8-18-2020

Carbon Pricing Approaches for Climate Decisions in U.S. Higher Education: Proxy Carbon Prices for Deep Decarbonization

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PRACTICE BRIDGE

Carbon pricing approaches for climate decisions in U.S. higher education: Proxy carbon prices for deep decarbonization

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Given the slow policy response by governments, climate leadership by other institutions has become an essential part of maintaining policy momentum, driving innovation, and fostering social dialogue. Despite growth in carbon pricing in government and the private sector, our review suggests low, but growing, adoption of internal carbon prices (ICPs) by higher education institutions (HEIs), who may be uniquely suited to implement and refine these tools. We analyze the range of ICP tools in use by eleven U.S. HEIs and discuss tradeoffs. Our analysis identifies several reasons why proxy carbon prices may be especially well-suited to decisions (especially at the system-scale) around carbon neutrality at a wide range of institutions. Using a unique dataset covering 10 years of real-world analysis with a proxy carbon price, we analyze the interaction of ICPs with life cycle cost analysis to start to identify when and how internal carbon pricing will be most likely to shift decisions. We discuss how schools and other institutions can collaborate and experiment with these tools to help drive good climate decision-making and inform climate policy at larger scales.

Keywords: Carbon management; Shadow price; Climate policy; Third sector; Non-state actor

1 Introduction

1.1 Carbon pricing in context

There is broad agreement among economists that an essential (but not necessarily sufficient) step to address the climate problem is to put a robust price on carbon (Akerloff et al., 2019). A price on carbon means that the cost of fossil fuels better reflects the damages they cause to society, leveling the playing field for low-carbon technology. As of 2019, there are 46 nations and 28 subnational jurisdictions with carbon pricing policies (World Bank Group, 2019). Ultimately, 88 countries representing 56% of global emissions are planning to, or considering, implementing carbon pricing policies (World Bank Group and Ecofys, 2018). However, existing and pledged actions under the Paris Agreement remain insufficient to keep temperatures below two degrees Celsius (Fawcett et al., 2015) (let alone 1.5°C) and only 3% of priced emissions have sufficiently strong carbon prices (Ball, 2018).

Given the slow policy response by governments, actions by non-state actors have become an essential part of maintaining policy momentum, driving innovation, and fostering dialogue. Here too, there has been notable progress. More than 600 businesses, including well-known firms like Microsoft and Royal Dutch Shell, have implemented internal carbon price (ICP) mechanisms (CDP, 2017). However, the stringency of these policies varies widely – with prices ranging from less than a dollar to hundreds of dollars – and only 37 firms have disclosed that the carbon price has actively changed decision-making (Bartlett et al., 2016), with limited detail on how. Little academic work exists to explain these patterns (Chang, 2017; Gillingham et al., 2017; Aldy and Gianfrate, 2019), in part due to the inherently sensitive nature of internal business decisions.

Higher education institutions (HEIs) have been leaders in confronting climate change. Over 600 U.S. HEIs have pledged to achieve carbon neutrality (Cortese, 2010) with over 400 actively tracking neutrality commitments (Second Nature, 2019), and many schools are actively engaged in other actions like fossil fuel divestment (Stephens et al., 2018). In the U.S., the aggregate emissions produced by academic institutions is at least 120 MMT CO_2e/yr (Sinha et al., 2010) – emissions very roughly on par with the direct energy-related CO_2 emissions from New Jersey (U.S. EIA, 2017). HEIs regularly make decisions about buildings, vehicle fleets and campus energy infrastructure that will affect their emissions for decades to come, amplifying the importance of making climate-smart decisions now.

However, despite the high profile of carbon pricing as a key policy tool and the significant adoption of ICPs by businesses, momentum is only now starting to build for the use of ICP tools in academia. These tools are being

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adapted for use by HEIs, with significant potential for institutional change, research, and education.

In this paper, we describe the limited, but growing, use of ICPs in higher education in the U.S. We explain how the choice of an ICP tool is likely to vary across institutional structures and decision types. We argue that increased adoption of life cycle cost analysis incorporating a proxy carbon price is one promising direction for HEIs to consider. Next, we use a dataset of life cycle cost analyses spanning ten years and three institutions to illustrate when and how often carbon pricing may alter investment decisions for HEIs. Finally, we briefly discuss methods for carbon price selection for HEIs before synthesizing lessons for practice and how these efforts can grow and contribute to the broader social discourse on carbon pricing.

1.2 Opportunities from expansion of carbon pricing in higher education

Internal carbon price policies can help institutions meet multiple goals, including managing transitions to a low-carbon future, incentivizing innovation, reducing regulatory risk, building social capital, and enabling their mission (Chang, 2017; Ecofys et al., 2017; Gillingham et al., 2017; Gajjar and Vivek, 2018). At its core, an ICP represents emissions in dollar terms, which can help institutions integrate their climate goals into economic decisions. ICPs can also "future proof" against financial risk from future climate legislation at the state and federal level (Aldy and Gianfrate, 2019). These risks are not entirely hypothetical; legislatures in several U.S. states are contemplating adoption of carbon taxes (NCEL, 2019) and a number of carbon tax proposals have recently been introduced in the U.S. Congress (SIPA Center on Global Energy Policy, 2019). Both would affect operating costs of long-lived infrastructure like buildings. New buildings and energy infrastructure represent important decision points that can "strand" assets in a lower-carbon future by committing to a trajectory of high fossil energy use (Caldecott, 2017; Gillingham et al., 2017). For example, a college might spend significant funds on a new fossil-fuel fired boiler, only to discover that an electricity-based system would have been cheaper to operate under a newly passed carbon price. Finally, in the competitive marketplace of higher education, adopting ambitious climate policies may help attract students and staff actively engaging social in movements like #FridaysForFuture and Sunrise (Fisher, 2019).

There are a number of factors that make ICPs especially promising for HEIs. First, unlike traditional businesses that focus on economic returns, the missions of HEIs often include a stronger focus on social benefits (e.g. reducing climate risk), and ICPs can help institutions incorporate these considerations into decision-making. Second, HEIs operate over very long timescales, which makes good decision-making about long-lived capital especially important. Third, research and education are part of the core mission of HEIs, and there is an opportunity to experiment, innovate, and educate with ICP tools (Wolak, 2014; Hall et al., 2015). Importantly, HEIs are more likely than businesses to share insights from carbon pricing experiments, speeding the diffusion of learning by doing.

HEIs also highlight the challenges (and associated learning opportunities) of applying a market tool in less-than-perfect markets. An ideal carbon price would carry through an economy where everyone can make informed decisions about reducing consumption linked to emissions or switching to alternatives (Metcalf, 2019a). In reality, market failures including imperfect information, split incentives, and monopolies are common (Brown, 2001; Stiglitz, 2019). Many of these failures exist within HEIs. For instance, many actors in HEIs are decoupled from price signals – students do not typically receive energy bills, and academic departments may not pay for their specific energy usage. Administrative structures often split capital decisions and energy costs (Hall et al., 2015). These aspects present design challenges but also an opportunity to test policy effectiveness in non-ideal (i.e. real-world) settings. Successes and failures from experimentation within HEIs can then help inform policy selection more broadly.

2 Methods overview

This section provides a brief summary of the methods used in our study. The primary approach of this paper was to catalog and study existing ICPs at U.S. HEIs and to analyze a dataset of HEI life cycle cost (LCC) analyses that used ICPs. We also share an illustrative analysis with an ICP and illustrate carbon costs relative to energy costs. For a detailed discussion, please see S1 Methods.

2.1 Cataloging of carbon pricing policies in higher education

Internal carbon pricing policies at U.S. HEIs were collected through a review of entries on the Association for the Advancement of Sustainability in Higher Education (AASHE) Hub (AASHE Campus Sustainability Hub, 2019), emails and phone calls to AASHE community members, and through the Internal Carbon Pricing in Higher Ed Toolkit Working Group (Second Nature, 2020) led by Yale University and Second Nature. We analyzed programs at the public pilot stage and beyond; programs at earlier stages of development were excluded from the dataset.

2.2 Cost estimates of retrofit options

To illustrate LCC with a proxy carbon price, we estimated LCC with and without a carbon price for five energy efficiency improvement options for a dormitory renovation at Smith College in Northampton, Massachusetts in the United States. The options were: insulate the attic to R-49, insulate the basement to R-13, insulate the above grade walls to R-20, air seal the windows and doors, and replace the single pane windows with double pane windows. Unit cost estimates for each option were provided by campus facilities staff and scaled by area. To model building energy, we selected the Department of Energy eQuest building energy simulation tool (Crawley et al., 2008). Details on modeling can be found in S1 Methods. Utility escalation rates and prices for water, electricity and natural gas were taken from historical data. All other rates and market prices were adopted from the Energy Information Administration (EIA) (Parker, 2018). A carbon price of $70 per ton, rising at 2.5% per year, was applied for the proxy carbon calculations. This value was recently adopted by

Smith College (Parker and Barron, 2018) and is roughly in line with the prior U.S. Government social cost of carbon estimates at a 2.5% discount rate (IWG, 2016).

2.3 Analysis of life cycle cost studies

We analyzed several LCC studies conducted with ICPs at three different institutions: Princeton University (Princeton, NJ, U.S.A.), Smith College (Northampton, MA, U.S.A.) and Cornell University (Ithaca, NY, U.S.A.). Data from Princeton University were analyzed under a data confidentiality agreement with Princeton University. Data from Smith College were taken from the example shown in **Figure 2** and an additional case study on off-road electric vehicles (available upon request) (n = 6 in total). Cornell University analyses were reported publicly (Cornell Senior Leaders Climate Action Working Group, 2016).

2.4 Estimating carbon share of energy costs

We illustrate the relative impact of a $70/MTCO$_2$e ICP on typical HEI energy costs using a range of data sources. Energy market prices were drawn from EIA data and emissions intensities from the U.S. Environmental Protection Agency (U.S. EPA, 2018). CO_2e intensity for electricity in the Northeast was estimated using data from the Independent System Operator New England (ISO-NE), which publicly reports emissions from marginal generation (ISO New England Inc., 2018). CO_2e intensity for electricity in the Southeast (SERC-Midwest) was taken from the EPA's eGRID dataset (U.S. EPA, 2020). On-campus electrical generation costs (via co-generation) were estimated by Smith College (Northampton, MA, U.S.A.) (Parker, 2018). These are likely to vary relative to other institutions with unique on-site generation infrastructure.

3 Results and discussion

3.1 Internal carbon pricing in higher education today

Our research identified three main tools in use by HEIs in the United States that are currently disclosing internal carbon pricing approaches: carbon charges, proxy carbon prices, and carbon funds (**Table 1**). *Carbon charges* levy a fee on the carbon emissions from departments or administrative units. The accrued funds can be used to finance sustainability projects or the charge can be made revenue neutral by providing each administrative unit a rebate to

Table 1: Differences between HEI internal carbon price tools. DOI: https://doi.org/10.1525/elementa.443.t1

	Carbon Charge	**Proxy Price**	**Carbon Fund**
Description	Fee on carbon emissions (optional rebate)	Virtual price on carbon emissions of a project	Share of budget to generate fund
Emission Scope	Scope 1 & 2 or 3 for air travel	Scope 1 & 2, Scope 3 purchasing	Scope 1 & 2 or 3 for air travel
Timeline Focus	Present Emissions	Future Emissions	Present Emissions
Scale	Institutional/Sector	Project by Project	Institutional
Institutional Role	Operational	Planning, Risk, Evaluation	Mitigation projects or Offsets
Financial Focus	Operational Expenditures (plus future design and constr.)	Design and Construction, Purchasing	Budgets
Impact	Across the Institution	Targeted Projects	Fund Use
Primary Data Requirements for Implementation	Unit-level energy metering (for buildings)	Present and future project costs	Emissions inventory
Accounting Level	Unit/Department	Project	Unit-level or above
Administrative Level of Effort	High	Depends upon project number and scope	Low (for fund itself)
Typical Size of Price Signal	Business: $2–$20/ton Academia: $10–40/ton	Business: $2–$893/ton Academia: $10–$268/ton	Zero (not passed to consumers)
Program Cost (to institution)	Administration, net cost of implemented measures	Added net cost of any new options selected, limited administration	Total value of fund minus cost savings, administration
Primary Visibility	Departments Air travelers Student engagement	Facilities and finance staff Student projects	Departments Fund recipients
Revenue for projects	If not revenue neutral	No	Yes
Other Potential Benefits	· Student learning · Promotes dialog · Funds/promotes low carbon investment · Promotes energy efficiency investment · Drives behavioral changes · Manages risk of carbon regulation	· Student learning · Promotes low carbon investment · Promotes energy efficiency investment · Promotes long term thinking (LCC) · Engages vendors · Manages risk of carbon regulation	· Student learning · Promotes dialog · Generates funds for climate, efficiency, and sustainability projects

reduce the impact of the charge (Gillingham et al., 2017). *Proxy carbon prices* (sometimes called shadow carbon prices) are virtual prices used to inform decision-making processes (CDP, 2017; Barron and Parker, 2018). The social cost of the carbon emissions is included in an analysis as though it were a private cost to the institution (as it would be under a government-run carbon tax). *Carbon funds* reserve funds from the budget (in an amount equal to institutional emissions multiplied by the set carbon price) to fund projects (Second Nature, 2020).

Not all of these approaches would fit with a typical economist's conception of a carbon price – both because, as we note in Section 1.2, HEIs are not perfectly competitive markets and because a governmental carbon price would usually be applied upstream, near the point where fossil fuels enter the economy. Instead, ICPs represent the adaptation of the principles and goals of carbon pricing to the unique settings of HEIs. For this paper, we have focused on the widest possible universe of tools, recognizing that resemblance to Pigouvian carbon prices is only one parameter that schools could apply in selecting a policy tool. Indeed, as we discuss below, data and structural limitations often favor slightly different tools. Some taxonomies of ICPs include implicit carbon prices, which are calculations of the per-ton cost of reductions, but as these are not a pricing approach and are frequently used to later set an ICP (Gajjar and Vivek, 2018), we exclude them here. Similarly, cap and trade is a potential ICP tool (Victor and House, 2006) but we are unaware of any HEIs exploring this option, possibly due to high monitoring and administrative requirements (Metcalf, 2019b). As our focus is on pricing tools, we also exclude complementary policies like carbon-neutrality commitments and fossil fuel divestment strategies from our analysis (Table S2.1 lists the announced carbon neutrality dates and fossil fuel divestment status for U.S. HEIs with an ICP in our dataset).

Despite the potential advantages of carbon pricing, uptake in the U.S. higher education sector has thus far been relatively low, with growth only in the last few years. Although more than 660 U.S. academic institutions have carbon neutrality commitments and 55 have endorsed putting a price on carbon at the state and federal level (Our Climate, 2017), our research identified only 11 U.S. academic institutions that are currently disclosing ICPs (**Table 2**). The actual number may be higher as there is no centralized tracking of the use of ICPs in U.S. higher education; we are aware of at least 10 other U.S. HEIs currently exploring ICPs.

The 11 U.S. HEI institutions with ICPs have selected a mix of the policy tools described above. Princeton University has been using a proxy carbon price in capital construction decisions since 2008 (Princeton University, 2008) (See Supplementary Information S2 for more detail on specific programs). After experimenting with a proxy carbon price in 2009, Yale University more recently piloted its carbon charge with four approaches, then launched the Yale Carbon Charge Project in 2016 to experiment with a revenue neutral carbon charge applied to administrative units on campus (Gillingham et al., 2017). The Yale Carbon Charge operates by measuring the carbon

Table 2: Existing publicly disclosed internal carbon prices at U.S. academic institutions. Broad scope policies apply to multiple emissions sources. Air travel policies are limited to that use. Prices reflect the most recent price of which we are aware. See supplementary information for citations and details. DOI: https://doi.org/10.1525/elementa.443.t2

Broad Scope ICPs

Year	School	Policy	Price/$MTCO_2e$	Notes
2008	Princeton University	Proxy price	$268	Capital projects
2015	Yale University	Carbon charge	$40	Revenue-neutral- across campus
2016	Swarthmore College	Carbon fund	$26	Percent (1.25) of department budgets plus voluntary contributions
2016	Swarthmore College	Proxy price	$100	Capital projects
2016	Cornell University	Proxy price	$38 + 1.75%/year	Used for a study of options for campus energy supply
2017	Arizona State University	Proxy price	$10	Pilot phase
2018	Smith College	Proxy price	$70 + 2.5%/yr	Pilot phase, capital projects

Air Travel ICPs

Year	School	Policy	Price	Notes
2012	Weber State University	Carbon fund	~$0.01/mile	Capped at $100,000 total, based on share of 2012 travel
2016	Whitman College	Carbon charge	$5–$40/trip	Student travel only; range varies by distance and vehicle
2017	University of Maryland	Carbon charge	~$5/trip	
2018	Arizona State University	Carbon charge	$8/trip	To purchase and develop offsets
2018	University of California Los Angeles	Carbon charge	$9/25/flight (Domestic/Intl)	Pilot phase
2020	Utah State University	Carbon charge	$10/flight	For on-campus projects to reduce carbon footprint.

emissions from each administrative unit (e.g. School of Law, Central Library) and levying the carbon fee on their emissions. Based on performance relative to a baseline, each administrative unit receives a proportional rebate. Swarthmore College developed a hybrid approach in 2017, with a carbon fund and a proxy carbon price. The carbon fund, which includes both the mandatory charge and voluntary donations by departments, has collected ~$1.3 million to fund lifetime emissions reductions of ~13 kMTCO$_2$e (roughly equivalent to 80% of a year's emissions) (Swarthmore College, 2017). The remaining institutions we identified are experimenting with either a carbon charge or carbon fund for travel (Ezarik, 2016; Utah State University, 2020) or a proxy carbon price (Cornell Senior Leaders Climate Action Working Group, 2016; Smith College, 2017; Dalrymple, 2018). Carbon charges on travel are all applied as a fixed charge per trip, due to data limitations in most travel systems. As **Table 2** demonstrates, many of the policies have been adopted quite recently, suggesting increasing momentum toward ICP policies within the academic sector.

Outside the United States, many academic institutions operate in jurisdictions with current or anticipated carbon price policies, but little research is published about how they use ICPs to incorporate that risk into internal decisions (Lau, 2013). In British Colombia, universities experience the costs of the $30CAN/ton provincial carbon tax and public sector institutions apply an internal $25CAN/ton carbon charge (to fund offsets) for their operational emissions, providing a strong financial incentive in decision-making to achieve internal climate goals (BC Ministry of Environment, 2018; University of British Colombia, 2018). University College London is piloting a "Carbon Accountability Scheme" with either rebates or rebates/charges of £30/tonne based on performance relative to a baseline (University College London, 2020).

ICP practices likely exist other places outside of business and academia, but we are not aware of comprehensive data on other types of nonprofit firms (e.g. hospitals, churches) using ICPs. The World Resources Institute, a U.S. nongovernmental organization, has a carbon charge of $50/ton for their staff's air travel, electricity consumption, and employee commuting, with the bulk of the proceeds going to metrics collection, policy development and implementation (Kamins et al., 2018). Thirty-one nonprofit hospitals in the U.S. recently added new climate commitments which may drive them to adopt ICPs (We Are Still In Coalition, 2018).

3.2 Choosing the right tool

Decisions that drive carbon emissions vary in type and occur throughout an organization in ways that vary by institutional structure. As different tools are more effective in different settings, we strongly encourage HEIs and

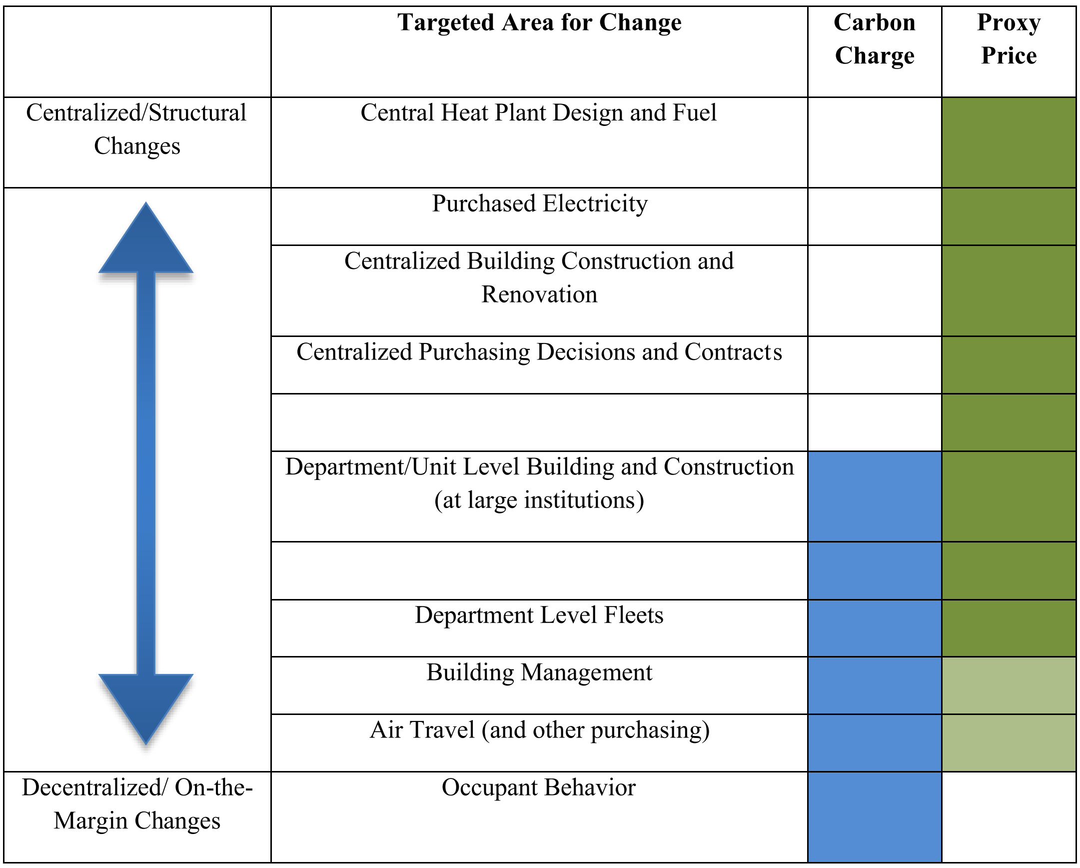

Figure 1: Critical decision types and associated ICP tools. Decisions that impact HEI emissions are made throughout the organization. Proxy prices are particularly useful for centralized decisions while carbon charges are a better tool for passing the cost of carbon emissions down to users in decentralized structures. DOI: https://doi.org/10.1525/elementa.443.f1

other institutions to explore all three ICP tools identified above depending upon the decisions they wish to target. To help schools select the right tool in a particular setting, we categorize emission reduction opportunities in two broad ways. First, we distinguish between two types of decisions: changes in current energy use versus changes in energy-using infrastructure and equipment. Many emissions changes are driven by altering energy use, holding infrastructure constant. Within the HEI sector, common examples include turning off lights, altering thermostats, or flying less frequently. However, many emission reduction opportunities are associated with changing infrastructure or equipment to alternatives that lower emissions. Examples in this category include zero-carbon campus energy generation, investments in energy-efficient buildings (both new and retrofits), and purchases of energy-efficient appliances and low emissions vehicles. Second, we consider the degree of centralization of decisions along a continuum. Decisions about campus energy generation are almost always centralized, user-level energy decisions like turning off lights are highly decentralized, and decisions about building retrofits and building temperatures may be either centralized or decided at the department or school level (**Figure 1**).

Each ICP approach has strengths and weaknesses in addressing these different types of decisions (**Table 1**, **Figure 1**). *Carbon charges* that target current emissions from infrastructure (direct combustion and electricity, known as Scope 1 and 2) can dedicate significant revenue for investments and are the most direct analog for policies that might be adopted at the national level (Gillingham et al., 2017). They can encourage building managers and departments to identify energy-saving behaviors or can provide some incentive for adoption of low carbon and energy-efficient infrastructure, depending on the institutional setting. However, at many HEIs, multiple departments are housed in the same building and do not pay for energy, making passage of the price signal challenging. These departments are like renters who do not "see" the cost of energy and therefore do not have an incentive to reduce energy use, thereby reducing the potential power of the tool. To succeed, carbon charges for buildings require detailed energy metering, which may not yet exist at many schools (U.S. EPA, 2002), and department-level energy billing, which also may not yet be in place at many institutions. In a broader sense, charging individual units for their current carbon emissions can be an important way to incentivize end-user behavior, but important decisions about the infrastructure that most influences emissions, such as campus energy generation, are usually made elsewhere. In these cases, a carbon charge can send a signal to reduce current energy use but can fail to incentivize important investment opportunities. Again, rental properties provide a useful real world analog; renters may pay their electricity bill and thus have an incentive to change the temperature on their air conditioner, but they may not control decisions about upgrading to a more efficient air-conditioning unit (Hausman and Joskow, 1982; Davis, 2010; Gillingham et al., 2012). Transaction costs can also be important here as schools that do not have energy billing systems will have to develop them and, presumably, provide budgetary and technical support to the department units responding to the program.

While revenue-neutral carbon charges can be effective for many institutions and for particular decision types, their effectiveness can diminish as decisions become more centralized. According to Gillingham et al. (2017), departments at Yale appear to respond to the net charge they face, rather than the gross charge. In an institution where each unit already pays their own utility costs, there is already a price signal to incentivize lowering energy use, and a carbon charge can amplify that price signal. However, if all of the facilities-related decisions are centralized – as they often are at small colleges, sometimes even including things like thermostat control – there is nowhere to "send" the price signal. Because there is only a single unit that would both pay the fees and receive the rebates, there is no net charge and no effective price signal.

Proxy carbon pricing is a decision-making tool that is typically applied on a project-by-project basis (**Table 1**, **Figure 2**). It can be applied for targeted decisions where students, faculty, project managers, or outside contractors can provide the technical input. A proxy carbon price's focus on targeted decisions may reduce the time and resources required to begin implementation and therefore make it easier to develop institutional support. Primary disadvantages are that it relies on decision-makers to actually weigh the virtual price in decisions and, unlike a revenue-positive carbon charge or carbon fund, it does not earmark budget dollars for emissions reduction projects. In contrast to a carbon charge, a proxy price is most effective for centralized decisions where buy-in to the carbon price policy from a small number of decision-makers can influence emissions across the institution.

Because many schools are targeting carbon neutrality or similarly deep reductions in emissions, smart *structural* changes in energy systems are essential and may favor proxy carbon prices for many schools. Price signals from carbon charges can effectively target *marginal* emission reduction opportunities within individual units (e.g. departments or schools) such as building energy management, use of more efficient equipment, or user behavior. As noted above, in many institutions (esp. smaller ones), individual administrative units do not directly control capital decisions that determine much of a building's emissions (campus heating fuel, electricity source). As a result, targeting decentralized decisions is not sufficient to meet goals. Deep decarbonization requires centralized changes such as transitioning to carbon-neutral heating (Cornell Senior Leaders Climate Action Working Group, 2016) or renewable energy contracts to drastically cut emissions; centralized decisions like these are most practically supported with a proxy carbon price (although a carbon charge can encourage similar changes at lower administrative levels when decision-making authority is spread across campus).

Carbon funds are a transparent way to dedicate funds for climate-related projects like energy retrofits as they show up as line items in departmental budgets (**Table 1**). However, because they are not dynamically tied to emissions like true carbon prices, they do not create a financial

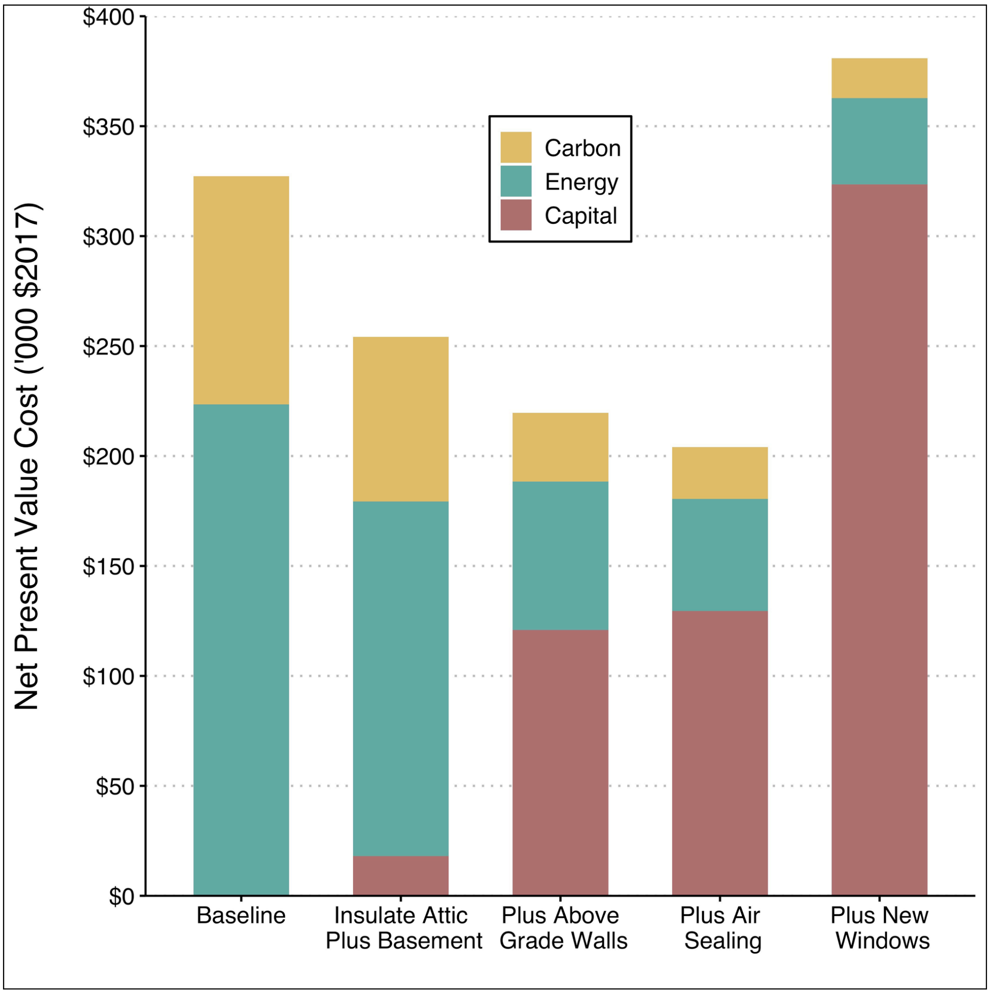

Figure 2: Example of a life cycle cost analysis with a proxy carbon price. Baseline energy and carbon costs (20-year net present value, \$70/ton CO_2 + 2.5%/yr) for a campus dormitory compared to increasing investments to reduce heating costs. Other than windows, all options offer a net private savings to the institution (energy plus capital), although adding above-grade wall insulation is only an improvement over attic and basement insulation when carbon costs are accounted for (yellow). DOI: https://doi.org/10.1525/elementa.443.f2

incentive to alter behavior or provide information on how ICPs would alter specific decisions. However, they can replicate the funding stream of a revenue-positive carbon charge without the administrative burden of metering and billing units. It is important to note that, unlike a federal carbon price which can bring new revenue into a government, both carbon charges and carbon funds only *reallocate* funds that were internal to the larger pool of finances at the institution. Like the other ICP policies, carbon funds represent an opportunity for the institution to engage internal and external stakeholders in conversations about climate change and mitigation choices.

3.3 ICP tools for emissions from purchasing

Emissions from purchasing (i.e. Scope 3) can also be addressed with ICP tools. While still challenging to assess, emissions from purchased goods and services can be 2–3 times the magnitude of built infrastructure emissions (Huang et al., 2009) and they often receive less attention in inventories and mitigation efforts (Gajjar and Vivek, 2018). Carbon charges can be applied to air travel in a way that encourages traditional economic responses like reduced flying and increased use of alternate technologies (e.g. videoconferencing), with the revenues used to fund reductions elsewhere. We lack research on the impact of these programs but, at current stringencies (typically <3% of average airfare (BTS, 2020)), they seem unlikely to significantly reduce air travel. Proxy carbon prices may be applied to an even broader set of decisions beyond energy use (Morris, 2015). Using a proxy carbon price to identify high value and cost-effective approaches to intervene in the supply chain (e.g. paper, food, building materials) on the basis of life cycle assessment or other data could be shared broadly and tools are starting to become available to make these calculations possible (Simonen et al., 2017). Carbon funds could be used to cover the added cost of lower embodied-carbon purchases.

3.4 Life cycle costing with an ICP

As noted above, a large fraction of HEI carbon emissions are associated with long-lived energy-using infrastructure like buildings. Institutions concerned about reducing their long-run emissions or mitigating the risk from future increases in fossil fuel prices must carefully consider their options to avoid "stranding" assets in the future or missing important emissions reduction opportunities

(Caldecott, 2017). Many schools already examine these kinds of major investments using life cycle costing (LCC) to address trade-offs between different combinations of up-front and operational expenses, calculating the net present value cost or discounted payback period. **Figure 2** illustrates an illustrative LCC analysis of a building retrofit project (Methods S1.2). Traditional LCC analysis would include only the capital, operations/maintenance, and energy costs while incorporating a carbon charge or proxy price would add the carbon cost. Technically, a life cycle analysis – which would also include embodied carbon from the manufacture of various goods in addition to LCC elements like emissions during use – would be the best measure for estimating the carbon cost. In practice, robust estimates of life cycle costs that can be included in future LCCs are now becoming available for select materials (Simonen et al., 2017) and choices (Woo et al., 2017).

Expanding the use of LCC on its own will help identify win-win projects that reduce carbon emissions while saving the institution money by reducing utility costs. However, it is relatively straightforward to also incorporate a proxy carbon price into LCC analyses, allowing carbon to be considered in the same units as other economic costs. This can identify options that are a win-win under a future climate policy. Similarly, an administrative unit facing a carbon charge could minimize its long run costs by conducting LCC analysis including the carbon charge when making investment decisions.

3.5 Lessons from past LCC analysis with a proxy carbon price in higher education

Economists modeling carbon prices at the federal level generally rely on large-scale macroeconomic patterns, such as responses to price shocks from the 1970s energy crisis, to estimate how the economy will respond to future carbon prices as a result of legislation. However, recent research has documented that these approaches often underestimate the real-life response for some fuels (Lawley and Thivierge, 2018; Andersson, 2019; Xiang and Lawley, 2019) while, in other cases, non-price barriers may make real-world responses smaller. All of this highlights that there is very little microscale data to suggest which institutional changes are impacted by carbon prices and which are not.

We analyzed LCC analyses compiled from 3 schools spanning 2008–2018 with initial project costs from a few thousand dollars to $1.4 M (median cost $500,000) (Methods S1.3). We plotted the energy savings of these projects (relative to baseline) against the investment (relative to baseline energy costs), which allows us to see which projects break even financially (**Figure 3a**). Incorporating a proxy carbon price increases the lifetime operating (energy plus carbon) cost, lowering the ratio of up-front investment to lifetime cost and shifting the points to the left in the diagram, closer to the breakeven line. The projects in our sample include a mix of pure energy efficiency projects, which reduce energy usage but maintain the

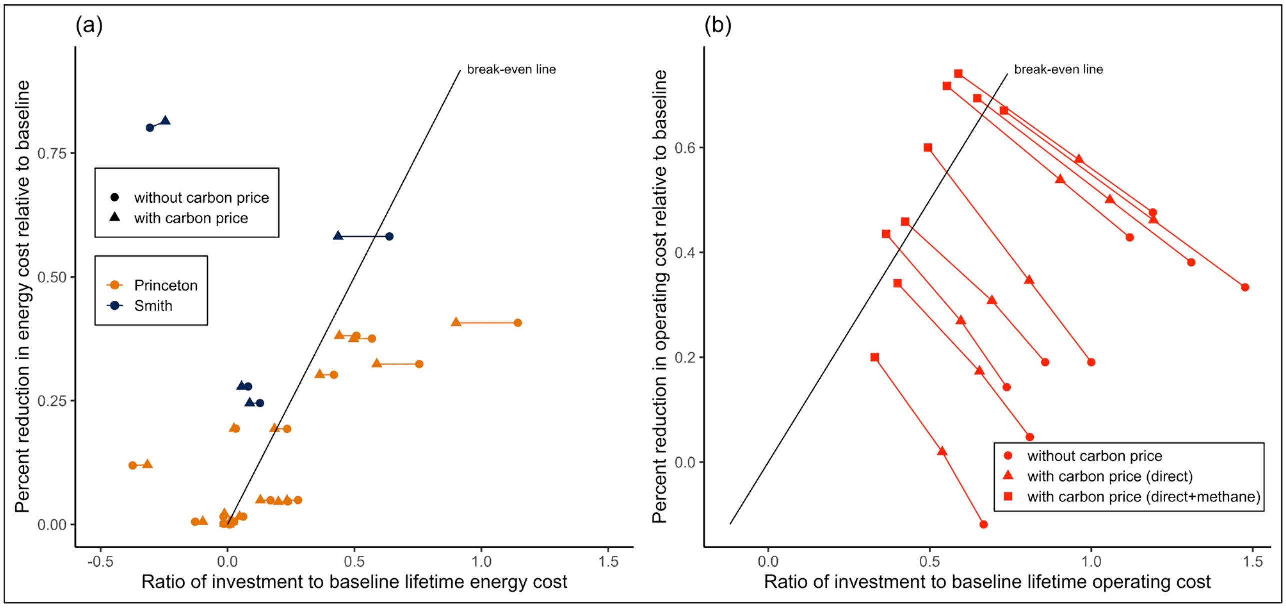

Figure 3: Financial viability of projects with and without a proxy carbon price. (a) Reduction in operating costs plotted against investment cost relative to life cycle operating costs for a wide range of projects (n = 25). Projects above the breakeven line save more money than they cost in net present value terms and are thus financially justified. Evaluations for the same project with (▲) and without (●) carbon prices included are joined by colored lines. For pure energy efficiency projects, including carbon costs lowers the ratio of investment to lifetime annual costs but does not change the percent reduction. For most (but not all) projects, both points are on the same side of the breakeven line, indicating that application of the proxy price did not alter the decision. Two projects with investment ratios over 1.5 not shown. **(b)** Analysis of a large campus heating system replacement that prices both carbon and upstream methane emissions (■). Operation and maintenance included with energy for operating costs in this figure. Decarbonization options lead to significant shifts in both axes and several options that now break even when considering climate (Cornell Senior Leaders Climate Action Working Group, 2016). DOI: https://doi.org/10.1525/elementa.443.f3

same energy source, and projects that incorporate switching to lower carbon fuel sources for some or all of the energy needs. The pure energy efficiency projects and the installation of zero marginal cost energy sources like solar power reduce energy and carbon costs by the same percentage, so the points with and without carbon costs have the same vertical coordinate. In contrast, fuel switching projects can reduce carbon costs by a much larger percentage than energy costs, causing the points to move upward in addition to leftward towards the breakeven line. Some fuel switching projects may even increase non-carbon energy costs (e.g. by switching to electricity which may be more expensive per unit energy) but can reduce total life cycle costs once the carbon cost is added (**Figure 3b**).

Multiple projects in our sample are above the breakeven line regardless of ICP and thus make financial sense even without including a proxy carbon price. This suggests that simply expanding the use of LCC with a long life cycle (e.g. 20 years) may often accomplish similar outcomes for many energy efficiency projects compared to adding an ICP. However, once the LCC has been calculated, adding the ICP is a trivial amount of workload and has the potential to identify useful decisions on the margin – especially as schools increasingly evaluate options which would cause major shifts in the carbon intensity of the energy used and/or more expensive and more ambitious energy conservation projects. Additionally, LCC without a carbon price is likely to underestimate future energy cost savings in a world where governmental carbon pricing seems likely to expand in scope and stringency, raising fossil fuel costs in the future. **Figure 3a** shows that even for the small dataset of projects evaluated, a carbon price sometimes highlights a different option; two of twenty-five projects (~8%) (both building insulation) ended up crossing breakeven with a carbon price.

We also note that a large number of projects did not break even when the carbon price was included. From an economic perspective, these projects are an inefficient use of resources for climate purposes as the added savings in energy and greenhouse gas costs exceed the value placed on them by the ICP (given the size of the institutions' ICP, discount rates, LCC time window, and other assumptions). There may be other reasons to select these options (for example, the triple-paned windows in **Figure 2** can increase occupant comfort or a demonstration wind turbine may have educational value) but, for climate purposes, the institution may want to reserve those funds to invest in another project that does break even. On the other hand, if a critical investment needed to meet a carbon neutrality deadline does not break even, that suggests that either the neutrality deadline is too expensive or the ICP is too low (demonstrating the ability of the ICP to impose analytical rigor in these tradeoffs).

It is not surprising that the carbon price only altered the financial conclusion in a small number of cases given the dominance of energy efficiency measures in this dataset. Even at a carbon price ($70/MTCO$_2$e) above the starting price in many current legislative proposals in the U.S. Congress, the carbon cost will be much smaller than the unit cost of energy for most fuels (Methods S1.4, **Figure 4**).

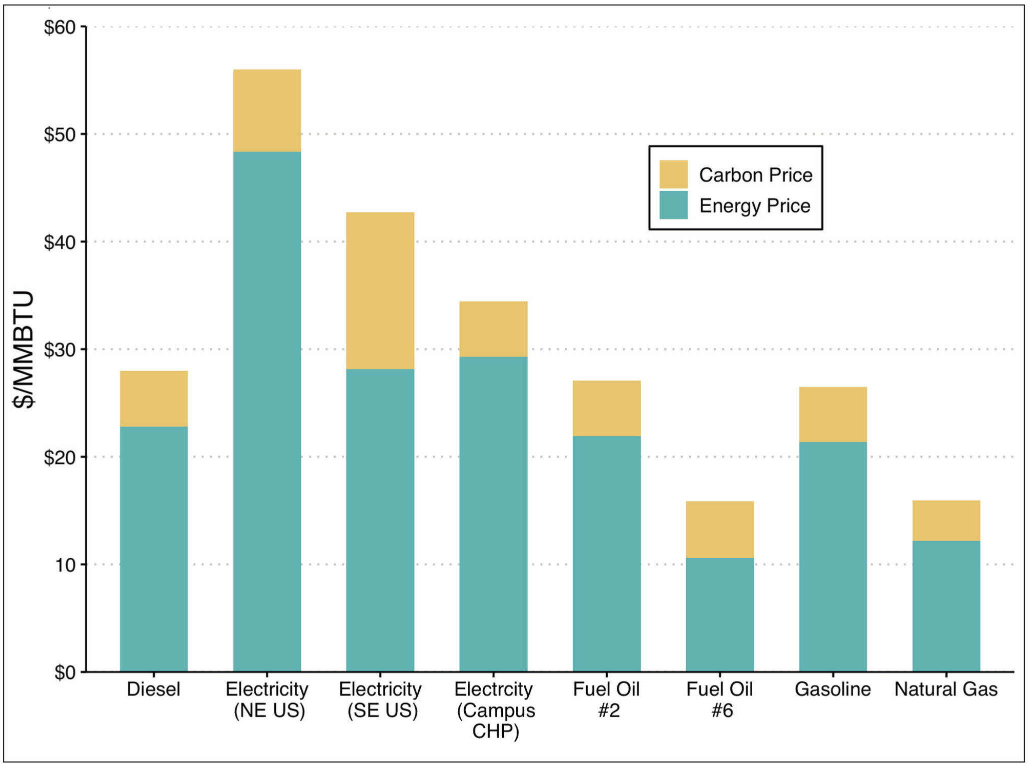

Figure 4: Carbon proxy price as a share of energy cost (per BTU). Illustrative U.S. prices (2019), assuming a $70/ton carbon price. New England retail electricity is primarily natural gas on the margin, while electricity in the Southeast has more coal generation. Carbon price estimates do not reflect upstream methane emissions. DOI: https://doi.org/10.1525/elementa.443.f4

As a result, the utility cost savings (captured without the ICP) are likely to dominate the carbon savings for many, if not most, efficiency projects. This suggests that policies that more thoroughly account for long-term energy costs might have an impact as large or larger than the increment that might come from applying the ICP (with the caveat that structural factors will limit the response). **Figure 3b** shows that relatively larger shifts toward breakeven occur when evaluating large shifts in carbon intensity. The shift from natural gas to renewably powered heat pumps (among others) drives projects significantly towards breakeven, especially when added emissions from upstream methane leakage are accounted for. Falling costs for clean energy also expand the universe of projects that might break even with an ICP, amplifying the potential for ICPs to change decisions. For instance, the solar projects we examined were from 2008 – when solar costs were roughly 300% higher (Barbose et al., 2017) – suggesting that some of these same projects today might fall in the region where a carbon price would alter decisions. In fact, many may now break even *without* a carbon price (but it requires an LCC analysis to know this).

3.6 Addressing the price problem

A challenge common to all ICP approaches is selecting the price. Guidance documents rightly emphasize avoiding the "right price trap" and starting to experiment with the potential to refine over time (Metzger et al., 2015; Ahluwalia, 2017). Because ICPs represent multiple overlapping goals and constraints, the prices are also likely to be tailored to institutional preferences (Barron and Parker, 2018). A wide range of approaches are available for selecting the price, including estimates of potential regulatory risk (usually selecting a value above current regulations (Ahluwalia, 2017)), costs to achieve internal targets, carbon prices needed to achieve national/global targets (IMF, 2019), avoided costs such as the price of offsets, the social cost of carbon (Greenstone et al., 2013), and willingness to pay (Walch et al., 2019), as well as prices used by peers or internal consultation (Ecofys et al., 2017).

The public-benefit focus of HEIs may mean that they differ in the balance of choice criteria for an ICP value. While industry is generally focused on regulatory risk from carbon price policies that may come in the future (Task Force on Climate-related Financial Disclosures, 2017), nonprofit institutions may be more likely to focus on the overall social need to respond to climate change and to adopt higher prices that are consistent with that response. Similarly, socially-focused discount rates are likely to be lower than those used for purely private costs (Summers and Zeckhauser, 2008) or to decline over time (National Academy of Sciences, Engineering, and Medicine, 2017), which would suggest higher values for ICPs based on the social cost of carbon.

Existing ICPs in the private sector point to disconnects between climate economics/policy and current practice that HEIs can avoid as they test approaches. One is adopting a fixed price (or even one that just keeps pace with inflation). Models generally agree that carbon prices will need to rise *faster* than inflation to achieve reductions in the future (Barron et al., 2018) and that the damages of emissions will also rise (although some recent work suggests starting with a high price and declining over time (Daniel et al., 2019)). However, only 15% of companies that disclose ICPs use escalating prices (CDP, 2017) and only two schools in our dataset had automatic escalation. Second, although prices are likely to be revised in the future, only a handful of companies disclose using carbon prices consistent with a 2°C trajectory. Firms with carbon charges often use values less than \$20/ton (Chang, 2017) while proxy carbon prices range up to \$909/ton but are often well below \$60/ton (CDP, 2017). Recent analysis suggests that prices of U.S.\$40–\$80/t CO_2e by 2020 and from U.S.\$50–\$100/t CO_2e by 2030 are required to put society on a trajectory to stay below 2°C (High-Level Commission on Carbon Prices, 2017; IMF, 2019). Higher prices will be needed to stay below 1.5°C. For example, a carbon price of ~\$160–\$200/t CO_2e by 2030 may be required by to get the U.S. on a trajectory to net zero emissions by 2040 (Kaufman et al., in press), which would be consistent with the U.S. achieving net zero in advance of global net zero emissions by mid-century (IPCC, 2018). Other schools may prefer to link their values to estimates of the full social cost of greenhouse gas emissions – although recent estimates in the literature vary widely (Ricke et al., 2018; Daniel et al., 2019; Wang et al., 2019). Schools may also wish to reflect other social costs from fossil fuels, including impacts on air quality and water quality (National Research Council, 2010; Epstein et al., 2011; Muller et al., 2011; Alvarez et al., 2012; Lemly and Skorupa, 2012; Lutz et al., 2013; Dennis Lemly, 2015; Shindell, 2015; Jha and Muller, 2017).

4 Implications for practice

Insights for practice associated with the application of ICPs will grow as more schools adopt and experiment with them. Indeed, this kind of research, practice, and knowledge diffusion is at the core of HEIs' missions. A recently developed toolkit for carbon pricing in higher education (www.secondnature.org/carbon-pricing) can help HEIs jump-start their efforts by building on the efforts of others (Second Nature, 2020). However, we draw several preliminary insights for practitioners based on our very small dataset of existing programs.

First, we strongly encourage HEIs and other institutions to explore all three ICP tools identified above depending upon their policy goals and institutional structures. The right tool for any given HEI will depend on the organizational setting, data availability, analytic capacity, and policy goals. Goals for an ICP will represent a mix of the factors we identified in Section 1.2, including incorporating the social damages of fossil-fuel use and greenhouse gas emissions into decision-making and managing financial risks associated with ignoring future climate policy. Those goals will, in turn, shape the selection and design of the ICP. ICPs targeted solely at air travel represent the most common ICP among the programs we identified. These charges represent a way for institutions to signal the climate impacts of flying and to generate funds for carbon mitigation projects. For larger institutions with many semi-independent units, a carbon charge on energy represents a potentially powerful way to incentivize incremental changes in energy use and to research the way these price signals alter behavior (it also requires detailed energy monitoring). For smaller schools, a carbon fund represents a good way to direct funds to climate-related projects like energy-efficiency upgrades. Swarthmore's carbon fund, which was the only broad-scope fund we identified, was adopted in a year of rising budgets, which may have helped reduce resistance to adoption (personal communication with Aurora Winslade, Swarthmore College). Two HEIs have found hybrid approaches useful where different components of their emissions are targeted with different tools (**Table 2**).

Our analysis suggests that proxy prices may be the ICPs best suited to the critical energy infrastructure decisions on the path to deep decarbonization. Proxy carbon approaches are scalable, can be targeted to the critical choices about infrastructure, and can be applied in relatively non-market-like settings, which may explain why they are slightly more common for building-related decisions among U.S. HEIs. Administrators also appreciated that proxy prices do not bind the decision-makers' hands – as with regular LCC, an option with a higher net present value cost can always be selected based on other factors (e.g. unquantified benefits, technology risk). This flexibility, in our experience, lowers the perceived risk of adopting the policy in the first place (while making transparency and accountability important). Implementing a proxy carbon price often requires the use of an LCC analysis and expanding this practice alone can have direct benefits in identifying good long-term investments for energy and carbon savings. Based on our analysis, schools should not be surprised if their ICP fails to alter the preferred option relative to LCC without the price in many cases. Significant research has gone into investigating the energy efficiency paradox, whereby firms fail to invest in apparently cost-effective efficiency projects (Gillingham and Palmer, 2014). HEIs can help us understand if expansion of the use of LCCs and the alteration of decision-making structures to accommodate an ICP may overcome barriers to adopting energy efficiency measures. For example, examining institutional discount rates and extending the timeframe of the LCC analysis may be important factors. Similarly, identifying the types of projects where inclusion of an ICP is most likely to alter decisions can help other adopters target their efforts. Our small sample suggests that evaluating projects that significantly change the carbon intensity (e.g. renewable electricity or ground-source/water-source heat pumps) or make large shifts in energy use (for example a large suite of complementary energy efficiency measures in a building project (Lovins, 2018)) will be the most likely have improved life cycle net present values with an ICP. Given the rapidly falling costs for renewables and battery storage, application of up-to-date cost information will be important to future assessments.

Moving forward, proxy prices or other ICPs can also be used to address embodied carbon in purchased goods. In our study, we found that schools with ICPs were beginning to think about how to incorporate life cycle emissions for purchased goods. For example, Cornell University accounted for upstream methane emissions (Alvarez et al., 2018) when evaluating natural gas fuel options (Cornell Senior Leaders Climate Action Working Group, 2016), students at Smith College used a proxy price to examine cost-tradeoffs for lower-carbon alternatives to beef and milk (Chiang et al., 2020), and data about life cycle costs for construction materials like concrete are becoming more available (World Green Building Council, 2019). Simply asking vendors for verified life cycle emissions data (as well as letting them know it may impact vendor choice) can represent an important way to begin to shift larger markets.

When selecting a value for the ICP, schools should realize that there is no one "right price" and that different types of ICPs are typically paired with different values (lowest for carbon charges for flights, highest for proxy carbon prices). However, recent studies have highlighted a range of prices consistent with broadly accepted policy goals. While these estimates will be refined with further research, they can act as a benchmark for institutions focused on supporting overall climate goals. In fact, the three schools with longer running ICP programs all have values close to or above this range ($40–$268/ton, **Table 2**). Academic institutions with more aggressive decarbonization goals, or who want to incorporate the higher social cost of greenhouse gas emissions reflected in some recent global SCC estimates (Dennig et al., 2015; Anthoff and Emmerling, 2018; Ricke et al., 2018), may want even higher prices. Experimenting with various levels of carbon price and documenting which decisions are influenced at those levels can help inform policy-setting at larger scales. For example, Princeton University has increased its proxy carbon price twice to better align with decarbonization planning. Discussions of how institutions should value carbon also offer educational opportunities to discuss the social and economic impacts of climate change. When schools operate in jurisdictions with federal or state carbon prices already in place, they can adjust their ICPs down accordingly in the sectors covered by the policy. However, we anticipate that these government carbon prices are unlikely to reflect full economic coverage or the full social cost in the near term and that even schools using ICPs solely as a hedge against risk may want slightly higher ICPs than the current policy to hedge against future increase in the government carbon price.

Finally, institutions should continue to regard an ICP as just one piece of the large ecosystem of urgent policy changes needed to move toward deep decarbonization (Waisman et al., 2019), both within their institutions and outside them. ICPs can act in concert with other institutional policies: goals like carbon neutrality, mandates like energy efficiency or net zero standards, and purchasing requirements. At the extreme, we acknowledge that an HEI could achieve institutional carbon neutrality without the use of an ICP at all, primarily by ensuring decarbonization of all key energy sources (combined with aggressive energy efficiency measures and appropriate land management) – although we suggest that the ICP can still help inform the decision-making in these contexts. ICPs can also form a strong rhetorical base for school officials and others to advocate for climate policies in government (Our Climate, 2017). All of these measures can continue to be combined with other HEI approaches to the climate issue, including education, research, shifts in endowment and pension investments, and public engagement.

5 Conclusion

Ultimately, our research reveals limited, but growing, application of ICPs in higher education in the United States. Proxy carbon prices and carbon charges are already in place at both public and private institutions in the United States that range in size from 1,500 to 120,000 students and that are located in states whose politics range from liberal (e.g. California, Massachusetts) to more conservative (e.g. Arizona, Utah). This suggests that institution size and structure are not fundamental barriers to adopting these tools (although public institutions may have less flexibility). The full potential (and limits) of these tools can only be established through creative experimentation and data-sharing. This will require support from faculty, staff, and students for measurement and analytics, decision-making, record-keeping, behavioral change, and communications, as well as from administrators willing to work to bring climate considerations more fully into decision-making and engage in the learning process.

Even though ICPs were developed as economic tools, a significant portion of the benefit may ultimately result from institutional changes needed to implement them. Frameworks that include proxy carbon pricing require consideration of low-carbon options early in the design process, careful consideration of emissions performance, a culture of pursuing cost-effective efficiency measures, "deep" buy-in among users to ensure that good options are tested and results taken seriously, and transparency around the decisions made. Administrators have found ICP tools appealing because they introduce consistency and provide a way to identify cost-effective uses of resources. HEIs could be leaders in exploring how to develop effective institutional culture around carbon prices by identifying hotspots for decisions, tools to translate/track/allocate broader institutional goals down to the project level, structures to provide resources for low carbon options when they are identified by the ICP, and ways to make decisions salient to the larger organization.

Failures of ICP policies may be just as informative as successes. For example, HEIs may find net zero building standards an administratively simpler route to making new building decisions. Similarly, electric vehicles can be incentivized by an ICP, but researchers generally recommend a carbon price as just one part of a large suite of policies that will promote electric vehicle adoption (IEA, 2019). Knowing where carbon prices work in the real world and where other measures are more effective is critical information as climate policy expands. If macroscale economic modeling suggests that a $75/ton carbon price in 2020 is consistent with a trajectory to decarbonization by 2050 but real-world microscale decisions at HEIs would still select for long-lived fossil infrastructure at those prices, it suggests a disconnect which needs to be understood and accommodated in policy design.

Although HEIs account for a small (but notable) share of emissions, ICPs illustrate the ways in which climate policy *within* HEIs can exercise policy leverage by building broader social capacity *outside* to operate under future climate policies. HEIs can help determine the frontier of economic feasibility (highlighting decisions where the carbon price made a difference) and drive investments that help bring down the costs of key technologies. Simply asking vendors for analysis with an ICP will build capacity in industry to help others make these kinds of judgements. For example, we have found that consultants that work with our schools often offer the option to include a carbon price to other clients.

Many of the arguments for HEI carbon pricing also support accelerated deployment of ICPs by other nonprofits (e.g. hospitals, NGOs, churches) and governments (Morris, 2015). HEIs that develop ICPs and experiment with them will be well-positioned to provide technical assistance, leadership, and well-trained students to these entities as they wrestle with approaches to climate-smart decision making. Ultimately, ICPs are just one tool with significant potential for tackling GHG emissions, and HEIs could help society figure out where and how they can be effectively applied.

Data Accessibility Statement

All non-CBI data are available in the supplementary materials.

Supplemental files

The supplemental files for this article can be found as follows:

- **Text S1, S2.** Methods. Supplementary Text on Higher Education Institution Internal Carbon Prices. DOI: https://doi.org/10.1525/elementa.443.s1
- **Data S1.** Life cycle cost calculator for Figure 2. DOI: https://doi.org/10.1525/elementa.443.s2
- **Data S2.** Processed life cycle cost data, Smith College and Princeton University. DOI: https://doi.org/10.1525/elementa.443.s3
- **Data S3.** Figure 4 data. DOI: https://doi.org/10.1525/elementa.443.s4

Acknowledgements

Casey Pickett, Nathan Graf, Aurora Winslade, Amy Johns, Mick Dalrymple, Leanne Bilodeau, Joanna Marshall-Cook, Mike Howard, Alexi Lamm, David DeSwert, Roger Mosier, Sarah Zemanick, Matt Pfannenstiel, Bob Dombkowski, Karl Kowitz, Elizabeth Drake, Charlie Conant, and Jennifer Bodine for comments and insight. Denise McKahn for energy modeling. Lucy Metz, Chhiring Lama, and Patricia Devine for research assistance.

Funding information

This work was supported by a Clark Science Center Undergraduate Research Fellowship to BP and a Smith College Center for the Environment, Ecological Design and Sustainability Faculty Fellowship to AB.

Competing interests

The authors have no competing interests to declare.

Author contributions

- Substantial contribution to research design: AB, BP, DW, SS
- Analysis and interpretation of data: AB, BP, SW, SS
- Data acquisition: AB, BP, SS, SW
- Drafting the article: AB, SW, BP, DW, SS
- Critical revision of article: AB, SS
- Final article approval: AB, BP, DW, SS, SW

References

AASHE Campus Sustainability Hub. 2019. Available at https://hub.aashe.org/. Accessed 2019 Jan 28.

Ahluwalia, MB. 2017. The Business of Pricing Carbon. Arlington, VA: Center for Climate and Energy Solutions. Available at https://www.c2es.org/site/assets/uploads/2017/09/business-pricing-carbon.pdf.

Akerloff, G, Auman, R, Baily, M and **Bernanke, B.** 2019 Jan 16. Economists' Statement on Carbon Dividends. *Wall Street Journal*. Available at https://www.wsj.com/articles/economists-statement-on-carbon-dividends-11547682910. Accessed 2019 Nov 7.

Aldy, JE and **Gianfrate, G.** 2019. Future-Proof Your Climate Strategy. *Harvard Business Review* (May–June 2019). Available at https://hbr.org/2019/05/future-proof-your-climate-strategy. Accessed 2019 May 10.

Alvarez, RA, Pacala, SW, Winebrake, JJ, Chameides, WL and **Hamburg, SP.** 2012. Greater focus needed on methane leakage from natural gas infrastructure. *Proc Natl Acad Sci* **109**(17): 6435–6440. DOI: https://doi.org/10.1073/pnas.1202407109

Alvarez, RA, Zavala-Araiza, D, Lyon, DR, Allen, DT, Barkley, ZR, Brandt, AR, Davis, KJ, Herndon, SC, Jacob, DJ, Karion, A, Kort, EA, Lamb, BK, Lauvaux, T, Maasakkers, JD, Marchese, AJ, Omara, M, Pacala, SW, Peischl, J, Robinson, AL, Shepson, PB, Sweeney, C, Townsend-Small, A, Wofsy, SC and **Hamburg, SP** 2018. Assessment of methane emissions from the U.S. oil and gas supply chain. *Science* **361**(6398): 186–188. DOI: https://doi.org/10.1126/science.aar7204

Andersson, JJ. 2019. Carbon Taxes and CO_2 Emissions: Sweden as a Case Study. *Am Econ J Econ Policy* **11**(4): 1–30. DOI: https://doi.org/10.1257/pol.20170144

Anthoff, D and **Emmerling, J.** 2018. Inequality and the Social Cost of Carbon. *J Assoc Environ Resour Econ* **6**(2): 243–273. DOI: https://doi.org/10.1086/701900

Ball, J. 2018. Hot Air Won't Fly: The New Climate Consensus That Carbon Pricing Isn't Cutting It. *Joule* **2**(12): 2491–2494. DOI: https://doi.org/10.1016/j.joule.2018.11.019

Barbose, GL, Darghouth, NR, Millstein, D, LaCommare, KH, Muller, NZ and **Widiss, R.** 2017. Tracking the Sun 10: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States. Report No.: LBNL-2001062. Available at http://trackingthesun.lbl.gov/. DOI: https://doi.org/10.2172/1398517

Barron, AR, Fawcett, AA, Hafstead, MAC, McFarland, J and **Morris, AC.** 2018. Policy insights from the EMF 32 study on U.S. carbon tax scenarios. *Clim Change Econ* **9**(1): 1840003. DOI: https://doi.org/10.1142/S2010007818400031

Barron, AR and **Parker, BJ.** 2018. Test proxy carbon prices as decision-making tools. *Nature* **553**(7689): 405–405. DOI: https://doi.org/10.1038/d41586-018-01078-2

Bartlett, N, Cushing, H and **Law, S.** 2016. Embedding a carbon price into business strategy. North America: CDP North America.

BC Ministry of Environment. 2018. Carbon Neutral Government – Program Requirements – Province of British Columbia. Available at https://www2.gov.bc.ca/gov/content/environment/climate-change/public-sector/carbon-neutral. Accessed 2018 Aug 30.

Brown, MA. 2001. Market failures and barriers as a basis for clean energy policies. *Energy Policy* **29**(14): 1197–1207. DOI: https://doi.org/10.1016/S0301-4215(01)00067-2

BTS. 2020. Average Domestic Air Fares. *Bureau of Transportation Statistics*. Available at https://transtats.bts.gov/AIRFARES/. Accessed 2020 Jun 17.

Caldecott, B. 2017. Introduction to special issue: stranded assets and the environment. *J Sustain Finance Invest* **7**(1): 1–13. DOI: https://doi.org/10.1080/20430795.2016.1266748

CDP. 2017. Putting a price on Carbon: Integrating climate risk into business planning. North America: CDP. Available at https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/002/738/original/Putting-a-price-on-carbon-CDP-Report-2017.pdf?1507739326.

Chang, V. 2017. Private firm incentives to adopt internal carbon pricing. *J Public Int Aff* **2017**(1): 56–77.

Chiang, E, Ness, A, Duncan, F and **Towne, K.** 2020. Reducing Smith College's Dining GHG emissions: An analysis of beef and milk substitutions. Northampton, Massachusetts: Smith College. Available at https://scholarworks.smith.edu/other_projects/46.

Cornell Senior Leaders Climate Action Working Group. 2016. Options for Achieving a Carbon Neutral Campus by 2035: Analysis of Solutions. Ithaca, NY: Cornell University. Available at https://sustainablecampus.cornell.edu/options-carbon-neutral-campus.

Cortese, A. 2010. Higher Education's Purpose: A Healthy, Just, and Sustainable Society. *Inspired Ethonomics*. Available at https://www.fastcompany.com/1527689/higher-educations-purpose-healthy-just-and-sustainable-society. Accessed 2018 Jun 27.

Crawley, DB, Hand, JW, Kummert, M and **Griffith, BT.** 2008. Contrasting the capabilities of building energy performance simulation programs. *Build Environ* **43**(4): 661–673. DOI: https://doi.org/10.1016/j.buildenv.2006.10.027

Dalrymple, M. 2018. Higher Education Leadership on Carbon Pricing [panel presentation]. San Francisco, CA: Global Climate Action Summit.

Daniel, KD, Litterman, RB and **Wagner, G.** 2019. Declining CO_2 price paths. *Proc Natl Acad Sci* **116**(42): 20886–20891. DOI: https://doi.org/10.1073/pnas.1817444116

Davis, LW. 2010. Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances? Cambridge, MA: National Bureau of Economic Research. Report No.: ID 1626603. Available at https://papers.ssrn.com/abstract=1626603. Accessed 2019 Sep 19. DOI: https://doi.org/10.3386/w16114

Dennig, F, Budolfson, MB, Fleurbaey, M, Siebert, A and **Socolow, RH.** 2015. Inequality, climate impacts on the future poor, and carbon prices. *Proc Natl Acad Sci* **112**(52): 15827–15832. DOI: https://doi.org/10.1073/pnas.1513967112

Ecofys, The Generation Foundation, CDP. 2017. How-to guide to corporate internal carbon pricing – Four dimensions to best practice approaches. London, UK: Generation Foundation. Available at https://www.tcfdhub.org/resource/how-to-guide-to-corporate-internal-carbon-pricing-four-dimensions-to-best-practice-approaches/. Accessed 2020 July 20.

Epstein, PR, Buonocore, JJ, Eckerle, K, Hendryx, M, Stout, BM, III, Heinberg, R, Clapp, RW, May, B, Reinhart, NL, Ahern, MM, Doshi, SK and **Glustrum, L.** 2011. Full cost accounting for the life cycle of coal. *Ann N Y Acad Sci* **1219**(1): 73–98. DOI: https://doi.org/10.1111/j.1749-6632.2010.05890.x

Ezarik, M. 2016. Students self-impose carbon tax on travel. *University Business Magazine*. Available at https://www.universitybusiness.com/article/students-self-impose-carbon-tax-travel. Accessed 2018 Jun 29.

Fawcett, AA, Iyer, GC, Clarke, LE, Edmonds, JA, Hultman, NE, McJeon, HC, Rogelj, J, Schuler, R, Alsalam, J, Asrar, GR, Creason, J, Jeong, M, McFarland, J, Mundra, A and **Shi, W.** 2015. Can Paris pledges avert severe climate change? *Science* **350**(6265): 1168–1169. DOI: https://doi.org/10.1126/science.aad5761

Fisher, DR. 2019. The broader importance of #FridaysForFuture. *Nat Clim Change* **9**(6): 430–431. DOI: https://doi.org/10.1038/s41558-019-0484-y

Gajjar, C and **Vivek, A.** 2018. Reducing Risk, Addressing Climate Change through Internal Carbon Pricing: A Primer for Indian Business. Washington, DC: World Resource Institute (WRI). Available at www.wri.org/publication/internal-carbon-pricingprimer.

Gillingham, K, Carattini, S and **Esty, D.** 2017. Lessons from first campus carbon-pricing scheme. *Nature* **551**(7678): 27–29. DOI: https://doi.org/10.1038/551027a

Gillingham, K, Harding, M and **Rapson, D.** 2012. Split Incentives in Residential Energy Consumption. *Energy J* **33**(2). DOI: https://doi.org/10.5547/01956574.33.2.3

Gillingham, K and **Palmer, K.** 2014. Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence. *Rev Environ Econ Policy* **8**(1): 18–38. DOI: https://doi.org/10.1093/reep/ret021

Greenstone, M, Kopits, E and **Wolverton, A.** 2013. Developing a Social Cost of Carbon for US Regulatory Analysis: A Methodology and Interpretation. *Rev Environ Econ Policy* **7**(1): 23–46. DOI: https://doi.org/10.1093/reep/res015

Hall, A, Bedecarre Ernst, S, Falino, J, Miller, J, Garafalo, N, Norell, E, Cunningham, M and **Ho, B.** 2015. Internal Carbon Accounting at a Small Liberal Arts College. Vassar College. Available at http://sustainability.vassar.edu/docs/9-15InternalCarbonAccountingataSLAC.pdf.

Hausman, JA and **Joskow, PL.** 1982. Evaluating the Costs and Benefits of Appliance Efficiency Standards. *Am Econ Rev* **72**(2): 220–225.

High-Level Commission on Carbon Prices. 2017. Report of the High-Level Commission on Carbon Prices. World Bank. Available at https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices.

Huang, YA, Weber, CL and **Matthews, HS.** 2009. Categorization of Scope 3 Emissions for Streamlined Enterprise Carbon Footprinting. *Environ Sci Technol* **43**(22): 8509–8515. DOI: https://doi.org/10.1021/es901643a

IEA. 2019. Global EV Outlook 2019. Paris, France: International Energy Agency. Available at https://www.iea.org/reports/global-ev-outlook-2019. Accessed 2020 May 20.

IMF. 2019. *Fiscal Monitor: How to Mitigate Climate Change*. Washington, DC: International Monetary Fund. Available at https://www.imf.org/en/Publications/FM/Issues/2019/10/16/Fiscal-Monitor-October-2019-How-to-Mitigate-Climate-Change-47027.

IPCC. 2018. Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Geneva, Switzerland: World Meteorological Organization. p. 32.

ISO New England Inc. 2018. 2016 ISO New England Electric Generator Air Emissions Report. Holyoke, MA: ISO New England. Available at https://www.iso-ne.com/static-assets/documents/2018/01/2016_emissions_report.pdf.

IWG. 2016. Technical support document: Technical update of the social cost of carbon for regulatory impact analysis under Executive Order 12866. Available at https://obamawhitehouse.archives.gov/

sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf. Accessed 2017 Oct 26.

Jha, A and **Muller, N.** 2017. Handle with care: The local air pollution costs of coal storage. Cambridge, MA: National Bureau of Economic Research. Report No.: w23417. DOI: https://doi.org/10.3386/w23417

Kamins, A, Metzger, E, Miao, L, Rubnitz, T, Trostmann, K, Waite, R and **Xu, S.** 2018. Stories from the WRI Sustainability "Living Lab": Annual Sustainability Report and 2015–2016 Greenhouse Gas Emissions Inventory. Washington, DC: World Resource Institute (WRI). Available at https://www.wri.org/publication/stories-wri-sustainability-living-lab.

Kaufman, N, Barron, AR, Krawczyk, W, Marsters, P and **McJeon, HC.** In press. A Near Term to Net Zero alternative to the social cost of carbon for setting carbon prices. *Nat Clim Change*.

Lau, KY. 2013. British Colombia's Carbon Neutral Government Mandate – Influent on Infrastructure Decisions [Master's Thesis]. Vancouver, BC: University of British Colombia. Available at https://pics.uvic.ca/sites/default/files/uploads/publications/Lau%2C%20Kim%2C%20masters%20thesis%20UBC_0.pdf.

Lawley, C and **Thivierge, V.** 2018. Refining the evidence: British Columbia's carbon tax and household gasoline consumption. *Energy J* **39**(2). DOI: https://doi.org/10.5547/01956574.39.2.claw

Lemly, DA. 2015. Damage cost of the Dan River coal ash spill. *Environ Pollut* **197**: 55–61. DOI: https://doi.org/10.1016/j.envpol.2014.11.027

Lemly, AD and **Skorupa, JP.** 2012. Wildlife and the coal waste policy debate: Proposed rules for coal waste disposal ignore lessons from 45 years of wildlife poisoning. *Environ Sci Technol* **46**(16): 8595–8600. DOI: https://doi.org/10.1021/es301467q

Lovins, AB. 2018. How big is the energy efficiency resource? *Environ Res Lett* **13**(9): 090401. DOI: https://doi.org/10.1088/1748-9326/aad965

Lutz, BD, Bernhardt, ES and **Schlesinger, WH.** 2013. The environmental price tag on a ton of mountaintop removal coal. Convertino, M, (ed.). *PLoS ONE* **8**(9): e73203. DOI: https://doi.org/10.1371/journal.pone.0073203

Metcalf, GE. 2019a. *Paying for Pollution: Why a Carbon Tax Is Good for America*. New York: Oxford University Press. DOI: https://doi.org/10.1093/oso/9780190694197.001.0001

Metcalf, GE. 2019b. Cap and Trade: The Other Way to Price Pollution. In: *Paying for Pollution: Why a Carbon Tax Is Good for America*. New York: Oxford University Press. pp. 73–85. DOI: https://doi.org/10.1093/oso/9780190694197.003.0006

Metzger, E, Park, J and **Gallahger, D.** 2015. Executive Guide to Carbon Pricing Leadership. Washington, DC: UN Global Compact and World Resources Institute. *A Caring for Climate Report*. Available at https://www.wri.org/publication/executive-guide-carbon-pricing-leadership. Accessed 2018 Sep 8.

Morris, A. 2015. Why the federal government should shadow price carbon. *Brookings Planet Policy*. Available at https://www.brookings.edu/blog/planetpolicy/2015/07/13/why-the-federal-government-should-shadow-price-carbon/.

Muller, NZ, Mendelsohn, R and **Nordhaus, W.** 2011. Environmental accounting for pollution in the United States economy. *Am Econ Rev* **101**(5): 1649–1675. DOI: https://doi.org/10.1257/aer.101.5.1649

National Academy of Sciences, Engineering, and Medicine. 2017. Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide. Washington, DC DOI: https://doi.org/10.17226/24651

National Research Council. 2010. *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*. Washington, DC: National Academies Press. DOI: https://doi.org/10.17226/12794

NCEL. 2019. Carbon Pricing. National Caucus of Environmental Legislators (NCEL). Available at https://www.ncel.net/carbon-pricing/. Accessed 2019 Aug 7.

Our Climate. 2017. A bold campaign to put a price on carbon. Our Climate. Available at https://www.leonardodicaprio.org/our-climate-a-bold-campaign-to-put-a-price-on-carbon/.

Parker, BJ. 2018. Designing a Proxy Carbon Price Strategy for Smith College [Undergraduate Honors Thesis]. Northampton, MA: Smith College. Available at https://hub-media.aashe.org/uploads/Parker_Thesis_Proxy_Carbon_Archive_Copy.pdf.

Parker, BJ and **Barron, AR.** 2018. Case Study: Proxy Carbon Price Strategy. *Second Nature. Internal Carbon Pricing in Higher Education Toolkit*. Available at https://secondnature.org/carbon-pricing/.

Princeton University. 2008. The Princeton University Sustainability Plan. Princeton University Press. Available at https://sustain.princeton.edu/sites/sustainability/files/Sustainability%20Plan.pdf.

Ricke, K, Drouet, L, Caldeira, K and **Tavoni, M.** 2018. Country-level social cost of carbon. *Nat Clim Change* **8**(10): 895–900. DOI: https://doi.org/10.1038/s41558-018-0282-y

Second Nature. 2019. Second Nature Reporting Platform. Available at http://reporting.secondnature.org/. Accessed 2019 Aug 7.

Second Nature. 2020. Internal Carbon Pricing in Higher Education Toolkit. *Second Nature*. Available at https://secondnature.org/carbon-pricing/. Accessed 2018 Nov 15.

Shindell, DT. 2015. The social cost of atmospheric release. *Clim Change* **130**(2): 313–326. DOI: https://doi.org/10.1007/s10584-015-1343-0

Simonen, K, Rodriguez, BX and **Wolf, CD.** 2017. Benchmarking the Embodied Carbon of Buildings. *Technol Des* **1**(2): 208–218. DOI: https://doi.org/10.1080/24751448.2017.1354623

Sinha, P, Schew, WA, Sawant, A, Kolwaite, KJ and **Strode, SA.** 2010. Greenhouse Gas Emissions from U.S. Institutions of Higher Education. *J Air Waste*

Manag Assoc **60**(5): 568–573. DOI: https://doi.org/10.3155/1047-3289.60.5.568

SIPA Center on Global Energy Policy. 2019. What You Need to Know About a Federal Carbon Tax in the United States. New York, NY: Columbia University. Available at https://energypolicy.columbia.edu/what-you-need-know-about-federal-carbon-tax-united-states. Accessed 2019 Aug 7.

Stephens, JC, Frumhoff, PC and **Yona, L.** 2018. The role of college and university faculty in the fossil fuel divestment movement. *Elem-Sci Anthr* **6**: 41. DOI: https://doi.org/10.1525/elementa.297

Stiglitz, JE. 2019. Addressing climate change through price and non-price interventions. *Eur Econ Rev* **119**: 594–612. DOI: https://doi.org/10.1016/j.euroecorev.2019.05.007

Summers, L and **Zeckhauser, R.** 2008. Policymaking for posterity. *J Risk Uncertain* **37**(2–3): 115–140. DOI: https://doi.org/10.1007/s11166-008-9052-y

Swarthmore College. 2017. The Carbon Charge: Carbon Pricing Policy. *The Carbon Charge*. Available at https://www.swarthmore.edu/sustainability/swarthmore-carbon-charge-program.

Task Force on Climate-related Financial Disclosures. 2017. Recommendations of the Task Force on Climate-related Financial Disclosures. Available at https://www.fsb-tcfd.org/publications/final-recommendations-report/.

University College London. 2020. Carbon Accountability Scheme. *Sustainable UCL*. Available at https://www.ucl.ac.uk/sustainable/carbon-accountability-scheme. Accessed 2020 Mar 4.

University of British Colombia. 2018. UBC's Climate Action Plan. Available at https://sustain.ubc.ca/campus-initiatives/climate-energy/climate-action-plan. Accessed 2018 Aug 30.

U.S. EIA. 2017. Energy-Related CO_2 Emissions Tables. U.S. Energy Information Administration (EIA). Available at https://www.eia.gov/environment/emissions/state/. Accessed 2018 Jul 5.

U.S. EPA. 2002. Sub-Metering Energy Use in Colleges and Universities: Incentives and Challenges. United States of America: U.S. Environmental Protection Agency's Energy Star. Available at https://www.appa.org/files/submeter.pdf.

U.S. EPA. 2018. Emission Factors for Greenhouse Gas Inventories. Available at https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf.

U.S. EPA. 2020. Emissions & Generation Resource Integrated Database (eGRID). U.S. EPA. Available at https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid. Accessed 2019 Jan 28.

Utah State University. 2020. President Cockett Commits to Reducing USU's Greenhouse Gas Emissions. Utah State Today. Available at https://www.usu.edu/today/story/president-cockett-commits-to-reducing-usus-greenhouse-gas-emissions. Accessed 2020 Jun 15.

Victor, DG and **House, JC.** 2006. BP's emissions trading system. *Energy Policy* **34**(15): 2100–2112. DOI: https://doi.org/10.1016/j.enpol.2005.02.014

Waisman, H, Bataille, C, Winkler, H, Jotzo, F, Shukla, P, Colombier, M, Buira, D, Criqui, P, Fischedick, M, Kainuma, M, La Rovere, E, Pye, S, Safonov, G, Siagian, U, Teng, F, Virdis, MR, Williams, J, Young, S, Anandarajah, G, Boer, R, Cho, Y, Denis-Ryan, A, Dhar, S, Gaeta, M, Gesteira, C, Haley, B, Hourcade, JC, Liu, Q, Lugovoy, O, Masui, T, Mathy, S, Oshiro, K, Parrado, R, Pathak, M, Potashnikov, V, Samadi, S, Sawyer, D, Spencer, T, Tovilla, J and **Trollip, H.** 2019. A pathway design framework for national low greenhouse gas emission development strategies. *Nat Clim Change* **9**(4): 261–268. DOI: https://doi.org/10.1038/s41558-019-0442-8

Walch, R, Cameron, TA and **Mital, S.** 2019. Determinants of Willingness-to-Pay For Internal Carbon Pricing Programs. Eugene, OR: University of Oregon. Available at https://static1.squarespace.com/static/5ba03fbd4eddec6938897ded/t/5dba26ecbd86ba53621d3b11/1572480752213/Walch_JMP.pdf.

Wang, P, Deng, X, Zhou, H and **Yu, S.** 2019. Estimates of the social cost of carbon: A review based on meta-analysis. *J Clean Prod* **209**: 1494–1507. DOI: https://doi.org/10.1016/j.jclepro.2018.11.058

We Are Still In Coalition. 2018. Do No Harm: America's Leading Health Systems Commit to Reducing Emissions. Available at https://www.wearestillin.com/news/do-no-harm-americas-leading-health-systems-commit-reducing-emissions. Accessed 2018 Aug 13.

Wolak, F. 2014. Universities can do better than symbolism: A revenue-neutral carbon tax. Stanford, California: Stanford Institute for Economic Policy Research. Available at http://siepr.stanford.edu/publicationsprofile/2821.

Woo, J, Choi, H and **Ahn, J.** 2017. Well-to-wheel analysis of greenhouse gas emissions for electric vehicles based on electricity generation mix: A global perspective. *Transp Res Part Transp Environ* **51**: 340–350. DOI: https://doi.org/10.1016/j.trd.2017.01.005

World Bank Group. 2019. Carbon Pricing Dashboard. Available at https://carbonpricingdashboard.worldbank.org/map_data. Accessed 2018 Nov 26.

World Bank Group, Ecofys. 2018. State and Trends of Carbon Pricing 2018. Washington, DC: World Bank Group. Available at https://carbonpricingdashboard.worldbank.org.

World Green Building Council. 2019. Bringing Embodied Carbon Upfront: Coordinated action for the building and construction sector to tackle embodied carbon. Toronto, Canada: World Green Building Council.

Xiang, D and **Lawley, C.** 2019. The impact of British Columbia's carbon tax on residential natural gas consumption. *Energy Econ* **80**: 206–218. DOI: https://doi.org/10.1016/j.eneco.2018.12.004

How to cite this article: Barron, AR, Parker, BJ, Sayre, SS, Weber, SS and Weisbord, DJ. 2020. Carbon pricing approaches for climate decisions in U.S. higher education: Proxy carbon prices for deep decarbonization. *Elem Sci Anth,* 8: 42. DOI: https://doi.org/10.1525/elementa.443

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Knowledge Domain: Sustainability Transitions

Submitted: 07 March 2020 **Accepted:** 15 July 2020 **Published:** 18 August 2020

ELEMENTA Science of the Anthropocene

Elem Sci Anth is a peer-reviewed open access journal published by University of California Press.

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