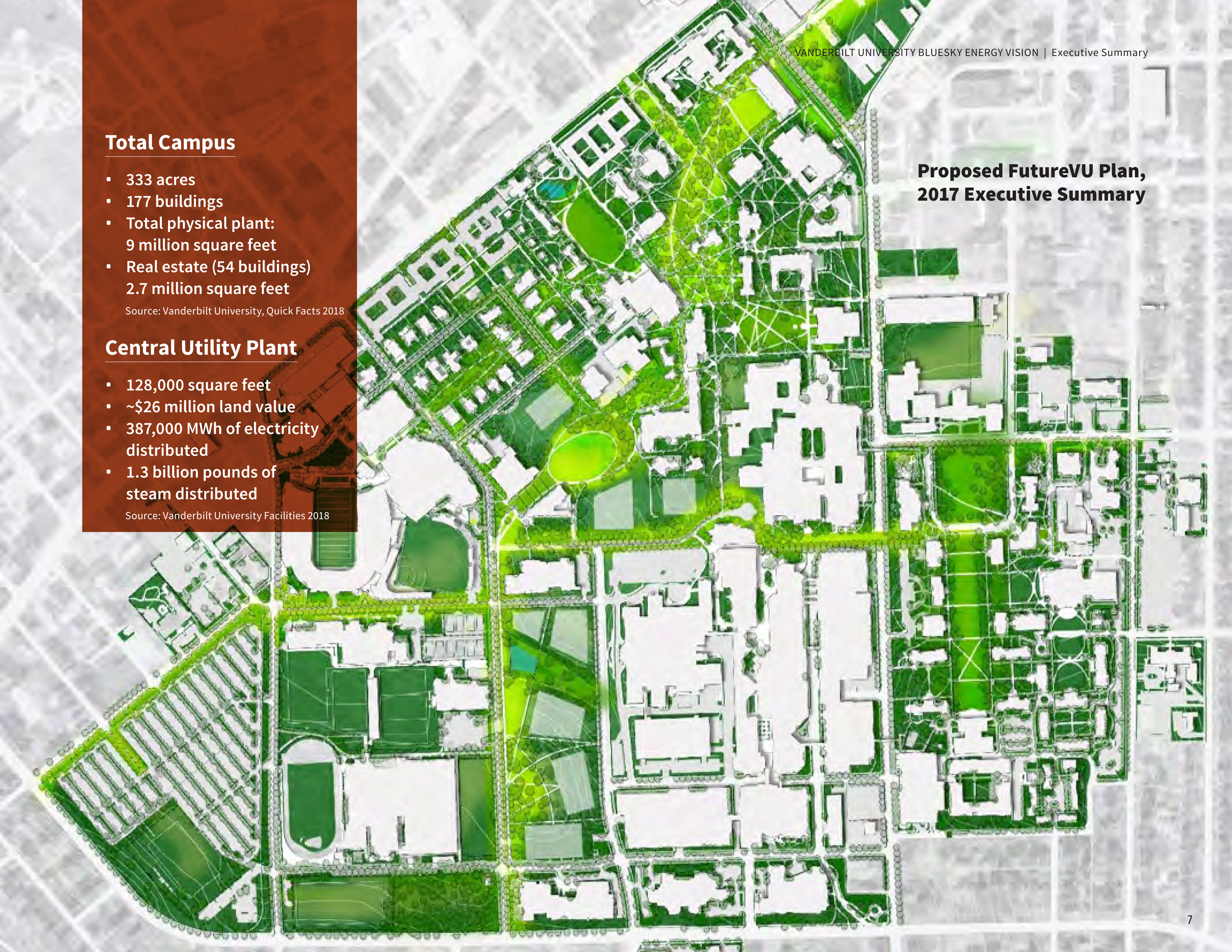
- 333 acres
- 177 buildings
- Total physical plant: 9 million square feet
- Real estate (54 buildings) 2.7 million square feet

Source: Vanderbilt University, Quick Facts 2018

Central Utility Plant

- 128,000 square feet
- ~$26 million land value
- 387,000 MWh of electricity distributed
- 1.3 billion pounds of steam distributed

Source: Vanderbilt University Facilities 2018



Proposed FutureVU Plan, 2017 Executive Summary

Crafting the BlueSky Vision

In order to develop a road map to reduce on-site emissions to zero, the BlueSky process uses a backcasting technique (rather than forecasting) to work backward from the desired future state, plotting necessary actions and milestones to achieve future goals. The BlueSky Vision supports FutureVU Guiding Principles and Vanderbilt's Academic Strategic Plan. Vanderbilt continues to demonstrate its commitment to its core values of teaching and student involvement (2018 Princeton Review Top 50 Green Colleges) and research and discovery (2018 Reuters Top 10 World's Most Innovative Universities). In 2018, 63% of students surveyed for the Princeton Review's "College Hopes & Worries Survey" reported that information about a college's commitment to the environment would positively influence their application or enrollment decisions.

Figure 3. Student participant at a visioning session (courtesy of Vanderbilt)

Crafting the BlueSky Vision included understanding how digital transformation and innovative research collaborations among faculty, students and staff will lead the university far beyond today's constraints. Further, planned strategic investments in expanding renewable energy sources, reducing energy consumption, and increasing energy storage will be integral to transforming the campus energy infrastructure.

Figure 4. Jason F. McLennan at a visioning session (courtesy of Vanderbilt)

Faculty, students, and staff looked to the blue sky and imagined a verdant, walkable campus with clean air supporting a healthy, resilient community. They imagined resources freed from external-flowing energy expenses reinvested in local, renewable energy infrastructure and in time redirected to the educational mission of the university. They imagined Vanderbilt as a center of energy research and innovation attracting funding and talent from around the world.

Engaged Stakeholders

A diverse group of faculty, students, and staff were engaged to share ideas for the BlueSky Vision. These university stakeholders emphasized the relationship between the university's reputational value and providing energy leadership within the region, the importance of taking a long-term view, and the need to positively impact the community.

Stakeholders determined that a successful BlueSky Vision would:

- Reduce Scope 1 (on-site direct) and 2 (purchased indirect) greenhouse gas emissions to zero by 2050
- Conserve energy and water
- Improve social, environmental and economic resilience
- Demonstrate leadership within the region and globally
- Help recruit and retain the best faculty and students
- Generate research initiatives and attract research funding
- Reduce operational and utility expenses
- Improve health and wellbeing
- Inspire and prepare students to solve the challenges of their future

BlueSky Vision Project Timeline

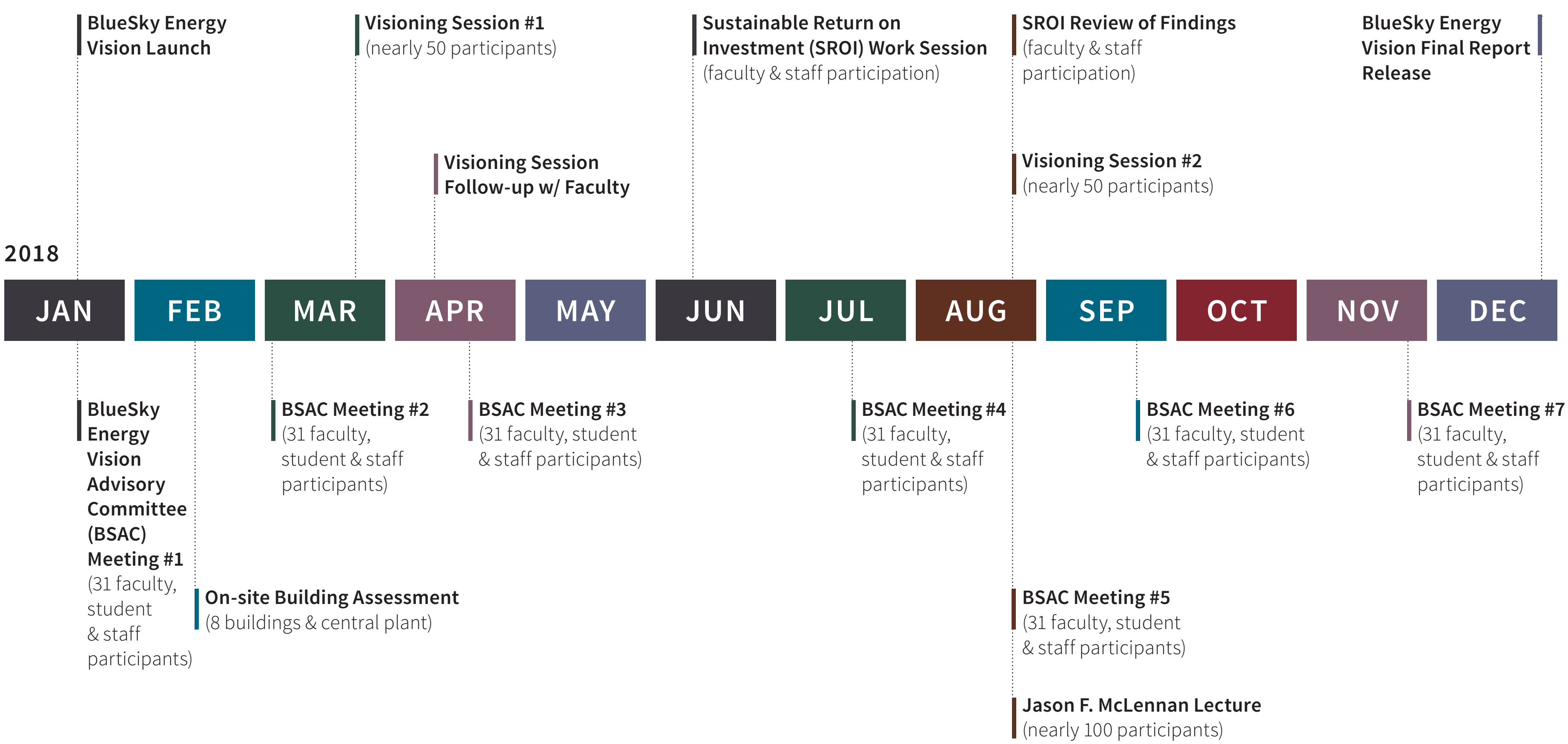
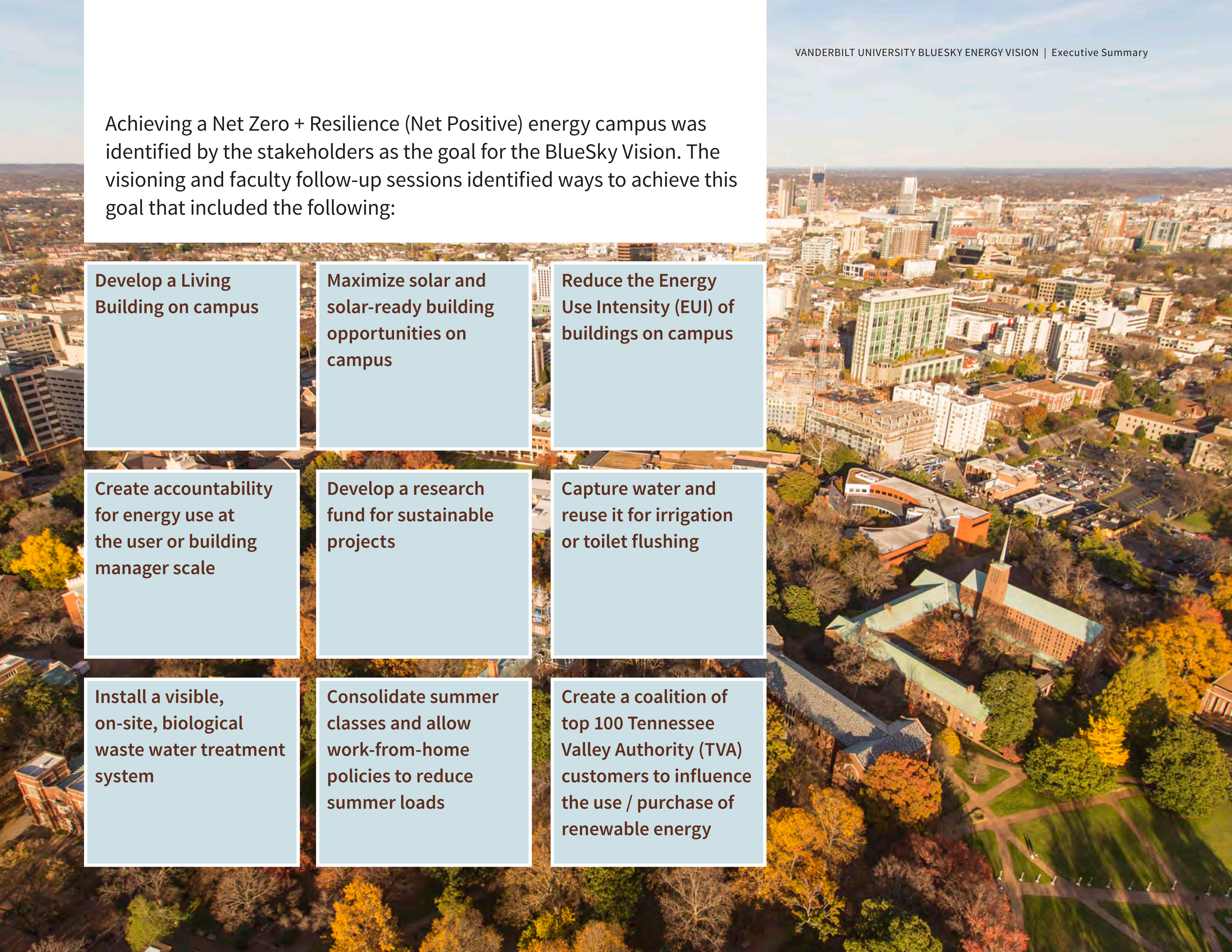


Figure 5. BlueSky Vision Project Timeline



Achieving a Net Zero + Resilience (Net Positive) energy campus was identified by the stakeholders as the goal for the BlueSky Vision. The visioning and faculty follow-up sessions identified ways to achieve this goal that included the following:

- **Develop a Living Building on campus**
- **Maximize solar and solar-ready building opportunities on campus**
- **Reduce the Energy Use Intensity (EUI) of buildings on campus**
- **Create accountability for energy use at the user or building manager scale**
- **Develop a research fund for sustainable projects**
- **Capture water and reuse it for irrigation or toilet flushing**
- **Install a visible, on-site, biological waste water treatment system**
- **Consolidate summer classes and allow work-from-home policies to reduce summer loads**
- **Create a coalition of top 100 Tennessee Valley Authority (TVA) customers to influence the use / purchase of renewable energy**

BlueSky Vision Opportunity for Leadership

The BlueSky Vision is critical for the planet, has taken a triple-bottom line approach to ensure economic, social and environmental factors are considered, and will allow us to attract top faculty and students. Among the 600-plus institutional signatories of the university President's Climate Leadership Commitments (PCLC) (formerly known as the American College and University President's Climate Commitment or ACUPCC), many are aiming for climate-neutral campuses by 2050 or sooner. Many are choosing to reduce Scope 1 and 2 emissions by reducing energy consumption for buildings and infrastructure and increasing renewable energy production. This represents nearly 20 percent of the students in the U.S. studying at institutions committed to making energy and carbon reductions a part of their educational model.

While the race is on, there is a space for leadership in becoming the first university to demonstrate how to dramatically reduce consumption, attain net zero energy, and incorporate resilience (energy storage) into the model. As a resilient campus, Vanderbilt can lend safety and security to its critical operations in the event of a disruption. Vanderbilt can provide the much-needed model of dramatic conservation, infrastructure innovations, and the economic advantages that a clean energy economy provides, such as green jobs, savings, and reinvested wealth. Energy storage and cutting edge green buildings also provide ample opportunity for faculty and student collaboration on research and innovation.

Figure 6. Participants at the Visioning Session (courtesy of Vanderbilt)

BLUESKY VISION RECOMMENDATION

BlueSky Vision Recommendation

The BlueSky Steering Committee, supported by the BlueSky Vision Advisory Committee and informed by outcomes of the 10-month study, recommends the following:

Vanderbilt, by the year 2050, will:

- be a leader in energy conservation
- produce on-site clean (without combustion) and renewable energy
- procure off-site renewable energy to mitigate campus greenhouse gas emissions
- store sufficient clean energy to provide campus resilience

The BlueSky Vision Study recommendation:

- supports FutureVU Guiding Principles
- embodies Vanderbilt's core values of teaching, research, and discovery
- establishes Vanderbilt as a leader among its peers, community, and the region
- incorporates impactful economic, environmental, and social factors

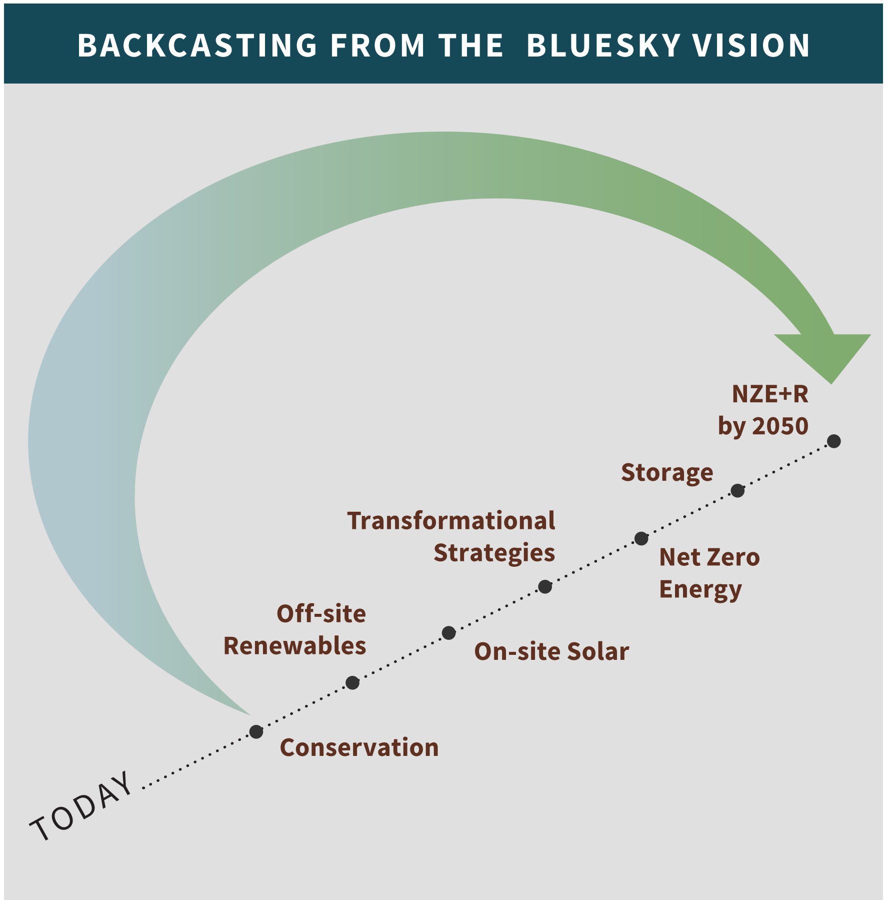

EMERGENCY
CHAARG

The Pathway to Net Zero Energy + Resilience

The 10-month study utilized a backcasting approach with Net Zero Energy + Resilience (referred to as "NZE+R" in this report) as the goal and worked back to the current state to develop an implementation plan supported by an Action Timeline[2] and Performance Targets.[3]

"Among our higher education clients, we find that many are trying to lead (or even race) to be the first net zero campus. However, there is a void (or a space for leadership) in the realm of Net Positive Energy. We think Vanderbilt could move into that space and distinguish themselves as a true leader. With a Net Positive focus, you will become a center for innovation in the Southeast, and in the nation."

JASON F. MCLENNAN



2 Provided on pages 42 and 43 of the Full Report

3 Provided on pages 46 and 47 of the Full Report

There are three primary points on the pathway to NZE+R:

ENERGY CONSERVATION

For the next 10 to 12 years, perform retro-commissioning for one million square feet of buildings each year and create a schedule and budget for corrective actions. Beginning today, every capital project is an opportunity to:

- Apply new design standards and performance targets
- Test new technologies and systems
- Implement energy conservation measures (ECM) that have a favorable benefit-cost ratio
- Provide flexible building systems that can connect to renewable technologies and future innovations in infrastructure
- Develop feedback loops with measurement technology for ongoing commissioning and operational improvements

RENEWABLE ENERGY

Begin the transition to:

- Install renewable energy across campus
- Develop a large-scale renewable energy strategy and portfolio for off-site renewable energy

TRANSFORMATIONAL STRATEGIES

Evaluate, design, and implement strategies that will:

- Utilize passive sources of heating and cooling
- Implement the most efficient and effective infrastructure solutions
- Transition from combustion-based to renewable sources of energy
- Store energy for resilience

from 2016 baseline
GHG Emissions Reduction: 28%

2025

GHG Emissions Reduction: 61%

2035

GHG Emissions Reduction: 100%

2050

2050 Timeline and Milestones

By 2025

- update policies, procedures and design standards aligned with the performance targets
- perform retro-commissioning
- implement energy conservation measures with the most favorable benefit-cost ratio
- evaluate and design infrastructure and technology improvements
- pursue large-scale off-site renewable power purchase agreements and begin to install renewable energy across campus
- measure results, share lessons learned and celebrate early wins

By 2035

- continue with ongoing commissioning
- continue implementation of energy conservation measures across campus
- begin to implement infrastructure and technology improvements
- continue off-site renewable power purchase agreements and installation of renewable energy across campus as technology and costs improve
- publish and share results to provide leadership outside the institution

By 2050

- continue with ongoing commissioning
- maintain energy efficiency measures
- continue to innovate
- continue infrastructure and technology innovations
- include energy storage strategies for resilience
- transfer technologies and intellectual property to the industry and publish the results of long-term studies with the community, nation and world

Potential Greenhouse Gas Emissions Reductions

By implementing the three primary points on the pathway to NZE+R (energy conservation, renewable energy, and transformational strategies) it is possible to reduce Scope 1 and 2 emissions significantly over time.

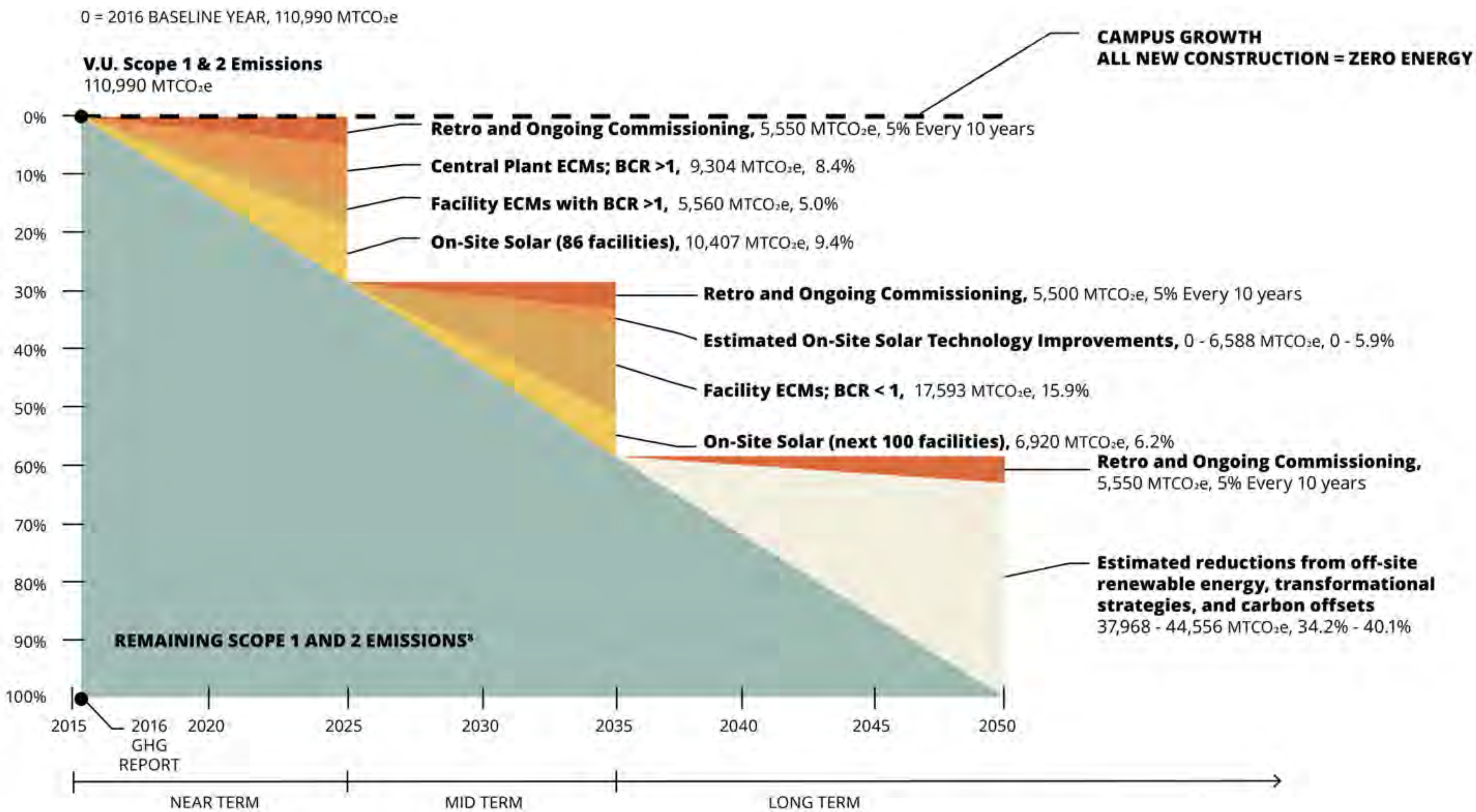
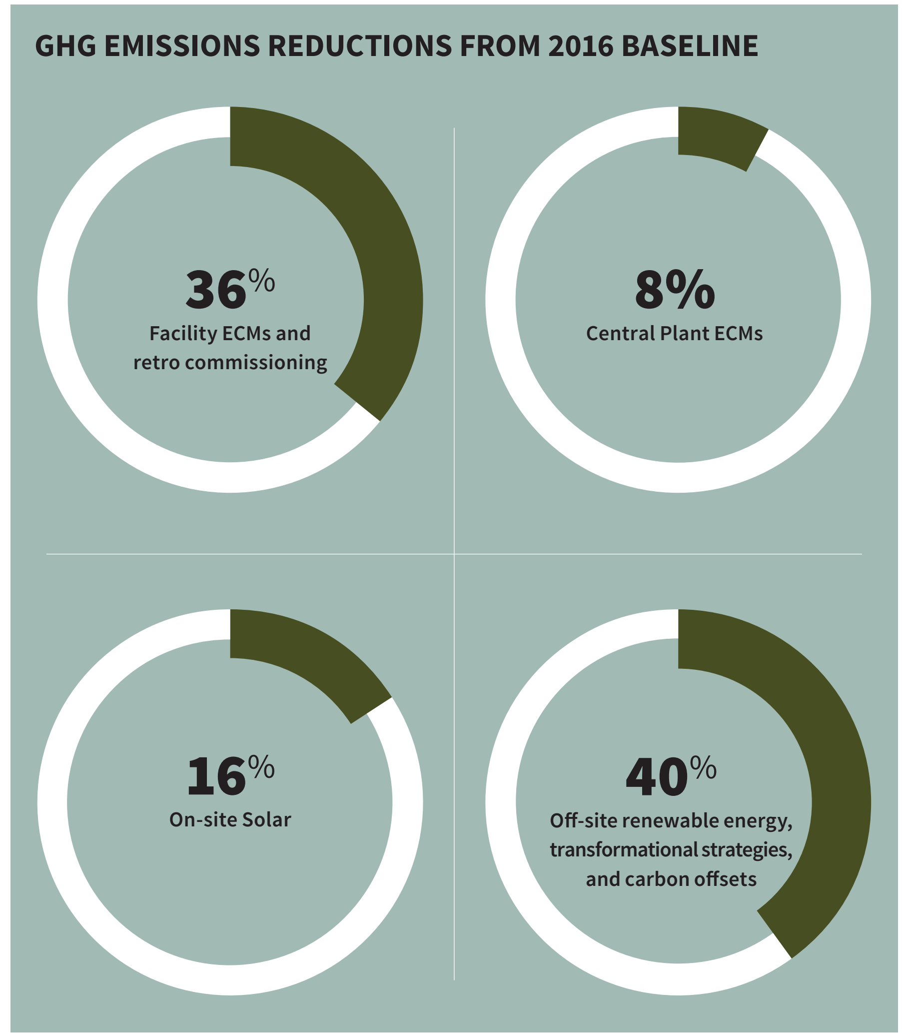


Figure 7. Potential Scope 1 & 2 Greenhouse Gas Emissions Reductions with all BlueSky Vision Strategies

Implementation Next Steps

Vanderbilt's commitment to the recommendation of Net Zero Energy + Resilience by 2050 is the first step in the timeline. Vanderbilt Facilities commits to performing deeper dive analyses and continuous reviews of operating and design protocols to inform recommendations to the Vanderbilt Public Utility Commission of near- to mid-term projects that are economically, environmentally, and socially impactful.

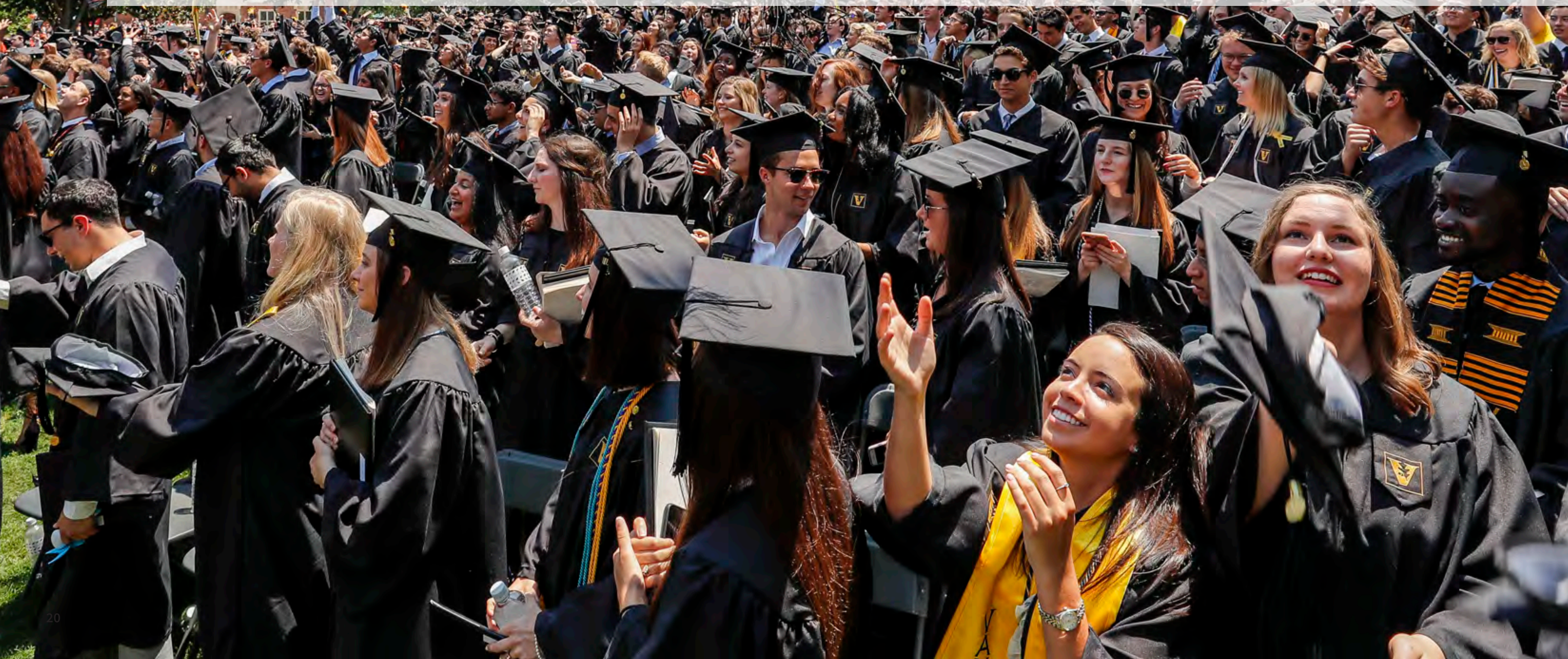
Projects recommended for implementation will recognize the initial cost to implement energy conservation measures, retro-commissioning, energy metering and monitoring, renewable energy, energy storage, and infrastructure and technology improvements. The recommendations will also recognize the longer-term view of a return on investment that encompasses a cleaner, more independent and resilient energy future and the transformative trajectory of integrating faculty, student, and staff collaborations with education, research, and discovery.



Into the Future

Vanderbilt is taking bold and visionary steps to shape its future and to be a leader - a leader in the Nashville community, a leader among universities, and an example for future leaders of our country. The BlueSky Vision sets the university's energy and greenhouse gas emissions reductions strategies for the next 30 years. This is just the first step.

The implementation process will require dedication, input, and support from the Board of Trust, the Chancellor and senior leadership as well as our faculty, students and staff. The BlueSky Vision of Net Zero Energy + Resilience by 2050 establishes the foundation upon which current and future university leadership can lead Vanderbilt to successful achievement of this vision.



Engagement Process

Figure 8. Visioning Session participants presenting to the group

The FutureVU engagement process facilitated the diverse Vanderbilt community to define Guiding Principles that will govern all future planning and infrastructure work on campus. The BlueSky Vision continues this engagement process to ensure that the Guiding Principles are realized in sustainability and energy strategies for campus. Visioning Sessions included a diverse group of faculty, students, and staff to share their values and perspectives, suggest goals, and define the BlueSky Vision.

Faculty articulated that alongside the tangible energy saving benefits of an energy vision of Net Zero Energy + Resilience (a net positive energy campus) there are also important intangible benefits that should not be overlooked:

REPUTATIONAL VALUE

Achieving Net Zero Energy + Resilience would establish Vanderbilt as the place to be for sustainability, positive environmental impact, and innovation – for faculty, students, and staff. The reputation of Vanderbilt has an extremely high value that may not always be precisely quantified. Reputation influences the attraction of students, faculty, grants, research projects, donations, and the ability to compete with peer schools.

LEADERSHIP

Achieving a net zero energy campus by 2050 is a typical goal for universities that signed the PCLC. It is grounded in academic climate change research and various Intergovernmental Panel on Climate Change (IPCC) reports as the condition that must be achieved to prevent catastrophic damage from climate change. Achieving a Net Zero Energy + Resilience campus would establish Vanderbilt as a leader among peer institutions. In addition to environmental benefits, it would provide unique teaching opportunities.

TIMING

The timeline of innovation is important. Vanderbilt needs to be slightly ahead of peer institutions. At the same time, the university can afford to take the long-term perspective and consider longer-term paybacks.

COMMUNITY IMPACT

It is important to have a positive impact on the larger community of Vanderbilt, Nashville, and the surrounding region as well as on the next generation of citizens and problem solvers. A Net Zero Energy + Resilience campus would prove what is possible with energy and carbon within the region.

Analysis Summary

Greenhouse Gas Emissions Benchmark Study

A greenhouse gas emissions benchmarking study was performed comparing Vanderbilt's greenhouse gas (GHG) emissions along with other sustainability goals (e.g. carbon reduction goals, green building standards, renewable energy efforts to 10 similar universities). AASHE[4] Stars Ratings, ACUPCC Commitments, and Scopes 1 and 2 GHG emissions[5] to 10 similar universities. The universities selected include schools that are academically benchmarked to Vanderbilt (e.g. Harvard, Duke, Emory), along with schools that are considered leaders in sustainability for higher education (e.g. Arizona State, Colorado State).

Based on this analysis, Vanderbilt is ranked near the best in lowest total Scope 1 & 2 GHG emissions (see Figure 9) of the 10 similar universities that track and publish this information; and has a fifty-five percent (55%) reduction in Scope 1 & 2 GHG emissions from the baselines of the eight similar universities that make this information available. In addition, Vanderbilt was named to the Top 50 Green Colleges by The Princeton Review (2018).

Peer Benchmarking Study - Scope 1 & 2 GHG Emissions
from 2017 or year most recently reported

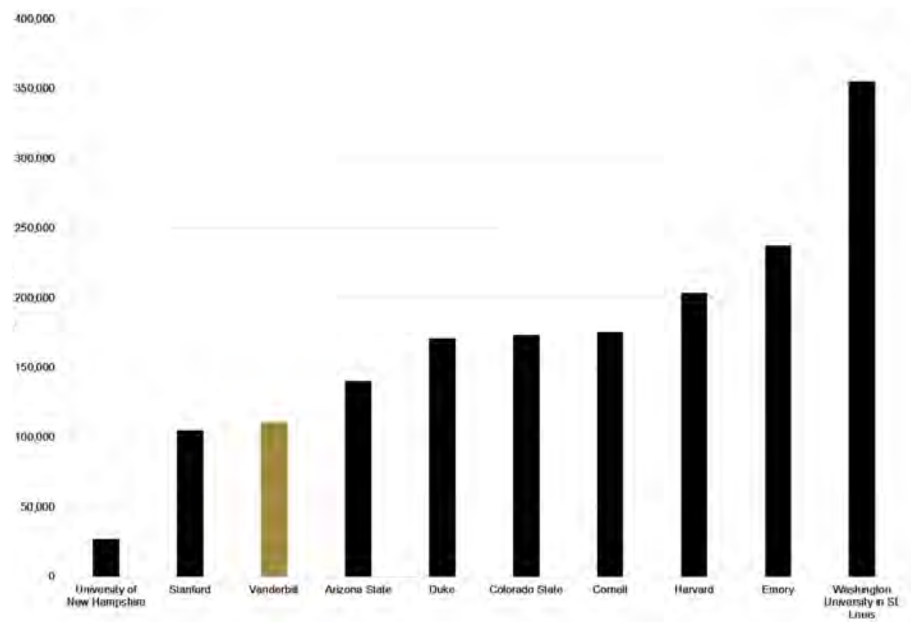


Figure 9. Peer Benchmarking Study of Scope 1 & 2 GHG Emissions

4 Association for the Advancement of Sustainability in Higher Education

5 Scope 1 emissions are direct emissions from owned or controlled sources (e.g. natural gas). Scope 2 emissions are indirect emissions from the generation of purchased energy (e.g. Nashville Electric Services).

On-site Building and Infrastructure Assessment

In February 2018, an on-site assessment of eight (8) campus buildings was performed. The buildings selected represent different building types (i.e. office, education, laboratory, library, residential, museum, and dining) that are typical to the campus. The assessment reviewed the energy operations of the buildings, determined their current energy consumption, and evaluated potential energy conservation measures (ECMs) that could be implemented to reduce energy use. In addition, the campus Central Utility Plant (CUP) electric and steam cogeneration and chilled water production facility was assessed. A summary of the buildings assessed is provided in Table 1.

BUILDING NAME	BUILDING TYPE	SQ. FOOTAGE
Baker Building (excluding garage)	Office	136,014
The Law School	Education	180,060
Molecular Biology	Laboratory	79,976
Central & Divinity Libraries	Library	201,693
North House	Residential Hall	55,004
Cole Hall	Residential Hall	34,157
Cohen Memorial Hall	Museum	30,133
The Commons Center	Dining Facilities / Student Centers	114,400

Table 1. On-site Assessment of Typical Buildings Summary

Energy Conservation Measures (ECM) Analysis

The outcomes of the on-site assessment were an energy and utility source analysis of the eight (8) campus buildings and the identification of ECMs that would reduce energy use and GHG emissions. The ECMs were analyzed for energy savings, cost savings, and "from scratch" implementation costs (i.e., each ECM was assumed to be a standalone project and not part of a major renovation project). The ECMs were then extrapolated, based on campus square footage for each building type, to provide an estimated energy reduction as well as high-level (and worst case) cost estimate for implementation.

Implementation costs may be reduced by incorporating ECMs into major renovation work and by updating design standards to include ECMs in new construction.

The results of the ECM Analysis were input into the Life-Cycle Cost Analysis (LCCA) and Sustainable Return on Investment (SROI) performed to understand the Triple Bottom Line (TBL)[6] impact. The ECM, LCCA, and SROI analyses included avoided carbon emissions, energy savings, implementation cost, discounted payback period (DPP)[7], the adjusted internal rate of return (AIRR)[8], and the Benefit-Cost Ratio (BCR)[9].

Favorable Energy Conservation Measures Details

ECM		Initial Cost $M	MTCO2e Reduction
ECM 12	On-site Solar*	37M	10,407
ECM 15	CUP Steam Trap Maintenance	<1M	3,625
ECM 1	Linear to LED Replacement	<2M	2,608
ECM 2	CFL to LED Replacement	<2M	2,535
ECM 16	CUP Steam Trap Monitor	<1M	1,397
ECM 17	Kissam Chiller Plant	<1M	1,324
ECM 14	CUP Chiller Plants	<1M	966
ECM 11	Smart Power Bar	<1M	417

Table 2. Favorable Energy Conservation Measures Details

6 Triple Bottom Line includes economic, environmental, and social factors.

7 Discounted Payback Period (DPP) - time required to recover implementation and other accrued costs, taking into account the time value of money (assumed 5% discount rate).

8 Adjusted Internal Rate of Return (AIRR): the ECMs rate of return taking into account the implementation cost and other accrued costs over the 30-year study period and a 5% discount rate (or hurdle rate).

9 Benefit-Cost Ratio (BCR) - the ratio of TBL benefits of the ECM over its economic costs; a BCR equal to or greater than 1 indicates the ECM is worth pursuing.

* ECM 12 initial cost of $37M for 86 on-site locations. Identified 49 sites of the total 86 for initial tranche for implementation based on payback <20 years, ~$7M initial implementation cost, and 3,600 MTCO2e annual emission reduction.

Favorable Energy Conservation Measures
(based on a Benefit-Cost Ratio of 1 or greater)

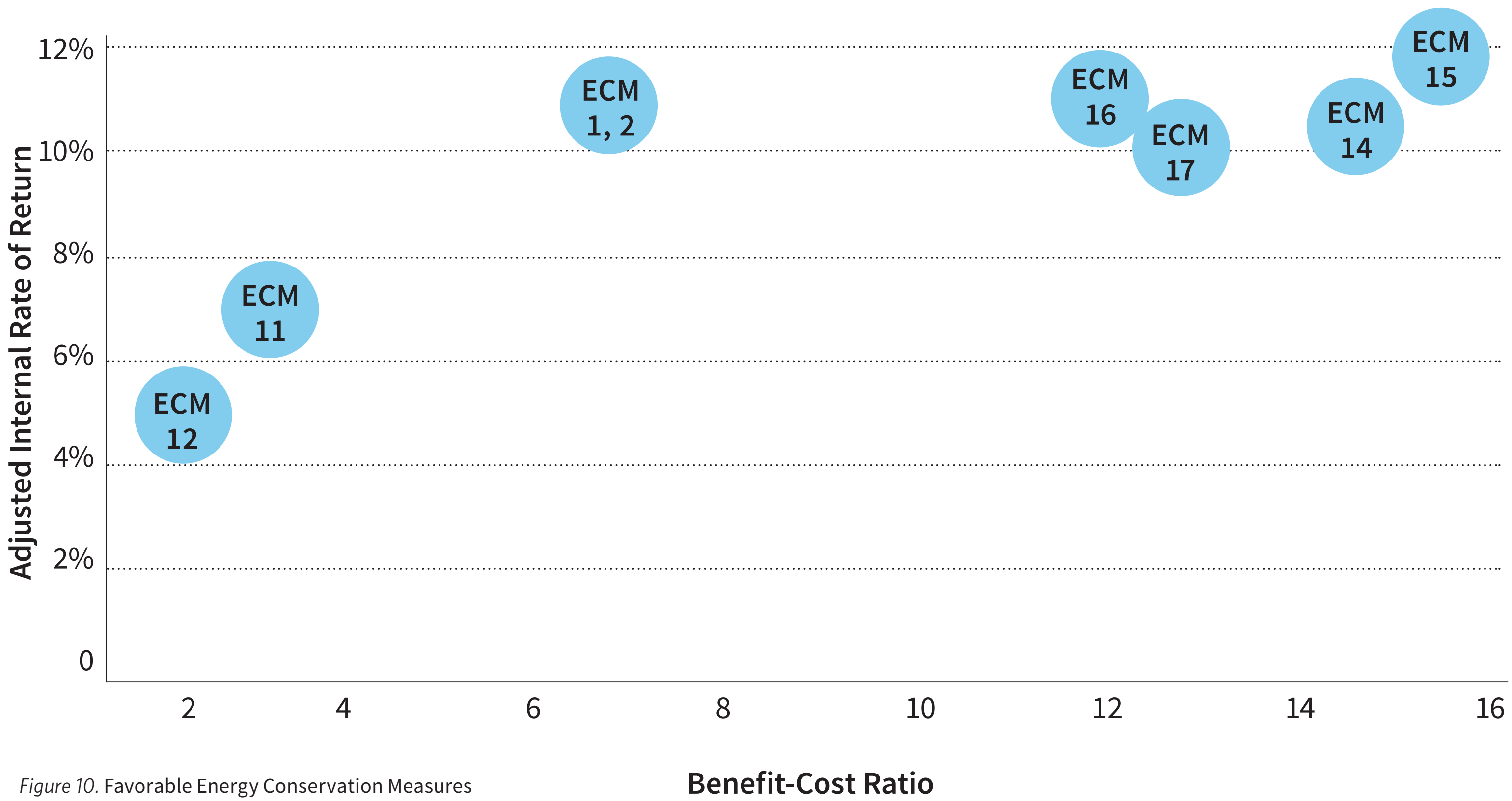


Figure 10. Favorable Energy Conservation Measures

ECM Summary

	ECM ID	DESCRIPTION	MTC02e AVOIDED	kBtu AVOIDED	ECM TOTAL COST ($)[1]	DPP	AIRR	BCR
			0 - 11,000 MTCO2e	0 - 110 million kBtu				
	15	CUP Steam Trap Maintenance			$0 - $10 M	1.0	12.1%	16.81
	14	CUP Chiller Plants			$0 - $10 M	4.0	11.1%	14.87
	17	Kissam Chiller Plant			$0 - $10 M	4.0	10.8%	13.49
	16	CUP Steam Trap Monitor			$0 - $10 M	3.0	11.5%	12.42
	1	Linear to LED Replacement			$0 - $10 M	4.0	10.8%	7.44
	2	CFL to LED Replacement			$0 - $10 M	4.0	10.6%	7.01
	11	Smart Power Bar			$0 - $10 M	5.0	7.5%	2.63
	12	On-Site Solar			$10 - $50 M	>30	4.9%	1.19

MTCO2e = Metric Tons of Carbon Dioxide Equivalent; kBtu = Units of heat energy; ECM = Energy Cost Measures; DPP = Discounted Payback Period; AIRR = Adjusted Interal Rate of Return; BCR = Benefit Cost Ratio; CUP = Central Utility Plant; CFL = Compact Fluorescent Lighting; LED = Light Emitting Diode

[1]Net total of capital costs, operations/ maintenance costs, and replacement costs. All numbers are preliminary estimates.

Figure 11. ECM Summary of Results with a Benefit to Cost Ratio Greater than One

ECM Summary

	ECM ID	DESCRIPTION	MTC02e AVOIDED	kBtu AVOIDED	ECM TOTAL COST ($)[1]	DPP	AIRR	BCR
			0 - 11,000 MTCO2e	0 - 110 million kBtu				
	6	Exterior Sun Shades			$10 - $50 M	>30	1.3%	0.88
	8	Energy Recovery			$10 - $50 M	> 30	-4.8%	0.73
	13	CUP Heat Recovery			$0 - $10 M	N/A	N/A	0.65
	10	High Efficiency Pump Motors			$0 - $10 M	>30	1.5%	0.52
	9	High Efficiency Fan Motors			$0 - $10 M	>30	0.4%	0.37
	7	Adjust Temperature Setpoints			$10 - $50 M	> 30	-2.8%	0.23
	4	Window Replacement			$100 M +	> 30	-7.7%	0.05
	3	Roof Insulation			$10 - $50 M	> 30	-8.6%	0.04
	5	Wall Insulation			$50 - $100 M	> 30	-9.3%	0.03

MTCO2e = Metric Tons of Carbon Dioxide Equivalent; kBtu = Units of heat energy; ECM = Energy Cost Measures; DPP = Discounted Payback Period; AIRR = Adjusted Interal Rate of Return; BCR = Benefit Cost Ratio; CUP = Central Utility Plant; CFL = Compact Fluorescent Lighting; LED = Light Emitting Diode

[1]Net total of capital costs, operations/ maintenance costs, and replacement costs. All numbers are preliminary estimates.

Figure 12. ECM Summary of Results with a Benefit to Cost Ratio Less than One

ON-SITE SOLAR SUMMARY STATISTICS

49

SITES RECOMMENDED (OUT OF >200 ANALYZED)[10]

16 years

AVERAGE DISCOUNTED PAYBACK PERIOD[11]

$7.3 million

NET INSTALLED COST[12]

On-site Solar Analysis

Vanderbilt performed a high-level assessment of over two-hundred (200) Vanderbilt campus buildings, parking garages, and parking lots to determine the ability for such facilities to utilize photovoltaic (PV) systems (or on-site solar). The analysis reviewed the shading of the roofs, equipment coverage on the roofs, and the amount of energy consumed by the facilities in 2016. Eighty-six (86) facilities with a roof size over 5,000 square feet and a roof surface with over 50% available for on-site solar were selected for consideration for near-term implementation. The eighty-six (86) facilities underwent a deeper-dive analysis that included roof solar layout of solar panels, predicted energy generation, system capacity by facility, estimated installation costs and tax credits, operation and maintenance costs, and simple payback timeframes.

A summary of the analysis of the 86 facilities is shown in Table 2

Of the eighty-six (86) facilities, forty-nine (49) have a payback of twenty (20) years or less. Vanderbilt Facilities will develop recommendations and priorities of the facilities for near-term-site solar implementation. A summary of the analysis of the 49 facilities is shown above.

A high-level extrapolation based on the eight-six (86) facilities was performed to determine the possible energy production and installation cost for an additional one-hundred (100) facilities on campus. This "Next 100" will be much more challenging for installation due to roof types and solar access. Therefore, the analysis assumed the solar panels would have a 50% reduction in energy output. A summary of the extrapolation is shown in Table 3.

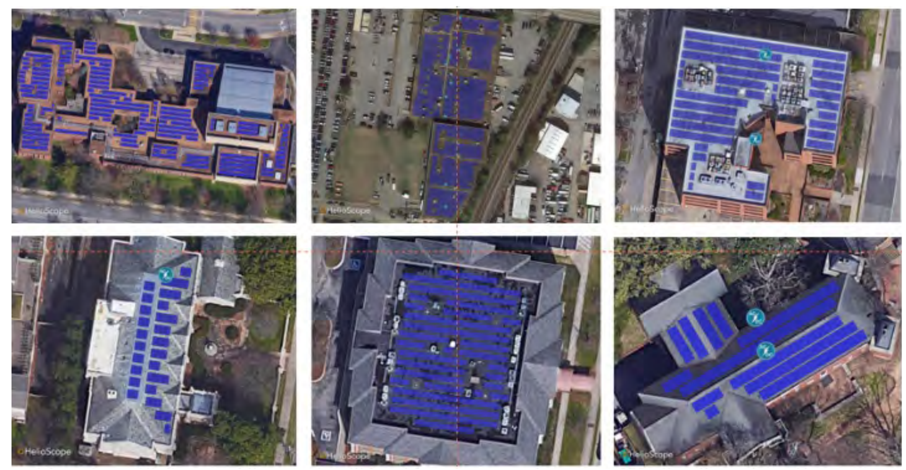


Figure 13. Example of On-site Solar Analysis Layouts on Selected Buildings

10 Sites with 5000 GSF minimum usable surface and mechanical equipment or shading of 50% or less. 49 locations selected.

11 Defined for each project as year at which NPV = 0.

12 Includes estimated gross installed cost minus 30% Federal tax credit. Net Installed Cost assumed third-party developer will take advantage of federal tax credits for new renewable energy projects.

3,600 MTCO2E

ANNUAL AVOIDED GHG EMISSIONS (3.3% OF VU GHG EMISSIONS)[13]

7,000 kW

TOTAL DC NAMEPLATE CAPACITY

9.4 M kWh

ANNUAL ENERGY PRODUCTION (1.7% OF VU ENERGY USE)[14]

Table 2. Summary of On-site Solar for 86 Facilities

Total Annual Production	30.0M kWh
Total Net Installed Cost[15]	$36.6M
Annual Energy Cost Savings	$2.5M
Avoided Annual GHG Emissions (MTCO2e)	10,407
Payback (years)	>30
Internal Rate of Return	4.35%
Benefit-Cost Ratio	1.19

Table 3. Summary of On-site Solar for "Next 100" Facilities[17]

Total Annual Production	18.1M kWh
Total Net Installed Cost[16]	$14.7M
Annual Energy Cost Savings	$1.4M
Avoided GHG Emissions (MTCO2e)	6,920
Simple Payback (years)	10.1

13 Based on campus GHG emissions of 110,990 MTCO2E

14 Based on campus energy use of 1,872 KBTU (M)

15 Includes estimated gross installed cost minus 30% Federal tax credit. Net Installed Cost assumed third-party developer will take advantage of federal tax credits for new renewable energy projects.

16 Includes estimated gross installed cost minus 30% Federal tax credit.

17 All results are estimated.

LARGEST PROPOSED ON-SITE SOLAR SYSTEMS

Of the 49 initial tranche with installed capacity of 7,000 kW, 10 represent 47% or 3,273 kW:

1. Student Life Center (610 kW)
2. McGugin Complex (523 kW)
3. Memorial Gym (506 kW)
4. Blair School of Music (296 kW)
5. Wesley Place Townhomes (277 kW)
6. Law School (264 kW)
7. 21 North (254 kW)
8. Central and Divinity Libraries (195 kW)
9. Village Apartments (188 kW)
10. Hill Center (159 kW)

Large-scale Renewable Energy (LSRE)

Vanderbilt engaged the consultants CustomerFirst Renewables (CFR) in 2017 to assist with developing a Large-scale Renewable Energy strategy for the university. The strategy is to seek off-campus renewable energy to reduce Scope 2 greenhouse gas emissions from purchased electricity using renewable energy credits (RECs). Vanderbilt is pursuing options to implement the recommended strategy. While off-site renewable energy does not reduce on-campus energy consumption, RECs from off-site renewable energy sources mitigate Scope 2 emissions[18] which will help Vanderbilt achieve the BlueSky Vision of NZE+R by 2050.

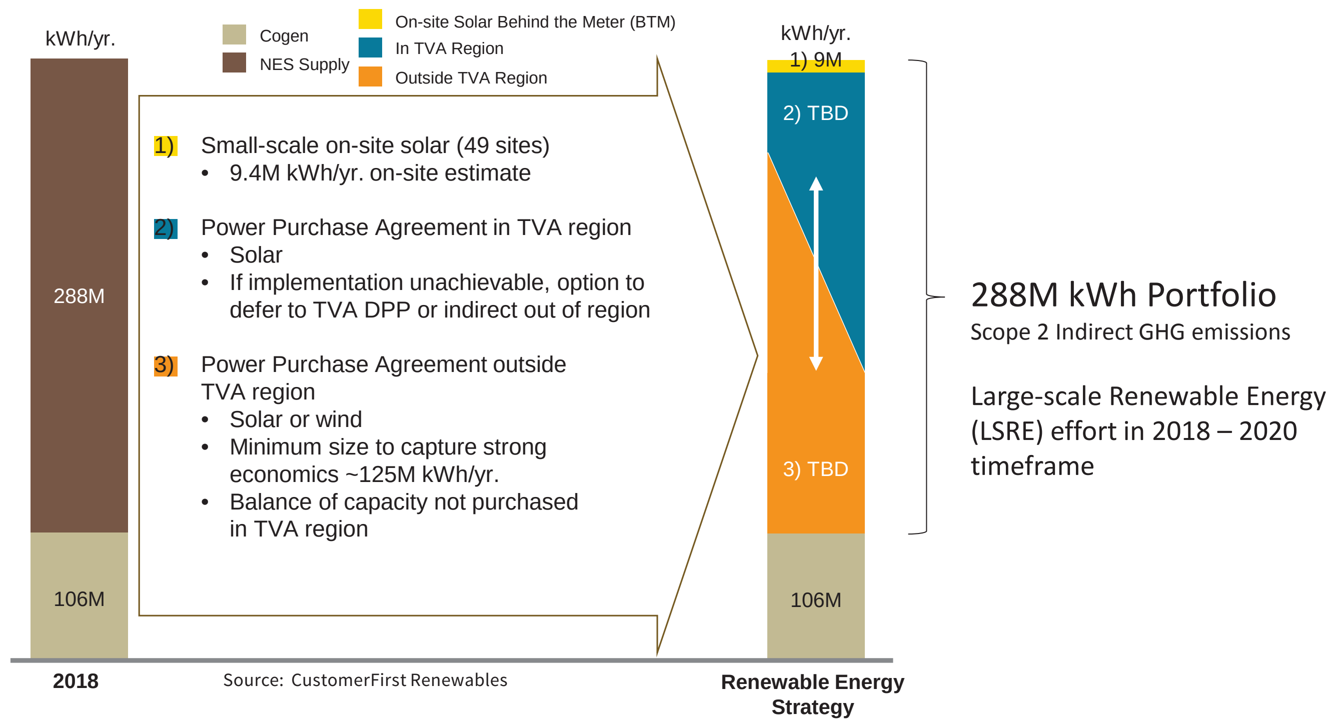


Figure 14. Large-scale Renewable Energy Portfolio

18 Scope 2 emissions are approximately 33% of Vanderbilt's total GHG emissions per Vanderbilt's 2016 Annual Sustainability Report.

Carbon Offsets

Vanderbilt is studying the potential of a Scope 1 carbon offset portfolio of initiatives:

- **Urban forestry** on Vanderbilt's campus, in areas where Vanderbilt does research, and possibly study abroad areas or through programs like Alternative Spring Break

- **Low income weatherization** and energy efficiency projects in the community

- **Commuting offsets** for Vanderbilt faculty, staff, and students

- **Air travel offsets** for university travel

- **Music City Solar** angel donation program to low-income electricity users in Metro

SROI/ SVA Analysis

Sustainable Return on Investment (SROI) analysis and Sustainable Value Analysis (SVA) were conducted to help prioritize the seventeen (17) ECMs and score the broader BlueSky Vision scenarios.

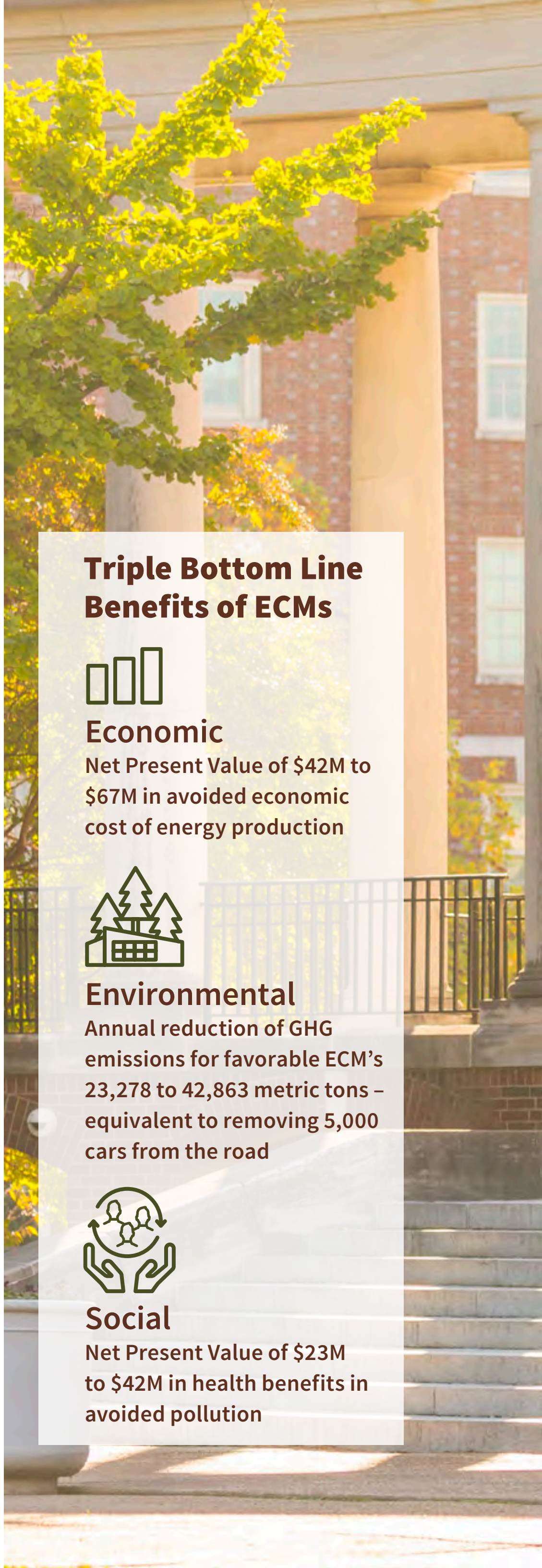
The SROI analysis weighs economic, environmental, and social benefits against capital, operations and maintenance (O&M), and replacement costs. The results provide several financial metrics that quantify the relative merit of each ECM from a triple bottom line perspective. These include the benefit-cost ratio, the net present value, the internal rate of return, and the discounted payback period. An overview of the process is provided in Figure 15.

SVA considers more qualitative benefits, as well as those benefits that can be quantified but not valued in monetary terms (i.e. not monetizable). The SVA helped evaluate the broader BlueSky Vision scenarios, which include ECMs, financial metrics, and other factors.

SVA, at its core, is a multivariate evaluation that considers various criteria and associated weights that are more challenging to monetize. For Vanderbilt, the SROI and SVA analysis process considered factors not easily incorporated into a strict return-on-investment analysis. This was particularly important because Vanderbilt was interested in factors, such as reputational value, that are not immediately monetizable. Using the SVA approach, the study team defined evaluation criteria that will guide and inform development of and decisions on implementation details to achieve the BlueSky Vision. Where available, metrics were identified to help score each criterion.

Table 5 provides information on what makes up each NZE+R scenario (e.g. on-site renewables) and what BlueSky Vision measures could be implemented to achieve NZE+R.

The NZE+R scenarios are used for comparison purposes and show different levels of investment required to achieve; specifically the level of investment increases as you move from left to right. The scenarios were developed to illustrate the different methods in which NZE+R can be achieved including different levels of infrastructure and fuel type changes to reduce energy use and greenhouse gas emissions. For example, the Centralized High Temp with 100% Combustion Scenario may be achievable using some of Vanderbilt's existing infrastructure, including the Central Utility Plant, but the Distributed Low Temp No Combustion is likely to require significant new investment. It should also be noted this is not meant to "force" Vanderbilt to choose one specific scenario, but provide information that will help Vanderbilt make decisions on how to implement NZE+R going forward.



Triple Bottom Line Benefits of ECMs

Economic
Net Present Value of $42M to $67M in avoided economic cost of energy production

Environmental
Annual reduction of GHG emissions for favorable ECM's 23,278 to 42,863 metric tons – equivalent to removing 5,000 cars from the road

Social
Net Present Value of $23M to $42M in health benefits in avoided pollution

SROI/ SVA Analysis

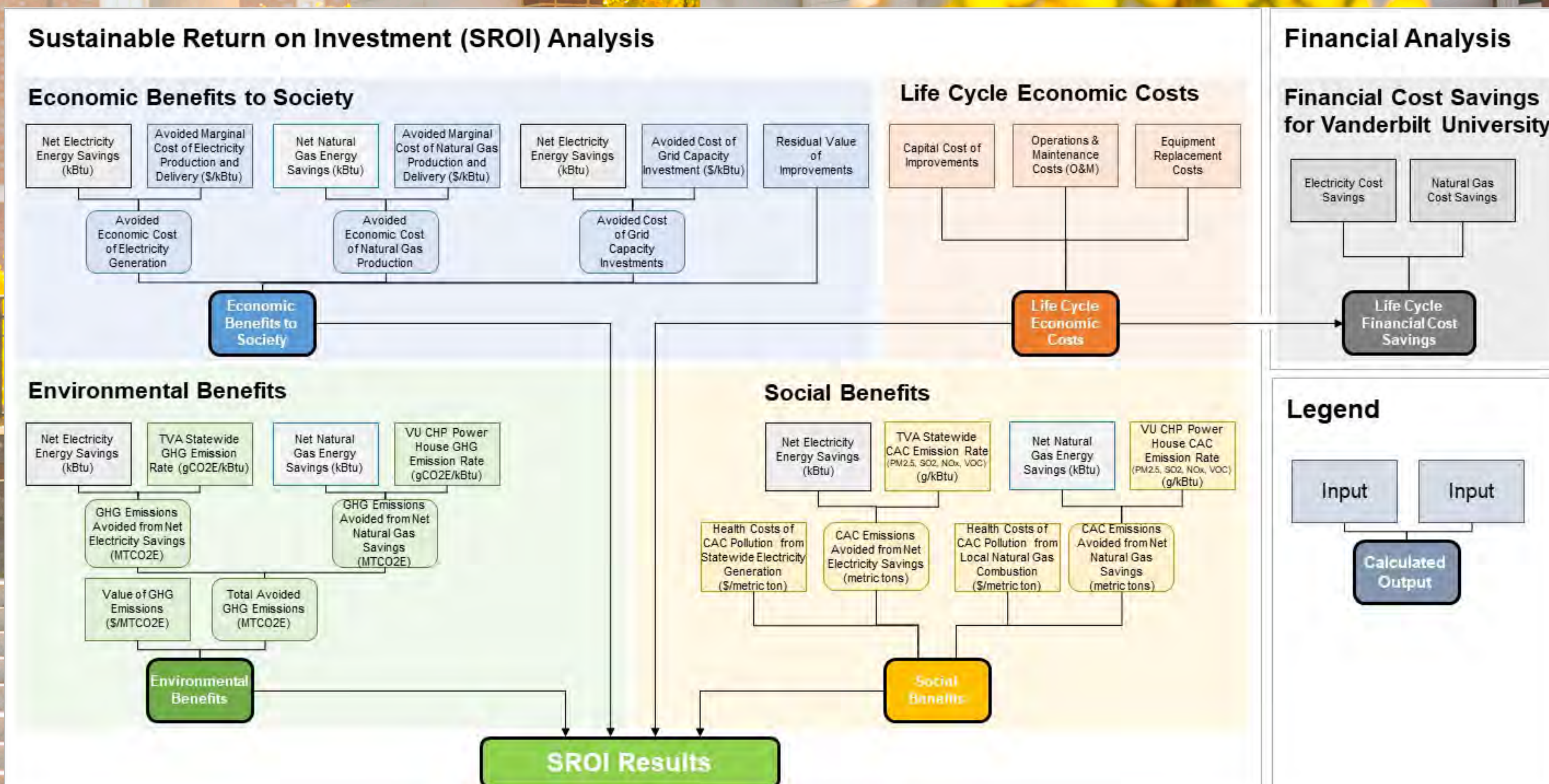


Figure 15. Sustainable Return on Investment Process Summary

Sustainable Value Analysis Scenarios

CRITERIA OF EACH SCENARIO	Centralized High Temp [4] 100% Combustion [1]	Centralized Low Temp [5] Backup Combustion [2]	Centralized High Temp [4] Backup Combustion [2]	Distributed Low Temp [5] Backup Combustion [2]	Distributed Low Temp [5] No Combustion (Vanderbilt)	Distributed Low Temp [5] No Combustion [6]
Energy Efficiency Retrofits (cost effective)	✔	✔	✔	✔	✔	✔
Radical Energy Efficiency Retrofits (no limits)				✔	✔	✔
Conversion of CUP to Biofuel or Carbon Capture	✔					
Upsize CUP for All Electric Loads (Biofuel Driven)				✔		
Biofuel for Back-up CHP / Boiler		✔		✔		
Shift CUP to Low-Temp Thermal (Baseload Only)		✔				
Shift CUP to Low-Temp Thermal (Sized for Peak)			✔		✔	✔
Biofuel Driven Fuel Cells (Waste Source Only) 3			✔		✔	✔
Hydrogen Driven Fuel Cells (from wind or hydro) 3			✔		✔	✔
On-site Solar	✔	✔	✔	✔	✔	✔
Expanded On-site Solar (no limits)				✔		✔
Large-scale Renewable Electricity (LSRE)	✔	✔	✔		✔	
Energy Storage	✔	✔	✔	✔	✔	✔

Table 4. Sustainable Value Analysis Scenarios

THIS SCENARIO IS THE BLUESKY VISION TO ACHIEVE NZE+R

1 Defined as the burning fire produced by the proper combination of fuel, heat, and oxygen. Source: https://www.energy.gov/eere/fuelcells/glossary.
2 Combustion is only used for backup energy sources.
3 Energy storage sources do not include combustion.
4 Utilizes campus existing infrastructure to provide heating water at temperatures in the 160-180F range.
5 Low-temperature thermal (LTT) system operates with heating water at temperatures around 120F. Using low-temperature heating water opens the possibilities for integrating recovery of various forms of free low-grade waste thermal or renewable energy as the primary energy sources for the LTT system. Typically, a LTT system recovers heat between simultaneous heating and cooling and is complemented by additional low-grade thermal energy sources/ sinks, and long-term thermal storage such as geo-exchange.
6 This scenario is equivalent to International Living Future Institute definition of Net Positive Energy.

SUSTAINABLE VALUE ANALYSIS SCENARIOS	Centralized High Temp 100% Combustion	Centralized Low Temp Backup Combustion	Centralized High Temp Backup Combustion	Distributed Low Temp Backup Combustion	Distributed Low Temp No Combustion (Vanderbilt)	Distributed Low Temp No Combustion
SVA SCENARIO TOTAL SCORE	2.45	2.44	2.69	3.09	3.50	3.70

Table 5. Sustainable Value Analysis Criteria Scoring Summary

THIS SCENARIO IS THE BLUESKY VISION TO ACHIEVE NZE+R

Once scenarios were constructed, each was evaluated based on how well it was expected to achieve the goals and objectives agreed upon as important to the Vanderbilt stakeholders. The evaluation involved three distinct steps:

1. Identifying evaluation criteria that align with Vanderbilt's goals related to the BlueSky Vision.

2. Determining what metrics may be available to "Score" each criterion in terms of how well the proposed strategy is likely to achieve the stated goal.

3. Weighting each criterion to reflect its relative importance.

Criteria that reflect the BlueSky Vision and were identified for use in the SVA are presented below. Criteria are assigned to the leg of the TBL stool with which they are best aligned.

ECONOMIC

- Reduces Life Cycle Costs
- Enhances Resilience and Reduces Level of Cost/Savings Risk
- Enhances Performance Reliability
- Attracts Funding Sources

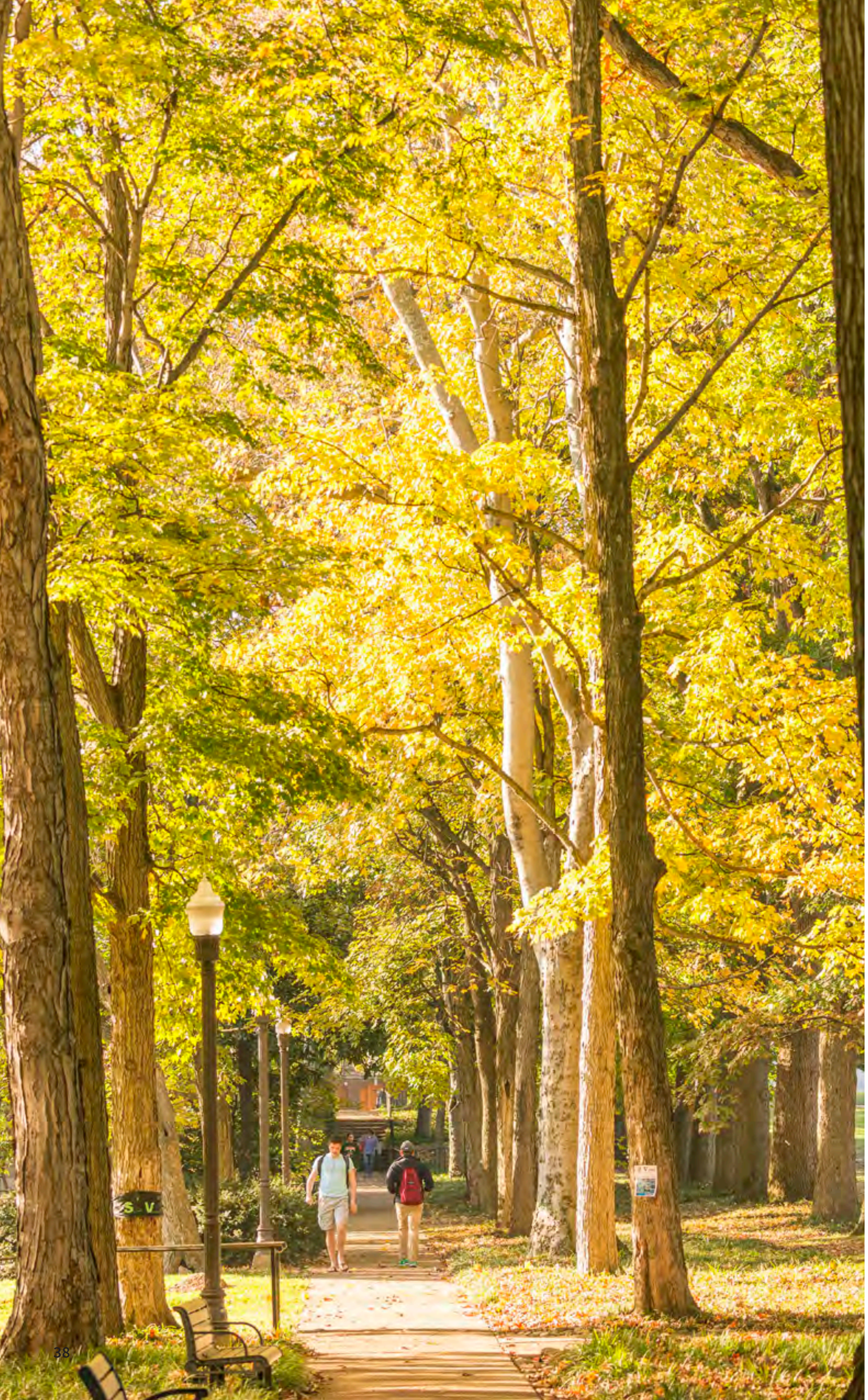
ENVIRONMENTAL

- Contributes to Negative Emissions / Increased RE Capacity
- Reduces Use of Potable Water / Decreases Wastewater
- Reduces Resource Waste

SOCIAL

- Shows Leadership in Energy / GHG Reduction Strategies
- Provides Education & Research Opportunities and Enhances Reputation
- Provides High SROI Outcomes (Triple Bottom Line)
- Contributes to Local Economy

The SVA assumes all ECMs will be implemented. The Net Zero Energy + Resilience BlueSky Vision is innovative and visionary. The scenario "Distributed Low Temp No Combustion" aligns with this Vision and with Vanderbilt's intended use of off-site large-scale renewable energy. The SVA total score for each scenario is provided in Table 5.



Impacts of BlueSky Vision Strategies

The wedge diagrams in Figures 16 and 17 show the cumulative impact of implementing all the strategies explored as a part of the BlueSky Vision process within the near-, mid- and long-term timelines. Each wedge diagram shows the potential impact of the strategy in reaching Net Zero Energy + Resilience by 2050.

At each milestone, the impact of retro and then ongoing commissioning and implementing conservation measures across campus can be seen. The reductions in GHG emissions and energy consumption paired with increases in on-site renewable energy demonstrate the gradual shift toward zero emissions by 2050.

Both diagrams show a conservative place-holder for the impact of improving technology over time. By studying trends in photovoltaic efficiencies and technology discoveries and enhancements over the past few decades, for example, it is possible to predict future improvements over time.

Both diagrams also show the incredible opportunity to drastically reduce energy demand and emissions in the near- and mid-terms. The diagrams reveal an opportunity for the full intellectual power of Vanderbilt to engage in solving the remaining challenges in the long-term through technology discoveries and developments and operational innovations.

Potential Greenhouse Gas Emissions Reductions

By implementing the three primary points on the pathway to NZE+R (energy conservation, renewable energy, and transformational strategies) it is possible to reduce Scope 1 and 2 emissions significantly over time.

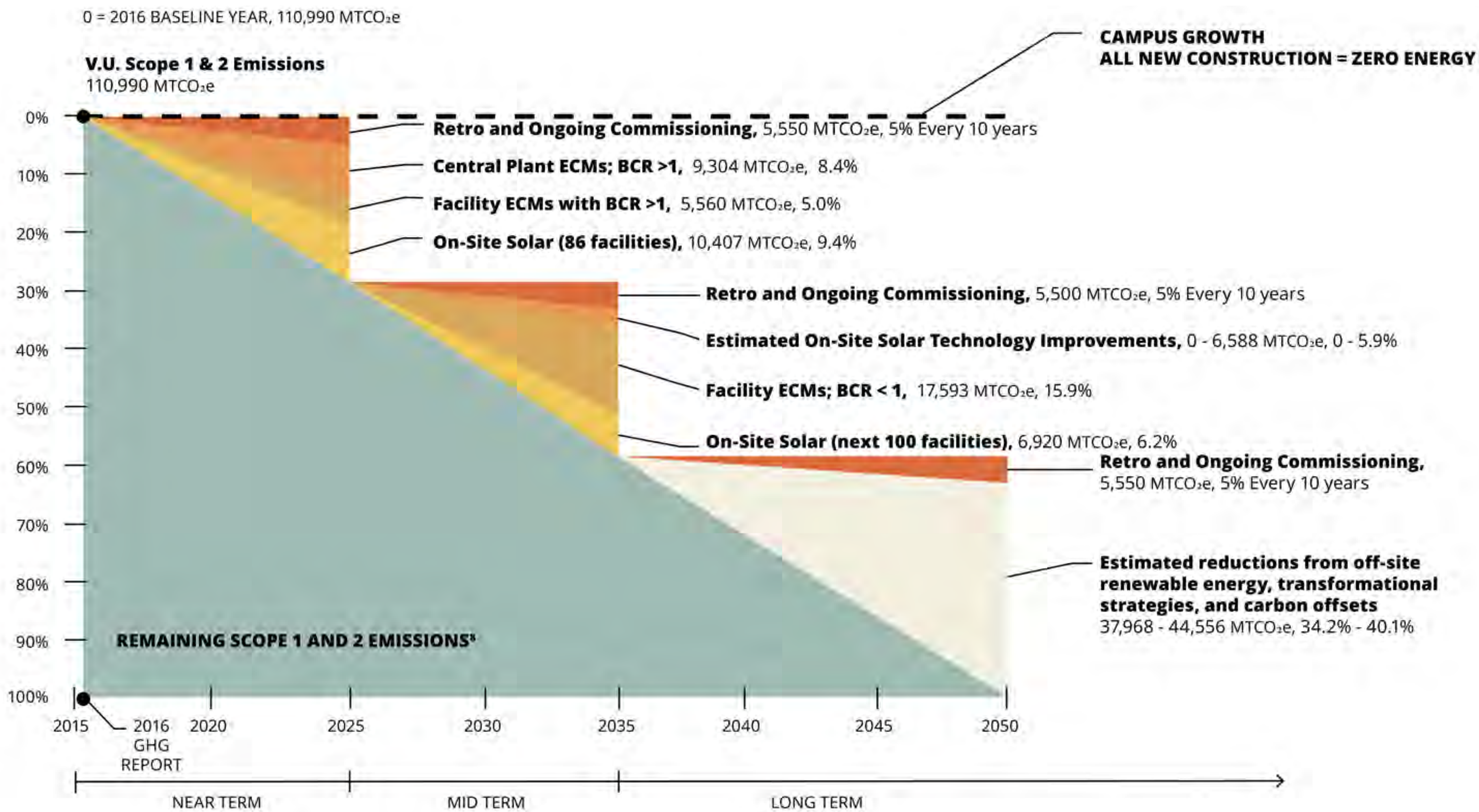


Figure 16. Potential Scope 1 & 2 Greenhouse Gas Emissions Reductions with all BlueSky Vision Strategies

Potential Energy Reductions

By implementing the three primary points on the pathway to NZE+R (energy conservation, renewable energy, and transformational strategies) it is possible to reduce energy consumption significantly over time.

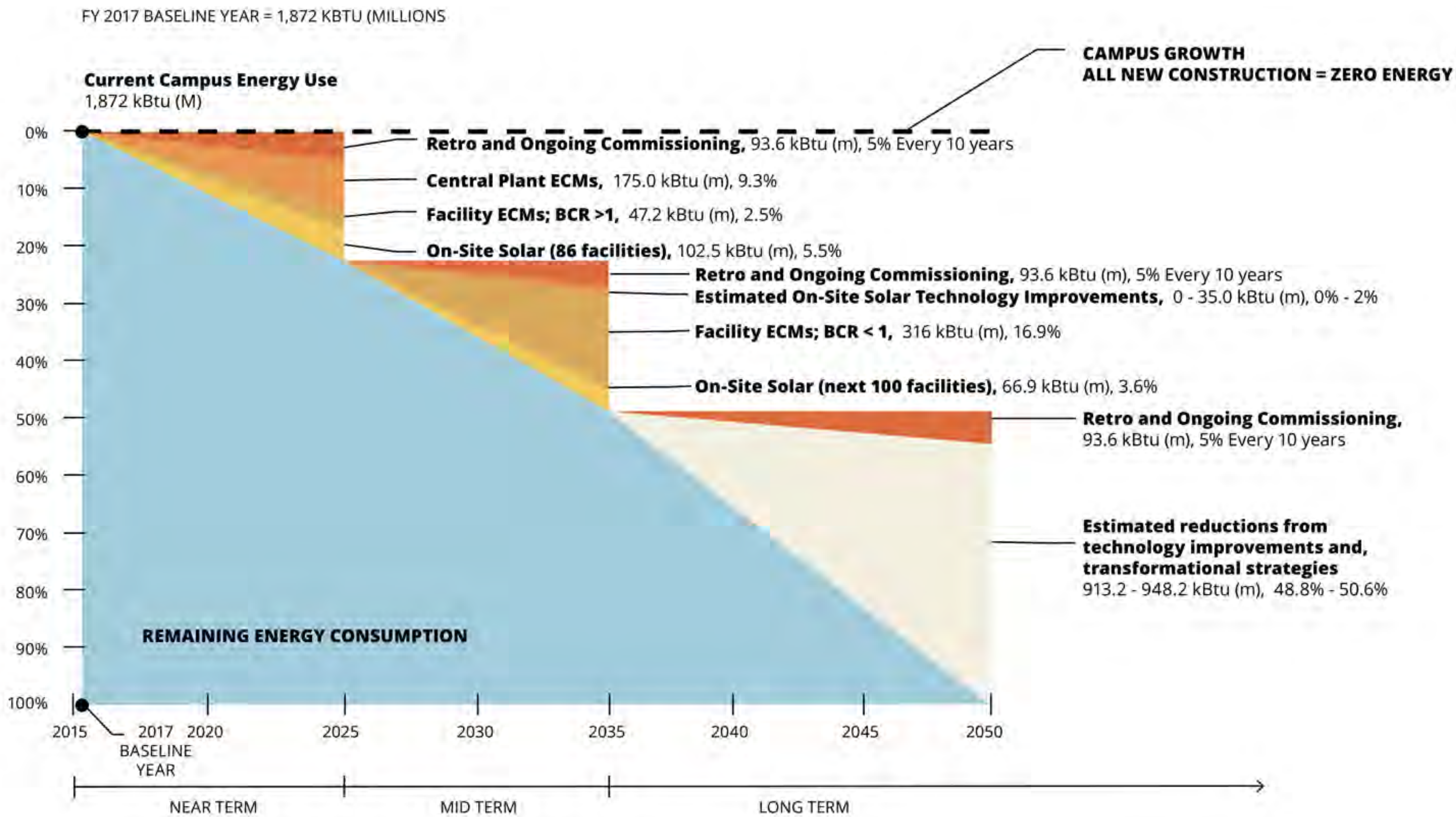


Figure 17. Potential energy savings with all BlueSky Vision Strategies

BlueSky Vision Implementation Plan

Achieving Net Zero Energy + Resilience by 2050

The results of the LCCA, SROI, SVA analysis, and input of Vanderbilt stakeholders support the BlueSky Vision of achieving Net Zero Energy + Resilience by 2050. The backcasting technique looks out toward this desired future state and works backward to determine the milestones from the current state. There are three key points on the pathway to achieving the BlueSky Vision by 2050. They are:

- Energy Conservation
- Renewable Energy (on-site and off-site)
- Transformational Strategies

This implementation plan provides a number of tools to assist with planning for the next 30 years. These tools describe steady progress toward Net Zero Energy + Resilience by 2050.

Energy Conservation

Renewable Energy

Transformational Strategies

The Action Timeline (Figures 18 and 19) is a tool that outlines the major studies, decisions, and milestones that are critical in the near-term (by 2025), mid-term (by 2035) and long-term (by 2050).

CONSERVATION INCLUDES:

- Setting performance targets for new and existing facilities
- Performing retro and continuous commissioning on existing buildings
- Implementing energy conservation measures

RENEWABLE ENERGY INCLUDES:

- On-site renewable energy
- Large–scale renewable energy (off-site)

TRANSFORMATIONAL STRATEGIES INCLUDE:

- Infrastructure – comprised of the Central Utility Plant, distributed equipment and distribution networks
- Energy Sources – comprised of different fuel types and energy sources
- Energy Storage – comprised of different methods to store energy for future use to achieve a resilient campus

Action Timeline

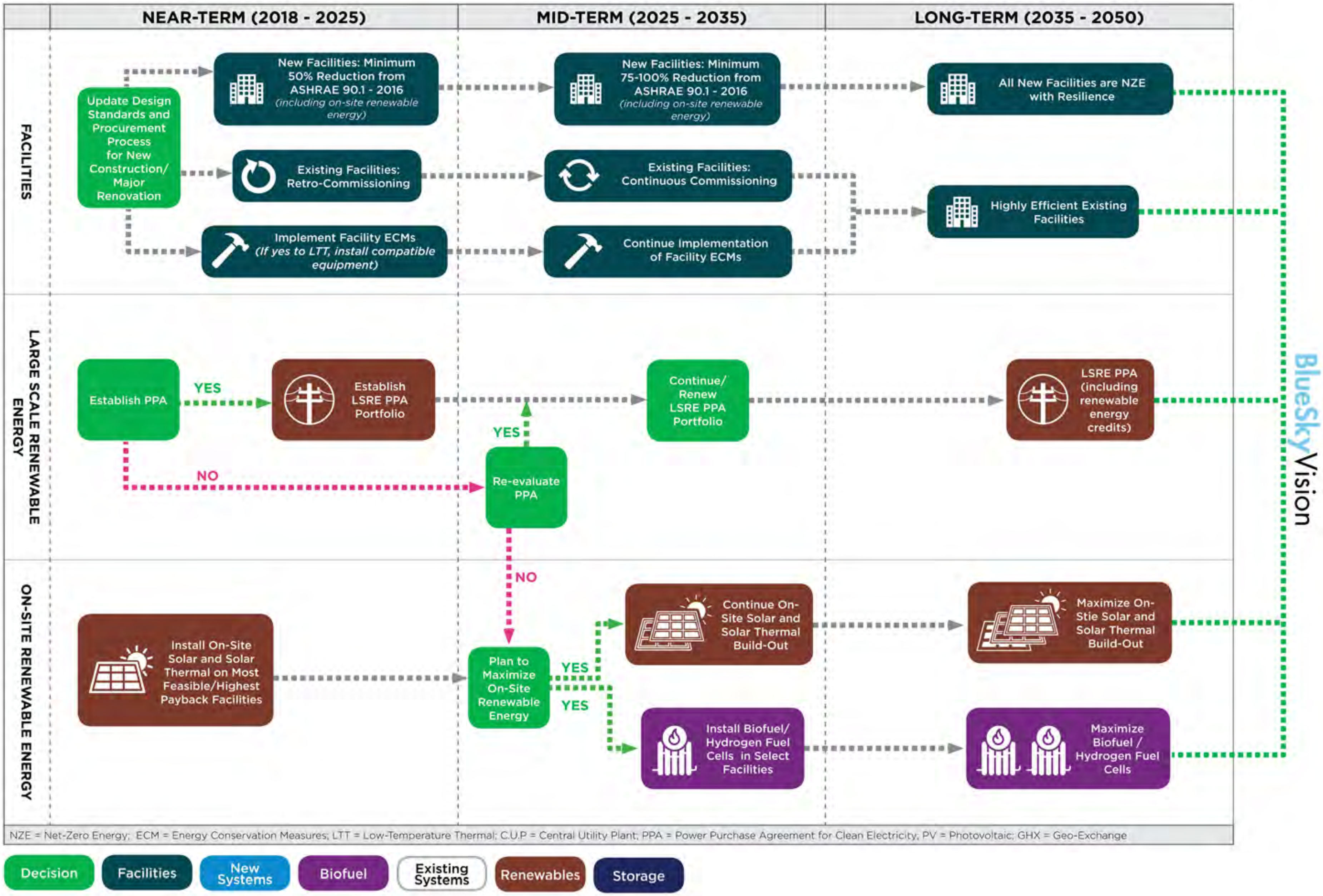


Figure 18. BlueSky Vision Action Timeline

Action Timeline

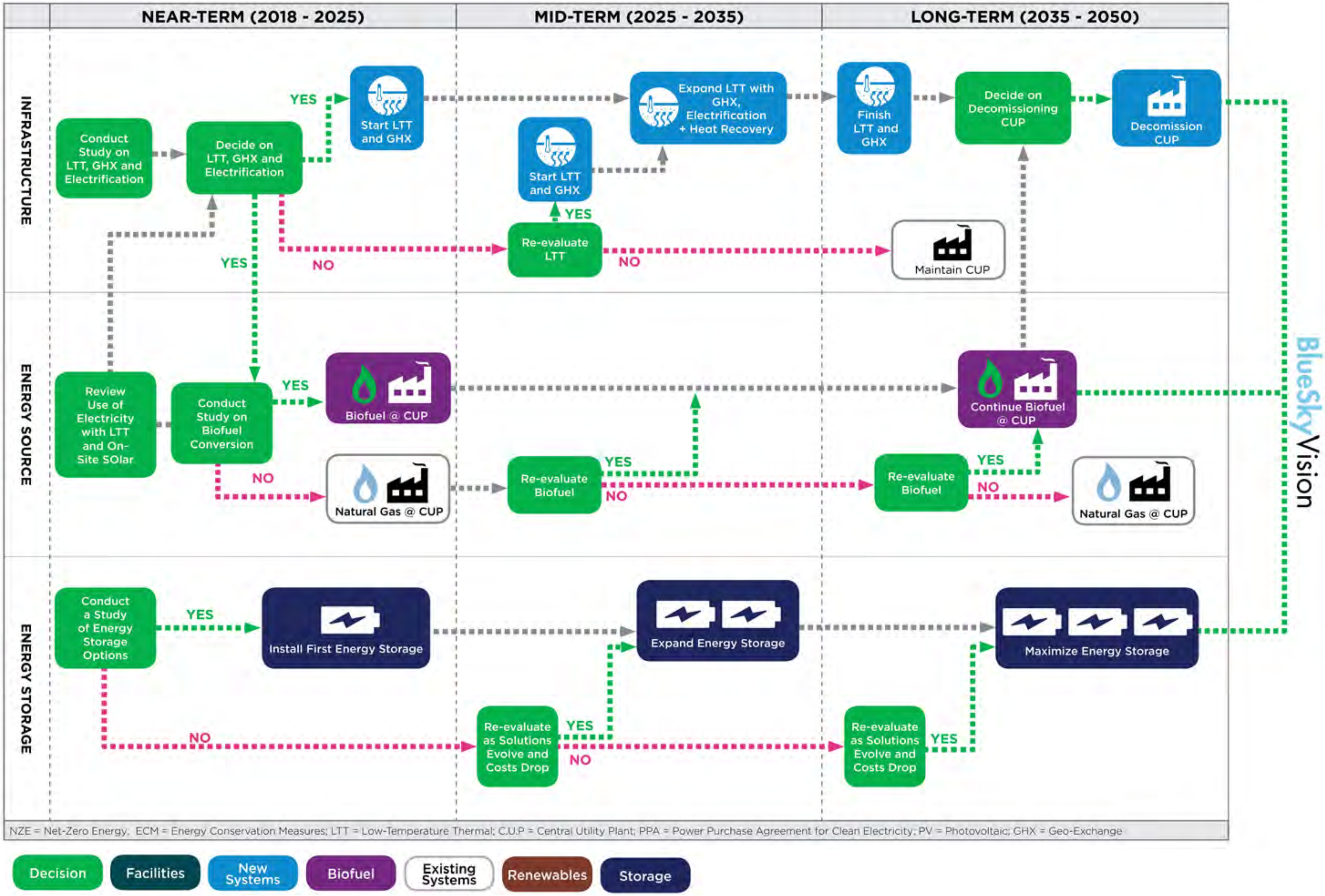


Figure 19. BlueSky Vision Action Timeline (continued)

The Performance Targets Matrix

Figures 20 and 21 is a tool that outlines the following performance targets for existing facilities and design standards for new facilities:

- Energy Use Intensity (EUI)
- Minimum American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) energy standards
- Water Use Intensity (WUI)
- Renewable Energy

The targets for each facility type[19] were developed using benchmarks established by the EPA Target Finder database and the American Institute of Architects (AIA) 2030 Challenge Zero Tool. Performance data compiled during the on-site facilities assessment are noted for the applicable facility type. The tool is designed to help Vanderbilt set progressively more stringent targets to improve the performance of existing facilities over time. Targets for new construction design standards are set at NZE+R, as applicable for the facility type, because it is more cost effective to achieve the highest performance targets during the initial design and construction of a new facility than to retrofit at a later date.

19 The building names in the Performance Targets Matrix used for benchmarking are provided in Table 1.

Performance Targets

LEGEND OF PERFORMANCE METRICS

Living Building Challenge: Full or Petal Certification

Zero Energy Certification: Meet Requirements

WELL BUILDING STANDARD:

Labs21 Meet Requirements

The matrix below examines the baseline goals for the near term, mid-term and long-term development projects for each facility type. Targets are recommended below with increasingly stringent requirements to achieve the BlueSky Vision over time.

- **Energy Use Intensity (EUI):** kBtu/sf/yr
- **Renewable Energy (RE) Production:** % of on-site renewable energy produced by the facility
- **NZE+R:** net-zero energy + resilience
- **Water Use Reduction (Water)[1]:** % reduction from 2018 Water Use Intensity (WUI) (gal/sf/yr)
- **LBC - Full:** Living Building Challenge Full Certification
- **LBC - Petal (energy):** Living Building Challenge Energy Petal Certification

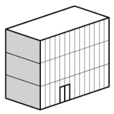
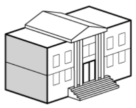
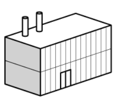
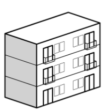
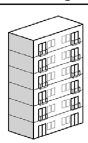
	FACILITY TYPOLOGY	RETROFIT NEAR-TERM 2018 - 2025 TARGET[4]:	RETROFIT MID-TERM 2025 - 2035 TARGET[4]:	RETROFIT LONG-TERM: 2035 - 2050 TARGET[5]:	NEW CONSTRUCTION TARGET[4] WITH OPTIONAL 3RD PARTY CERTIFICATIONS[6]
OFFICE	 Baker EUI: 69 Benchmark[2]: 117 **Office Facilities** Academic/administration	**EUI:** 53 **RE:** 15% of energy use **Water:** 25% reduction of WUI[6]	**EUI:** 34 **RE:** 30% of energy use **Water:** 40% reduction of WUI	**EUI:** 29 **RE:** 60% of energy use **Water:** 50% reduction of WUI	**EUI:** 23 **RE:** NZE+R **Water:** 100% reduction of WUI *WELL - Platinum; LBC - Full*
EDUCATION	 Law EUI: 177 Benchmark: 108 **Classroom Facilities** General instructional spaces	**EUI:** 70 **RE:** 10% of energy use **Water:** 25% reduction of WUI	**EUI:** 54 **RE:** 25% of energy use **Water:** 40% reduction of WUI	**EUI:** 38 **RE:** 50% of energy use **Water:** 50% reduction of WUI	**EUI:** 22 **RE:** NZE+R **Water:** 100% reduction of WUI *LBC - Full*
EDUCATION	 Mol. Bio. EUI: 258 Benchmark[3]: 222 **Laboratory Facilities** Specialized instruction	**EUI:** 144 **RE:** 5% of energy use **Water:** 20% reduction of WUI	**EUI:** 111 **RE:** 10% of energy use **Water:** 30% reduction of WUI	**EUI:** 78 **RE:** 20% of energy use **Water:** 40% reduction of WUI	**EUI:** 44 **RE:** NZE+R **Water:** 75% reduc. of WUI *ZERO-ENERGY; LABS 21*
RESIDENTIAL	 Benchmark: 47 **Apartment Buildings** Housing 1-4 floors	**EUI:** 31 **RE:** 15% of energy use **Water:** 20% reduction of WUI	**EUI:** 24 **RE:** 30% of energy use **Water:** 30% reduction of WUI	**EUI:** 17 **RE:** 60% of energy use **Water:** 40% reduction of WUI	**EUI:** 9 **RE:** NZE+R **Water:** 75% reduction of WUI *WELL - Platinum; LBC - Petal (energy)*
RESIDENTIAL	 Cole Hall EUI: 158 North Dorm: 121 Benchmark: 78 **Residential Facilities** Housing for students, faculty, staff, visitors; 4-6 floors	**EUI:** 51 **RE:** 10% of energy use **Water:** 20% reduction of WUI	**EUI:** 39 **RE:** 25% of energy use **Water:** 30% reduction of WUI	**EUI:** 28 **RE:** 50% of energy use **Water:** 40% reduction of WUI	**EUI:** 16 **RE:** NZE+R **Water:** 75% reduction of WUI *WELL - Platinum; LBC - Full*

Figure 20. BlueSky Vision Performance Targets

1 Industry-wide WUI may be available when the 2018 EIA CBEC survey is complete. Actual data may also be used. Reductions to WUI are estimated to reduce over time based on the water intensity of the building type.

2 Regional EUI benchmarks are provided by U.S. EPA Target Finder and AIA 2030 Challenge Zero Tool

3 Laboratory benchmark provided by the Labs21 Program

See footnotes 4-6 below Figure 21 on page 47 of the Full Report

Performance Targets

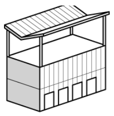
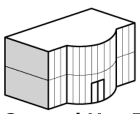
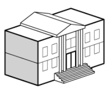
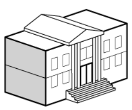
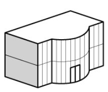
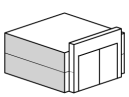
		RETROFIT NEAR-TERM 2018 - 2025 TARGET[4]:	RETROFIT MID-TERM 2025 - 2035 TARGET[4]:	RETROFIT LONG-TERM: 2035 - 2050 TARGET[5]:	NEW CONSTRUCTION TARGET[4] WITH OPTIONAL 3RD PARTY CERTIFICATIONS[6]
RESIDENTIAL	 Benchmark: 41 **Organizational Housing** Housing 1-2 stories	**EUI:** 27 **RE:** 15% of energy use **Water:** 25% reduction of WUI	**EUI:** 21 **RE:** 30% of energy use **Water:** 40% reduction of WUI	**EUI:** 15 **RE:** 60% of energy use **Water:** 50% reduction of WUI	**EUI:** 8 **RE:** NZE+R **Water:** 100% reduction of WUI *WELL - Platinum; LBC - Full*
ATHLETICS	 Benchmark: 42 **Special Use Facilities** Athletics, media	**EUI:** 27 **RE:** 15% of energy use **Water:** 10% reduction of WUI	**EUI:** 21 **RE:** 30% of energy use **Water:** 20% reduction of WUI	**EUI:** 15 **RE:** 60% of energy use **Water:** 30% reduction of WUI	**EUI:** 8 **RE:** NZE+R **Water:** 50-75% reduction of WUI *ZERO-ENERGY*
CULTURE	 Commons: 243 Benchmark: 191 **General Use Facilities** Dining, bookstores, student union activities	**EUI:** 124 **RE:** 5% of energy use **Water:** 10% reduction of WUI	**EUI:** 95 **RE:** 10% of energy use **Water:** 20% reduction of WUI	**EUI:** 67 **RE:** 20% of energy use **Water:** 30% reduction of WUI	**EUI:** 38 **RE:** NZE+R **Water:** 50-75% reduction of WUI *LBC - Petal (energy)*
CULTURE	 Cent. & Div.: 133 Benchmark: 97 **Study/Library Facilities** Traditional library space and related study space	**EUI:** 63 **RE:** 10% of energy use **Water:** 25% reduction of WUI	**EUI:** 49 **RE:** 25% of energy use **Water:** 40% reduction of WUI	**EUI:** 34 **RE:** 50% of energy use **Water:** 50% reduction of WUI	**EUI:** 19 **RE:** NZE+R **Water:** 100% reduction of WUI *LBC - Full*
CULTURE	 Cohen: 104 Benchmark: 52 **Museum** Climate controlled collections	**EUI:** 34 **RE:** 10% of energy use **Water:** 25% reduction of WUI	**EUI:** 26 **RE:** 25% of energy use **Water:** 40% reduction of WUI	**EUI:** 18 **RE:** 50% of energy use **Water:** 50% reduction of WUI	**EUI:** 10 **RE:** NZE+R **Water:** 100% reduction of WUI *LBC - Full*
HEALTH CARE	 Benchmark: 104 **Health Care Facilities** Examinations rooms, nursing station, wating area	**EUI:** 68 **RE:** 10% of energy use **Water:** 10% reduction of WUI	**EUI:** 52 **RE:** 25% of energy use **Water:** 20% reduction of WUI	**EUI:** 37 **RE:** 50% of energy use **Water:** 30% reduction of WUI	**EUI:** 21 **RE:** NZE+R **Water:** 60% reduction of WUI *WELL - Platinum; LBC - Petal (energy)*
SUPPORT	 Benchmark: 104 **Support Facilities** Shops, storage, mailroom, printing service, childcare	**EUI:** 68 **RE:** 10% of energy use **Water:** 25% reduction of WUI	**EUI:** 52 **RE:** 25% of energy use **Water:** 40% reduction of WUI	**EUI:** 37 **RE:** 50% of energy use **Water:** 50% reduction of WUI	**EUI:** 21 **RE:** NZE+R **Water:** 75-100% reduction of WUI *LBC - Petal (energy)*

Figure 21. BlueSky Vision Performance Targets Continued

4 EUI Targets for Near, Mid-term, and New Construction are reduced to align with the AIA 2030 Challenge targets for new and existing buildings

5 EUI Targets for Long-Term are interpolated between Mid-Term and New Construction Targets

6 Third-party rating systems are applicable to different building types as shown and can be pursued as desired for each project

See footnotes 1-3 below Figure 20 on page 46 of the Full Report

Glossary

ADJUSTED INTERNAL RATE OF RETURN (AIRR)
Measure of the annual percentage yield from a project investment over the study period; a relative measure of cost effectiveness.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)
Organization devoted to the advancement of indoor-environment-control technology in the heating, ventilation and air conditioning (HVAC) industry. ASHRAE also publishes a set of standards and guidelines relating to HVAC systems and issues (including energy efficiency), that are often referenced in building codes and used by consulting engineers, mechanical contractors, architects, and government agencies.

ENERGY USE INTENSITY (EUI)
Expressed as energy per square foot per year and is calculated by dividing the total energy consumed by the building in one year (measured in kBtu) by the total gross floor area of the building.

SAVINGS INVESTMENT RATIO (SIR)
Measure of economic performance for a project alternative that express the relationship between its savings and its increased investment cost (in present value terms) as a ratio.

BENEFIT-COST RATIO (BCR)
Determines whether an alternative's benefits outweigh its economic costs from societal triple bottom line perspective, and a BCR that is equal to (or greater) than 1 indicates that the alternative is worth pursuing. The BCR is calculated by dividing the life cycle value of the project's benefits by the life cycle value of the costs and measures the societal return on each dollar invested in the ECM.

LOW-TEMPERATURE (OR LOW-TEMP) THERMAL (LTT)
An LTT system operates with heating water at temperatures below 140F (60C) (ideal temperature for LTT is 120F and that is what is recommended for Vanderbilt) that can be generated with standard, single stage heat pump/ heat recovery chiller which is the primary energy conversion technology of a LTT system. Using low-temperature heating water opens the possibilities for integrating recovery of various forms of free low-grade waste thermal or renewable energy as the primary energy sources for the LTT system. Typically, a LTT system recovers heat between simultaneous heating and cooling and is complemented by additional low-grade thermal energy sources/ sinks, and long-term thermal storage such as geo-exchange.

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