Carbon neutrality should not be the end goal:
Lessons for institutional climate action from U.S. higher education

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Abstract
Aggressive climate action pledges from governments, businesses and institutions have increasingly taken the form of commitments to net carbon neutrality. Higher education institutions (HEIs) are uniquely positioned to innovate in this area, and over 800 U.S. colleges and universities have pledged to achieve net carbon neutrality. Eleven leading U.S. HEIs have already attained this status. Here, we examine their approaches to achieving net carbon neutrality, highlighting risks associated with treating emissions reduction approaches such as carbon offsets, renewable energy certificates, and bioenergy as best practice in isolation from broader policy frameworks. While pursuing net carbon neutrality has led to important institutional shifts toward sustainability, the mix of approaches used by HEIs is out of alignment with a broader U.S. decarbonization roadmap; in aggregate, these carbon neutral schools underutilize electrification and new zero-carbon electricity. We conclude by envisioning how HEIs can refocus climate mitigation efforts towards decarbonization (with net carbon neutrality as a possible milestone), with an emphasis on actions that will help shift policy and markets at larger scales.

Introduction
One of the most visible forms of leadership in the face of the climate crisis are net carbon neutrality commitments. As of 2020, at least twenty-five national governments and the EU have pledged to achieve net carbon neutrality (also referred to as net zero emissions, though the precise meaning of “net zero” varies by jurisdiction) by 2050¹, and many subnational governments have done the same. Broadly, these individual commitments can help align global emissions with a pathway that reduces emissions 45% by 2030 and to net zero emissions by 2050, which is necessary to have a two in three chance of avoiding catastrophic climate change². However, these recent pledges, and the full set of additional national commitments to reduce emissions under the Paris Agreement—even if they were fully implemented—are not sufficient to keep temperature increases well below 2°C³. Because current government policies are not sufficient to avoid dangerous anthropogenic interference with the climate system⁴, non-state actors have
become an important source of leadership to advance climate action. Voluntary carbon mitigation by non-state actors can achieve reductions in carbon emissions, pilot and demonstrate innovations in decarbonization approaches, and signal to policy-makers a willingness to participate in a low- or zero-carbon economy in ways that can induce more ambitious action targets from governments. Numerous non-state actors, including nonprofit and for-profit organizations, have begun pursuing internal carbon pricing across supply chains, purchasing renewable electricity, making carbon neutrality commitments, and, increasingly, adopting targets for climate mitigation consistent with temperature increases below 2°C, including pledges to become carbon negative.

As enduring nonprofit institutions with educational missions (and an ability to make investments with longer return times), United States higher education institutions (HEIs) are uniquely positioned to play a role as climate action leaders. Beginning in 2006, U.S. HEI presidents signed onto the American College and University Presidents’ Climate Commitment (ACUPCC) to develop targets and plans to achieve carbon neutrality “as soon as possible.” These early commitments to the ambitious goal of carbon neutrality make this sector unique in the United States and represent one of the earlier efforts to advance institutional carbon mitigation. Indeed, HEIs are now one front in a global proliferation of net carbon neutrality commitments made by governments, businesses, and institutions. Given this movement, it is appropriate to ask what pathways to neutrality look like in practice. The approaches adopted by U.S. HEIs from 2006 to 2020 represent an empirical case study for what achieving neutrality might entail, and for exploring whether this approach represents a scaleable solution to the climate crisis. Here, we analyze the pathways to carbon neutrality taken by the eleven leading U.S. HEIs that have already announced carbon neutrality as of November 2020 (See SI1 Methods). Our assessments center on the combinations of infrastructure changes and accounting-based reductions (from off-site activities) used for claiming neutrality. We then review the risks and limitations of three critical components of the pathway to neutrality for these institutions: the use of Renewable Energy Certificates (RECs) (certificates which represent the environmental attributes of electric power produced by renewables), the use of bioenergy as a fuel source, and the use of purchased carbon offsets (payment to a third party for avoided emissions or sequestration equivalent to one’s own emissions). We analyze the collective mix of approaches used by HEIs in the context of a broader U.S. decarbonization roadmap. We conclude by envisioning how HEIs can refocus climate mitigation efforts towards decarbonization (with net carbon neutrality as a possible milestone), with an emphasis on actions that will help shift policy and markets at larger scales.

**Carbon Neutrality Commitments in U.S. Higher Education**

U.S. HEIs, like all parts of society in developed economies, have significant greenhouse gas emissions that must be rapidly reduced to avoid dangerous anthropogenic climate change. Indeed, many HEIs function like small cities with their own heating, power, and transportation infrastructure. If all full-time students, faculty, and staff at HEIs in the United States were counted together, U.S. HEIs would...
be the second most populous state in the United States with over 29 million people.

Consistent with practices in the for-profit sectors, carbon neutrality in the context of U.S. HEI commitments is "net" neutrality, allowing for continued emissions, so long as an equivalent amount of off-site emissions reductions or carbon sequestration activities are purchased or undertaken to offset those continued emissions. Under current guidelines, HEI carbon neutrality commitments usually apply to emissions from direct on-site fossil fuel use (Scope 1 emissions) and purchased electricity (Scope 2 emissions). Some also include institutionally-funded air travel and employee commuting (a subset of Scope 3 emissions), but few encompass other supply chain emissions.

Since the start of the ACUPCC in 2006, over 800 institutions have signed the carbon neutrality commitment. In 2015, the nonprofit Second Nature, which has administered the commitment since 2009, rebranded the ACUPCC as the Carbon Commitment and expanded the program to include a stand-alone climate resilience commitment. Second Nature maintains a database of the 426 institutions still actively reporting annual emissions under this commitment, 362 of these institutions have set carbon neutrality target dates, which range from 2012 to 2100 (median date of 2050 (Figure S1)).

**Carbon Neutral Institutions in the US**

While hundreds of institutions are working towards carbon neutrality, eleven HEIs in the United States have already announced neutrality under the terms of the Carbon Commitment as of November 2020: Allegheny College (2020), American University (2018), Bates College (2019), Bowdoin College (2018), Colby College (2013), Colgate University (2019), Colorado College (2020), Dickinson College (2020), Green Mountain College (2011), Middlebury College (2016), and the University of San Francisco (2019). Another 17 institutions have set a neutrality target date of 2020 or earlier but have not yet announced achieving neutrality. We commend these HEIs on their leadership, their ambitious climate actions, and their achievement of carbon neutrality within the standards of the Climate Leadership Commitments.

We refer to the approach taken by these schools as “neutrality first.” The institutions have combined on-campus emissions reductions with off-campus accounting-based reductions to meet neutrality across Scope 1, 2, and 3 earlier than major campus infrastructure would generally allow. As many of these institutions have emphasized, a “neutrality first” approach is based on the scientific consensus that we must reduce emissions rapidly to get on track for less than 1.5 degrees of warming. Figure 1 shows the aggregate emissions of the carbon neutral HEIs in their year of neutrality (see SI 2 for more details on each school).
Figure 1: Aggregate reductions in emissions across eleven carbon neutral U.S. higher education institutions by type of reduction, as well as aggregate emissions by scope in the baseline years. Renewable Electricity Certificates (RECs) are divided according to whether they were associated with a power purchase agreement (bundled) or not associated with a power purchase agreement (unbundled). At schools that switched to bioenergy between their baseline and carbon neutral year, we attributed all reductions in on-site stationary combustion emissions to bioenergy.

Each institution achieved neutrality through a different pathway (Figures 2 and 3), yet there are some similarities in approaches. First, roughly half of institutions achieved meaningful reductions in their Scope 1 on-site fossil fuel emissions between their baseline year (the year against which they measure reductions, ranging between 2007 and 2012) and neutrality year. The median reduction in fossil-fuel based Scope 1 emissions for these institutions was 28%, but three institutions actually saw their gross Scope 1 emissions increase from the baseline year to the carbon neutrality year. Schools generally achieved Scope 1 reductions through building and transportation efficiency measures or by switching heating fuels, for example to bioenergy. The four institutions with the largest reductions in Scope 1 emissions all deployed bioenergy strategies (box in Figure 2), which we discuss in more detail below.
Figure 2: Reductions by Scope for each Carbon Neutral HEI before offsets.

Reductions (as %) from baseline are shown below zero; increases in emissions are shown above zero. Colored dots represent the same institution across scopes, bars are the median. Scope 1 represents on-site combustion, Scope 2 purchased electricity, and Scope 3 institution-funded air travel and employee commuting. In this figure, we treat bioenergy (HEIs in the dotted box) as carbon neutral, consistent with reporting guidelines. Scope 2 emissions are shown including all RECs purchased (bundled and unbundled), only counting RECs tied to a power purchase agreement (No Unbundled RECs), and before accounting for RECs (No RECs, i.e. gross changes in Scope 2 based on electricity consumption and grid intensity). One school had a significant increase in local grid intensity since the baseline year.

Approaches to reducing Scope 2 emissions varied. Many schools installed some amount of on-site solar generation to reduce purchased electricity emissions, while most (9) schools purchased Renewable Energy Certificates (RECs) to “cover” Scope 2 emissions (Figure 2). RECs represent the environmental attributes of renewable energy generated elsewhere; “bundled” RECs are associated with new power purchase agreements (PPAs) for renewable electricity, while unbundled RECs are purchased from voluntary markets without associated electricity contracts (see below). All institutions reduced Scope 2 emissions simply due to the fact that the carbon intensity of their electric grid improved from the baseline year to the year of neutrality. For example, in the New York State electric grid, the carbon intensity of electricity decreased by nearly half from 2007 to 2017. If a New York-based HEI purchased the same amount of electricity each year, they would have seen their Scope 2 emissions reduced by nearly 50% simply because the grid itself got greener. Without accounting for REC purchases, the median reduction in Scope 2 emissions was 31%. With all RECs, the median reduction was 100%.
Finally, these institutions reduced Scope 3 emissions covered by the commitment (primarily institution-funded airline travel and employee commuting) through on-campus incentive programs. The median reduction was 11%, but reductions varied widely. Some schools reduced Scope 3 emissions by over 50%, whereas four schools saw their Scope 3 emissions increase from their baseline year to their neutrality year (Figure 2). It is also important to note that changes in other Scope 3 emissions, such as embodied carbon in the supply chain from purchased goods (e.g. food and building materials), are not required to be reported under standard accounting practice for the Carbon Commitment. This is particularly relevant for natural gas, as schools substituting natural gas for other fuels are “shifting” some emissions outside of their neutrality commitments, moving them from Scope 1 (combustion) to Scope 3 (upstream leakage from natural gas infrastructure)\textsuperscript{18}.

No institution achieved net neutrality without significant use of accounting-based instruments (Figure 3). The majority of all claimed emissions reductions come from purchased offsets and unbundled RECs rather than direct emissions reductions by the institution (Figure 2). The median use of offsets and unbundled RECs as a share of emissions reductions at the time of neutrality was 63% (46–107%). The purchased carbon offsets came primarily from landfill methane and forestry practices (Figure 4). When bioenergy is included, the median use of accounting-based measures rose to 81% (53–107%) (see discussion below).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Share of reductions in HEI GHG emissions coming from three accounting-based reductions.}
\end{figure}
Finally, two institutions relied considerably on carbon sequestration from college-owned land (Figure 1, Figures S9 & S13). In this case, the annual carbon sequestered in institution-owned forests was considered as an emissions reduction (a “credit” against gross emissions). Current guidance discourages schools from counting institution-owned land sequestration without a demonstration of additionality (i.e. all of the reductions represent genuine reductions relative to the status quo). These institutions effectively treat the carbon sequestered on their forest land as additional relative to the regional landscape of forest management in their areas (namely that by owning and conserving/managing the forest, the institution is sequestering more carbon than in a world in which the forest land was not owned by the institution). One institution has highlighted that this would make their institution-owned land eligible for offsets under California’s Forest Management Compliance Offsets Program, which considers carbon sequestered from activities that are not “common practice” to be additional. However, a more protective approach to assessing additionality at the project level would find that a forest stewardship plan that has been largely unchanged since the baseline year is unlikely to result in additional carbon sequestration relative to business as usual. Our discussions with these institutions highlight ongoing challenges in additionality assessments that are playing out beyond U.S. HEIs. While differences in analyses of additionality frequently turn on differing approaches to counterfactuals, we have discussed the land sequestration approaches with these
institutions and remain unconvinced that this sequestration, although associated with positive land management practices, is additional in a way that should be counted towards neutrality at the institution. At the same time, it is critical for institutions to model good land management practices for a climate constrained world, and both institutions who have chosen to count sequestration from institution-owned land have highlighted the attention to sustainable practices involved in their decisions (and the risks associated with institutions ignoring land management emissions).

The Benefits of Neutrality First

The neutrality-first approaches taken by these institutions have important benefits. First, every ton of greenhouse gas emissions reduction that is real, permanent, and additional—whether from on-site fossil fuel use reductions, improvements in energy efficiency, or high quality off-site reductions—reduces the damages from climate change. Second, early neutrality pledges have catalyzed infrastructure changes, motivating institutions to update heating technology, deploy energy efficiency measures, and build on-site renewable generation (see SI2 for school profiles). Finally, aggressively pursuing carbon neutrality has led to cultural changes at several institutions, putting in place institutional structures for advancing sustainability that will continue into the future. Sustainability directors at these institutions report that achieving carbon neutrality “early” relative to other institutions mainstreamed climate-focused thinking throughout institutional decision-making processes (K. Payson and J. Pumilio, personal communications).

Several institutions also note that they are actively continuing to pursue emissions reductions even after meeting neutrality, for example by expanding agreements for renewable energy\textsuperscript{21,22}, demonstrating that achieving neutrality was a catalyst for further action at these institutions.

Accounting-Based Emissions Reduction Strategies in Context

Our analysis shows that the majority of emissions reductions at neutrality-first HEIs have come from accounting-based strategies. We underscore that these strategies are widely used and are standard under the guidelines used to administer the Second Nature Carbon Commitment. Depending upon the specifics, some can represent real, permanent, and additional reductions in emissions. However, given that HEIs are among the first large sectors to adopt carbon neutrality goals and thus serve as a highly visible model for pathways to carbon neutrality, it is worthwhile to assess these institutions’ strategies in detail. In the next sections, we discuss three salient strategies used by carbon neutral HEIs: (1) the use of unbundled RECs to reduce Scope 2 emissions, (2) the use of bioenergy sources to reduce Scope 1 emissions, and (3) the use of purchased carbon offsets. We also examine the limitations of these strategies in the current regulatory context and the scalability of these strategies as a model for broader societal decarbonization.

Unbundled Renewable Energy Certificates

Claiming emissions reductions from off-site renewable sources that enter the electrical grid requires accounting-based approaches because you cannot track...
specific electrons from generation source to outlet. Renewable Energy Certificates (RECs) were created as a means to track quantities of electricity (not emissions) associated with the generation of renewable energy such as wind and solar. They can be understood to represent the “environmental attributes” of renewable generation, and the holder of a REC has the right to claim that environmental attribute.

RECs can be contracted with their corresponding electricity at the time when new renewable generation is financed. This approach provides capital to put new renewable energy on the grid and can force utilities to build additional renewable energy to comply with state renewable mandates. These RECs are considered “bundled RECs” because the REC is purchased in a “bundle” with the rights to the electricity in a power purchase agreement (PPA). Although the approach is not perfect, the use of bundled RECs appears to represent a common best practice in purchasing off-site renewable electricity\(^{9,23}\). Potential pitfalls include the fact that new renewables in states with binding cap and trade programs do not reduce the overall capped emissions\(^{24}\), the actual impact of any renewable generation depends upon the electricity it displaces\(^{25}\), and some institutions undercut the benefit of the RECs through REC arbitrage.

Unbundled RECs, on the other hand, are sold through voluntary secondary markets separately from the purchase of the power itself, and they can derive from existing renewable generation that is likely to run regardless of the sale of the REC. Thus, the act of secondary purchase itself may lead to little or no actual change in emissions\(^{26–28}\). Claims of emissions reductions based on unbundled secondary RECs are problematic because they conflate the environmental attribute of renewable generation with the additionality of emissions reductions. Modeling and analysis of voluntary REC purchases suggests that, in some cases, they are unlikely to increase the amount of renewable energy on the electricity grid\(^{29,30}\).

Most RECs used by the U.S. HEIs in our data are not bundled (and Second Nature guidelines do not require it) (Figure 1). Of the nine schools that purchased RECs to achieve Scope 2 emissions reductions goals, seven purchased only unbundled RECs. From conversations with higher ed sustainability practitioners, most in the field regard bundled RECs as “higher quality,” and three institutions have pursued PPAs with bundled RECs in subsequent years (SI2).

Absent more evidence that unbundled RECs are having an impact on the amount of new renewable energy generation, these credits may represent a “dead end” as a systems solution—providing the illusion of action but de minimis systems or atmospheric impact. Bundled RECs from new PPAs offer, at a minimum, an opportunity to scale the finance to renewables and help accelerate their deployment. However, even these projects rest on an assumption that they will reduce emissions ton for ton. Ultimately, most HEIs cannot escape the fact that they depend on the larger overall grid and policy-induced shifts in generation, transmission, and storage to achieve meaningful decarbonization.

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**Bioenergy**

In the Northeast United States, home to many of the HEIs leading on carbon neutrality efforts, bioenergy has been a popular option for carbon mitigation but
one that is challenging given the scientific uncertainty and the lack of a broader U.S. policy strategy. Five of eleven institutions deployed biomass or biomass-derived fuels as part of their neutrality strategy (Figure S2). Many current accounting practices (including those in higher education) effectively treat bioenergy as carbon neutral by assuming that carbon uptake during regrowth of forests post-harvest offsets carbon emitted to the atmosphere through biomass combustion. The U.S. Congress has directed the Environmental Protection Agency to treat biomass this way via budget rider, and various European governments view biomass similarly (but with a range of sustainability and carbon neutrality criteria).

However, treating all bioenergy as carbon neutral is not supported by the best available science. The carbon footprint of bioenergy depends strongly on what happens to forest regrowth post-harvest, and it is difficult to trace biomass sources to ensure their neutrality. A 2012 report by EPA’s Science Advisory Board concluded: “Carbon neutrality cannot be assumed for all biomass energy a priori. There are circumstances in which biomass is grown, harvested and combusted in a carbon neutral fashion, but carbon neutrality is not an appropriate a priori assumption; it is a conclusion that should be reached only after considering a particular feedstock’s production and consumption cycle.”

Bioenergy accounting is complicated by the fact that analyses in the peer-reviewed literature still reach widely divergent conclusions, with some studies claiming that wood pellets offer lower emissions relative to coal in the UK within a few years and others suggesting that the use of biomass increases net emissions for decades. Recent work suggested that even relative to coal (most institutions are displacing less carbon intensive natural gas), carbon payback periods for Northeastern forests were likely to range from 50–100 years. Significantly, even if the “carbon debts” are short, front loading of emissions to be offset by later sequestration (i.e. net carbon neutrality over time) still may not be climate neutral. System lags mean that the impacts of the early pulse of CO₂ can persist for decades, increasing the total heat trapped in the climate system even if that pulse has been offset completely by sequestration. Furthermore, warming in the short term may push the climate system into feedback loops that accelerate warming regardless of longer time carbon reductions.

Several carbon neutral institutions took substantial steps to locate bioenergy with the best environmental profile possible. For them, this meant sourcing biomass from thinning or waste, from within a particular radius so that there would be fewer emissions from biomass transport and/or from forests that were registered as sustainable working forests so that the land was likely to see regrowth. While bioenergy use at these institutions represents an optimistic scenario where “sustainably” harvested biomass from forested regions is used in high-efficiency cogeneration of heat and electricity, certifying whether a biomass feedstock is sufficiently sustainable—or even agreeing on what constitutes sustainable biomass—has its own challenges, particularly as demand increases and sources become global. Certifications around forest practices are not by themselves capable of ensuring a short-term neutral climate impact. The supply of “sustainable” biomass which is actually near-neutral may place strong constraints on the
availability of these solutions to scale\textsuperscript{41}, limiting the ability of HEIs that utilize
bioenergy to model approaches for scalable change.

Particularly important from a systems perspective is the global impact that
large-scale bioenergy production could have on land use and air quality in a climate-
constrained world. The most recent IPCC special report on Climate Change and Land
modeled the potential of various global responses to climate change and concluded
that while bioenergy can contribute to mitigation, it could also have negative
impacts on food security, desertification, and land degradation if best practices are
not followed to limit bioenergy production to marginal lands or abandoned
cropland\textsuperscript{42}. Conversely, economists project that economic uses for forest products
could slow the rate of land conversion by making it economic to maintain ownership
of forests and intensify management for more biomass\textsuperscript{43}, a dynamic that will be very
sensitive to markets and local conditions\textsuperscript{44}.

The neutrality-first HEIs that switched to bioenergy reported substantial
reductions in Scope 1 emissions when they counted it as carbon neutral. If they
treated the biogenic CO\textsubscript{2} as emissions (with zero offsetting land uptake), most would
have seen an emissions increase (See Figure S2). The truth likely lies somewhere in
between. It is beyond the scope of our study here to resolve the debates around
bioenergy’s neutrality or detail best practices to account for biomass resources.
Instead, we highlight the fact that current accounting for carbon neutrality views
bioenergy as carbon neutral even though the scientific literature does not support
that categorical treatment and the significant challenges of ensuring good climate
outcomes in the absence of broader state or national policy.

Offsets

Although the carbon management hierarchy generally urges that offsets be
used as a last resort to cover hard-to-reduce emissions like air travel, purchased
offsets are the single largest source of reductions for nine of the eleven schools that
have announced carbon neutrality (Figure 3)—well in excess of what is needed to
offset air travel (5–31\% of emissions). One institution achieved carbon neutrality
with essentially no net on-site reductions, entirely through the purchase of offsets
(Figure S15).

In theory, offsets represent a way for actors to reduce emissions at the
lowest cost possible, finance reductions in other countries, and address sectors that
might not otherwise be covered by a carbon pricing program (e.g. land use
emissions, biogenic methane) by paying a third party for real, permanent, and
verifiable emissions reductions. In practice, offsets have been a controversial policy
tool. Early implementation of offsets under the Kyoto Protocol and the Clean
Development Mechanism led to some high profile failures, including cases where the
financial gain from credits themselves created perverse incentives to generate more
fluorinated GHG emissions \textsuperscript{45–47}. Ensuring that offset projects are truly additional
and that they are permanent (i.e. the carbon sequestered through an offset project is
not later lost to the atmosphere) is extremely challenging\textsuperscript{48–51}, even for best-in-class
programs like California’s regulatory Offset Compliance Program\textsuperscript{52}.

Voluntary (non-regulatory) carbon offset markets\textsuperscript{53}—those most available to
HEIs—are a special challenge because the lack of government oversight can mean
that transparency and quality enforcement suffer\textsuperscript{54}. Work has been done to try to demonstrate that offsets in the “high quality” voluntary market meet “PAVER” requirements (Permanent, Additional, Verifiable, Enforceable and Real). However, the relatively small amount of academic literature on offsets\textsuperscript{51,52,55} in comparison to their complexity and policy relevance creates real challenges for schools looking to achieve neutrality. Nonetheless, offsets are widely and frequently purchased by firms, institutions, and individuals; the voluntary offset market represents $\sim$300 million each year\textsuperscript{56}.

The use of carbon offsets to achieve emissions reduction goals also raises potential equity and justice concerns. Environmental justice groups and researchers point out that if neutrality is achieved primarily through offsets, conventional air pollution from fossil energy sources (potentially including those on campuses) may continue to impact vulnerable and marginalized populations\textsuperscript{57}. In the United States, local air pollution from fossil fuel combustion disproportionately impacts communities of color\textsuperscript{58}. The 2019 New York Climate Leadership and Community Protection Act, which requires that offset projects have local co-benefits and limits their use to settings where on-site reductions are not feasible, represents policy makers’ growing concerns with the excessive use offsets to achieve neutrality\textsuperscript{59}.

These concerns about offsets are not lost on neutrality-first institutions. The prevalence of landfill methane among neutral HEIs is consistent with a focus on quality, as these offsets can have lower additionality and reversal concerns. Nearly all of the carbon neutral schools have adopted policies guiding their procurement of offsets to promote offset quality and to align with other environmental and social concerns. Colby College, for example, adopted a policy that all offset projects must advance the UN Sustainable Development Goals\textsuperscript{60}. We note that there is an emerging practice of offsetting historical emissions\textsuperscript{61} or pursuing “climate positive”, where risks around additionality are somewhat less critical as they are not “displacing” emissions reductions elsewhere and can form an important source of finance.

Ultimately, while the best offsets do represent a potential mechanism to get urgently needed GHG reductions and finance to neglected sectors, we suggest that there are limitations to voluntary market offsets as a tool to support societal decarbonization. Cost pressures may push schools to seek lower cost (and therefore potentially lower quality) offsets, a concern raised even by offset developers\textsuperscript{56}. Increased demand for offsets does not currently seem to be raising prices in the beneficial way that would shift consumers to other actions; forestry and land use offset demand doubled from 2017 to 2018 but prices fell\textsuperscript{56}. At worst, supporting voluntary markets can strengthen incumbents who might lobby against regulation of those sources\textsuperscript{52} (for example landfill methane could also be reduced by EPA regulations) or for weaker offset provisions in a Federal program (as happened in 2009)\textsuperscript{62}.

\textbf{The Scalability of Current HEI Approaches to Neutrality}

The original ACUPCC is a strong framework for working towards system-scale change with leverage greater than the quantity of emissions reduced\textsuperscript{63}. An analysis of a subset of schools under the ACUPCC found that schools participating in...
the commitment had 47% lower purchased electricity emissions and 27% less
energy use (both on a per square foot basis) compared to non-signatories. In
general, neutrality commitments, combined with the associated reporting, planning,
and implementation, have played an important role in driving education and
greenhouse gas emissions reductions.

However, a firm quantitative metric for carbon neutrality risks falling victim
to Goodhart’s law, which states that metrics quickly lose effectiveness as individuals
and firms optimize to the metric rather than its intent. (“When a measure becomes a
target, it ceases to be a good measure.”) Strict adherence to letter-of-the-law
neutrality goals has the potential to introduce behaviors that look more like
regulatory compliance than true climate leadership and innovation. As described
above, a few of the schools announcing carbon neutrality relied substantially on
offsets and/or unbundled RECs to “achieve” carbon neutrality. Simply put,
regardless of their quality and environmental integrity, it is hard to argue that
purchasing of unbundled RECs and offsets is sufficient climate leadership.

Our goal here is not just to flag the uncertainty surrounding emissions
reductions from RECs, bioenergy, or purchased offsets. We recognize that, for each
of these accounting-based emissions reductions strategies, there are emerging best
practices and norms to ensure high quality emissions reductions. Instead, as we
note above, there are significant questions about the scalability of these approaches.

Climate leadership should demonstrate early-mover pathways and norms
that can be more widely adopted to achieve broad-scale climate goals. Reliance on
off-site reductions cannot scale to the larger U.S. economy; we cannot achieve
urgent climate goals (e.g. 45–50% emissions reductions by 2030) without direct
decarbonization of electricity, transport, industry and buildings. In particular, when
collectively compiled, the strategies of these schools differ significantly from the mix
of strategies that large-scale studies of decarbonization predict for the United States
as a whole (Figure 5). Relative to the U.S. Government’s official Mid-Century
Strategy (MCS) for Deep Decarbonization, which characterized reductions needed to
offset growth and reduce emissions 80% by 2050, HEIs have underinvested in
energy efficiency, new zero carbon electricity, and electrification (which make up
71% of total reductions in the MCS) in favor of bioenergy and methane reductions.
While this is an imperfect comparison between national and institutional strategies
(we cannot estimate how much energy efficiency offset growth for HEIs), the
relatively small amounts of new clean energy, CO2 removal, and electrification
suggest that HEIs may be missing opportunities to catalyze progress in these critical
approaches. Bowdoin College was the only school in our dataset that we are aware
is moving rapidly from “neutrality” under the terms of the ACUPCC towards a
detailed decarbonization plan that will electrify campus heat and provide 100%
renewable energy via power purchase agreements.
Figure 5: Share of Emissions Reductions by Strategy for the U.S. Deep Decarbonization Study vs. HEI Strategies. Emissions reductions by type under the Obama Administration’s U.S. Mid-Century Strategy and under current carbon neutral U.S. HEIs. HEI reductions do not sum to 100 because we do not assume here that unbundled REC purchases lead to changes in emissions. Renewable energy from offsets and college-owned land sequestration are shown in lighter red. The percentages shown are meant to illustrate trends rather than provide exact numerical information.

Institutional carbon neutrality as a milestone not an end goal

The choice of appropriate climate actions by individual institutions is complex and fundamentally represents trade-offs that each institution must make on its own in the context of constantly updated best practices. At the same time, practices set out nearly two decades ago to get institutions started on climate action no longer serve us well as we rapidly approach mid-century with dangerously high emissions.

Given the increasingly widespread adoption of neutrality targets across the world and the concomitant concerns about the accounting-based reduction strategies highlighted above, we envision a “systems” rather than “compliance” approach that focuses on the aspects of neutrality that can help contribute to the policy and market shifts needed at larger scales. Importantly, a systems approach can work in tandem with a carbon neutrality target, taking advantage of the catalytic effects and institutional changes that aggressive pursuit of neutrality entails. In this approach, a neutrality target is an optional milestone rather than an end goal and should be considered one component of the broader system-wide decarbonization that can be led by HEIs. A few HEIs in our study displayed aspects of a systems approach to decarbonization (with neutrality as a milestone), but this type of
approach is not yet codified or established as general practice, either in HEI carbon
accounting or in other sectors.

What does a systems approach to climate action look like for HEIs? Robinson
(2004) discusses the strengths of HEIs as change agents, noting that they have
“agency to change structures,” “agency to pursue novel practices,” and “agency to
link novel practices to structures”.

Changing structures (i.e. decarbonizing systems) should include transforming
the campus heating and transportation infrastructure to run on zero carbon
electricity. While not easy, reframing a goal around decarbonization is essential.
Separating emissions reductions/decarbonization from negative emissions
technologies and offsets can reduce risks associated with technology lock in and
excessive offsetting. Strikingly, the first U.S. HEI to achieve carbon neutrality,
College of the Atlantic, did so in 2007 but subsequently stopped purchasing offsets
in order to focus on full fossil-free infrastructure by 2030. To demonstrate the
pathway to decarbonization, institutions should immediately begin planning a rapid
transition to CO₂ emissions-free heating and cooling on campus (e.g. heat pumps
combined with renewable energy power purchase agreements), combined with
efforts to increase energy efficiency of buildings. These efforts not only reduce
emissions with certainty but also help build technical capacity in the region.

Novel practices (i.e. innovation) would include piloting new experimental
technologies, decision-making tools, or policy approaches. Innovation includes
ongoing research, development and deployment of carbon capture and storage,
direct air capture, new energy efficiency approaches, and other new technologies.
Rather than neglect most Scope 3 emissions outside the current ACUPCC
framework, HEIs can actively address them. In 2017, California passed the Buy
Clean California Act to set performance benchmarks for embedded carbon in steel,
glass and mineral wool in state-funded construction. HEIs can use their purchasing
power to create further market pressure to account for and reduce emissions in
their supply chains. HEI dining services can continue to explore ways to shift norms
and purchases towards more climate-friendly diets.

Given the likely continued use of some offsets on the pathway to
decarbonization, the potential for research by HEIs to innovate in this space and
address the substantial concerns about offsets is largely underutilized. Recently
released guidelines from the Offset Network—a partnership that grew out of Duke
University’s Offset Project and is now administered through Second Nature—
support planning around offsets to encourage more innovation and attention to co-
benefits. They provide a way for schools to implement their own offset projects,
including types already participating in the offset market or new project types such
as those coming out of campus research, and have those projects peer-verified by
student-mentor teams from another institution. The University of California
recently released a “Request For Ideas” to catalyze new UC-led offset projects.
More institutions could harness their research capacity to implement innovative
projects that support campus research and education goals, investigate the quality
of existing offset projects, develop new frameworks to support the reduction of
these emissions, and identify those projects that provide benefit to local
communities and vulnerable populations to ensure climate justice.
Linking novel practices to structures (i.e. scale) could include partnering with local governments to deploy transportation strategies or district heating. These kinds of measures all produce knowledge that can be transferred outside the institution to help drive technical and policy innovation. For example, the University of California has created a working group combining facilities and academic expertise across campuses and have focused on areas that could scale and create significant learning spillovers, including energy efficiency and electrification. More research that evaluates whether sustainable forest management actually produces net carbon gains across all pools in the long term and whether bioenergy demand alters regional economics to increase net forest carbon would also be especially useful.

More broadly, it will be important for HEIs to engage more fully with policymakers to visit campus and see them. In this approach, institutions can focus less on ton-by-ton compliance through accounting and more on demonstrating technological and institutional innovation needed for rapid emissions reductions at scale in a socially responsible way. It is our goal to use this paper to galvanize HEIs (and others) with future neutrality commitments to focus first on advancing climate actions that secure a just, equitable and sustainable future. While a focus on broader systems impacts is admittedly more challenging to quantify, it is important to emphasize that schools targeting higher leverage interventions should not be freed of the urgency to reduce their own footprint to zero as fast as possible.

One possible solution is that any school achieving a “neutrality” milestone should pair it with the announcement of a firm commitment to decarbonization of Scope 1 and 2 emissions. This commitment can ensure that schools resist the temptation to “coast” on cheap offsets instead of following the lead of the schools that have continued to work diligently on campus emissions. Given the incoming Biden-Harris administration’s commitment to net zero by no later than 2050, leading US institutions should have targets before that date.

Conclusions

Our analysis demonstrates strengths and limitations of non-state action to reduce greenhouse gas emissions. It mirrors conversations in the business sector about whether a firm can be considered responsible in the climate space if it is individually carbon neutral but fails to use its full leverage for policy changes at the state, national, or international level and the ways institutional actions can be undermined by the lack of strong standards and broad-scale policies for electricity, land use, bioenergy, and transportation. While virtually any climate action was constructive when HEI carbon neutrality efforts began, time is running out, and institutions need to think carefully about how to take action that charts a pathway toward decarbonization for society.

The next wave of best practice in climate leadership combines strong, science-based emission reductions (i.e. decarbonization) on a trajectory in line with
the Paris Agreement with net zero or carbon neutrality commitments before 2050. Where at one time having one or the other was seen as leadership, initiatives like Race to Zero and We Mean Business are building momentum around both as the best way to address climate risk, reduce tipping points, and send a signal to policy makers that businesses, cities, regions, and investors are united around decarbonization goals. The intent of this approach is that continued stringency around emissions reduction goals is essential and will lead most entities to net zero with significant direct decarbonization, but that the additional investments in natural and technical carbon removal technologies through net zero goals will help us meet our global target of carbon neutrality by 2050 and negative emissions into the second half of the century. While leading HEIs are already far ahead of most in achieving net carbon neutrality well before 2050, this paper highlights the need for HEIs to continue to set and achieve ambitious emission reduction targets that support a shift away from carbon-emitting energy systems towards true decarbonization, while expanding their focus to emissions in their supply chains and the broader policy environment.

As resources are limited in the wake of the COVID-19 pandemic, it will be more important than ever for all institutions to prioritize the many rapid system-scale changes needed to avoid the worst impacts of the climate crisis. The increasing number of national governments, subnational governments, and multinational corporations making pledges—and adopting substantive policies—to pursue net carbon neutrality in the near future can learn from early climate action leaders. One lesson is that, even if the substantial risks/uncertainty associated with some accounting instruments are addressed through careful selection and time-intensive consideration, there are limits to the ability of certain accounting-based strategies to advance societal decarbonization. A second lesson is that climate leadership is best represented by those institutions that have used their push for neutrality to help catalyze broader efforts to decarbonize. Most notably, these lessons highlight the need for global “rebranding” of commitments to pursue net neutrality as a milestone that can catalyze further action toward decarbonization rather than the end goal of sustainability initiatives. Youth climate activism, on the rise globally through the #FridaysforFuture movement, the Extinction Rebellion, and the Sunrise Movement, means that students will have a critical role keeping HEI leadership focused on both campus action and larger leadership questions.

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- Substantial contribution to research design: AB, AS
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- Critical revision of article: n.a.
- Final article approval: AB, AS, LD, MD, LM

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Supplemental Information

SI 1 Methods

Carbon Neutral Schools

U.S. Higher Education Institutions (HEIs) that have achieved carbon neutrality were assembled by reviewing press reports and consulting with staff at Second Nature, which manages the Presidents’ Climate Leadership Commitments (previously the American College and University Presidents’ Climate Commitment (ACUPCC)). Eleven schools that achieved neutrality under the terms of the “carbon commitment” were identified as of June 31st, 2020. One of those schools, Green Mountain College, announced in 2019 that it was ceasing to operate but we include it for our analysis here. Bates College is no longer paying dues under the Second Nature Climate Leadership Commitments but achieved neutrality consistent with the terms of the commitment and is included in our analysis. One other school—College of the Atlantic in Maine—declared neutrality in 2007 under an effort predating the formulation of the ACUPCC and has not maintained that status. Similarly, Arizona State University declared neutrality in 2020, but only for Scope 1 and 2 emissions (64% of the emissions that they report to Second Nature). Neither were included in our analysis.

To ensure equivalent comparison across HEIs (e.g. differing amounts of time since neutrality) and reflect the terms of the ACUPCC, all reductions are represented for the year in which the school announced neutrality (subject to minor adjustments as described below). Post-neutrality plans and measures are described in detail in SI 2.

Data Sources

Information on schools with neutrality commitments were obtained from the Second Nature reporting portal. Gaps in reporting were supplemented with data from the Association for the Advancement of Sustainability in Higher Education (AASHE), schools emissions inventory spreadsheets, and correspondence with the sustainability staff of the institutions. Scopes one, two, and three emissions (typically only commuting and air travel for Scope 3, no other purchasing or upstream methane leakage, etc.) are all included in the institutions’ gross baseline and carbon neutral year emissions. Carbon storage from compost and solid waste management is counted towards the institutions’ gross emissions as permitted by the University of New Hampshire Sustainability Indicator Management and Analysis Platform (SIMAP).

A number of adjustments, documented in the R code noted below, were needed to ensure uniform and representative comparisons. The institutions were not fully consistent in their accounting for renewable energy certificates (RECs). Most schools appear to match the number of kilowatt-hours of RECs (bundled and unbundled) to kilowatt-hours of electricity usage, treating them as 1:1 offsets. Some listed zero Scope 2 emissions in their neutrality year, whereas others listed exactly
equal emissions for Scope 2 and mitigation from RECs. Where necessary, we estimated gross Scope 2 emissions using kilowatt-hours of purchased electricity and RECs multiplied by SIMAP “market-based” emissions intensity factors (produced by Green-e)\(^2\). Our analysis was designed to provide a snapshot of emissions in the first year of carbon neutrality. However, in order to ensure that our analysis was representative of a typical year, we adjusted Colgate’s data to reflect one year pre-neutrality (a biomass boiler was offline for a significant portion of the year they declared neutrality). Allegheny data were adjusted to correct for a reporting error in the Second Nature database based upon more recent data from the institution. Data for 2020 schools reflect pre-COVID-19 emissions. While a few schools bought RECs and offsets in their baseline year, we used gross baseline emissions (i.e. no RECs or offsets) when calculating percent changes from baseline to carbon neutral year. Detailed descriptions for each school and waterfall charts of strategies in their carbon neutral year are presented in SI 2.

Data on enrollments were obtained from the Integrated Postsecondary Education Data System (IPEDS), using a public data compiler\(^8\). In order to give a rough comparison of the relative mix of strategies across schools, we compared the breakdown of aggregate emissions reductions from HEIs to the Obama Administration’s Mid-Century Strategy (MCS) for Deep Decarbonization\(^84\) by making a few simplifying assumptions. For bioenergy, we assumed complete carbon neutrality of fuels and estimated emissions reductions using the decrease in Scope 1 stationary emissions at schools that use this strategy. We contacted schools directly for estimates of major electrification projects (geo-exchange heating and cooling systems). Non-CO2 reductions includes offsets associated with landfill and dairy methane, fertilizer nitrous oxide, and industrial emissions abatement, as well as Scope 3 reductions from solid waste, compost, and agriculture. Land use change includes relevant offsets and college-owned land sequestration. We treated all bundled RECs as driving new generation. In the new generation category, we also included renewable energy offsets, and cookstove offsets purchased by Colgate, which replaced coal stoves with concentrating solar cookers. Finally, this category includes 85% of non-REC Scope 2 reductions. Scope 2 reductions were divided between new generation and energy efficiency using eGrid emission intensities for each school in the baseline and carbon neutral year. (We used eGrid data rather than Green-E residual emissions intensities, because the Green-E rates are only available for 2015–2020.) While the construction of on-campus renewables constitutes new zero carbon generation, we found that their impact was negligibly small (only ~0.2% of total reductions), so they are omitted from the figure. Energy efficiency includes all remaining Scope 1, 2, and 3 reductions, plus offsets associated with efficient transportation, water filtration, and cookstoves. This is an imperfect comparison, as the MCS reductions are for 2050 and are measured against a baseline with considerable growth, rather than relative to a historical baseline year.

Data Accessibility Statement and Code Availability
All data and R code (R v4.0.0, R Studio v1.3.1056) used to generate the figures is located at https://github.com/barronlab/heicarbonneutrality
Figure S1 Year of Neutrality Goal for U.S. HEIs. Reflects the neutrality target year for schools reporting to Second Nature under the Carbon and Climate Commitments (n = 362). An additional 64 schools signed the commitment but have not yet established a target neutrality year.
Figure S2. Total emissions in the baseline and carbon neutral year including on-site gross biogenic CO₂ emissions. One school did not report gross CO₂ emissions from biomass combustion.
<table>
<thead>
<tr>
<th>Measure</th>
<th>Advantages</th>
<th>Tradeoffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus Heat Electrification</td>
<td>Certain emissions reductions</td>
<td>Large capital expense</td>
</tr>
<tr>
<td></td>
<td>Demonstrates fossil-fuel free infrastructure</td>
<td>Long lead times for planning</td>
</tr>
<tr>
<td></td>
<td>Builds local/regional technical capacity</td>
<td></td>
</tr>
<tr>
<td>Renewable Power Purchase Agreement with Retired RECs</td>
<td>Produces new RE generation (ideally paired with storage)</td>
<td>Relevant RECs may be expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limited emissions impact in cap and trade regions</td>
</tr>
<tr>
<td>On-site Renewable Power</td>
<td>Reduces demand from grid</td>
<td>Limits to potential at many sites</td>
</tr>
<tr>
<td></td>
<td>Visibility</td>
<td>Less cost effective</td>
</tr>
<tr>
<td>Investments in Emerging Technologies</td>
<td>Broad benefits if successful</td>
<td>Financial and operations risk</td>
</tr>
<tr>
<td>Advocacy, research for policy</td>
<td>Impacts much broader than campus</td>
<td>Limited advocacy options for state-funded schools</td>
</tr>
<tr>
<td>Vehicle Electrification</td>
<td>Showcases technology</td>
<td></td>
</tr>
</tbody>
</table>

**Transition Strategies**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Advantages</th>
<th>Tradeoffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Power Purchase Agreement with Arbitraged RECs</td>
<td>Finances new construction</td>
<td>May not increase RE generation</td>
</tr>
<tr>
<td>High quality offsets</td>
<td>Reduces emissions, can allow time for decarbonization work</td>
<td>Time intensive to screen for quality.</td>
</tr>
<tr>
<td></td>
<td>Finances important sink sectors</td>
<td>Less certainty than on-site decarbonization</td>
</tr>
<tr>
<td>Experimental off-site reduction projects as research</td>
<td>Builds knowledge for reductions in these sectors</td>
<td>May not deliver expected reductions</td>
</tr>
<tr>
<td>Bioenergy linked to a research agenda</td>
<td>Informs policy design</td>
<td>Concerns about net climate impact, air quality</td>
</tr>
</tbody>
</table>

**Avoid**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Advantages</th>
<th>Tradeoffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low quality offsets</td>
<td>Low cost</td>
<td>Weak additionality tests and/or risk of reversal undercuts climate benefits</td>
</tr>
<tr>
<td>Bioenergy Without Careful Study of Sourcing and Life Cycle</td>
<td>Low cost, due to subsidy through federal policy</td>
<td>Opportunity cost of purchasing offsets rather than spending money on direct reductions</td>
</tr>
<tr>
<td>Campus Land Sequestration without Additionality</td>
<td>Promotes tracking and management of forest or agricultural land</td>
<td>Non-local sourcing further reduces ability to monitor impacts and quality</td>
</tr>
<tr>
<td>Unbundled RECs</td>
<td>Low cost</td>
<td>Without a change in practice, unlikely to produce climate benefits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very limited impact on emissions or markets</td>
</tr>
</tbody>
</table>

**Table S1. Illustrative Ranking of Selected Measures**
School summaries:

**Allegheny College** is a small liberal arts college in Meadville, PA with 1,800 students that declared neutrality in 2020. Since setting their carbon neutrality goal in 2010, they increased energy efficiency by 19.2% while increasing the square footage of campus. They also equipped four buildings with geothermal heating and cooling systems, reducing emissions by about 46 MT CO2e annually (K. Boulton, personal communication). Allegheny generates 8,500 kWh of electricity annually from on-campus photovoltaic arrays. The remainder of their purchased electricity is offset with unbundled RECs from wind generation sources. Allegheny used budget savings from increased energy efficiency to purchase offsets for their remaining Scope 1 emissions without allocating additional funds. Allegheny worked with two different companies to purchase roughly even shares of offsets from a Pennsylvania dairy methane digester, a water filtration project in Haiti, a soil conservation project in Colorado, and an industrial emissions abatement project in Mississippi. Reductions from college owned land sequestration were reported to Second Nature but will not be counted towards neutrality (K. Boulton, personal communication).

**American University** is an urban university in Washington, D.C. with 12,500 students that declared carbon neutrality in 2018. Between the baseline and carbon neutral year, physical space at AU increased by 20% and the university population
increased by 24%, but per square foot energy demand decreased 30% as a result of efficiency efforts. AU made investments in renewable energy, including rooftop solar on campus and a 54 MW solar installation in North Carolina funded with a 20-year PPA in collaboration with George Washington University and George Washington University Hospital. That PPA now accounts for about half of AU’s annual electricity usage, with unbundled REC purchases used for the remainder. AU also engaged in significant waste reduction efforts. AU maintains a sustainability fund that can be used for projects in the community and chose offsets that provide tree cover in nearby low-income neighborhoods. They linked other offset purchases with a study abroad program, creating opportunities to study international offsets.

**Figure S6.** American University pathway to neutrality.

**Bates College** is a small liberal arts college in Lewiston, Maine with 1,800 students. Bates declared carbon neutrality in 2019, although they no longer report data to Second Nature. Many of their direct emissions reductions came from energy efficiency improvements, and they also converted their central heating plant to a pyrolysis-derived Renewable Fuel Oil produced by Ensyn. One recent study estimated pyrolysis derived fuel oil as a 77% reduction in lifecycle greenhouse gas emissions relative to natural gas. Energy efficiency measures included ventilation based on building occupancy, window replacements, and insulation. Bates does not appear to have invested significantly in on-campus renewable electricity projects but recently signed a PPA for solar that will provide roughly 75% of their electricity in the future; they plan to sell the RECs and replace them with unbundled RECs (T. Twist, personal communication). Students were engaged in research on offset...
selection, “strongly recommend[ing]” that local and on-campus projects be prioritized²⁸.

![Bates College Emissions Graph]

**Figure S7. Bates College pathway to neutrality.** Does not represent pending PPA for electricity.

**Bowdoin College** is a small liberal arts college in Brunswick, Maine with 1,800 students that declared carbon neutrality in 2018. They reduced emissions by installing a natural gas cogeneration plant, insulating steam heat tunnels and other pipes, switching from oil to gas in buildings not connected to the cogeneration plant, weatherizing buildings, installing LED lighting and automatic switches, reducing landfill waste by half, and giving the campus police bicycles. Bowdoin recently signed contracts to cover almost all of its electricity consumption with bundled RECs from Maine solar projects, including a 4.9 MW array on college property (Keisha Payson, personal communication).

The college focuses on all-electric thermal loads in new construction, and several projects utilize passive house standards. Some new construction contains cross-laminated timber in an effort to reduce Scope 3 emissions. Bowdoin is actively exploring next steps to address Scope 1 emissions with consultants through a campus energy master plan that proposes the electrification of the campus heating load utilizing geo-exchange and an electric boiler for peak load and system back up (Keisha Payson, personal communication) and explicitly described offsets as a “bridge” strategy in its neutrality announcement²¹,⁹⁰,⁹¹.
Figure S8. Bowdoin College pathway to neutrality. Bowdoin primarily reduced Scope 2 emissions and closed the gap with offsets and unbundled RECs. This figure does not reflect a new power purchase agreement for solar that should replace the unbundled RECs.

Colby College is a small liberal arts college in Waterville, Maine with 1,800 students that declared carbon neutrality in 2013. Colby reduced emissions directly through the installation of a biomass gasification plant with cogeneration, LEED certification requirements for all new buildings and major renovations, two geothermal projects, and fuel-efficient campus vehicles. All wood for the biomass plant is harvested under the guidelines of the Sustainable Forestry Initiative, Forest Stewardship Council, or via a Master Logger with a certified harvest plan. Colby additionally requires a minimum of 80% of the wood chips to be “waste” wood (treetops, branches, etc.) from logging operations. The 20% allowance for chipped pulpwood is necessary to ensure an adequate supply during “mud season” in Maine when many of the roads are posted and logging trucks cannot operate (Sandy Beauregard, personal communication).

Colby began purchasing RECs equivalent to their electricity usage in 2003. A small 26 kW solar installation on the alumni center roof was completed in May 2015. In 2017, Colby joined a PPA that supplies ~16% of their electricity. (The PPA electricity comes from a 1.9 MW solar farm on Colby land installed by NRG Energy Inc.) Colby reports that they spend over six times more on energy efficiency projects than they do on offsets each year.
**Figure S9. Colby College pathway to neutrality.** Current gross biogenic emissions (in this case from biomass gasification) are “outside” of Second Nature reporting and are represented by the grey bar. Gross biogenic emissions will be offset by some amount of uptake during forest regrowth. Scope 2 does not reflect their more recent 1.9MW solar farm.

**Colgate University,** a small liberal arts college with 3000 students, declared carbon neutrality in 2019 for its bicentennial. The majority of the university’s on-site fossil carbon reduction efforts have centered around its biomass heating plant, which uses locally sourced wood chips certified by the Forest Stewardship Council/Sustainable Forestry Initiative or the American Tree Farm System. In 2014, the college upgraded the biomass plant, switching the backup fuel from oil to natural gas. Total biogenic emissions from the plant have decreased over time, presumably due to efficiency improvements in buildings, steam tunnels, and the plant itself. Purchased electricity through the local municipal utility largely comes from hydroelectric power, and the college also purchases unbundled RECs. Colgate installed geothermal heating in one of its houses, offsetting roughly 56 MTeCO2, and solar thermal panels on one of its dorms (John Pumilio, personal communication). The university’s green revolving loan fund has funded lighting efficiency upgrades.

At Colgate University, The Patagonia Sur Reforestation Project is a prime example of a university-catalyzed offset project. The university has entered into a fifteen-year agreement with the Patagonia Sur reservation to fund reforestation through the offset purchases; the project also involves study opportunities for students and faculty. More recently, Colgate engaged in a detailed offsets evaluation process, examining over 70 project types and asking vendors for their
alignment with UN Sustainable Development Goals. They ultimately chose projects including grassland conservation, solar cookers and deforestation prevention. For their forestry offsets, they purchased “supertons” (additional credits from a methane project) as a hedge against quality issues with forest projects.\(^9\)

Colgate manages their 1,539-acre forest under the American Tree Farm System and tracks the carbon stocks with an inventory (John Pumilio, personal communication). Unlike other schools, Colgate effectively treats baseline carbon uptake by these forests as negative emissions as part of their Scope 1 emissions. While they account for changes in these stocks from construction projects (e.g. cutting down trees), it is our understanding that they do not adjust their estimate of carbon uptake based on what would have occurred in the absence of their sustainability efforts, as would be required for most offset projects or report reductions net of baseline carbon sequestration (“net-net”) as is done in national inventories.

![Colgate University](image)

**Figure S10. Colgate University pathway to neutrality.** Gross biogenic emissions are “outside” of the ACUPCC commitment and are represented by the grey bar.

**Colorado College** is a small liberal arts college in Colorado Springs, Colorado with roughly 2000 undergraduate students. They declared carbon neutrality in 2020. The college reduced on-campus emissions through renewable energy development, efficiency upgrades, building renovations (including geothermal energy at their renovated library and a housing project for ~800mT CO\(_2\)e of reduction), and a behavioral change program targeting electricity, heat and water use. They purchase all of their electricity through a long-term green power contract with their local
utility (essentially a 20-year PPA) and also partner with the utility to help increase renewables in the local grid. Remaining Scope 1 and 3 emissions are met with verified offsets, although they are looking at ways to incentivize lower-carbon travel.

![Figure S11. Colorado College pathway to neutrality.](image)

**Dickinson College** is a small liberal arts college in Carlisle, Pennsylvania with roughly 2,300 full-time students. It met its carbon neutrality goal in 2020 and, unlike most institutions, includes students’ study abroad air travel in addition to college-funded travel in the total. The college achieved a 25% reduction in emissions relative to its 2008 baseline through conservation, energy efficiency and renewable energy projects. They note that some of their Scope 2 reductions are due to increases in renewable energy on their grid since their baseline. In 2020, they procured Green-e Certified RECs and Climate Action Reserve certified carbon offsets that help finance a project that reduces N₂O emissions from a fertilizer plant in Oklahoma. Dickinson recently installed 3 EV charging stations in past year, and the campus farm has converted vehicles to solar-charged electric (Neil Leary, personal communication). In addition to several on-campus solar arrays, which produce about 140,000 kWh annually, Dickinson entered a 25-year PPA for a 3 MW solar field in 2018. The solar field is located on college land; some of the associated RECs are retained by the college and some are sold (Ken Shultes, personal communication). In addition, Dickinson is collaborating with Lafayette College, Lehigh University, and Muhlenberg College to establish a PPA with a solar farm in Texas.  

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43
**Figure S12.** Dickinson College pathway to neutrality. This figure does not reflect a pending power purchase agreement.

**Green Mountain College** was a small liberal arts college in Poultney, Vermont that focused on sustainability studies. It had ~800 students. GMC declared carbon neutrality in 2011 but closed permanently in 2019. Direct emissions reductions came from switching their central heat plant from #6 fuel oil to wood chips and improving the efficiency of the plant over time. GMC required two thirds of its biomass to come from college’s own Poultney Woodshed Project and the remaining third to come primarily from woods within 250 miles of the college that followed sustainable harvesting practices. The college also replaced underground steam tunnels and residence hall windows, audited building thermal efficiency, and replaced a backup boiler at the central heat plant with a more efficient one. GMC made an explicit choice to purchase offsets\(^96\) rather than RECs to guarantee emissions reductions, and worked to extract educational benefits from their offset policies; students in several classes\(^97\) worked with Second Nature’s guidelines to help select the offset projects purchased by the school.
Middlebury College is a small liberal arts college with 2,800 students in Middlebury, Vermont that declared carbon neutrality in 2016. Their direct reduction measures included a number of projects with Efficiency Vermont, which they claim reduce electricity use by about 4,520,000 kWh per year. Middlebury has a 1.5 acre, 143-kilowatt solar farm on college land. Middlebury began buying all of the electricity produced by the nearby 2.2MW South Ridge Solar Farm in 2015, and the college entered a PPA with the 500kW Wilbur Solar project in 2016. Together, the electricity from these projects accounts for ~8% of campus usage. The college retains the RECs associated with these projects but does not list them in their inventory. Middlebury sources the wood for its biomass gasification plant from within a 75-mile radius of the college, and says that it is “working to develop a system to provide us with more information about our suppliers’ practices and help us understand the extent to which ecologically sustainable forestry practices are being used.”

Middlebury's offsets came entirely from on-campus land management, which was certified by the American Carbon Registry. The offset plan suggested that the project passed the “common practice” test for additionality because “The forest type for this project is most similar to industrial forestland ownership...the industrial forestland type is heavily cut and managed for maximizing NPV of the forestland investment...If the Blue Source – Middlebury Improved Forest Management Project...
was not implemented, the forest management could feasibly resemble that of industrial forestland ownership in the region.” However, the same project documentation notes that “Current use is as a conservation and carbon sequestration forest” and that Middlebury “does not commercially harvest timber.” Middlebury notes that campus forest lands have been harvested for campus building projects and commercial timber sales but that those levels of harvest have been much lower that commercial harvests in the area (Jack Byrne, personal communication). Thus while the project has been certified in meeting the common practice test, it is not clear how much these offsets alter carbon storage vs. business-as-usual.

Figure S14. Middlebury College pathway to neutrality. Gross biogenic emissions are “outside” of the ACUPCC commitment and are represented by the grey bar.

The University of San Francisco is a research university in San Francisco, California that declared carbon neutrality in 2019. As of 2018, the university had 8,700 students. The university’s direct reduction efforts included on-campus solar installations and upgrades to boilers, heating systems, windows, and lighting systems. The university also focused on conserving water and diverting waste from landfills. They have reduced water usage by 30% since 2014 and planned to be diverting 64% of waste from landfills as of 2015–2016. The university provides public transportation passes for students.
offsets as a “last resort strategy to achieve carbon neutrality, for indirect emissions such as air travel emissions”\textsuperscript{101}. 

\textbf{Figure S15. University of San Francisco pathway to neutrality.}