From budgets to boilers:
Yale University's experiment in internal carbon pricing

Case Study Teaching Notes

Minna Brown, Case Study Integration Manager, Yale School of Forestry & Environmental Studies
Thuy Phung, Master of Environmental Management 2018, Yale School of Forestry & Environmental Studies

Case Summary

There are few issues that sit so clearly at the nexus of socio-environmental systems as climate change. Human actions drive the emission of heat-trapping greenhouse gases. Temperatures then climb, weather patterns shift, and human and natural systems are altered. Research into the drivers, effects, and extent of climate change, as well as possible mechanisms to minimize its impacts is happening on a variety of levels around the world.

With experts at the forefront of climate change research and management, a desire to use the campus as a living lab, and an engaged community of faculty, staff, students, and alumni, Yale University has a variety of goals around mitigating and adapting to climate change. This case study looks closely at one of those approaches – the institution of an internal carbon pricing mechanism.

In 2015, the University decided to move forward with a pilot program designed to price the carbon emissions generated by the buildings on campus, thereby driving greenhouse gas emissions reductions and modeling behavior change around energy use. This pilot stemmed from a task force report that recommended moving forward with the concept of a carbon charge, and was proposed to test the effectiveness of four different models/incentive programs. A group of 20 buildings was selected and divided into four treatment groups with building managers and stakeholder groups engaging to reduce energy consumption.

This case study will help students explore the concepts of

- why carbon pricing might play a role in mitigating climate change,
- how Yale built its pilot program,
- how the program was implemented on the ground,
- which stakeholders were involved,
- and the lessons and limitations of internal carbon pricing.

We have designed the case to be used in undergraduate and graduate level courses covering topics of environmental economics and policy, corporate social responsibility, and climate change mitigation. It may also be useful for organizations seeking to learn from the application of an internal carbon charge.

Note: The authors are happy for other institutions to use this case study. Please let us know (email minna.brown@yale.edu) if you will be using it in your courses, if you would like to discuss ideas prior to use, and if you have feedback following the exercises.

Case Study Activities

You will cover this case over the course of three class sessions. Some background reading is expected in advance of the first two sessions. While the instructor will introduce the topic of each session, the majority of time in each session will be devoted to group work. The final session will be largely used for you to present proposals to the class.

Session 1 **Theme: Project Motivation & Design**
Readings/Prep (approx. 2 hours): For the first session, please read sections 1-3 of the case study material and the below reports and articles. Please take notes on the concept of carbon pricing, as well as the overall design of the Yale carbon charge pilot program. Readings: ● Sections 1-3 (page 5-20) of case study content ● Main text (page 1-17) of Yale Presidential Carbon Charge Task Force. (2015). Report to the President and Provost of Yale University: Findings and Recommendations on a Carbon-Charge Program at Yale. Yale University, New Haven, CT. http://carbon.yale.edu/sites/default/files/files/Carbon-charge-report-041015.pdf. ● Carbon Pricing Leadership Coalition. (2016). What is Carbon Pricing? http://www.carbonpricingleadership.org/what and Why Price Carbon? http://www.carbonpricingleadership.org/why (also watch the video and read the infographic) ● Goulder, L. H., & Schein, A. R. (2013). Carbon Taxes versus Cap and Trade: A Critical Review. *Climate Change Economics*, 4(3), 1350010. ● Executive Summary (page vii-viii) of World Bank. (2015). The FASTER principles for successful carbon pricing : an approach based on initial experience. Washington, D.C. http://documents.worldbank.org/curated/en/901041467995665361/The-FASTER-principles-for-successful-carbon-pricing-an-approach-based-on-initial-experience In class, the primary activity will focus on the elements of an effective carbon pricing scheme. In groups, you will use your reading of the case study materials and assigned readings to describe the schemes selected for pilot testing and how a select scheme might, on paper, address (or fail to address) the World Bank's FASTER criteria for carbon prices: ○ **F**airness ○ **A**lignment of policies and objectives ○ **S**tability & predictability ○ **T**ransparency ○ **E**fficiency & cost-effectiveness ○ **R**eliability & environmental integrity Your group will then be expected to describe your assessment. Possible additional readings: ○ World Resources Institute. (2015). Putting a Price on Carbon: A Handbook for U.S. Policymakers. Washington, DC. http://www.wri.org/publication/putting-

price-carbon

- Carbon Disclosure Project. (2016). Embedding a carbon price into business strategy. https://www.cdp.net/en/reports/downloads/1132
- Roberts, D. (2016, June 28). 5 reasons there's more to climate policy than a price on carbon. http://www.vox.com/2016/6/28/12045860/carbon-tax
- Hepler, L. (2015, April 16). How putting a price on carbon saved Microsoft $10 million a year. https://www.greenbiz.com/article/how-microsofts-internal-price-carbon-saved-it-10-million-year
- Skuce, A. (2015, March 24). Shell: internal carbon pricing and the limits of big oil company action on climate. http://www.skepticalscience.com/Shell.html

Session 2
Theme: Pilot Implementation & Assessment

Readings/Prep (2 hours): For the second session, you will read sections 4-5 of the case study content and the below reports and articles. This session will see the class diving into questions of how the carbon charge worked on the ground - the barriers and opportunities of actually reducing emissions through decreased building energy use. Readings:

- Sections 4-5 (page 20-27) of case study materials
- Section 5-6 of Laemel, R. & Milikowsky, J. (2016). Yale University's Carbon Charge: Preliminary Results from Learning by Doing. http://carbon.yale.edu/sites/default/files/files/Carbon_Charge_Pilot_Report_20161010.pdf
- Watch 1-hour webinar on the Yale Carbon Charge: https://youtu.be/mVVNr7DIs34
- Yale Carbon Charge Project. (2016). Carbon Charge Case Studies. http://carbon.yale.edu/case-studies
- Gillingham, K., Kotchen, M. J., Rapson, D. S., & Wagner, G. (2013). Energy policy: The rebound effect is overplayed. *Nature*, 493(7433), 475–476.

The primary activity will involve a small group discussion designed to break down the ways in which different types of buildings in different schemes interacted with the carbon charge. Each group will be assigned a building that participated in the carbon charge, and will have 25 minutes to discuss their strategies and approaches to their assigned scheme and overall carbon charge involvement.

Considerations:

- Who would need to be involved?
- What are the major challenges and opportunities?
- What would motivate action?
- How would you integrate carbon charge participation into your other priorities?
- What type of data would you need to take the most targeted action?
- How would your experience compare to other campus buildings?
- Would you have preferred to be a part of a different scheme?

The class will then take 25 minutes to report back.

Assignment: After the first two sessions, you will take the lessons learned from the class discussion and apply them to an external audience. Individually or in pairs, you will select an organization (school, company, etc) and write a 5-page (single-spaced) memo proposing action around a possible carbon charge given the lessons learned at Yale. In your memo, your task is to act as advisors to the organization - you have been tasked with making a recommendation for or against a carbon charge, and will need to show why their advice is sound. Consider the following:

- What are the organization's goals? What is the organization currently doing in terms of climate action?
- What kind of target and price would the organization want to set for the program?
- Who would need to be involved? At what time/scale?
- What would be the ideal timeline?
- What activities (and buildings) would be covered by the charge?
- What schemes would best fit the organization?
- What other information, resources, or people would be needed for future program design and implementation?
- How much might this program cost?
- What kind of feedback mechanisms would be involved?
- How would the program be evaluated?

How would the organization leverage the lessons learned at Yale and/or avoid pitfalls experienced with the carbon charge pilot project?

You will also be responsible for turning your memo into a short (5 minute) powerpoint presentation.

Possible additional readings and videos:

- Carbon Charge Interviews with Faculty of Yale School of Forestry & Environmental Studies. (2016). https://www.facebook.com/pg/Yale-FES-Carbon-Charge-934256436660846/videos/?ref=page_internal
- Melton, P. (2011, November 1). Occupant Engagement: Where Design Meets Performance. https://www.buildinggreen.com/feature/occupant-engagement-where-design-meets-performance
- O-Power. (2012). Successful Behavior Energy Efficiency Program. O-Power White Paper No 3. Arlington, VA. http://viget.opower.com/uploads/files/BEE_Whitepaper.pdf
- Ivanovich, M. (2010, September 29). Retrocommissioning: Big Savings for Big Buildings. https://www.buildinggreen.com/feature/retrocommissioning-big-savings-big-buildings

Session 3 **Theme: Carbon pricing proposals - student presentations**
This class session will be devoted to class presentations.

Case study content

1. Introduction & Background

It was November 2015, and Sue Wells had a lot on her plate. As the Director of Finance and Administration for the Yale School of Forestry & Environmental Studies (F&ES), she was responsible for every aspect of the School's operations, from overseeing the budget to keeping track of construction projects. And now she had a new challenge. Yale had identified F&ES' landmark building, Kroon Hall, as a candidate for the University's new internal carbon charge pilot project and Dean Peter Crane had nominated her to take the lead. This was not a complete surprise. She had been involved in early conversations about the endeavor and fully supported the concept, especially given how well it aligned with the mission of the Forestry school. Yet, in moving from theory to practice, Sue knew she would have a wide range of tasks ahead of her. She was already balancing multiple projects and teams. Kroon was a new, state of the art building without a lot of room for energy use improvement. Would they be penalized for having the best building on campus? Who would she need to involve to ensure real results? How would this impact her financial planning? She had been assured that the pilot program would represent an insignificant burden, and would have administrative support, but would she have time to take on this new responsibility?

As an academic institution, Yale University strives to be a leader in sustainability research and teaching. In addition to the work of the School of Forestry and Environmental Studies, Yale has "over fifteen institutes, centers, and programs directly linked to the study and promotion of the environment across the University".[1] Yale also leads by example with its ambitious program to reduce campus greenhouse gas (GHG) emissions through measures such as energy efficiency, renewable energy and improved waste management. In its new 2025 Sustainability Plan, Yale sets a goal of reducing GHG emissions by 43% by 2020 compared to 2005 level and becoming carbon-neutral by 2050. However, the University's policies on climate change and energy use have mostly concerned central units such as facilities and the sustainability office and were not the primary focus of most departments and schools across the university. At the same time, as a part of broader national movements, student activists have called for the divestment of Yale's endowments from fossil fuels, urging the University to consider climate change as an investment and overall financial priority.

Within this context, an internal carbon charge was proposed to expand Yale's sustainability efforts by providing decentralized incentives for emissions reduction and generating knowledge to inform the broader national and global conversation on carbon pricing.

Carbon Pricing Background and Trends

Although not a new concept, carbon pricing has recently gained momentum in both the public and private sectors as an efficient and effective way to promote climate change mitigation. In

[1] http://carbon.yale.edu/reports/announcements/formation-task-force

2016, almost 40 countries and more than 20 cities, states and provinces are implementing emission trading programs or carbon taxes. The share of global emissions covered by carbon pricing initiatives has increased threefold over the last decade, to about 13% in 2016.[2] Of the 189 countries who submitted pledges to reduce GHG emissions through their Nationally Determined Contributions (NDCs), more than 100 mentioned the use of carbon pricing and other market-based mechanisms, suggesting broader government action in the future.

There has also been growing adoption of voluntary carbon pricing in the private sector. In 2016, over 1200 companies reported the use of or plans for internal carbon pricing to the Carbon Disclosure Project, a remarkable eightfold increase from 2014. Over 140 of these companies are taking this approach further by embedding a carbon price within business strategies and operations to achieve established climate targets. Within these, 37 are disclosing impact of their internal carbon pricing.[3]

One of the main justifications for carbon pricing is that it helps decision makers internalize the costs of current and future damages from their carbon emissions. Many believe that a price on carbon dioxide and other greenhouse gases is critical to successful emissions reductions, as it provides the necessary financial incentives for individuals and firms to shift consumption to low- or zero-carbon goods and services. However, carbon pricing alone is not sufficient and must be part of a larger package of policies to reduce greenhouse gas emissions.[4]

There are two main approaches to carbon pricing: cap-and-trade and carbon tax. Cap-and-trade establishes a cap on emissions and allows participants to buy and sell allowances for emitting more or less than permitted. This creates a market for emissions allowances and the carbon price (the price of the allowances) is determined by the interaction between demand and supply. The emissions allowances are usually auctioned by governments to raise revenues. Cap-and-trade is a quantity-based approach to carbon pricing.

A carbon tax establishes a fee per ton of carbon dioxide (or equivalent) emitted from an activity and is often defined based on the carbon content of the fossil fuels used. A carbon tax also generates revenues; however, it is different from cap-and-trade in that the quantity of emissions reduction is not pre-defined but the carbon price is. Carbon-tax is a price-based approach to carbon pricing.[5]

Unlike government-imposed cap-and-trade systems or carbon taxes, corporate carbon pricing is internal and voluntary. Many companies adopt internal carbon pricing as a compliance strategy—to anticipate and prepare for GHG regulations or respond to investor and customer demands. An increasing number of companies however is moving beyond compliance and using carbon pricing as a tool for innovation and growth. Companies report the use of an internal carbon price to help provide an incentive or added reason to reallocate resources

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[2] https://openknowledge.worldbank.org/handle/10986/25160
[3] CDP. 2016. Embedding a carbon price into business strategy.
[4] http://www.carbonpricingleadership.org/what/
[5] http://www.worldbank.org/en/programs/pricing-carbon

toward low-carbon activities, make the business case for R&D investments, and reveal hidden risks and opportunities in a company's operations and its supply chains.[6]

There are generally three types of corporate carbon pricing: implicit price, shadow price, and internal taxes, fees or trading systems.[7]

- **Implicit price**: The implicit cost per ton of carbon is calculated based on how much the company spends to reduce GHG emissions, e.g., the amount of money a company allocates to energy efficiency or renewable energy projects to achieve its climate target. This is analogous to marginal abatement cost—the amount of money spent to reduce one tCO_2e.
- **Shadow price**: A shadow price is a hypothetical or assumed cost applied to carbon emissions to assess the profitability of potential investments under different carbon regulation scenarios. It is often used in carbon-intensive industries like oil and gas; however, a shadow price on carbon has not been found to drive decision-making in oil and gas companies.[8] There are nevertheless cases where shadow price has made an impact. For example, Suez, an utility company, has used shadow pricing to drive investments in low-carbon technologies such as installation of new water pumps that increase energy performance.[9]
- **Internal taxes, fees or trading systems**: These are formal programs to create incentives to reduce emissions by charging a price for the emissions associated with the energy used. The revenues from these carbon charges are used in a variety of ways. For example, Microsoft uses them to fund internal energy efficiency initiatives, green power procurement and carbon offset projects.[10]

While many corporations have been working through the design and implementation of internal carbon charges, Yale is the first academic institution to join the Carbon Pricing Leadership Coalition, and the first University to institute a formal internal carbon charge. The Yale carbon charge is an internal fee system and was designed to test multiple models of carbon pricing, including both quantity- and price-based approaches. This case study looks at how Yale decided to implement the internal carbon charge, how the University rolled out its initial pilot, and what was learned from the process and results**.** The case study focuses on two key aspects of the Yale carbon charge: the design and management of the project by the Carbon Charge team, and the implementation of energy conservation measures in response to the carbon charge by the administrative units and building managers. It provides information and lessons learned for other institutions interested in internal carbon pricing, as well as raising unresolved questions and issues for discussion and further research.

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[6] CDP. 2016. Embedding a carbon price into business strategy.
[7] Metzger et al. (2015). Executive Guide to Carbon Pricing Leadership. World Resources Institute, Washington, DC. http://www.wri.org/publication/executive-guide-carbon-pricing-leadership
[8] For example, see http://www.skepticalscience.com/Shell.html.
[9] CDP. 2016. Embedding a carbon price into business strategy.
[10] CDP. 2016. Embedding a carbon price into business strategy.

2. Yale context & history of the Carbon Charge

In 2013, a group of students called “Fossil Free Yale” urged the University to divest its endowment from fossil fuels as part of a global divestment movement that was spreading across governments, universities, private foundations and other institutions. Following a referendum by the Yale College Council, which indicated substantial support among undergraduate students for fossil fuel divestment at the University, Fossil Free Yale submitted a proposal for divestment to the Yale Corporations’ Committee on Investor Responsibility (CCIR).[11]

On August 27, 2014, the CCIR issued a statement endorsing sound governmental policies and business practices to reduce the threat of climate change and announced a new policy guideline on Yale’s investments and climate change:

> *“Yale will generally support reasonable and well-constructed shareholder resolutions seeking company disclosure of greenhouse gas emissions, analyses of the impact of climate change on a company’s business activities, strategies designed to reduce the company’s long-term impact on the global climate, and company support of sound and effective governmental policies on climate change.”*[12]

However, the CCIR decided against divestment, arguing that the greatest impact Yale would have in addressing climate change was instead through its core mission in research, scholarship and education. On the same day, Yale President Peter Salovey released a letter concurring that:

> *“Yale has a role as an investor, but […] Yale’s most important contributions come from its teaching and research, its internal practices, and its leadership by example and encouragement among peer institutions.”*[13]

President Salovey then announced six new initiatives to expand Yale’s sustainability efforts, one of which was the formation of a Presidential Carbon Charge Task Force to determine whether a carbon charge should be introduced at Yale, and if so how. The Carbon Charge Task Force was accompanied by a $21 million capital investment for energy conservation, expanded deployment of renewable energy, GHG disclosure and verification, green innovation fellowships for student ventures, and school-specific sustainability plans. While associated with divestment conversations, the history of the Task Force is described in the Yale Carbon Charge Initial Pilot report as such:

> *“The idea for the task force started at an Earth Day event convened by the Offices of the President and Sustainability in 2014. Students, faculty, and staff were sharing thoughts*

[11] https://fossilfreeyale.org/about
[12] Statement of the Yale Corporation Committee on Investor Responsibility. http://acir.yale.edu/pdf%20and%20hyperlinks/CCIR%20Statement%20(2014).pdf.
[13] http://carbon.yale.edu/reports/announcements/formation-task-force

on how Yale might use its campus as a test-bed for environmental policy when Professor William Nordhaus proposed that the university experiment with carbon pricing. Many economists, climate scientists, policymakers, and business leaders regard this financial tool as an important part of efforts to mitigate climate change.

Following this event, undergraduate and graduate students from Professor Daniel Esty's class wrote a letter to Yale's administration recommending that the campus serve as a living lab for experimenting with carbon pricing. At the same time, the Office of Sustainability had been researching internal carbon pricing in the private sector. This campus-wide interest and thought-leadership culminated in the creation of Yale's Presidential Carbon Charge Task Force."

The Task Force was chaired by Sterling Professor of Economics William Nordhaus and included a number of professors, students and administrators with deep expertise and involvement in sustainability at the University.[14] Over the course of six months, the Task Force had bi-weekly meetings, held interviews and discussions with faculty, students, administrators and outside experts, formed four Working Groups to investigate the different aspects of a carbon charge, and organized a campus-wide prize competition to solicit ideas for energy innovation. In April 2015, the Task Force concluded that a carbon charge was both feasible and effective and recommended a pilot of the concept during the 2015-2016 academic year.

The Task Force based its recommendation on the following advantages of a carbon charge:

- It provides incentives for individuals and administrative units to reduce emissions;
- It extends the reach of Yale's policies on climate change and energy use to more people and units on campus. By contrast, Yale's quantitative emission targets are mostly the concerns of central units such as facilities or the sustainability office;
- It prepares Yale for a higher carbon-price future;
- It integrates academics with operations and provides faculty and students with opportunities to engage with internal policymaking; and
- It expands Yale's role as a pioneer in the research, teaching and design of practical climate and energy solutions, thereby contributing to society's learning about ways to slow climate change while advancing Yale's educational mission.

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[14] Members of the Task Force included William Nordhaus (chair), Daniel Esty (Professor of Environmental Law and Policy), Bradford Gentry (Co-chair of Yale's Sustainability Advisory Council and Associate Dean for Professional Practice at Yale School of Forestry and Environmental Studies), Peter Glazer (Professor and Chairman of the Department of Therapeutic Radiology), Sharon Oster (Professor of Management & Entrepreneurship & Economics), Mark Pagani (Professor of Geology and Geophysics and Director of the Yale Climate & Energy Institute), Frances Rosenbluth (Professor of Political Science), Ted Snyder (Dean of School of Management), John Bollier (Associate Vice President for Facilities), Virginia Chapman (Director of the Office of Sustainability), Linda Koch Lorimer (Vice President for Global and Strategic Initiatives), Ted Wittenstein (Director of International Relations & Leadership Programs for Yale's Office of International Affairs), Robin Canavan (Graduate Student in Geology & Geophysics), Sophie Janaskie (Undergraduate Student in Environmental Engineering) and Jennifer Milikowsky (Graduate Student at the School of Forestry and School of Management).

The Task Force recommended that Yale set the price at the social cost of carbon, which is the social damage caused by a ton of CO_2 emissions and is estimated by the Federal Government's Interagency Working Group on the Social Cost of Carbon to be $40 per tonne of CO_2e[15] for 2015, rising at 3% per year plus inflation. The Task Force proposed two possible carbon pricing schemes, one of which would guarantee revenue-neutrality and the other would not. Revenue-neutrality means that the sum of all carbon charges and rebates to all units would be zero. The carbon charge would however not be revenue-neutral for individual administrative units – those whose emissions grow faster than the university average would incur a net charge, while units whose emissions grow slower than the average would receive a rebate.

There was disagreement within the Task Force over the desirability of revenue-neutrality. On one hand, revenue-neutrality is key to generate political buy-in for carbon pricing in many countries, including the US and Canada, as it avoids the disproportionate impacts of a carbon price on energy-intensive sectors. Similarly at Yale, revenue-neutrality is important to avoid penalizing heavy energy users such as IT, the medical school and physics department (by returning some of the carbon charges back to them at the end of the fiscal year). Revenue-neutrality also provides cost certainty to the University as a whole. However, a revenue-neutral system with a rebate mechanism reduces the salience of the carbon price signal (see **Price signals and information** section). Despite the disagreement, an executive decision was made to recommend revenue-neutrality or near revenue-neutrality for the carbon charge program.

A Steering Committee and a Project Team were then formed to implement the pilot. The Steering Committee[16] consisted of staff in key administrative functions that would need to interact in order to oversee the carbon charge. The Project Team included two staff members who were responsible for the design, implementation and evaluation of the pilot project (see Organizational Chart). Some members of the Steering Committee and Project Team were also members of the original Task Force. The Steering Committee and Project Team noticed several issues with the two schemes proposed by the Task Force: both would result in reduced price signals, and one could allow total university emissions to increase year after year due to the lack of a cap, as well as creating an unlevelled playing field because buildings with different marginal costs of abatement would be compared against each other. However, a collective decision was made to continue their testing instead of waiting for the perfect design. Two additional schemes were also added – one to test the impact of information in isolation by distributing an energy report to participants with indicative carbon charges but no financial

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[15] Carbon dioxide equivalent (CO_2e) is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential.

[16] The Steering Committee included Benjamin Polak, Provost and William C. Brainard Professor of Economics; Timothy Pavlis, Assistant Vice President for Strategic Analysis and Institutional Research; John Bollier, Associate Vice President for Facilities; Virginia Chapman, Director, Office of Sustainability; Martha Highsmith, Senior Advisor, Office of the President and Lecturer, Divinity School; Julie Paquette, Director of Energy Management; and Edward Wittenstein, Director, International Relations & Leadership Programs.

consequences, and another to test the effectiveness of an energy efficiency earmark (provision of funding designated for energy efficiency investments only). More information on each scheme and their pros and cons is provided in the “**Scheme selection**” section below.

The pilot was implemented between December 2015 and May 2016. The following sections discuss the key design features, implementation, results and key challenges of the pilot.

Figure 1. Rough sketch of Carbon Charge Organizational Chart

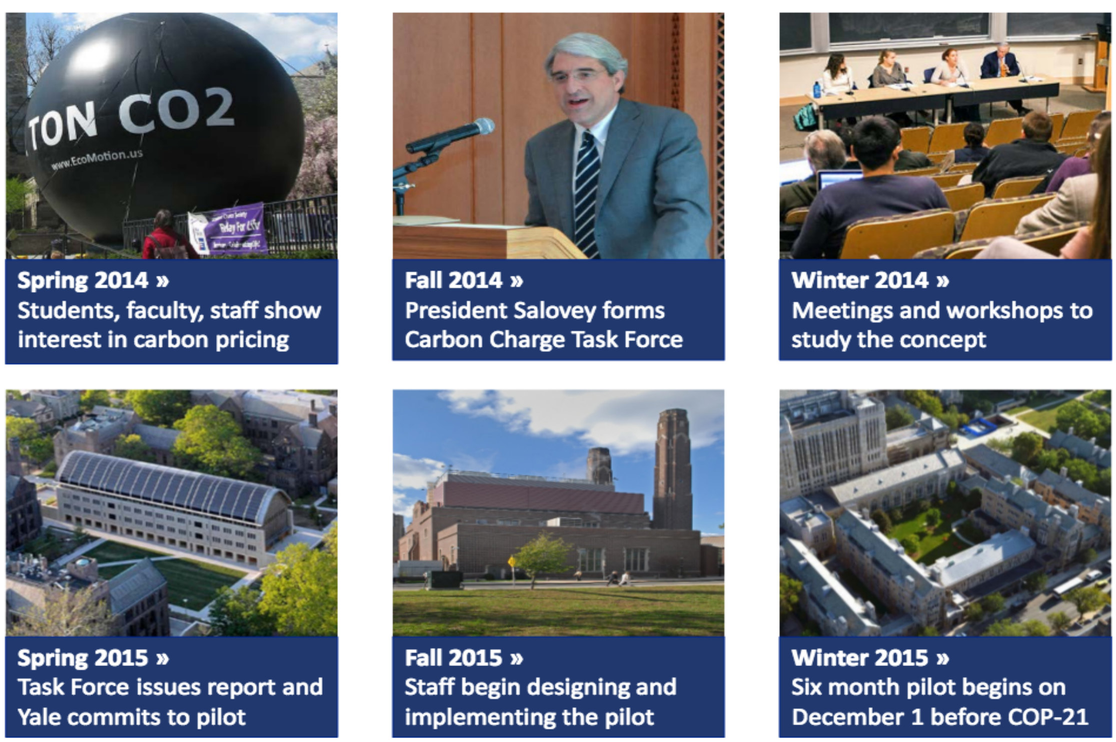


Figure 2. Timeline of the Yale Carbon Charge Pilot

3. Key decisions: pilot design

3.1. Goal and objective setting

As a research and teaching institution, Yale's first and foremost objective with the carbon charge was to experiment with market-based solutions to climate change and test how carbon pricing would work in practice, using its campus as a living laboratory. The University aimed to expand its role as a leader in sustainability by sharing the project's findings widely with the academic community, as well as the private and public sectors, to inform climate and energy policies and actions. As Yale is not a company and not subject to competition law, the University can be transparent about its experience and fill a knowledge gap on internal carbon pricing.

Furthermore, Yale aimed to reduce campus energy use and GHG emissions through the creation of financial incentives to encourage behavior and decisions that align with the principles of a low-carbon economy. The University envisioned that a price on carbon would shift the focus from small actions (e.g., closing windows during winter, turning off lights) to ones that have more significant and long-term impacts (e.g., construction of new buildings, installation of solar panels).

Finally, Yale would like to the use the carbon charge to support education and research and integrate academics with operations, thereby improving operations and staff engagement while furthering the educational mission of the University.

The carbon charge pilot was designed to reflect these objectives. For example, since Yale's primary objective was to establish the right incentives and not to raise revenues for other goals, including sustainability, one of the carbon pricing schemes tested was revenue-neutral. A desire to engage the broader Yale community and test different types of buildings and organizational structures, rather than to generate the largest possible emissions reductions, led to the selection of diverse buildings instead of the biggest energy users or those with the most low-hanging fruits in terms of energy efficiency.

3.2. Participant selection

Energy use is highly diverse at Yale due to different building uses, ranging from teaching and research facilities to residential colleges, athletic facilities, offices and public museums, among others. There are also differences in how buildings and activities are metered and how energy charges enter departments' budgets.

Administrative units on campus differ with regard to their control over budgets and energy bills. "Self-support" units are those responsible for their own budgeting and fundraising, and therefore are energy ratepayers. These include six self-support schools and a few autonomous entities. Centrally-supported units, on the other hand, are not responsible for their own fundraising or utilities expenses.

Within the set of centrally supported units, there are larger units that, while not paying their own bills, are attentive to and have more control over their budgets. These include the balance of schools, the collections (e.g., museum and art center), the main library, athletics, and the officer units (e.g., Office of the President, Office of Development). Finally, there are units that are either small, have limited budget authority, or are co-located with other units, which makes estimating energy use and carbon charges difficult. These include small departments and the residential colleges. This last group represents the largest challenging for carbon charge application.

An important goal of the pilot was to test how the carbon charge would impact the whole campus. As a result a diverse set of buildings were selected based on three criteria: building and budget type, meter data quality, and carbon footprint.

Carbon emissions were calculated for 300 buildings on campus to establish quintiles of largest to smallest emitters. The 20 selected buildings (see handout 1) were then categorized by building type (e.g., classroom, lab, office, dorm, etc.) and budget type (i.e., self-support vs. centrally-support), then assigned to the four carbon pricing schemes until each scheme had a building from each quintile and a profile of building and budget types that is representative of the whole campus. The 280 remaining buildings served as the control group (see handout 1). It should be noted that an administrative unit can have multiple buildings, but only one building from each administrative unit was chosen, hence “buildings” and “units” were used interchangeably when discussing the pilot. More information on the 20 selected buildings is provided in Table 1.

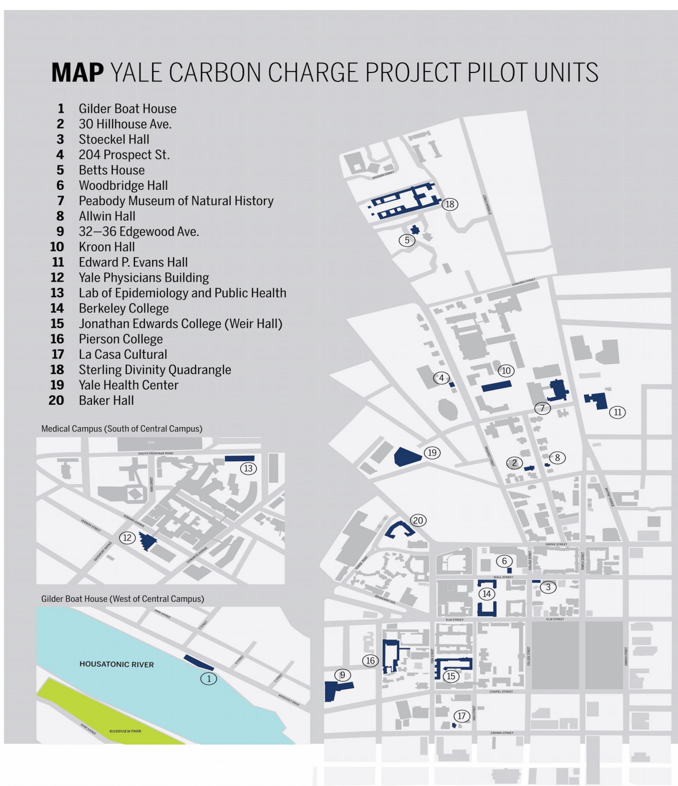


Figure 3. Map of Yale’s carbon charge pilot units

3.3. Scheme selection

Yale decided to test four carbon pricing schemes, two of which were proposed by the Task Force and two were added by the Steering Committee and the Carbon Charge Team through conversation with stakeholders.

3.3.1. Redistribution scheme

The first scheme proposed by the Task Force is referred to as the **Redistribution** scheme (see handout 1). A monthly $40 per tCO_2e charge is applied to carbon emissions associated with building energy use. At the end of the fiscal year, Yale returns all of the revenues to the units based on their individual performance compared to the university's average change in emissions from a baseline. Buildings with percent changes below this average receive a full refund and additional payment that together are more than they were charged, resulting in a net rebate. Those with percent changes above this average receive a refund amounting to less than they were charged initially, resulting in a net charge. The sum of charges and rebates is zero and, as a result, the scheme is revenue-neutral for the university. However, it is not revenue-neutral for the individual buildings and administrative units.

Applying this design to the pilot, the five units in this scheme were compared to the group's overall percent change in emissions from baseline. Those emitting above this value incurred net charges while those emitting below this value received net rebates. The charges and rebates again added up to zero.

The main advantage of this scheme is that it is revenue-neutral for the university as a whole while still providing incentives for each unit to reduce emissions. In addition, individual units will not bear an exorbitant amount of cost in any given year, which especially benefits those who have relatively small budget.

However, this scheme can allow the total university's emissions to increase year after year without any penalty as there was no cap to emissions and units were only compared with their average collective performance. The scheme also lacks simplicity (because the charge/rebate depends on performance relative to others) and predictability (because units are unable to forecast the number by which they will be judged, making it difficult to conduct cost-benefit analysis to inform decision making).

Despite the benefits of revenue-neutrality, participants in the pilot felt that this scheme made them compete against each other and reduced the level of cooperation. They also perceived the scheme as unfair because buildings vary in size, history, and/or use and thus have different marginal abatement costs (meaning more or less expensive reduction opportunities). The unique energy profile of each building makes comparison among them unreasonable.

3.3.2. Target scheme

The second scheme proposed by the Task Force is referred to as the "Target" scheme. This scheme addresses the simplicity and predictability issues by providing a specific reduction target, which can be universally applied to all buildings or customized for each building. The reduction target chosen for the pilot was 1% below baseline.

Similar to the "Redistribution" scheme, a charge of $40 per tCO_2e is applied monthly to units' building energy use. However, at the end of the fiscal year, Yale returns most of the revenues to each unit based on its individual performance relative to the fixed target (-1% in the pilot) rather than to the university's average percent change in emissions.

The "Target" scheme thus improves fairness by focusing the competition internally, which was preferred by pilot participants than comparison with their peers. It also establishes a cap on the university's total emissions. However, this scheme does not guarantee revenue-neutrality. It can result in a deficit or surplus for the university depending on whether the buildings collectively exceed or fall short of the target (see handout 1).

A deficit is not a negative outcome for the centrally-supported units, as it resulted in a small financial reward for the units but significant energy cost-savings for the university. This is because utility costs for centrally-supported units are paid for by the university and are much higher than the carbon rebate. Both a deficit and a surplus are however undesirable outcomes for the self-support units. A deficit would represent a subsidy to the self-supporters for reducing their emissions below the target, while a surplus would represent a tax for increasing their emissions relative to the target. As these units are self-financed and do not receive significant revenue from or pay taxes to the university, these outcomes are challenging administratively.

This scheme is also subject to gamability—units may negotiate to receive a more preferable reduction target. Additionally, to make the scheme completely fair, the target needs to be customized to each unit based on the characteristics of their buildings. Yet this will be too administratively burdensome to be implemented.

3.3.3. Investment scheme

In order to simulate the second year of a carbon charge when a portion of the revenues would be returned to the buildings as rebates earmarked for energy efficiency, the Steering Committee added an "Investment" scheme. Five units received an energy efficiency earmark equal to 20% of their baseline carbon charge for spending on self-guided energy actions, which can be educational initiatives or capital investments. This represented a scenario in which all of the revenues from carbon charges are sent back to the units, 20% of which is earmarked for energy efficiency while the rest is returned without restrictions (see handout 1). The scheme aimed to test the effectiveness of decentralizing energy efficiency investment.

The advantages of this scheme are that it guarantees investment on energy efficiency and is somewhat revenue neutral, as a certain percentage or all of the revenues from the carbon charge are returned to the units. However, it has the potential to incentivize overinvestment or underinvestment, as units try to use up or do not want to spend more than the earmarked amount. Decentralized capital investment may also be less cost-effective than centralized investment. The pilot found that the level of energy efficiency investment was lower than expected, but this may have been due to the relatively short duration of the pilot.

3.3.4. Information scheme

Quality meter data are available at Yale and in many cases are provided to the units. However, the data were buried in departmental budget statements and provided without much context (e.g., in comparison to past energy use or other buildings with similar characteristics), making it difficult to find and interpret them. Furthermore, the realization that the carbon charge would require changes in the budgeting system led to a desire to test an “information only” approach. The need to communicate energy, carbon, and cost information to financial and operational decision-makers, coupled with the desire to isolate the effect of information, led the Steering Committee to add another scheme to the pilot. The five units in this group received a monthly building energy report with a $40 per tCO_2e price signal but no financial consequences (see handout 1). The other three schemes in the pilot also receive this information report in addition to the financial incentives.

The pilot found that information can be helpful, or at least that energy savings could accompany being a part of the information scheme. In Gilder Boathouse, a building that holds crew operations, the team was motivated simply by the new energy report and reduced their emissions by 20% below baseline during the pilot. However, the overall result for this group showed that information in isolation was insufficient: Only two out of the five units reported “higher” or “much higher” levels of motivation and action. In general, the pilot found that information coupled with incentives was the most effective in increasing motivation for energy action.

3.4. Baseline setting

An average of the previous three fiscal years (FY 2013-2015) was set as the baseline for all of the schemes. This baseline was chosen due to two factors: it provides some degree of control over weather and annual programmatic changes that influence energy use; and it allows for long-term growth, not penalizing units for bringing in new faculty with energy intensive research equipment or adding more students. However, this decision washes out benefits every few years by resetting the baseline constantly. How to set an appropriate baseline remains a challenge for Yale.

3.5. Boundary setting

In defining the boundary of the carbon charge, Yale uses emissions scopes from the World Resources Institute’s Greenhouse Gas Protocol[17], which is the most commonly used standard for GHG accounting. The three scopes of emissions include:

Scope 1: Direct emissions from owned or controlled sources. This includes the onsite combustion of fossil fuels from power plants and the vehicle fleet.

[17] http://www.ghgprotocol.org/

Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.

Scope 3: Other indirect emissions, which were further divided into two subcategories - emissions for which Yale has operational control (Scope 3A) and those for which Yale does not (Scope 3B).

> **Scope 3A**. Emissions embedded in supplies, materials, food purchased by Yale, student/staff/faculty travel paid for by Yale, on-campus construction, and waste disposal.
> **Scope 3B.** Emissions embedded in commuting, off-campus housing, and student/staff/faculty travel not paid for by Yale.

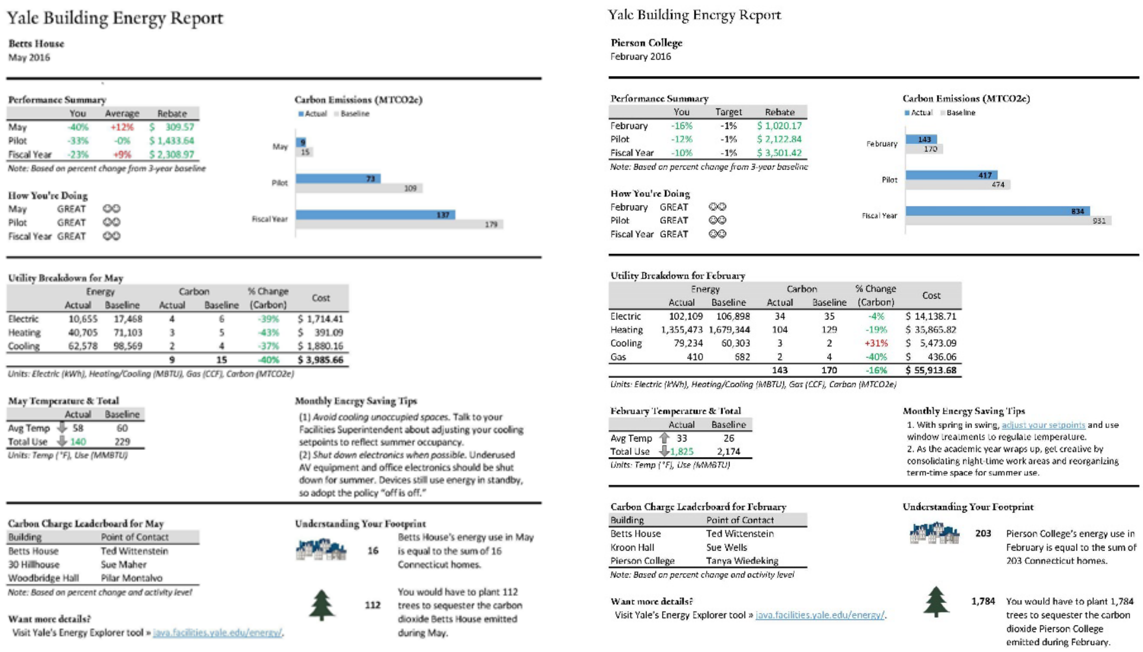
The pilot covered Scope 1 and 2 emissions from building energy use. Most buildings at Yale get their electricity, steam, and chilled water from the University's own power plants (Central, Sterling, and West), with a few purchasing electricity and natural gas directly from local utility providers. Both emissions from Yale's own power plants and energy purchased from the grid were included in the pilot. Yale calculated these emissions by applying campus-wide emissions factors, which eliminate the differences between energy sources such as the Yale power plants and local utilities. This adjustment is important because units have no control over where their energy comes from.

In the future, Yale plans to incorporate Scope 1 emissions from transportation, which includes vehicles owned and operated by the university. The Task Force also recommended that Yale incorporate some Scope 3 emissions into the carbon charge down the road. Specifically, it suggested looking into Scope 3 emissions controlled by the university such as those from faculty and staff's air travel and those embedded in construction materials (e.g., the use of cement).

3.6. Price signals and information

One of the four schemes tested during the FY 2016 pilot was purely informational and the other three received an energy report in addition to the financial incentives. Prior to the pilot, buildings were able to run a report showing energy use and cost, but this information did not affect energy use decisions due to several factors: none of this information was provided with context (e.g., in comparison to past energy use or other buildings with similar characteristics); it was not compiled in an easy-to-read, one-page document; and it was not dispatched to the relevant decision-makers.

In an effort to address these issues, a new monthly energy report was sent to each pilot building with information on current energy consumption, carbon emissions and carbon charge compared to historical trends. The report also included monthly energy saving tips, best performing pilot buildings for the month, and carbon equivalency to help participants understand their carbon footprint (Figure 4). Quantitative results from the pilot and comments from the pilot participants indicate that this informational report was helpful in monitoring energy use, carbon performance, and, in some cases, identifying energy use issues. However, some participants found it confusing, especially since, in an attempt to integrate feedback and continuously improve on the report, the Pilot team updated the report template several times, thereby changing expectations of what the report included and how that information was presented. And compiling the reports ended up taking much longer than anticipated, making them less actionable than was hoped.



Yale Building Energy Report

Betts House
May 2016

Performance Summary

	You	Average	Rebate
May	-40%	+12%	$ 309.57
Pilot	-33%	-0%	$ 1,433.64
Fiscal Year	-23%	+9%	$ 2,308.97

Note: Based on percent change from 3-year baseline

Carbon Emissions (MTCO2e)

How You're Doing

May	GREAT	☺☺
Pilot	GREAT	☺☺
Fiscal Year	GREAT	☺☺

Utility Breakdown for May

	Energy		Carbon		% Change	Cost
	Actual	Baseline	Actual	Baseline	(Carbon)	
Electric	10,655	17,468	4	6	-39%	$ 1,714.41
Heating	40,705	71,103	3	5	-43%	$ 391.09
Cooling	62,578	98,569	2	4	-37%	$ 1,880.16
			9	15	-40%	**$ 3,985.66**

Units: Electric (kWh), Heating/Cooling (MBTU), Gas (CCF), Carbon (MTCO2e)

May Temperature & Total

	Actual	Baseline
Avg Temp	⇩ 58	60
Total Use	⇩ 140	229

Units: Temp (°F), Use (MMBTU)

Monthly Energy Saving Tips

(1) *Avoid cooling unoccupied spaces.* Talk to your Facilities Superintendent about adjusting your cooling setpoints to reflect summer occupancy.
(2) *Shut down electronics when possible.* Underused AV equipment and office electronics should be shut down for summer. Devices still use energy in standby, so adopt the policy "off is off."

Carbon Charge Leaderboard for May

Building	Point of Contact
Betts House	Ted Wittenstein
30 Hillhouse	Sue Maher
Woodbridge Hall	Pilar Montalvo

Note: Based on percent change and activity level

Want more details?
Visit Yale's Energy Explorer tool » java.facilities.yale.edu/energy/.

Understanding Your Footprint

16 — Betts House's energy use in May is equal to the sum of 16 Connecticut homes.

112 — You would have to plant 112 trees to sequester the carbon dioxide Betts House emitted during May.

Yale Building Energy Report

Pierson College
February 2016

Performance Summary

	You	Target	Rebate
February	-16%	-1%	$ 1,020.17
Pilot	-12%	-1%	$ 2,122.84
Fiscal Year	-10%	-1%	$ 3,501.42

Note: Based on percent change from 3-year baseline

Carbon Emissions (MTCO2e)

How You're Doing

February	GREAT	☺☺
Pilot	GREAT	☺☺
Fiscal Year	GREAT	☺☺

Utility Breakdown for February

	Energy		Carbon		% Change	Cost
	Actual	Baseline	Actual	Baseline	(Carbon)	
Electric	102,109	106,898	34	35	-4%	$ 14,138.71
Heating	1,355,473	1,679,344	104	129	-19%	$ 35,865.82
Cooling	79,234	60,303	3	2	+31%	$ 5,473.09
Gas	410	682	2	4	-40%	$ 436.06
			143	170	-16%	**$ 55,913.68**

Units: Electric (kWh), Heating/Cooling (MBTU), Gas (CCF), Carbon (MTCO2e)

February Temperature & Total

	Actual	Baseline
Avg Temp	⇧ 33	26
Total Use	⇩ 1,825	2,174

Units: Temp (°F), Use (MMBTU)

Monthly Energy Saving Tips

1. With spring in swing, adjust your setpoints and use window treatments to regulate temperature.
2. As the academic year wraps up, get creative by consolidating night-time work areas and reorganizing term-time space for summer use.

Carbon Charge Leaderboard for February

Building	Point of Contact
Betts House	Ted Wittenstein
Kroon Hall	Sue Wells
Pierson College	Tanya Wiedeking

Note: Based on percent change and activity level

Want more details?
Visit Yale's Energy Explorer tool » java.facilities.yale.edu/energy/.

Understanding Your Footprint

203 — Pierson College's energy use in February is equal to the sum of 203 Connecticut homes.

1,784 — You would have to plant 1,784 trees to sequester the carbon dioxide Pierson College emitted during February.

Figure 4 (See full size examples, Handout 2). Examples of the building energy reports sent to the pilot units. Left is May 2016 data for Betts House (Scheme 3). Right is February 2016 data for Pierson College (Scheme 2). Note that the two reports are reflective of the month, building, and scheme.

Because units received a rebate at the end of the fiscal year, the effective price signal was much less than the original $40 per tCO_2e. Participants noted that they paid more attention to the net equivalents, which were shown on the energy report, than to the gross carbon prices, charges and rebates. The pilot report gave examples of significantly lower net carbon charges:

> *"For example, consider a building in "redistribution" scheme, Betts House. While Betts House pays $40 per tCO2e on 73.24 emissions, totaling $2,929.69, it receives a rebate of $4,363.33, resulting in a net rebate of $1,433.64. Dividing the net rebate of $1,433.64 by the aggregate emissions of 73.24 produces a marginal carbon price of $19.57 per tCO2e. This value is nearly half the SCC. There is a similar result in the "target" scheme. The Lab of Epidemiology and Public Health incurs a net carbon price of $1.62 per tCO2e, nearly one-fortieth the SCC."*

This combination of information and psychology was found to reduce the price signal by a factor of ten in many cases. In the future, Yale could show "gross" charges only on the report, but after one year the participants would figure out the net equivalents. To maintain the incentives, Yale would have to raise its carbon prices, which may be politically difficult to do. Another way to solve this problem is to decouple the rebates from performance: the revenues from carbon charge would be used to reduce costs elsewhere such as fixed-rate facilities costs (e.g., custodial services and maintenance); the savings would then be allocated to the buildings on a per square-footage basis, or based on a unit's share of university's service charges.

3.7. Marketing and communication to stakeholders

Throughout the pilot, the Carbon Charge team sought to engage closely with the participants. The engagement process started with an invitation letter sent from the Steering Committee on behalf of the Provost to the head of the 20 selected administrative units, requesting their participation and appointment of a representative to administer the pilot. The project recommended the nomination of Lead Administrators or Operational Managers due to their extensive knowledge of finances and operations, and most of the nominees fit these profiles.

A period of two weeks then followed to address all questions and concerns before the units agreed to participate in the pilot. The representatives then participated in an orientation and bi-monthly meetings with the carbon charge project staff, in which they reviewed the utility bill, received advice and support, and provided feedback on the project. At the end of the pilot the representatives took part in two interviews, an exit survey and a focus group to help evaluate the carbon charge.

Since the nomination process put the spotlight on selected managers, the resulting actions might have been driven by a sense of personal responsibility and motivation rather than the price signal of the carbon charge itself (see the **Evaluating the results** section for further discussion on this issue). If this was the case, the carbon charge's impact will be reduced as the project extends to the whole university and diminishes the spotlight effect.

The Project Team had difficulty balancing their role of "regulator" and "supporter"—whether to just send the price signal or provide hands-on support to participants with their energy projects, the latter of which required much more time and expertise in energy management. While the team could have benefited from extra staff, within the constraints they turned to experts on campus, including faculty in environmental economics and staff with expertise in financial and energy management. While this was time-consuming, it has helped engage a diverse set of stakeholders, built support for the carbon charge, and created momentum for the next phase of the project.

3.8. Use of revenues

Yale's carbon charge schemes were designed primarily to encourage behavior change and increase awareness within buildings' constituencies for reducing energy use. This focus on decentralized behavior change is why the schemes are revenue-neutral or nearly revenue-neutral, instead of a straight tax to raise revenues for centralized investment in energy efficiency, renewables, and other low-carbon investments. One of the four schemes in the pilot tested an energy efficiency earmark.

Yale also consciously avoided the redistribution of revenues in service of some other policy goal (e.g., financial aid), even though there is tendency among governments to do so. The university did not want to add another layer of debate on where the revenues should go.

3.9. Evaluating the results

Evaluation of the pilot was based on semi-structured interviews, focus group discussions, survey data and metered energy use. The four schemes were assessed based on three criteria: administrative feasibility (including technical and political), effectiveness (whether the carbon charge increases understanding, motivation, and action for reducing energy use), and impact (whether the carbon charge reduces emissions).

The treatment groups (20 pilot buildings) performed better than the control groups (the 280 other Yale buildings) across the board. However, participants cited many reasons for their energy reductions. Some said that the price signal and energy report directed their attention to energy use and carbon emissions. Others stated that the net financial incentive was motivating and they wanted to win a rebate. Then, there were individuals who reported that the financial incentive had no effect on their motivation. Rather, they felt personally responsible for managing their building's energy use because their unit head nominated them. It is probably a combination and compounding of these factors, including the price signal, information provided by the energy report, and the engagement from the Project Team, fellow participants, and other stakeholders in the carbon charge, that motivated participants to take energy action. Still, more work is needed to evaluate the relative importance of each factor in driving impacts.

4. Pilot implementation at the building level

Each building at Yale has a unique energy profile due to its age, primary use and investment history. Furthermore, Yale has a complex institutional structure with multiple layers of actors that makes it challenging to implement a carbon charge. This section looks at the different responses of buildings to the carbon charge and the challenges and opportunities they faced in taking energy actions. See Table 1 below for a detailed list of the buildings included in the pilot.

Table 1. Carbon charge pilot building participants by scheme and type

Scheme	Building	Affiliation	Budget type	Building Type	Gross Sq.ft.
Information	Berkeley College	Yale College	Centrally supported	Dormitory	146,338
	Baker Hall	School of Law	Self-supported	Mixed use building: 25% Law, 75% Yale College residential housing	137,443
	Gilder	Department of	Centrally	Athletic facility	23,616

	Boathouse	Athletics	supported		
	Woodbridge Hall	Office of the President	Centrally supported	Office	11,346
	Allwin Hall	Ethics, Politics, Economics	Centrally supported	Office	7,433
Target	Lab of Epidemiology	School of Public Health	Centrally supported	Lab	116,529
	Pierson College	Yale College	Centrally supported	Dormitory	173,012
	32-36 Edgewood Ave	School of Art	Centrally supported	Classroom, studio, office	64,118
	30 Hillhouse Ave	Department of Economics	Centrally supported	Classroom, office	15,988
	204 Prospect St	Department of Sociology	Centrally supported	Classroom, office	7,545
Redistribution	Yale Physicians Building	School of Medicine	Self-supported	Medical facility	98,040
	Peabody Museum	Peabody Museum	Centrally supported (78%) Self-supported (22%)	Museum	88,468
	Betts House	Office of International Affairs	Centrally supported	Office, event venue	21,889
	Kroon Hall	School of Forestry & Environmental Studies	Self-supported	Classroom, office	52,635
	Weir Hall	Yale College	Centrally supported	Dormitory	19,718
Investment	Sterling Divinity Quadrangle	School of Divinity	Self-supported	Classroom, office	160,365
	Edward P Evans Hall	School of Management	Self-supported	Classroom, office	342,545
	Yale Health Center	Yale Health	Centrally supported	Medical facility	147,006
	Stoeckel Hall	Department of Music	Centrally supported	Classroom, office	22,775

	301 Crown St	La Casa Cultural	Centrally supported	Cultural center	7,938

4.1. Stakeholder engagement

> *"Many economists think that putting a price on carbon is how the world should address climate change. But there's a long way to go between theoretically setting a price on carbon and having it change people's behavior." - Brad Gentry, Professor and Associate Dean for Professional Practice at Yale School of Forestry & Environmental Studies, member of the Yale Carbon Charge Task Force.*

The Yale pilot confirmed that a price signal itself may not be enough to change behavior, especially when the financial incentives (net charges/rebates) were much less than the original $40 per ton CO_2e price. The small financial incentives made stakeholder engagement even more important in achieving energy reductions. While Lead Administrators and Operational Managers (those nominated to take charge of pilot implementation within a building) understand finances and energy management, engaging other stakeholders, was both crucial and challenging. Some, though not all of those stakeholders include:

- Faculty
- Students
- Program staff
- Administrative staff
- IT staff
- Facilities staff
- Alumni
- the public

Yet each building and unit is made up of a different mix of these stakeholder groups, and priorities, knowledge levels, and energy needs run the gamut. The most successful units in the pilot were those that were able to bridge this gap between different stakeholders.

An example, perhaps not surprisingly, is Sue, the Director of Finance and Administration and head of the carbon charge at the School of Forestry & Environmental Studies (F&ES)'s Kroon Hall, which was put in the "redistribution" scheme. She took on the challenge, seeing the larger imperative of the experiment and formed a dedicated team of students to work on the project. The carbon charge was viewed as a platform to direct attention to the School's ongoing work in managing the most energy-efficient building on campus. Despite being LEED Platinum-certified[18], Kroon Hall's energy consumptions had fluctuated above and below energy model predictions since its completion in 2009. The dedicated team, led by James Ball (a master's student specializing in green buildings) and Sara Smiley Smith (a PhD student and coordinator

[18] Leadership in Energy and Environmental Design (LEED) is a rating system devised by the United States Green Building Council (USGBC) to evaluate the environmental performance of a building and encourage market transformation towards sustainable design. LEED Platinum is the highest certification level for new construction.

of the Environmental Stewardship Committee and The Yale College Environmental Studies program), performed analysis of data from around 2,000 sensors around Kroon Hall[19] to identify the main cause of excess energy consumption.

These measurements revealed that Kroon Hall's energy consumption was especially high in the winter. It took as much as five hours for the system to warm up in the morning and reach the desirable temperatures at 9 am for the start of the day. After reviewing the data, the team found that this was due to a problem with air intake, in which the system was constantly bringing in cold air from the outside for ventilation. Three months later, Kroon Hall reconfigured the system with a winter warm-up mode, which recirculates indoor air and only brings in outdoor air when necessary. The action is expected to reduce Kroon Hall's warm-up time from from five to two hours.

A survey conducted in the spring of 2016 also found that more than 60% of staff members in Kroon Hall were dissatisfied with the thermal comfort in their offices. The carbon charge team experimented with installing thermal curtains and found that they lowered air temperature variation, warmed the surface temperature and increased improved comfort (Figure 10).

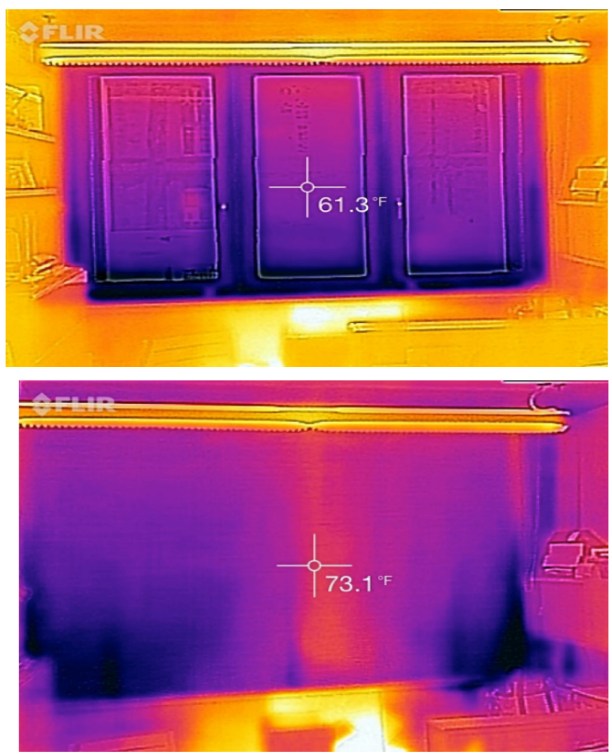


Figure 5. Visual evidence of the impact of thermal shade. Above: Thermal image taken with the shade up. Below: Thermal image taken with the shade down, showing higher surface temperature near the window.[20]

[19] http://yaledailynews.com/blog/2016/04/19/fes-leads-carbon-charge-program/

On the communications front, the team created a public Facebook page to share their research with the broader Yale community and engage their fellow F&ES students in energy reduction efforts. They posted Kroon Hall's energy use data, called for students' ideas for energy reduction, as well as shared videos of interviews with F&ES faculty about their views on the carbon charge. The active engagement and implementation of energy conservation measures helped Kroon Hall achieve a 17% reduction during the pilot term of December to May, despite being 5% above baseline for July through May of the same year. Kroon Hall's experience shows that there are potential cost-effective solutions even in a LEED Platinum building.

Most importantly, the F&ES team emphasized the importance of connecting the carbon charge with the educational and research mission of Yale:

> *"You can reduce energy and still learn valuable lessons, or you can reduce energy and not learning anything from it. But in an academic institution, the learning has to be front and center." "The learning opportunities for [F&ES] are perhaps more than other schools, but the interesting thing is that energy use exists for everybody regardless of what their studies are." - James Ball, Master's of Environmental Management '16 Graduate and Head of Carbon Charge Team (2015-2016) at Yale School of Forestry & Environmental Studies.*

Sara Smiley-Smith attributed the success of Kroon Hall to the enthusiasm and research efforts of students like James, rather than economic incentives: "We feel empowered by the students to act on the carbon charge." F&ES also took leadership in engaging fellow participants in the pilot. Despite being placed in the zero-sum competition ("redistribution" scheme), Sue Wells convened a meeting with other building administrators in the same group to encourage the sharing of best practices and taking a collaborative approach to the carbon charge. Sue and others found that this practice of collaborating and uncovering best practices was the "fun part" of participating in the pilot program.

Other examples of stakeholder engagement include Pierson College and Jonathan Edwards College, two of Yale's twelve residential halls. Pierson College worked to reduce unnecessary electricity and thermal use during winter and spring breaks. The College's Operations Manager, Tanya Wiedeking, worked with the Head of College, Facilities Superintendent and several students to develop a checklist with a menu of energy-saving actions. Students who closed windows and adjusted radiators were eligible for a prize. The competition saw a nearly 50% participation rate. Jonathan Edwards College conducted a poll to survey students' awareness and found that only half of the respondents knew how to operate the radiators in their rooms, which presented significant education and outreach opportunities.

The Allwin Hall experience reflected a different situation. The building is divided between two departments, and Pilot lead Ella Sandor had the challenge of reaching out to those outside of

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[20] Ball, James and Turk, Zachary. 2016. Kroon Living Lab: Thermal Curtain Experiment.

her unit to drive participation and results. Her office is in a different building, and both her physical presence and the building's split use limited the sense of community engagement. She found that it was difficult to sustain promotion of the carbon charge beyond relaying information provided to her or asking building users to identify low-hanging fruit. The Baker Hall team had a similar experience due to shared occupancy. Yale Law School Associate Dean for Finance and Administration Joe Crosby said: "the Law School only occupies the 4th floor of Baker Hall and the remaining floors are used by the College for residential housing. We did not control what happened in 75% of the building nor did we communicate anything to the students in the building."

Stakeholder engagement at times led to interesting outcomes. When the School of Arts wanted to increase studio hours during winter break, Jonathan Rohner, the Finance and Administration Manager, brought the extra energy and carbon charge costs to the Dean's attention. As it was his final year in office, the Dean decided that the increased student productivity was worth the extra charges. While energy use increased, this is an example of how the carbon charge was used in decision-making. A higher carbon price in the future may or may not change this decision depending on the stakeholder's cost-benefit calculation and perception.

4.2. Operational changes

Several buildings achieved substantial emissions reductions by making operational changes. The School of Art revised the architect's desire to make the building a "beacon of light" for the neighborhood at night and worked with Facilities to turn the lights off at reasonable hours. Betts House, home to the Office of International Affairs, worked with students from Office of Sustainability to identify energy saving opportunities, and found that one of the thermostats was jammed, locking the building into occupied mode for a long period of time. Betts House worked with its independent energy service consultant to replace the thermostat, achieving significant energy savings with a simple solution. The building also worked with Facilities to adjust heating and cooling setpoints and HVAC schedules, and are currently considering physical solutions including lighting retrofits and occupancy sensors.

A major factor in the success of Betts House is the leadership of its carbon charge manager, Ted Wittenstein, Director of International Relations & Leadership Programs for Yale's Office of International Affairs. As Ted served on both the Carbon Charge Task Force and Steering Committee, it is likely that energy actions at Betts House were driven by its leader's intrinsic motivations rather than by the price signal from the carbon charge.

4.3. Capacity constraint

While the carbon charge was aimed at individual buildings and units, most of campus building's energy operations at Yale are centrally managed by the Office of Facilities. This can result in a tension over where responsibilities lie. One participant said "Facilities thinks they own the building. We think we do." As the carbon charge increased demand for energy services, the Office of Facilities found it difficult to meet all requests on top of their existing workload. Participants in the pilot noted that if the request was deemed as "not critical", it could take weeks or even months for the Office of Facilities to take action. For example, the Kroon Hall team submitted a work order to lower thermostat set points over winter break, and came back to find records of high energy consumption as usual. It turned out that the Office of Facilities did not approve the request as they were afraid that the pipe would freeze. However, they did not communicate this to the team - leading to much time and effort being spent looking into the cause of continued high energy use. This bottleneck of requests could, at times, lead to frustrating feedbacks, with one participant reflecting “when you don’t have control, the incentives are hollow.” On the other hand, when a building is independently managed like Betts House, participants had greater flexibility to address needs and, in one example, an outside energy service company came just one day after it was called.

There were also technical constraints in engaging with advanced building management systems. Kroon Hall has a building management system that is programmed entirely in German. While the air intake problem was discovered in February, it took until May to address the issue as an energy consultant had to be flown in from Germany to set up the new system.

5. Key challenges and remaining issues in the Yale carbon charge

5.1. Incorporation of the carbon charge into budget and accounting

To make the carbon charge an integral part of decision-making, it needs to be included as a line item in the budget. According to Tamara Dicaprio, coordinator of Microsoft’s innovative internal carbon pricing program, “the moment we got the carbon charge on our Profit and Loss (P&L) statement, everything clicked”. It is challenging to determine how the carbon charge should be put in the accounting system of Yale, as the units will pay a monthly carbon fee but will get back the rebates at the end of the fiscal year. There are different views on how this should be done and Yale is going through consultation to develop the appropriate system.

5.2. Trade-offs between fairness, efficiency and political feasibility

There are trade-offs between fairness, efficiency and political feasibility among the schemes tested in the initial pilot. The redistributive scheme has high efficiency as it focuses on on-the-margin incentives to reduce carbon emissions. However, this scheme was perceived by some as unfair for two reasons. One, it ignores the different marginal cost of abatement of buildings and penalizes early-adopters while benefiting late-adopters. The School of Forestry and Environmental Studies for instance has a building that is already highly efficient and therefore has less room for improvement than other units. Two, it involves a tension between self-supported and centrally-supported units as described in the pilot report:

> *“Self-support units do not want to pay centrally-supported units if they perform poorly and vice-versa. Moreover, centrally-supported units consider competing with self-supports unfair because self-supports have their own capacity and capital for carbon reduction projects. Conversely, self-supports consider competing with centrally-supported units unfair because centrally-supported units can access the university’s operational resources without footing the bill.”*

The energy efficiency earmark or subsidy approach is the fairest and most politically feasible, but is highly inefficient. In the middle is the target scheme, which compares each unit to its own baseline. However, to make the target scheme really fair, the baseline would need to be customized to each building, which is overly administratively burdensome.

To increase political feasibility, Yale has designed a carbon charge system with rebates. However, this has compromised efficiency as it results in a less salient price signal. A potential solution being considered is to return the revenues by reducing fixed-rate facilities costs (e.g., custodial services and maintenance) based on a per square-footage basis or a unit's share of university's service charges. This is similar to tax shifting as done in British Columbia, where the government uses the carbon tax revenue to reduce income and labor taxes.

5.3. The landlord-tenant split incentive

Centrally-supported units at Yale present the classic landlord-tenant split incentive challenges—these units have small incentives to reduce energy use as they do not bear the cost of their energy consumption. Since about 90 percent of energy spending at Yale is by units that do not pay their own energy bill, a priority for the carbon charge is to make energy cost more visible to energy use decision makers, with regards to both day-to-day and longer term decisions.

5.4. Implementing a policy with imperfect information

Yale faces the challenge of building the infrastructure of the carbon charge with imperfect information. Yale's initial pilot ended on May 31, 2016 and the second pilot is scheduled to start in Spring 2017. While there have been lessons learned from the first pilot, there are still many unresolved issues. In addition, the University is always balancing a variety of priorities. This raises a series of questions on how Yale can modify a policy in real time.

5.5. Impact on capital investments

An important goal of carbon pricing is to influence major capital investments toward lower-carbon options. Yale can do this by using the carbon charge as a shadow price for capital investments such as new constructions and energy-intensive equipment purchase. Impact on investments will also require institutionalization of the carbon charge to provide a strong and clear price signal to decision-makers. A further question is whether decisions on major new facilities and equipment or programmatic expansion should be more centralized or left to individual administrative units. These questions were not studied during the pilot and will need to be investigated in the next phase of the Yale carbon charge.

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