PRESIDENT'S COMMISSION ON CARBON NEUTRALITY

UNIVERSITY OF MICHIGAN

Fall 2019 Interim Progress Report

December 2, 2019

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- Jennifer Haverkamp, Director, Graham Sustainability Institute and Professor from Practice in Law and Policy, UM

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- Andrew Berki, Director, Office of Campus Sustainability, UM
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PRESIDENT'S COMMISSION ON CARBON NEUTRALITY
UNIVERSITY OF MICHIGAN

Table of Contents

EXECUTIVE SUMMARY

Background

University of Michigan (UM) President Mark Schlissel has stated that "human influenced global climate change is the defining scientific and social problem of our age" and has since established the President's Commission on Carbon Neutrality (PCCN). The PCCN's mission is to contribute to a more sustainable and just world by creating approaches and solutions regarding UM carbon emissions that are sustainable (environmentally, socially, and economically), involve the regional community, and can be scaled and replicated beyond the university. Toward that aim, the PCCN is charged with recommending a plan for UM (Ann Arbor, Dearborn, & Flint campuses) to achieve carbon neutrality, which is mandated to be submitted to President Schlissel in the fall of 2020. This is the second of three interim progress reports (including the initial Work Plan) that the PCCN will submit during the process.

Progress Summary

- The PCCN Commissioners include UM faculty, UM students, UM administrators, and external partners. They have met as a group twelve times since the launch in February 2019.

- As recommended by the PCCN, UM signed on to the University Climate Change Coalition (UC3) to share knowledge and ideas to accelerate climate change solutions, and collaborate with local, regional and national institutions working to achieve their climate goals.

- The PCCN hired an external firm, Integral Group, to evaluate potential pathways for evolving heat and power generation infrastructure (e.g., power plant, boilers, etc.) toward carbon neutrality on the UM Ann Arbor, Dearborn and Flint campuses.

- Faculty leads and student research assistants have been selected for eight internal analysis teams and have begun investigating key topics, including bio sequestration, building standards, campus culture and communication, commuting, energy consumption policies, external collaboration, food, and university travel. Membership of these analysis teams includes participants from all 3 campuses.

- The Commission has formed several additional subgroups to explore other key issues, including social justice considerations, carbon offsets, carbon accounting, and vehicle fleet electrification.
  - The carbon accounting subgroup is addressing, as part of its work, the carbon intensity of methane leakage in the natural gas supply chain.

- In addition to the 17 commissioners, there are currently 75 UM faculty, staff, students, and external consultants working directly on the project, plus many advisors both internal and external to UM.

- The PCCN has conducted a range of engagement activities since launching its work in February, including:
  - Hosting three public community forums on the Ann Arbor campus that included Q&A with the co-chairs and small table break-out conversations around specific topics and questions.
  - Sponsoring a special public Q&A session with President Schlissel in April 2019.
  - Engaging (via Co-chairs) with the Dearborn campus strategic planning process and giving a presentation to administrators, faculty and students on the PCCN's mission, progress and how they can get involved.
  - Working (via Co-chairs) with the Chancellor of the Flint campus to hold an informational meeting with Flint faculty and students on the PCCN and its progress.
  - Working with the City of Ann Arbor to design and deliver town-gown fora focused on our interconnected carbon neutrality interests.
  - Obtaining feedback from the Student Advisory Panel on multiple public documents prior to finalization.
  - Consulting with various other advisors (UM faculty, staff, and external experts) on specific issues related to the Commission's work.

- The PCCN website complements and reinforces the Commission's direct outreach efforts with:
  - A public comments portal for community members to share ideas, and a synthesized and categorized summary of all 157 public comments received to date.
  - Video recordings and slide presentations of public events
  - Co-chair summaries for all Commission meetings, with meeting slide presentations posted.
  - An updated FAQ webpage with answers to many questions that are frequently asked by students and other community members.

PRESIDENT'S COMMISSION ON CARBON NEUTRALITY
UNIVERSITY OF MICHIGAN

FALL 2019 INTERIM PROGRESS REPORT

Overview of the Charge

UM President Mark Schlissel launched the President's Commission on Carbon Neutrality (PCCN) with the overarching goal of contributing to a more sustainable and just world. The PCCN's purpose is to recommend a plan for UM to achieve carbon neutrality that includes defining a goal for, and clarifying parameters of, UM carbon neutrality; and outlining a timeline, pathway and approaches for achieving that goal that:

- are environmentally sustainable, involve the regional community, and create scalable and transferable models;
- include the participation and accountability of all members of the university community; and
- are financially responsible in the context of UM's mission of education, research and service.

Phases of the Work

The first phase of the PCCN's work focused on defining the many dimensions of the challenge, developing a structure and work plan to effectively address them, securing the expertise needed to carry out robust analyses across multiple geographies and subject areas, and getting that work underway. Commission meetings have also focused on establishing a shared baseline for understanding key issues among all commissioners, which will be critical when deliberations take place later in the PCCN process. This level-setting phase will continue into early 2020, in conjunction with the development of wide-ranging analyses that will inform Commission recommendations. This will shift to an active deliberation phase in the spring of 2020, when the PCCN will digest the analyses and guidance emerging from the various streams of work. In the fall of 2020, the PCCN will finalize its recommendations and draft its final report, which is to be delivered to President Schlissel by the end of the Fall 2020 Semester. Prior to submission, the draft report will be open for public comment. More detail on the evolution of the PCCN's work is available in the final section of this report titled: "Next Steps".

Commission Timeline

	Fall '18	Winter '19	Spring '19	Summer '19	Fall '19	Winter '20	Spring '20	Summer '20	Fall'20
President announces Commission	complete								
Online comments forum open	complete	complete	complete	complete	in process	pending	pending	pending	pending
Commission formed and work begins		complete							
Commission meetings		complete	complete	complete	in process	pending	pending	pending	pending
Community engaged sessions		complete	complete		in process	pending	pending		pending
Advisory Panel consultation		complete	complete	complete	in process	pending	pending	pending	pending
Analysis Team work					in process	pending	pending		
Interim Progress Reports			complete		in process		pending		
Draft final report writing								pending	pending
Public comment period and report revision									pending

complete in process pending

Emissions Scope Categories

Established in 2011, UM's current 2025 greenhouse gas (GHG) reduction goal is concerned only with scope 1 emissions (those generated on campus) and scope 2 emissions (those associated with purchased electricity), and is limited to the Ann Arbor campus. To date, the PCCN has held several discussions of scope, and it expects to recommend that some scope 3 emission categories (those occurring indirectly as a result of university-related activities) also be included in future UM accounting and goals, and to recommend strategies for addressing them.

Scope 3 emissions are more complex because they are challenging to measure and not under the university's direct control. Commission recommendations regarding which scope 3 emission categories should be included in future UM accounting and goals, along with associated timelines, will be contained in the PCCN's final report, and will be based on two primary factors: 1) UM's ability to confidently estimate its emission levels, and 2) UM's ability to exert direct influence on the emission category.[1]

The table below illustrates the PCCN's preliminary assessment along these two dimensions:

UM's Ability to Directly Influence Emission Levels (*without offsets*)

Ability to Confidently Estimate Emission Levels	High	Med-Hi	Med-Lo	Low
High	• Central Power Plant • Boilers & Other Stationary • U-M Vehicle Fleet • Maintenance Equipment	• Purchased Electricity	• Waste Disposal	
Med-Hi		• Methane losses (on campus)	• Commuting • UM-sponsored Travel	• Methane losses (supply-chain) • Electricity T&D losses
Med-Lo			• Compressed Gas in Labs • Refrigerants	• Food Purchasing
Low				• General Puchasing

scope 1 scope 2 scope 3

Several work streams are underway to address the various scope categories noted above. For example:

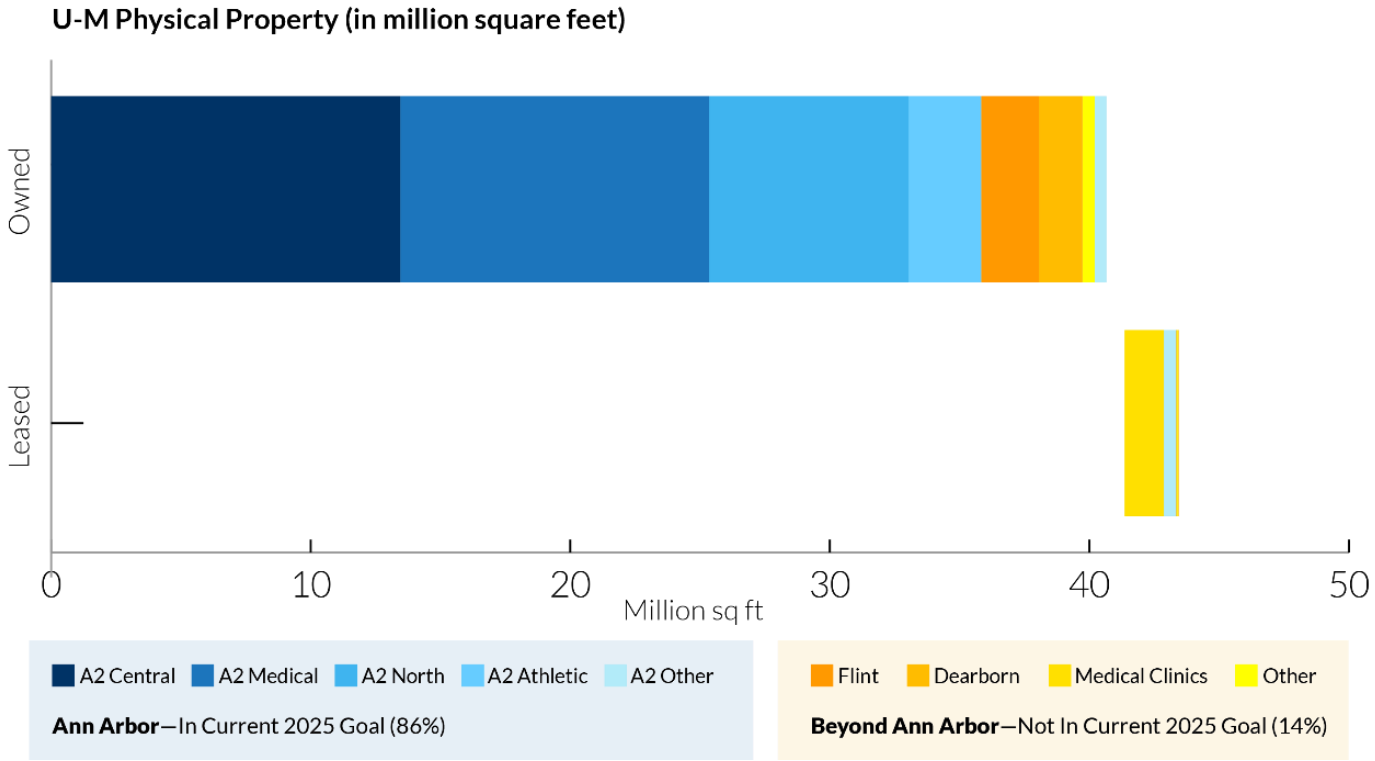
- Options for transitioning the Central Power Plant, boilers, and other stationary sources to carbon neutral alternatives are being analyzed as part of a heat and power infrastructure alternatives analysis (see "External Analyses" section below and Appendix A)
- Methane leakage, electricity transmission and distribution (T&D) losses, and UM's vehicle fleet are being explored through commission subgroups (see "Subgroups" section below and Appendices B and C)
- Purchased electricity, waste disposal, compressed gases and refrigerants will be handled at the commission level, with subgroups likely tasked with consulting experts and providing guidance on these issues.
- Commuting, food purchasing, and UM-sponsored travel each have a dedicated analysis team (see "Internal Analysis Teams" below and Appendices D, E and F.

[1] As directed by President Schlissel, endowment investments are not included in the PCCN's scope of work and therefore they will not be addressed by the PCCN. In addition, the PCCN has determined that emissions associated with off-campus student housing are beyond UM's footprint and accounting, but the PCCN is interested in exploring ideas for partnering with the City of Ann Arbor to help mitigate these emissions.

With regard to scope 3 emission categories, the PCCN seeks to identify actions that could be taken to decrease emissions in all categories illustrated, but mitigating them entirely would require both accurate accounting and the application of carbon offsets. As part of its work, the PCCN will consider whether carbon offsets should be part of a UM plan, and if so, under what circumstances and parameters. Extensive discussion of offsets with a diverse panel of experts has yet to take place, but is expected to occur in the coming months.

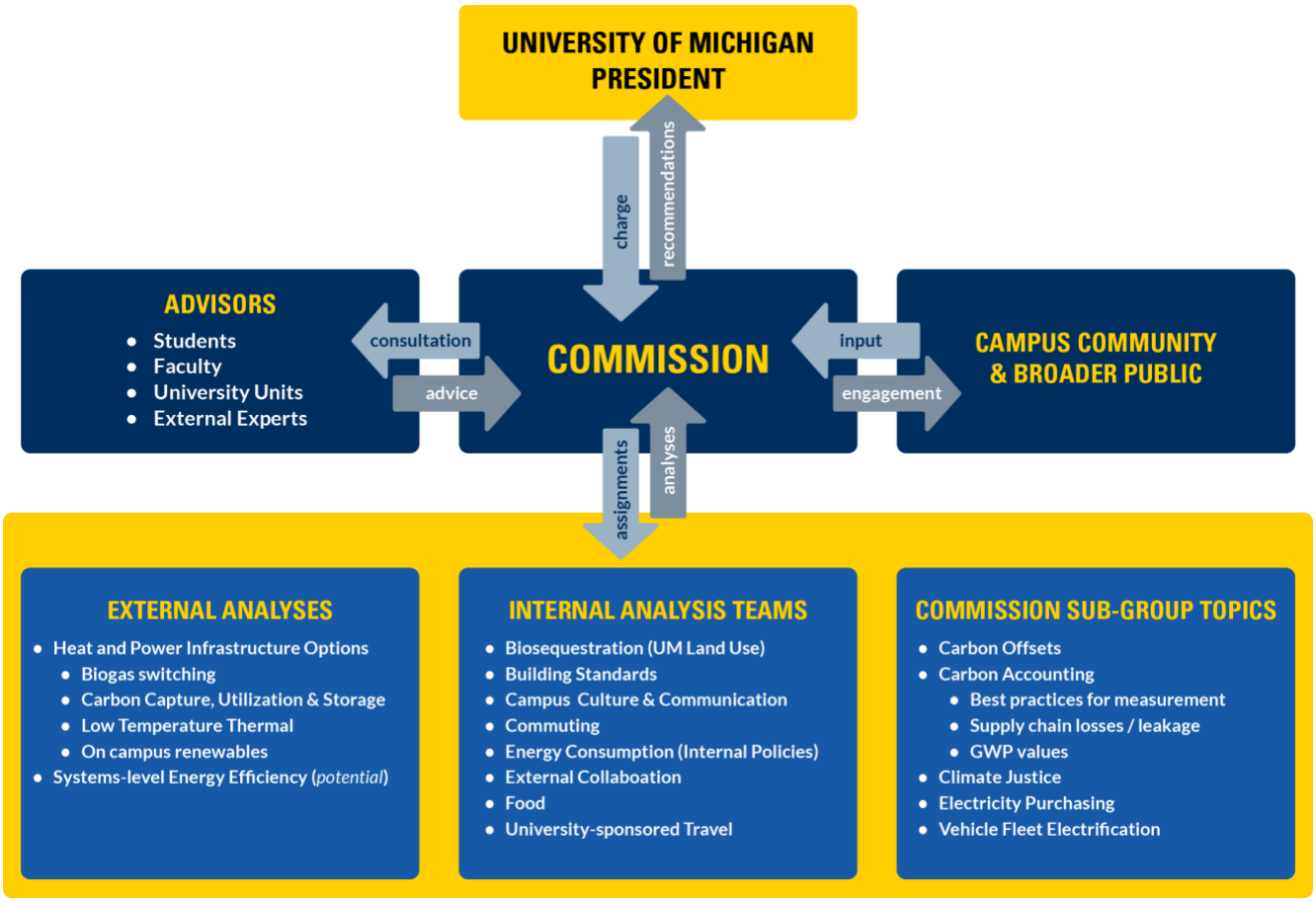
Geographic Scope

While UM's current 2025 GHG reduction goal is applicable only to the Ann Arbor campus, the PCCN's work will include both the Flint and Dearborn campuses. The Commission is considering the ramifications of including all UM-owned off-campus properties, as well as UM-leased properties where utility bill data are available. The PCCN will explore whether sustainability standards should apply to leased properties so that each lease positively contributes to UM's future goals. The table below illustrates the extent of UM's physical plant.



Commission Structure

The PCCN's work is multi-faceted and complex, which necessitates a structure comprising many coordinated groups, including the core Commission, groups of advisors (students, faculty, staff/units, and external experts), the campus community and broader public, and several internal and external analysis teams and subgroups to dive deeper into specific topic areas. The following figure illustrates the PCCN structure; the various roles are described in more detail below.



Commissioners

Co-chaired by UM Professors Stephen Forrest and Jennifer Haverkamp, the Commission includes 17 members from both within and outside UM, representing faculty, administration, students, the community, and the utilities. These Commissioners will collectively recommend to the President a plan for UM to achieve carbon neutrality that defines parameters, establishes goals and associated timelines, and outlines approaches for achieving those goals. In developing this plan, many analyses are being delegated to specialized teams, as illustrated above and as described below. Drawing from these analyses, and with input from many advisers and stakeholders, the Commissioners will synthesize the various work streams with the goal of constructing a carbon neutrality framework that is comprehensive, affordable, sustainable, equitable, inclusive, transparent, and scalable.

Subgroups

In the course of its work thus far, the PCCN has constituted various subgroups to drive progress more efficiently than would be possible meeting only in plenary sessions. Commission subgroup topics currently include the following, and others may be formed during the process in response to identified needs:

The Social Justice subgroup is exploring social equity impacts arising from potential Commission recommendations, and how these may be addressed in efforts to achieve carbon neutrality (see Appendix G). The subgroup will interface with analysis teams to help them apply best practices for addressing these considerations in their work.

The Carbon Accounting subgroup is verifying appropriate emissions accounting methods based on current scientific knowledge of global warming potentials, 20- vs. 100-year impact analysis, and the impacts of supply chain losses. The group has also been tasked with examining fugitive methane emissions from natural gas supplies from their point of origin to delivery on the campus. At President Schlissel's request, the group compiled information on this issue, and a memo delivering their analyses can be found in Appendix B.

The Vehicle Fleet Electrification subgroup is investigating benefits and challenges in shifting UM's buses and other vehicles to electric battery technology (see Appendix C). The group is working closely with UM Facilities and Operations on possible design and funding options, and the PCCN is supportive of pursuing the concept.

Analysis Teams

As described in more detail below, many topics require specialized research and analysis that will be conducted by external firms, or by internal analysis teams comprising faculty, students, and staff, in consultation with external advisors and key stakeholders. All analyses conducted by external and internal teams will be submitted to the Commission for consideration and potential inclusion in PCCN recommendations.

Internal

Eight internal analysis teams have been formed to address a variety of issues central to achieving the goal of carbon neutrality. The topics include:

- Bio sequestration
- Building standards
- Campus culture and communication
- Commuting
- Energy consumption policies
- External collaboration
- Food
- University travel

Each internal analysis team is led by one or two UM faculty members, staffed by UM students with relevant knowledge and training, and charged with collaborating closely with senior UM staff who have relevant responsibilities and expertise. The eight internal analysis teams are fully staffed and have begun their work. The eight different team kickoff meetings took place between October 15 and November 4. Their initial workplans have been submitted to the Commission and are included in the appendices (linked above). Each team will provide periodic updates to the Commission through their check-in reports, and an interim progress report. A PCCN staff member attends 1-2 of the individual

team meetings each month to best support the internal analysis work, and keep the Commission in the loop on the teams' progress and various workstreams. The teams will report to the Commission in January 2020 on their progress, and conclude their analyses in April 2020 with a formal report and Q&A session with the Commission. IAT reports will be made public as appendices to the final Commission report. For more information on the structure, timeline and deliverables of the internal analysis teams, see Appendix M.

External

After forming a subgroup to shape the scope of work, the PCCN issued a request for quote (RFQ) in July 2019 seeking an external firm to evaluate potential pathways for evolving UM's heating and power generation infrastructure toward carbon neutrality. See Appendix A for the full Heat and Power Infrastructure RFQ. In October, the Commission selected Integral Group to complete the work, which will run through April 2020. Integral Group has completed several similar studies at campus- and city-scale in locations within and outside the United States. The project, which is being supported by a range of UM Facilities and Operations staff, will follow a four-stage process:

1. Developing in-depth knowledge about historic energy consumption and campus infrastructure characteristics;
2. Leveraging information to create a dynamic, iterative process to explore and analyze a range of strategies;
3. Selecting several options for conceptual design, modeling pinpoint emissions reductions, and financial analysis;
4. Delivering a plan that provides a roadmap for decarbonizing UM's heat and power infrastructure.

Other external analyses may be commissioned in response to identified needs. One potential analysis under discussion is a systems-level approach to energy efficiency for existing facilities. To explore this path, the Commission convened a group of UM faculty with relevant expertise to consider what should be included in the analysis. The next steps will be to further focus the scope of work to see if such an analysis will add significant value beyond the work already being conducted by the Integral Group and other energy efficiency efforts on campus. Two Internal Analysis Teams (Building Standards and Energy Consumption Policies) are also conducting relevant work in this area.

Advisors

The President's charge to the PCCN envisioned the creation of four "Advisory Panels". The general intent was to ensure the PCCN involved critical expertise and a wide range of stakeholders in the work, recognizing that the PCCN membership, while diverse, did not represent all the perspectives needed. Determining the panels' respective roles and how they should be constituted was placed within the PCCN's mandate.

As illustrated above, the structure established by the PCCN has multiple dimensions, including subgroups and analysis teams, and now has approximately 75 people working directly on the project (see Appendix N for more information). The analyses of the various subgroups and teams will also include input from a wide array of internal and external experts and stakeholders. This direct involvement of UM faculty, students, staff, and external experts in PCCN analysis teams and subgroups, which was not foreseen when the charge was issued, largely satisfies the original intent of the "Advisory Panels." The PCCN nevertheless sees considerable additional value in gaining the broad-based perspectives of UM students, faculty, and organizational units, with each bringing a unique and important voice to inform the overall work. Current plans for engaging each of these groups are as follows:

Students: A group of student advisors has been active throughout the process, providing perspectives on Commission-related matters and documents. It was originally conceived that this group would also provide research contributions on specific topic areas – a role that is now being fulfilled through student participation on the internal analysis teams.

Faculty: As originally conceived, the purpose of this group was to provide expert contributions on specific topic areas – a role that is now being largely fulfilled through faculty leadership of the internal analysis teams and through faculty participation on PCCN subgroups. However, the Commission plans to convene a separate, more broadly representative group of faculty to provide feedback and guidance, especially in the later stages of the process when recommendations are taking shape.

Staff/Units: As originally conceived, the purpose of this group was to provide key perspectives, information and data on specific topic areas – a role that is now being fulfilled through staff collaborations with internal analysis teams. However, the Commission plans to convene a group composed of key administrators to provide perspectives on potential implications for their units and the people who work within them. This group will be engaged in the latter half of the PCCN process, when recommendations are taking shape.

External Experts: The purpose of this group is to provide key perspectives, information and data on specific topic areas. These individuals will constitute a wide range of expertise advising the PCCN and analysis teams throughout the process. Given that each of these individuals will be called upon to share expertise on a specific topic, the PCCN does not envision these advisors meeting as large group, though bringing together small groups of advisors on specific topics may be warranted.

As the Commission receives results from the analysis teams and begins deliberations in the spring of 2020 (see PCCN timeline), input from the student, faculty and staff advisors will become increasingly important. This will include check-ins at key milestones and at times when the Commission may be "stuck" on a particular issue. These advisors may bring issues to the PCCN for consideration, and will have opportunities to review PCCN reports before they are made public. They may also direct topically-focused advice to internal analysis teams to inform their work. To help ensure effective communication throughout the process, these advisors also serve as critical conduits of information between the constituents they represent and the Commission.

Community Engagement

Since launching its work in February, the PCCN has conducted several public engagement activities designed to educate the community on the PCCN activities and to garner input and ideas from a wide range of stakeholders. This included three public community forums (March 11, April 3, and September 25) on the Ann Arbor campus, which involved Q&A with the co-chairs and small table break-out conversations around specific topics and questions where notetakers at each table documented and collected suggestions and recommendations.

All ideas received are summarized and published online, and more detailed ideas have been shared with relevant analysis teams. There were 397 total registrations across these three events (186 students, 49 faculty, 109 staff, and 53 community members), although actual participation was

unfortunately lower due to "no shows". The Commission also hosted a special public listening session with President Schlissel on April 9, 2019, where he took questions from the audience. Video recordings of all these events are available here.

On October 18, 2019, the PCCN Co-chairs presented to faculty, staff and students at UM-Dearborn as part of their campus strategic planning process. A similar engagement event is being planned for the UM-Flint campus.

On October 21 and 22, several PCCN affiliates served as judges for a Ross School (Zell-Lurie Institute) business pitch competition, where co-chair Haverkamp delivered the keynote on the PCCN's work. As part of the core curriculum, all BBA juniors worked in teams to develop entrepreneurial solutions to address carbon neutrality in the areas of building standards, energy consumption, transportation, and university dining. Ross selected this year's topic in direct response to the creation of the PCCN, and as a result approximately 600 UM students gained practical experience in productively addressing the challenges of carbon neutrality.

As a part of its recent commitment to joining UC3, the university will be working with the City of Ann Arbor and other area constituents to design and host a community engagement event focused on intersecting goals for carbon neutrality in the local area.

Throughout their work, analysis teams will engage with a variety of internal and external stakeholders related to their specific research topics and all engagement is being tracked and documented.

The PCCN website serves to complement and reinforce the Commission's in-person engagement efforts with a comments portal that has received 157 submissions to date. The Commission has also published a synthesized and categorized summary of all public comments to date, posts co-chair summaries for all commission meetings, and an updated FAQ page which answers many of the questions that are frequently posed by students and community members.

Next Steps

The PCCN has been in its first phase of work since February 2019. This phase focused on better defining the multi-dimensional scope of work, developing an organizational structure to carry out the work, securing the expertise required to complete the extensive analyses, and beginning to establish a shared baseline understanding for all commissioners on key topics relevant to their ability to make informed recommendations for UM's path to carbon neutrality.

During the PCCN's second phase of work (Nov. 2019 – Apr. 2020), PCCN analysis teams – internal and external – will conduct research on their topics, consult a wide range of experts and stakeholders, develop recommendations to present to the Commission, and draft detailed reports describing their work along with recommendations.

Commission meetings during this phase will serve two primary purposes:

1. Advising and tracking the analysis teams. This will include learning from the analysis teams (internal and external) about the directions their work is heading, and what types of recommendations are likely to emerge from their work. This will allow commissioners to provide critical feedback to analysis teams that can be factored into their work and final recommendations.
2. Continuing to establish a shared understanding for all commissioners on key topics that are relevant to UM's path to carbon neutrality. This common baseline will be critical when the PCCN's deliberation phase begins in the spring of 2020. Key topics to be explored will include, among others:
    a. UM budget model and associated decision-making processes
    b. Carbon offsets and their various characteristics, levels of quality, and future supply and cost
    c. State of Michigan policy considerations
    d. Plans for utility-scale natural gas transition (non-electric)
    e. Effective collaborative mechanisms with the external communities, particularly the cities of Ann Arbor, Dearborn, and Flint, Washtenaw County, and the State of Michigan.

On this last point, phase one engagement activities focused primarily on introducing the Commission's work to, and soliciting ideas from, the community. In the next phase, engagement will focus more specifically on informing the various analyses now underway. During this time, Commission subgroups will also continue to make progress on their respective areas of focus. Through the course of all of these activities, the Commission may identify opportunities it believes the university should act upon in the interim, which will be shared with the President for consideration as they arise. The PCCN's next interim progress report will be delivered in the spring of 2020.

The third and final phase of PCCN's work will begin in the late spring of 2020 and continue through the Fall 2020 semester. During this phase, internal and external analysis teams will deliver their final reports and recommendations. After thoroughly examining the reports, including Q&A sessions and consultations with relevant teams and individuals, the PCCN will deliberate on and develop recommendations for carbon neutrality at UM. This process will be informed by the final recommendations of analysis teams, Commission subgroup analyses, conversations with, and presentations by topical experts, input from various groups of advisors, and public comments. Engagement during this phase will focus on understanding the wide range of stakeholder-related considerations associated with potential recommendations, and a solicitation for public comment on the draft final report. The PCCN will issue its final report with recommendations in the fall of 2020.

The recommendations in the final report will include, but will not be limited to:

- The scope of UM carbon neutrality, including emission types and geographic boundaries
- A carbon neutrality timeline for emission scope categories included within the goal-setting framework
- Pathways and specific strategies for moving toward carbon neutrality across all emission scope categories analyzed as part of the PCCN's work
- Updated carbon accounting methods and emissions baselines reflecting the best available science
- If and when carbon offsets should be used, with relevant guidance regarding quality criteria
- Financial costs/benefits, organizational challenges/opportunities, and stakeholder implications associated with the various recommendations
- Critical next steps for moving UM swiftly forward towards carbon neutrality and for maintaining a carbon neutral university over the long term.

APPENDICES

APPENDIX A

Heat & Power Infrastructure RFQ
Introduction
University of Michigan (UM) President Mark Schlissel established the President's Commission on Carbon Neutrality (PCCN) to recommend a timeline and pathways for UM to achieve carbon neutrality across multiple campuses. Central to its mission, the PCCN seeks to contribute to a more sustainable and just world by creating approaches and solutions regarding UM carbon emissions that are financially, environmentally and socially sustainable, involve the regional community, and create scalable and transferable models. The PCCN has published a comprehensive work plan outlining its approach, which can be found online at: http://sustainability.umich.edu/media/files/PCCN-Work-Plan-Overview-050119.pdf

As a critical component of the PCCN's work plan, it seeks help from an external firm with deep expertise and experience in developing concept studies for large and complex institutions to evaluate potential pathways for evolving heat and power generation infrastructure toward carbon neutrality. Demand-side management approaches are not within the scope of this particular RFP.

Project Timeline
Phase 1 (Oct '19 – Dec'19)
- Work with a small UM team to collaboratively scope productive approaches for conducting the analysis, including a plan for ongoing engagement throughout the project
- Identify options for carbon neutral heat and power generation infrastructure including but not limited to: low-carbon and carbon free fuel sources; conversion to low-temperature district heating, carbon capture, etc.
- Prioritize and recommend optimal strategies for the various campus locations and facility types based on a set of screening criteria likely to include technical feasibility, greenhouse gas emissions reduction, capital and operating costs, disruptions to campus activities, and other risks and uncertainties.

Phase 2 (Jan '20 - April '20)
- Provide in-depth planning guidance on the optimal strategies that address a wide range of considerations, including but not limited to:
    - Resultant greenhouse gas reductions
    - Financial estimates (e.g., capital cost, operating cost, payback, NPV, IRR, total cost of ownership)
    - Optimal implementation timelines considering current realities, technology cost trends, etc.
    - Implementation disruptions to campus operations (both critical and non-critical)
    - Building level considerations across wide-ranging facility types (healthcare delivery, high-tech laboratories, student residential, classroom, office, etc.)
    - Scale and reliability requirements associated with mission critical operations
    - Key considerations associated with social equity and people-oriented impacts

Selection Criteria
- The selected vendor will:
    - Clearly articulate an understanding of the challenge
    - Clearly articulate a work plan that inspires confidence and demonstrates innovative and creative approaches
    - Demonstrate significant experience successfully executing similar projects, with relevant examples provided

- Exhibit exceptional expertise as demonstrated by team member resumes
- Deliver a compelling on-site presentation (by invitation)
- Submit a cost-competitive proposal relative to the scope of work

Deliverables

- Ongoing meetings and workshops with UM team (and external partners as needed)
- Interim outlines and drafts
- Interim Report (Dec 2019)
- Final Report (April 2020)

APPENDIX B

To: President Schlissel
From: Stephen Forrest and Jennifer Haverkamp, PCCN Co-Chairs
Re: Methane Leakage in Natural Gas Supply Chain
Date: November 8, 2019

The PCCN established a subgroup to respond to your request to better understand the issue of methane leakage in the natural gas supply chain and its implications for U-M. To summarize the findings of this subgroup, their analysis concludes that after accounting for methane leakage throughout the natural gas supply chain, the expansion of U-M's Central Power Plant (CPP) will significantly reduce U-M's overall Greenhouse Gas (GHG) emissions relative to "business as usual". Also note that methane leakage in the supply chain is one of many Scope 3 emissions categories, none of which were included in UM's 2025 GHG goal or factored into the setting of its corresponding 2006 baseline. Accordingly, U-M remains on track to meet its 2025 GHG goal as it was defined in 2011, and there is not a reason to adjust that expectation without reopening the 2006 baseline (which isn't possible given current information, not to mention a distraction from the task before us now). That said, going forward, the PCCN is considering Scope 3 emissions, including the contributions from supply chain leakage of methane, which will be included in PCCN recommendations pertaining to carbon accounting. As described below, there are also potential opportunities to better quantify methane leakage in the local distribution system, which we encourage you to consider as a next step.

U-M Professor Eric Kort (Climate and Space Sciences) is a globally respected scholar who specializes in quantifying methane emissions associated with oil and gas production and distribution. At our request, Prof. Kort led the drafting of a memo (Appendix A), which argues that the best estimate of the loss rate from the U.S. natural gas supply chain is 2.3%. This estimate comes from the 2018 study by Alvarez et al.[2] that estimates that for every 100 tons of CO_2 emitted from the combustion of natural gas, methane emissions contribute an additional 27 tons of CO_2-equivalent assuming a 100-year Global Warming Potential (GWP), and an additional 68 tons of CO_2-equivalent assuming a 20-year GWP.

Using this estimate, the Office of Campus Sustainability estimated (Appendix B) the corresponding impacts associated with expanding U-M's CPP. They conclude that the CPP expansion will have an overall positive impact on U-M's GHG emissions, with a cumulative reduction of more than 400,000 metric tons of CO_2 equivalent (CO_2e) expected within the first ten years of operation. Year-over-year GHG reduction benefits associated with the CPP expansion will gradually decrease over time as DTE Energy's fuel mix becomes cleaner.

In addition to this methane leakage analysis, Prof. Greg Keoleian (SEAS) has been investigating other upstream emissions associated with producing natural gas. He has developed a preliminary summary of this issue (Appendix C), which similarly concludes that methane leakage and other upstream GHG emissions do not make natural gas more carbon intensive than coal.

[2] R. A. Alvarez, D. Zavala-Araiza, D. R. Lyon, D. T. Allen, Z. R. Barkley, A. R. Brandt, K. J. Davis, S. C. Herndon, D. J. Jacob, A. Karion, E. A. Kort, B. K. Lamb, T. Lauvaux, J. D. Maasakkers, A. J. Marchese, M. Omara, S. W. Pacala, J. Peischl, A. L. Robinson, P. B. Shepson, C. Sweeney, A. Townsend-Small, S. C. Wofsy, S. P. Hamburg, Assessment of methane emissions from the U.S. oil and gas supply chain. *Science* (2018), doi:10.1126/science.aar7204.

At our request, Prof. Kort identified some actions U-M could take to track local sources of emissions if we wished to develop a more customized methane leakage rate instead of relying simply on a national average rate. Note however that such measurable "downstream" fugitive emissions contribute but a small percentage to the overall emissions, with "upstream" emissions constituting the dominant source. Specifically, we should consider:

1. A Leak Detection and Repair (LDAR) program executed by facilities personnel and the natural gas supply company. This is a mechanism for finding and reducing losses with large mitigation potential, although without the ability to directly quantify the system-wide loss rate.
2. Atmospheric monitoring to quantify total methane emissions from a region, and/or to pinpoint locations with large losses. These measurements can be made via discreet aircraft campaigns, through continuous observations from ground-measurements, or from regular vehicle surveys. We might wish to explore conducting such monitoring in partnership with the local government and extending beyond the U-M campus.

APPENDIX B-1

Methane Emissions and the University of Michigan

Daniel Raimi, Eric Kort, Austin Glass

September 2019

Executive Summary: Natural gas is primarily composed of methane, and combustion of natural gas, like all fossil fuels, produces carbon dioxide. Because methane is itself a much more potent greenhouse gas than carbon dioxide, losses of methane along the natural gas supply chain can compromise the climate benefits of switching from coal-fired to natural gas-fired power plants. Although the latest data show methane emissions exceed U.S. EPA estimates, natural gas power generation, as is planned in the UM power plant upgrade, creates fewer emissions than coal-based power generation. In the long term, achieving carbon neutrality will require eliminating all emissions, including those from natural gas, but in the short term, this transition provides clear climate benefits, even when accounting for the latest science on methane emissions.

Oil and natural gas production have increased rapidly in the United States in recent years due to advances in technologies such as horizontal drilling and hydraulic fracturing ("fracking"). This growth has reduced domestic natural gas prices, and encouraged broader use of the fuel for power generation and other purposes. Because combustion of natural gas produces approximately half as much carbon dioxide (CO_2) as combustion of coal for the same amount of electricity generated, displacement of coal by gas in the power sector has reduced U.S. CO_2 emissions.

Methane's climate impact

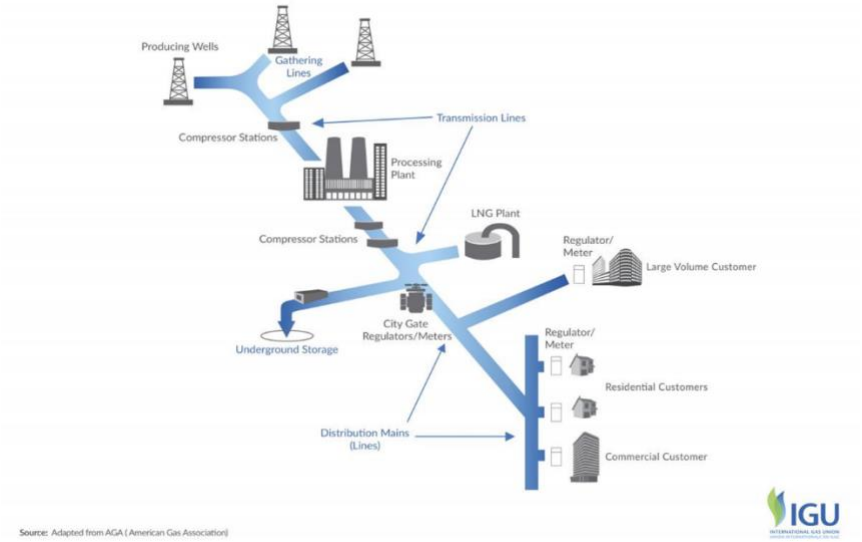
Methane—the primary component of natural gas—is itself a potent greenhouse gas, and a gram of methane (CH_4) traps more heat than a gram of CO_2. However, methane is chemically active in the atmosphere, and as a consequence its lifetime is roughly a decade, much shorter than the effective lifetime of hundreds of years for the relatively chemically inert CO_2. Because of these differing effects, the relative climate impacts of methane and CO_2 vary with the chosen time horizon.

The heat-trapping effectiveness of methane relative to CO_2 is conveyed through its "Global Warming Potential" (GWP). The most recent Assessment Report (AR5) from the IPCC applies what is currently considered the most representative GWP of methane: 34 over a 100-year time frame, and 86 over a 20-year time frame. These GWP values indicate that one ton of methane traps 34 times more heat than one ton of CO_2 over a 100-year time frame, and 86 times more heat over a 20-year time frame (*1*).

The warming associated with methane contributes significantly to the overall climate impact of natural gas, as methane may be released into the atmosphere prior to combustion. If more than approximately 8% of natural gas escapes into the atmosphere before it is burned and converted into CO_2, the climate benefits of switching from coal to natural gas for electric power vanish over a 100-year time frame, and if approximately 4% escapes, those benefits disappear over a 20-year period (*2*).

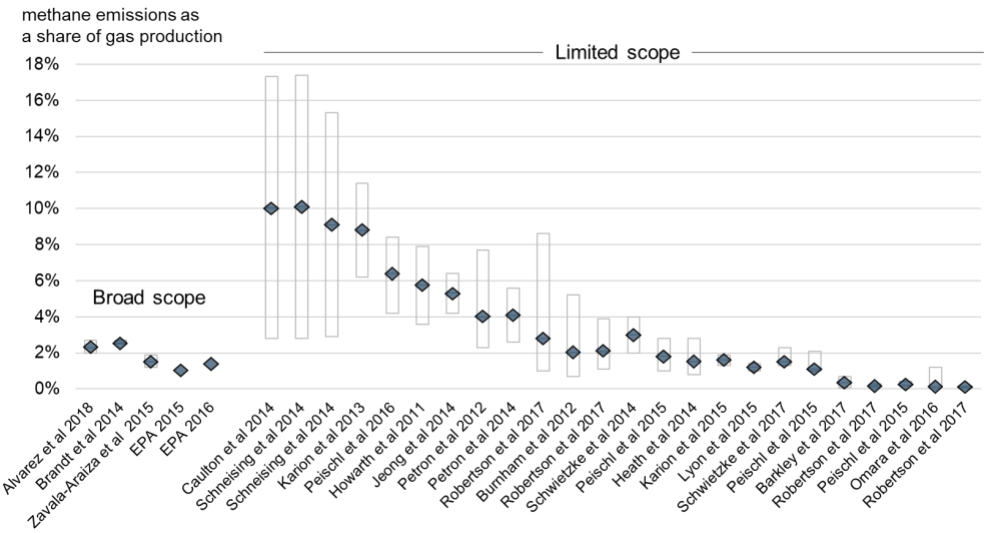
Estimating methane emissions

Methane emissions can occur at virtually every stage of the natural gas system, as illustrated in the figure below.



Methane can escape from leaky valves or malfunctioning equipment at oil and gas well sites, natural gas pipelines, gas processing facilities, and elsewhere. Because there are over 1 million active oil and gas wells, thousands of natural gas processing facilities, and over 2 million miles of natural gas pipelines in the United States, it is difficult to precisely measure the scale of emissions from the whole system.

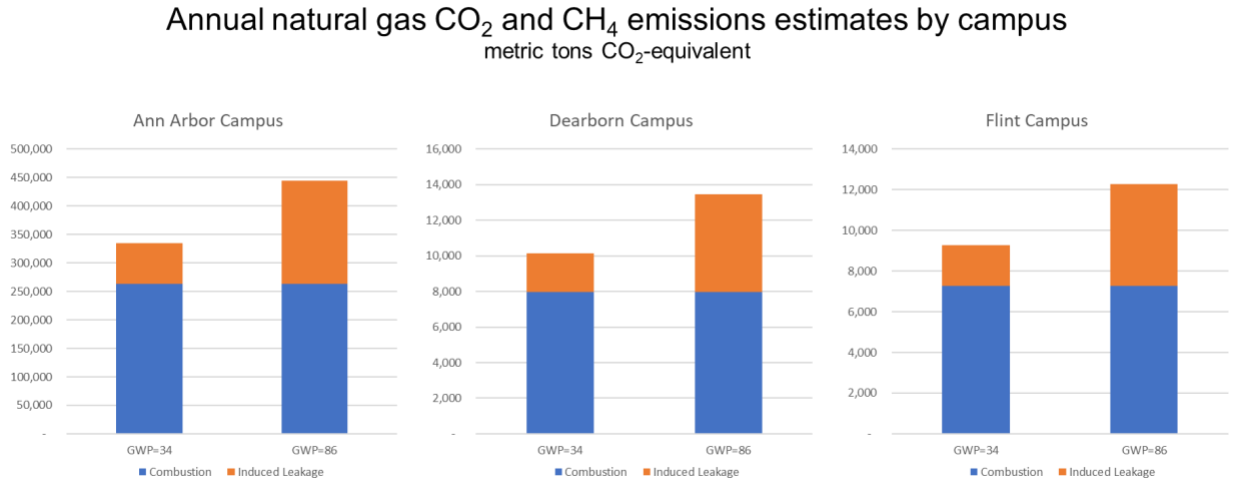
The U.S. EPA, which estimates oil- and gas-related methane emissions each year (*3*), had, until recently, relied on outdated emissions factors in its accounting protocols. In an effort to provide better data, dozens of studies have been carried out in recent years to measure emissions in a variety of locations and from a variety of sources. These studies have yielded a wide range of results, with estimates in some regions as low as 0.1 percent, and others as high as 10 percent or more, as illustrated in the figure below.



The best available summary of this work comes in a recent study from Alvarez et al. (*4*) (including UM co-authorship), which synthesizes the results of numerous studies (many involving UM researchers) carried out across the U.S. This study estimates that roughly 13 Teragrams of methane were emitted to the atmosphere by U.S. oil and gas systems in 2015, equivalent to roughly **2.3%** of domestic production in that year. This is roughly 60% higher than the EPA's estimate for that same year. This is the current best-estimate of the loss rate from the U.S. natural gas supply chain.

Some uncertainty remains in this estimate and they may continue to be revised upwards if new research shows that natural gas storage, local distribution systems, and other downstream infrastructure are 'leakier' than currently estimated. Recent work from UM has indeed shown that cities are 'leakier' than currently estimated (*5*), however these results do not change the overall assessment of using natural gas for power plants.
As summarized by Alvarez et al. (4), although many studies have shown that methane emissions are greater than previously estimated by the EPA, natural gas power plants have a lower climate impact than coal plants of the same power output. Further, these studies have highlighted opportunities for reducing loss of methane in the natural gas supply chain.

Implications for the University of Michigan
The above analysis suggests that for every 100 tons of CO_2 emitted from the combustion of natural gas at the University of Michigan or elsewhere, methane emissions contribute an additional 27 tons of CO_2-equivalent assuming a 100-year GWP, and an additional 68 tons of CO_2-equivalent assuming a 20-year GWP. The figure below illustrates the effect of adding both metrics to the existing CO_2 footprint of the University's annual natural gas use.



Opportunities
This analysis assumes the natural gas used at UM is lost at the average U.S. rate. Further work could be done to track the sources of the natural gas used at UM, and create a custom loss rate for UM's natural gas supply chain. This could involve tracking the natural gas chain for campus and using production-basin-specific loss rates, and could involve new measurements along the supply chain, from the production field to end-use in Ann Arbor, in order to directly observe loss rates. At this point it is

unclear if tracing the origin of natural gas used at UM is tractable, or if the nature of the natural gas supply chain too thoroughly obfuscates the originating production basin.

Options for measurement action that could be taken in Ann Arbor range from practical to more experimental. Examples include:

A vigorous Leak Detection and Repair (LDAR) program.
A LDAR would be executed by facilities personnel and the natural gas supply company. This is a mechanism for finding and reducing losses with large mitigation potential, though without the ability to directly quantify the system-wide loss rate. LDAR programs come with some upfront hardware costs, though typically the deployment of personnel for monitoring and repairs represents the bulk of costs.

Atmospheric monitoring (aircraft, stationary ground sites, repeat vehicle surveys).
Atmospheric measurements provide the potential to quantify total methane emissions from a region, and/or to pinpoint locations with large losses. These measurements can be made via discreet aircraft campaigns, through continuous observations from ground-measurements, or from regular vehicle surveys. Perhaps most relevant here would be regular vehicle surveys to map methane values in and around campus, where persistent peaks are indicative of local leaks (https://www.edf.org/climate/methanemaps). Depending on objectives, such a program could involve students or researchers to support the work and hardware costs from ~$10,000 to >$100,000.

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1. G. Myhre, D. Shindell, F.-M. Breon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, G. Stephens, T. Takemura, H. Zhang, *Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge ; New York, 2013).
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3. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2016" (EPA 430-P-18-001, U.S. Environmental Protection Agency (EPA), Washington, DC, 2018), p. various, (available at https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf).
4. R. A. Alvarez, D. Zavala-Araiza, D. R. Lyon, D. T. Allen, Z. R. Barkley, A. R. Brandt, K. J. Davis, S. C. Herndon, D. J. Jacob, A. Karion, E. A. Kort, B. K. Lamb, T. Lauvaux, J. D. Maasakkers, A. J. Marchese, M. Omara, S. W. Pacala, J. Peischl, A. L. Robinson, P. B. Shepson, C. Sweeney, A. Townsend-Small, S. C. Wofsy, S. P. Hamburg, Assessment of methane emissions from the U.S. oil and gas supply chain. *Science* (2018), doi:10.1126/science.aar7204.
5. G. Plant, E. A. Kort, C. Floerchinger, A. Gvakharia, I. Vimont, C. Sweeney, Large fugitive methane emissions from urban centers along the US East Coast. *Geophysical Research Letters*. **0**, doi:10.1029/2019GL082635.

APPENDIX B-2

U-M Central Power Plant Expansion
Greenhouse Gas Emissions Projections

October 1, 2019

Summary

The University of Michigan is expanding its Central Power Plant (CPP) to enhance power reliability and reduce greenhouse gas emissions (GHG), in accordance with a recommendation by the 2015 President's Committee on Greenhouse Gas Reduction. This report summarizes an analysis of factors affecting the CPP's emissions to determine how the expected reductions will change over time.

Findings

- GHG reductions associated with the CPP expansion will lessen over time when factoring in DTE Energy's changing fuel mix and indirect emissions, such as methane leakage and transmission and distribution (T&D) loss.
- However, the expansion will still have an overall positive impact on U-M GHG emissions. A cumulative reduction of more than 400,000 metric tons of carbon can be expected within the first ten years of operation.

Assumptions

Estimates calculated in this analysis are dependent upon the following assumptions:

- The ability of DTE to achieve projected GHG reductions requires a significant shift in utility infrastructure.
- Methane leakage rates and transmission losses may change over time with system efficiency improvements.

Overall Emissions Reduction

Emissions reduction due to CPP expansion ($MTCO_2e$)	2020	2025	2030	2040
Per 2025 GHG reduction goal accounting (including increased natural gas consumption and DTE fuel mix changes)	57,000	38,000	26,000	Zero savings
Including indirect emissions (methane leakage 20-year Global Warming Potential and T&D losses)	52,000	35,000	25,000	10,000

Factors Affecting CPP Emissions Estimates

I. Increased natural gas consumption required due to the CPP expansion – The expansion increases U-M's capacity to generate more energy from natural gas and reduces the amount of coal-based electricity it purchases, *reducing* U-M's overall GHG emissions.

II. DTE fuel mix – DTE Energy (U-M's energy provider) plans to reduce emissions associated with purchased electricity by eliminating coal-burning plants and switching to natural gas and renewable energy by 2040. While this is an overall positive development, it reduces the relative emission savings associated with expanding the CPP.

III. Indirect emissions –Methane leakage associated with the drilling and transportation of natural gas and transmission and distribution losses associated with the delivery of electricity across the grid.

Brief Methodology

I. Estimates of increased natural gas consumption
- Annual increased natural gas consumption: 4,500,000 ccf
- Annual decrease in electricity purchase: 125,000 MWh

DTE fuel mix: estimates based on DTE information provided September 25, 2019.

DTE fuel mix and emission estimates	2020	2025	2030	2040
Coal (% fuel mix)	60	50	40	0
Natural Gas (% fuel mix)	10	15	20	40
Nuclear (% fuel mix)	20	20	20	20
Renewables (% fuel mix)	10	15	20	40
GHG Emissions ($MTCO_2$/MWh)	0.64	0.50	0.40	0.19

II. Indirect emissions

Methane leakage – One analysis by the President's Commission on Carbon Neutrality Carbon Accounting Subgroup suggests that for every 100 metric tons of carbon dioxide ($MTCO_2$) created through natural gas combustion, an additional 68 $MTCO_2$ equivalent of methane is released into the environment as measured by a 20-year *global warming potential (GWP)* or an additional 27 $MTCO_2e$ for a 100-year GWP. Global warming potential refers to the amount that a given gas warms the Earth compared to CO_2 over the same time period.

This analysis assumes the natural gas used at U-M is lost at the *average* U.S. rate. A custom loss rate for U-M's natural gas supply chain could be established by tracking the sources of the natural gas used at U-M.

Methane leakage	2020		2025		2030		2040	
	Conversion factor	Emissions ($MTCO_2e$)	Conversion factor	Emissions ($MTCO_2e$)	Conversion factor	Emissions (MTCO2e)	Conversion factor	Emissions ($MTCO_2e$)
20-year GWP ($MTCO_2e/MTCO_2$ natural gas combustion)	0.68	+16,000	0.68	+16,000	0.68	+16,000	0.68	+16,000
100-year GWP ($MTCO_2e/MTCO_2$ natural gas combustion)	0.27	+6,500	0.27	+6,500	0.27	+6,500	0.27	+6,500
20-year GWP ($MTCO_2e$/MWh purchased electricity)	0.047	-5,900	0.071	-8,900	0.095	-12,000	0.19	-24,000
100-year GWP ($MTCO_2e$/MWh purchased electricity)	0.019	-2,400	0.028	-3,500	0.038	-4,700	0.075	-9,400

Transmission and distribution (T&D) loss – The U.S. Energy Information Administration estimates an average T&D loss of 5% nationally and 5.7% for electricity from DTE. It is calculated as a percentage of electricity purchase.

APPENDIX B-3

To: President's Commission on Carbon Neutrality
From: Greg Keoleian
PCCN Carbon Accounting Subcommittee, chair

Date: November 12, 2019
Re: Methane leakage and other greenhouse gas emissions from natural gas fuel cycle
Cc: Subcommittee members: Austin Glass, Catie Hausman, Ken Keeler, Eric Kort, Geoff Lewis, Daniel Raimi

This memo and attachments provide a summary of the Carbon Accounting subcommittee analysis of upstream (precombustion) greenhouse gas (GHG) emissions associated with the natural gas fuel cycle, including methane leakage.

Two separate analyses were conducted to characterize these GHG emissions based on FY2019 natural gas consumption at University of Michigan Ann Arbor campus:

1. **DEA Analysis** Analysis of methane leakage by Daniel Raimi, Eric Kort, and Austin Glass (DEA). This analysis used methane leakage rates (2.3%) from Alvarez et al. (2018) for natural gas production. See Attachment A.
2. **CSS Analysis** Analysis of precombustion GHG emissions (methane leakage and other sources from the natural gas fuel cycle) by Greg Keoleian and Geoff Lewis at the Center for Sustainable Systems (CSS). This analysis was based on the GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model from Argonne National Laboratory, which has two options for methane leakage (one based on EPA estimates and the other based on adjusted Alvarez et al. (2018) data, called EDF in GREET). See Attachment B.

Notes:

a. The DEA Analysis has a higher value for methane leakage rates than the GREET model used to characterize methane leakage in the CSS Analysis.
b. The DEA Analysis does not include precombustion GHG emissions other than methane leakage.
c. Global Warming Potentials (GWPs) indicate the relative effectiveness of GHGs in trapping the Earth's heat over a certain time horizon. CO_2 is used as the reference gas and has a GWP of one. GWP values used in these analyses differ slightly. DEA used a GWP_{100} (CH_4) = 34; GWP_{20} (CH_4) = 86. GREET uses GWP_{100} (CH_4) = 30 and GWP_{20} (CH_4) = 85, which were used in the CSS analysis. These values are all cited by IPCC in AR5 and reflect different assumptions regarding inclusion of carbon cycle feedback effects and CO_2 effects of oxidized CH_4.

Key Findings

The results of these two studies show the significance of methane leakage and other upstream GHG emissions related to natural gas use and how they compare to natural gas combustion emissions. **Both analyses show that methane emissions and other upstream GHG emissions associated with the natural gas fuel cycle are significant.** Note the combustion related GHG emissions (shown in blue) are the same for all analyses.

The DEA analysis in Figure 1 indicates that methane leakage (shown in orange) increases GHG emissions above natural gas combustion emissions (shown in blue) by 27% for the 100 yr horizon and 69% for the 20 yr horizon cases.

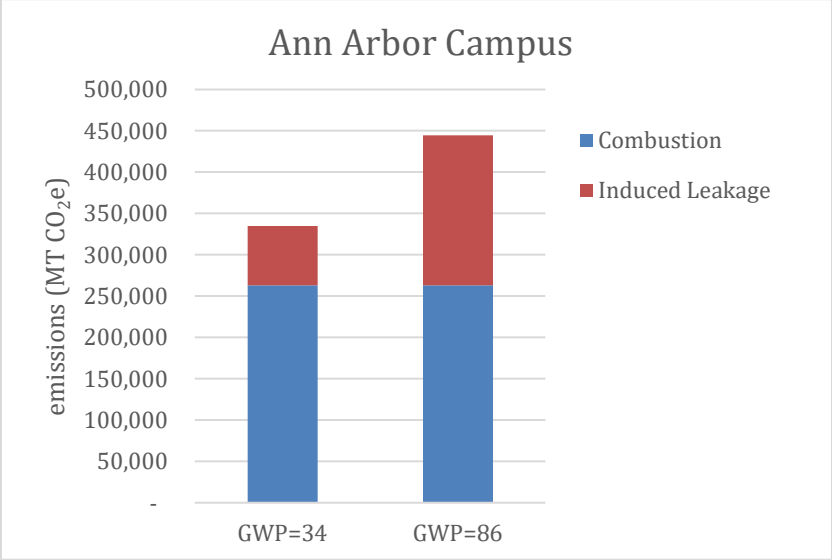

Figure 1 – DEA GHG emissions results for Ann Arbor campus, including NG combustion and CH_4 leakage, using GWP_{100} (CH_4) = 34 and GWP_{20} (CH_4) = 86.

The CSS analysis in Figure 2 indicates methane leakage (shown in orange) and other GHG upstream emissions (shown in grey) relative to natural gas combustion emissions (shown in blue) for EPA and the GREET adjusted Alvarez methane leakage rates and based on 100 yr horizon and 20 yr horizon GWP values. Note in the GREET model that cites Alvarez the methane leakage from natural gas and oil production is allocated according to production of each fuel so this value is less than 2.3% reported by Alvarez and used by DEA. The orange bars for leakage are therefore lower in the CSS analysis compared to the DEA analysis.

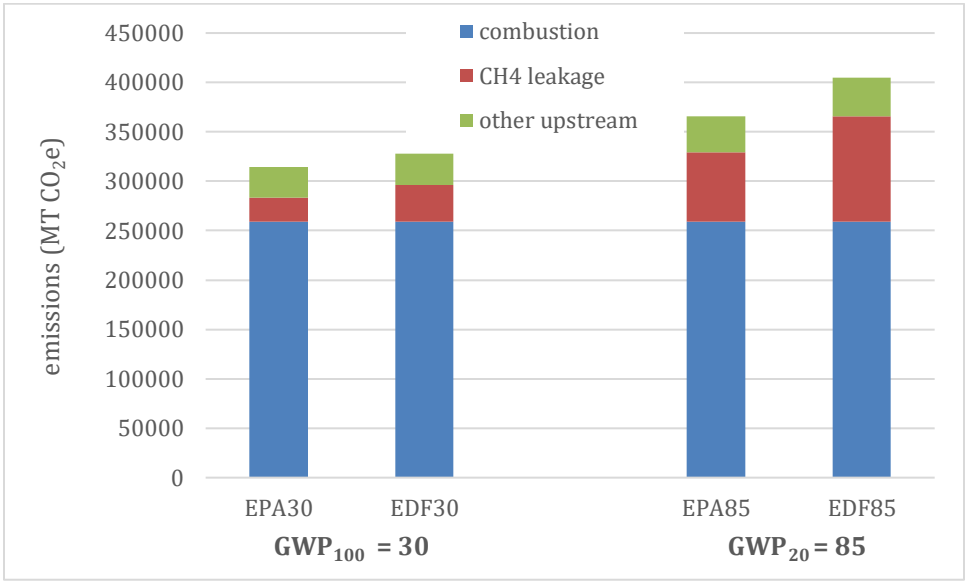

Figure 2 – CSS GHG emissions results for Ann Arbor campus, including combustion, CH_4 leakage, and other upstream emissions, using both EPA and EDF (Alvarez et al. 2018) estimates, GWP_{100} (CH_4) = 30 and GWP_{20} (CH_4) = 85.

For the Alvarez (EDF) case, accounting for methane leakage (shown in orange) and other GHG upstream emissions (shown in grey) increases GHG emissions above natural gas combustion emissions (shown in blue) by 15% for the GWP_{100} and 41% for the GWP_{20} cases.

Accounting for methane leakage and other upstream GHG emissions when comparing electricity from coal and natural gas power plants does not make natural gas more carbon intensive than coal. Coal based electricity is still more carbon intensive than natural gas based electricity. Alvarez et al. (2012), referenced in the memo by DEA, and the GREET model both demonstrate this.

CSS compared natural gas and coal power plants using GREET using both the EDF and EPA methane leakage cases. Values of **GHG intensity for electricity (combustion + all upstream)** that span the range of GHG intensity for natural gas and coal plants in GREET (IGCC denotes integrated coal gasification combined cycle, which is an efficient coal plant) are:

GWP_{100} (EPA)	**NG**	combined cycle 462 g/kWh	simple cycle 747 g/kWh
	Coal	IGCC 981 g/kWh	basic boiler 1062 g/kWh
GWP_{20} (EDF)	**NG**	combined cycle 584 g/kWh	simple cycle 944 g/kWh
	Coal	IGCC 1056 g/kWh	basic boiler 1144 g/kWh

Increasing the output of the UM Central Power Plant will displace DTE electricity but the benefits in terms of GHG savings are significantly reduced when accounting for methane leakage, and will decline over time as DTE's CO_2 intensity shrinks. DTE supplied CO_2 intensity projections for 2019-2040, which are plotted in Figure 3 below. They use both Fleet and Net Short (EPRI) annual accounting methods. The Fleet method divides total generating fleet CO_2 emissions by the sum of dispatchable and non-dispatchable generation, while the Net Short method divides net short emissions (the sum of non-dispatchable and purchased emissions) by adjusted load. These methods are described more fully in an EPRI report commissioned by DTE (EPRI, 2019). DTE's 2018 fuel mix is 64% coal, 19% nuclear, 9% NG, and 8% renewables, and their estimated 2040 mix is 40% NG, 30% wind, 20% nuclear, and 10% solar.

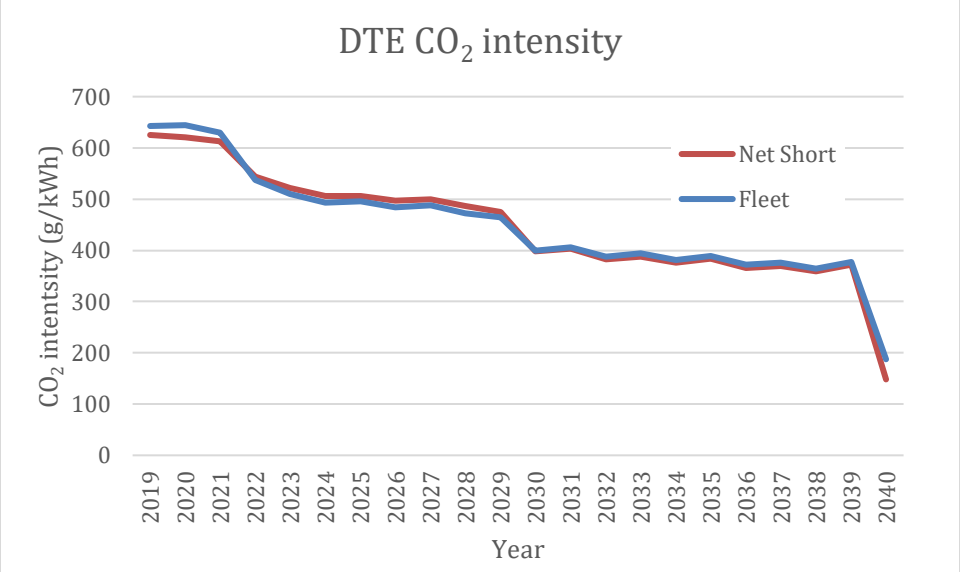

Figure 3 – DTE projected combustion-only CO_2 intensity, 2019-2040, using both Fleet and Net Short methods.

Ken Keeler of the UM Office of Campus Sustainability recently completed a draft estimate of combustion only GHG savings resulting from installation of a new NG combustion turbine at the Central

Power Plant. This estimate includes the increase in CPP GHG emissions due to the new turbine (both combustion and CH_4 leakage based on the DEA analysis), boiler retirement, and the decrease in emissions due to reduced purchases of electricity from DTE, incorporating the changing mix of DTE's generating resources between 2018 and 2040 and including transmission and distribution losses. Ken found that the GHG emission reduction benefit of the NG turbine decreases over time due to DTE shifting to less carbon-intensive electricity generation, but that the overall benefit is positive. His analysis, however, did not include methane leakage from the electricity imported from DTE or the other upstream GHG emissions associated with natural gas combustion.

Related Carbon Accounting Future Work

1. Develop accounting methods and categories for Scope 3 emissions
    a. in collaboration with internal analysis teams
    b. e.g., make recommendations on inclusion of methane leakage and other precombustion emissions; accounting for offsets and RECs.
2. Resolve GWP values and time horizons to use
    a. one option is to report GHG emissions based on both the 100 yr and 20 yr horizon GWP values
3. Explore level of effort by UM and Utilities (DTE and Consumers) to assess and reduce methane leakage in the local transmission and distribution system.

Attachments

A. Note and slides from DEA analysis
B. CSS Analysis of GHG emissions from NG Fuel Cycle (xlsx file)

References

Alvarez, R. A., D. Zavala-Araiza, D. R. Lyon, D. T. Allen, Z. R. Barkley, A. R. Brandt, K. J. Davis, S. C. Herndon, D. J. Jacob, A. Karion, E. A. Kort, B. K. Lamb, T. Lauvaux, J. D. Maasakkers, A. J. Marchese, M. Omara, S. W. Pacala, J. Peischl, A. L. Robinson, P. B. Shepson, C. Sweeney, A. Townsend-Small, S. C. Wofsy, S. P. Hamburg, Assessment of methane emissions from the U.S. oil and gas supply chain. *Science* (2018), doi:10.1126/science.aar7204.

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DTE 2040 estimated generation mix from: https://www.utilitydive.com/news/dte-clarifies-goal-to-cut-carbon-emissions-80-from-2005-levels-by-2050/442948/

Methods to Account for Greenhouse Gas Emissions Embedded in Wholesale Power Purchases. EPRI, Palo Alto, CA. Technical Update 3002015044, March 2019.

APPENDIX C

Fleet Electrification Subgroup

Faculty Lead: Anna Stefanopoulou
Members: Andrew Berki, Stephen Dolen, Austin Glass, Brandon Hofmeister, Gregory Keoleian, William McAllister, Camilo Serna, Missy Stults
Staff support: Juan-Jie Sun, Jason Siegel, John DeCicco

SCOPE OF WORK

Objective: To analyze the operational, financial and environmental implications of, and identify optimal strategies for, converting gasoline and diesel internal combustion engine vehicles (ICEVs) to grid-connected electric vehicles (EVs), including cars, trucks, vans and buses.

Background: The Vehicle Fleet Electrification subgroup of the President's Commission on Carbon Neutrality (PCCN) is analyzing the potential and developing plans for converting U-M operated motor vehicle fleets to electric vehicles (EVs). It is also examining ways for the university to facilitate and encourage EV use by staff, faculty, students and visitors to campus.

The U-M fleet includes the campus bus service ("Blue Bus") fleet; various light and medium-duty trucks and utility vehicles used for operations and maintenance across the U-M campuses; plus cars, vans and other vehicles available to university units for daily rental or for short- and long-term leasing. As of 2018, the U-M fleet accounted for about 7,000 metric tons of CO_2-equivalent greenhouse gas (GHG) emissions, or roughly 2%, of the university's Scope 1 GHG inventory.

Substituting an EV for a gasoline or diesel vehicle in the U-M fleet will zero out that portion of Scope 1 GHG emissions. Depending on how the EV is charged, it would incrementally increase Scope 2 emissions. Analysis is needed to assess net GHG emissions impacts as well as total cost of ownership for the fleet electrification options identified.

Also needed are analyses of opportunities for reducing Scope 3 transportation emissions, which are not under the direct control of the university. For those incurred by individuals travelling to and from campus and in the surrounding community, U-M could invest in charging infrastructure for U-M parking facilities and finding other ways to encourage individual EV use. Scope 3 also includes the GHG emissions associated with goods and services purchased by the university, and the transportation aspects of those emissions could be considered as part of a broader "green procurement" strategy.

Tasks

1. Blue Bus electrification. Prior consultation with U-M Facilities and Operations has identified an opportunity for a pilot project to establish electric bus ("eBlueBus") service on key route, replacing

diesel buses that are now serving the route. Partial funding for such a project might be obtained as part of VW settlement funds administered by the State of Michigan.

a. Analyze options for various eBlueBus pilot project choices (type and number of buses, routes served, charging system needs) to project operational, financial and environmental impacts.

b. Write a report on eBlueBus options with recommendations for project design (Dec 13, 2019).

c. Write a proposal for State of Michigan VW settlement funds to support eBlueBus acquisition (have proposal materials ready in mid-December 2019 to enable fast response when RFP is released).

2. Other electrification opportunities. Assess other U-M owned or managed vehicles and identify opportunities to encourage individual EV use by faculty, students and staff.

a. Gather data on the existing characteristics and usage of these other U-M fleet vehicles, including those used for campus operations, renting and leasing to university units and vanpools, conferring with the Logistics, Transportation and Parking (LTP) office to understand needs and issues.

b. Analyze options for EVs to replace additional (non-bus) fleet vehicles, identifying the types of EVs now or soon-to-be available suitable for such applications, and evaluating their costs and benefits.

c. Analyze EV charging infrastructure requirements to serve both additional EVs in the U-M fleet and private EVs used by U-M staff, students and visitors.

d. Explore options to encourage students, faculty and staff to switch to EVs, connecting U-M infra-structure deployment to programs offered by state, utilities and OEMs.

e. Examine opportunities for appropriate use of e-bike and electric scooters to replace automobile use without degrading the environment for non-motorized travel.

f. Initiate PCCN discussions on the issues associated with reducing Scope 3 transportation sector GHG emissions as associated with university procurement of good and services.

g. Write a report summarizing additional opportunities for fleet electrification, with recommendations for EV acquisition and the development of charging infrastructure for serving both U-M owned and managed vehicles as well as private EVs in U-M parking facilities (March 2020).

APPENDIX D

Commuting Team

Faculty Lead: Jonathan Levine

Proposed Scope of Work

The commuting team will develop an approach to measuring the carbon impact of the commute to the three University of Michigan campuses; will study approaches used by peer institutions to reducing the carbon impact of the commute and their effectiveness; will adapt promising approaches used elsewhere to the specific conditions of the UM campuses and their surrounding areas; and will develop prioritized recommendations for reducing the commute's carbon footprint, including metrics and indicators for tracking progress in order to operationalize the decision of the President's Commission on Carbon Neutrality to incorporate the commute to campus within the scope of its measurements for tracking the University of Michigan's progress toward carbon neutrality.

Measuring the commute's carbon impacts will make use of the Sustainability Cultural Indicators Project (SCIP) survey, and the team will recommend modifications and possible expansion of the survey for its tailoring to this purpose. The team will augment this analysis with an approach to tracking the distance traveled by faculty, staff, and students to campus and its change over time. Reducing the commute's carbon impact involves reducing emissions associated with using a car, including policies and investments to affect the energy efficiency of the vehicle mix used for the commute. More significantly, it involves modifying University policies that encourage car use, including parking pricing and development; decisions regarding the transit, pedestrian, and cycling environment; and land-use planning.

The team will also explore options in carpooling and new mobility. The team will simultaneously consider carbon-mitigation and environmental-justice goals and will incorporate both in its formulation of policy recommendations. University stakeholders include Logistics, Transportation and Parking; Architecture, Engineering and Construction; and similar bodies for the Flint and Dearborn campuses. External stakeholders include the City of Ann Arbor, Ann Arbor Area Transportation Authority, SMART, and the Flint Mass Transportation Authority, and University of Michigan commuters

APPENDIX E

Food Team

Faculty Co-Leads: Lesli Hoey and Andy Jones

Proposed Scope of Work

The Food Analysis Team sees our scope of work as largely focusing attention on the role that dining services plays in shaping the University of Michigan (UM) food system. With this in mind, we plan to:

1. Map UM's dining services practices and data availability/needs by:
    1. a) Determining which dining operations are in-house or contracted out,
    2. b) Identifying what types of sustainability-oriented practices and/or agreements have been
    established with outside contractors and caterers, including how procurement and caterer contract language currently shapes the types of products that are sourced and the type of data and sourcing information that is shared by caterers/contractors, and
    3. c) Reviewing the type of data collection and data management systems that exist in relation to GHGE and other sustainability metrics associated with UM's various supply chains.
2. Collect all relevant research that has already been conducted on UM's food system
3. Speak with representatives from other universities of comparable size that have undertaken efforts to reduce GHGEs (greenhouse gas emissions) associated with food service operations to
understand lessons learned related to scalable actions that UM might enact
4. Gather additional perspectives about key metrics and actions from relevant UM, regional and national experts and stakeholders
5. Understand the state of science that justifies/theorizes why particular institutional actions would lead to the greatest reductions to food systems-related GHGEs at both the institutional level and catalytically across the sector
6. Explore emergent opportunities that could take advantage of UM's cutting-edge research capacity and other core strengths to research, develop, pilot and implement innovative strategies and practices that advance carbon neutrality in the food system
7. Compare possible actions in terms of:
    1. a) The potential impact each would have on UM's GHGEs (and possible unintended positive or negative impacts on other equity or sustainability concerns),
    2. b) The political and financial feasibility of different actions, the steps required to implement each and how implementation might differ at the Ann Arbor, Flint and Dearborn campuses and various dining services, and
    3. c) The potential scalability of UM's actions elsewhere

As part of our scope of work, our key priorities for analysis include the following:

1. Map out UM's dining services supply chains, existing data and current practices relevant to GHGE reductions across MDining, Athletics, Michigan Medicine, Ross School of Business, UM Dearborn, UM Flint, and strategic caterers. Data we will attempt to collect could include:

• Who runs each operation,

PCCN – Food Analysis Team – Scope of Work – August 16, 2019 1

- Number of people and volume of food served,
- Sourcing data related to GHGEs (e.g., products that have Environmental Product Declarations (EPDs), products with eco-labels, etc.)
- Volume of waste, what's done with waste at each site, and the cost of disposal, and
- Actions taken in the last 10 years to improve the sustainability of dining operations and any evaluation of the impact/outcome/challenges of attempting certain changes.

2. Use MDining as a case study or proof of concept, particularly if much of the data above is not available from other dining services sites. This could include:
    - Analysis of procurement data collected by MDining for the past 3-5 years to understand the potential GHGEs associated with the supply chain and how these have changed in recent years, particularly after implementing different practices (e.g., meatless Mondays, mushroom blended burgers, trayless dining),
    - Analysis of bulk food waste data from MDining to examine annual and seasonal trends and the impact of implementing different practices, and
    - Development of a model for collecting, standardizing and organizing food systems data to make it easier to track GHGE related indicators in an ongoing manner
3. Identify "low-hanging fruit" initiatives that:
    - Already have an evidence base of effectiveness elsewhere or are fertile ground for new data collection (e.g., standardizing benchmarks of progress for sustainability efforts, implementing a carbon footprint labeling scheme within dining services), and
    - Present unique opportunities for research, development and implementation of novel, high impact approaches to reducing GHGE in the food system based on existing UM research strengths

      We plan to involve a number of stakeholders through informational interviews, focus group discussions and/or as reviewers of our ongoing analysis and draft reports. This may include but is not limited to:

1. UM dining procurement staff, service administrators, contract organizations and chefs from MDining, Athletics, Michigan Medicine, Ross, UM Dearborn, UM Flint, and strategic caterers
2. Dining services leaders at universities of comparable size where sustainability measures have been implemented (e.g., University of Toronto, Ohio State, University of MA-Amherst, Stanford, Yale, Boston University, University of Maryland, University of Washington, North Carolina State)
3. Faculty at UM who conduct research on food systems and climate change
4. The student-led UMSFP (UM Sustainable Food Program) leadership team and individual student-
   led organizations that are part of UMSFP that are most relevant (e.g., Food Recovery Network, Friends of the Campus Farm, Maize and Blue Cupboard)
5. Key MI stakeholders (e.g., the Center for Regional Food Systems' Michigan Farm to Institution Network, state-level policy advocates and experts on food waste management/composting)
6. *Researchers and experts nationally who focus on food-focused campus sustainability (e.g., Directors of food-focused or campus sustainability certification systems and campaigns such as the Real Food Challenge, Cool Food Pledge, Menus of Change, AASHE, EPA's Food Recovery Challenge, Local Food Plus).*

APPENDIX F

University Travel Team

Faculty Co-Leads: John Williams and Ming Xu

Proposed Scope of Work

Goal 1. Compile all published literature on travel footprints, footprint of academic meetings, university and other travel policies, relationship of travel to academic success, methods of calculating footprints for different modes of travel.

Goal 2. Determine quantitatively the amount of University travel in 2018 by extracting information from the Concur reimbursement data base for employee business related travel, departments and/or Travel Registry for student-related travel, and Shared Services Center for guest-related travel. We hope at least to obtain the name and job title of travelers, destinations, mode of travel, length of travel, and general purpose of travel for each travel event. We are already working with Concur staff to establish the overall number of travel events, number of travelers, and number traveling by air as well as what other information can be mined. We will use this data and data from departments, Travel Registry, and Shared Service Center to calculate the travel footprint for each travel event. This may require follow-up with individual travelers. We expect a reasonable amount of cooperation as we are dealing with a recent time period and can relate the importance of our work for the President's Commission.

Goal 3. Understand why University personnel travel. We expect most travel will be by faculty and graduate students but some will be by undergrads and staff. Understanding the importance of travel by the four groups will be approached by surveys and focus groups. These will also help provide information on the level of understanding of how travel affects the University's carbon footprint. We first need to establish who will be surveyed. One approach would be to survey individuals identified as travelers during 2018 from the Concur data base. This should survey all four groups but will continue the bias to those using Concur. We could survey a fraction of the entire University but this will be weighted towards the largest groups (undergrads and staff) who likely do the least traveling. Those who haven't traveled may just not respond lowering the overall response rate. We are currently drafting a questionnaire to use for discussion with survey experts.

Goal 4. Propose ways to educate the University community to consider the carbon footprint when deciding whether travel is warranted and how to carry it out to minimize the carbon footprint per travel. This will include the importance of attendance at regional versus national or international meetings, using alternatives such as video links for presentations or virtual meetings, and selection of travel mode for intermediate distances (100 to 500 miles) where this is feasible by bus, train or car.

Goal 5. Propose a system of offsets for travelers to use in a voluntary or compulsory manner. The social cost of the carbon footprint for the travel event will be determined and possible ways to use the offset funds will be recommended. This will be carried out in conjunction with the Offset Working Group.

Goal 6. Propose changes for travel-related data management systems for Concur, Travel Registry, Shared Services Center, and any other relevant university functions to track necessary data for estimating carbon footprint of each travel in future

APPENDIX G

Factoring Climate Justice into Carbon Neutrality: Project Overview

Faculty Lead: Larissa Larsen
Associate Professor of Urban and Regional Planning
Taubman College of Architecture and Urban Planning

Student Research Assistants:
Roshan Krishnan, Graduate Student, Master of Science in Environment and Sustainability
Daphne Onsay, Graduate Student, Master of Science in Environment and Sustainability
Ifeoluwa Owolabi, Graduate Student, Master of Urban Design

The University of Michigan has played an important leadership role in the environmental justice movement. In 1990, the University of Michigan hosted a seminal conference, referred to as the Michigan Conference, that helped distinguish environmental justice as an issue of concern at the national level. Today, University of Michigan faculty, students, and alumni continue to make powerful contributions around this important topic. Therefore, as the University of Michigan undertakes the creation of a Carbon Neutrality Plan, it is appropriate that we include environmental justice concerns in our efforts.

It is difficult to differentiate climate justice from environmental justice concerns. In our review of the literature, we have come to believe that climate justice is a subset of environmental justice concerns that focuses on the inequitable impacts of climate change on vulnerable communities. In their report, *African-Americans and Climate Change: An Unequal Burden*, the Congressional Black Caucus concluded that efforts to reduce the impacts of climate change, whether mitigation or adaptation-oriented, have the potential to either reduce or worsen existing inequities. As we proceed with our research on climate justice efforts and specifically on efforts to approach carbon neutrality, we will bear this in mind.

Our process has three steps. In the first step, we are reviewing the content of international, national, municipal, and university climate action plans (31 in total) to gather definitions of vulnerability and collect a range of actions or programs proposed to address climate justice. We are approaching the conclusion of this first step. In our second step, we will assemble the findings from the review and share these with members of the U of M environmental justice faculty and members of non-profit advocacy organizations to ask their opinion on what would be appropriate actions. Finally, in the third step of our process, we will compile our findings from the review and interviews to create two products. The first product will be a summary of our research with associated recommendations and the second product will be a set of questions that each analysis team should consider in relation to the creation of their own recommendations.

APPENDIX H

Bio sequestration Team

Faculty Co-Leads: Heather Dawson and Rebecca Tonietto

Proposed Scope of Work

The brief scope of the bio sequestration team's work in the charter is to "evaluate and recommend optimal approaches for potential carbon sequestration projects on land owned or controlled by UM." The team interprets and defines this scope as having three overarching goals: 1) assessment of current UM landholdings, 2) categorization of land use on these properties, and 3) evaluation of land use changes, where possible, that would maximize bio sequestration potential. Additionally, we will evaluate opportunities and challenges of different methods for changing land use, at multiple scales, to increase sequestration. The bio sequestration team does not request any significant changes be made to the brief scope listed in the PCCN charter document.

Key priorities of the analysis would include:

1. Identification of UM-owned lands that contain a significant portion of undeveloped land and/or turf grass (definition of "significant portion" to be determined later, which may vary by ground-cover type at scales outlined below).

2. Evaluate methods of land use change to optimize sequestration and minimize barriers to implementation.

Analyses for priority 1 (thorough assessment of UM-owned land):

First, we will accumulate data on all UM landholdings and hope to obtain direction from PCCN administrative staff in this regard. We will work at two landscape scales. At the broader scale, we will assess the amount of undeveloped land for large- scale bio sequestration projects. This would include properties across the state and one significant property in Wyoming. For large UM landholdings, this would require talking with site directors and staff. At the finer scale, we will assess turf grass cover on UM landholdings for smaller-scale, yet impactful bio sequestration projects. At all scales, we will utilize mapping tools such as remote sensing and GIS. We will conduct site visits at locations with the most potential for bio sequestration projects to further assess land use and the logistic feasibility of making land use changes for sequestration. For example, access to a site may be limited, or a site may be habitat for threatened or endangered species, which would be barriers to implementing potential bio sequestration projects.

Analyses for priority 2 (optimal approaches for sequestration):

Initial analyses for this priority begin with review of the primary literature on bio sequestration potential of different approaches to changing land use. This research 1 will help us determine the increased bio sequestration potential above and below ground for candidate approaches, such as increased native plantings, or using water bodies to store carbon. We will also investigate approaches used by other universities or institutions to increase bio sequestration. We will communicate with project directors to share potential bio sequestration approaches on UM landholdings to best understand the scope of the projects and the potential barriers to implementation.

We identify key stakeholders as the public, UM faculty, staff, and students, UM Facilities and Operations, and the U.S. Fish and Wildlife Service. The sustainable use of land and its alteration is a consideration of the public, and UM administrators, faculty, staff, and students who may be involved in the use and/or implementation of potential projects. UM Facilities and Operations would be a stakeholder, as small-scale projects and possibly large-scale bio sequestration projects would involve Grounds Services and potentially Environmental Health and Safety staff. U.S. Fish and Wildlife would be a stakeholder, as proposed land use changes may need to be assessed for benefits for or risk to threatened and endangered species.

APPENDIX I

Building Standards Team
Faculty Lead: Jen Maigret

Proposed Scope of Work

The building standards analysis team has been charged with evaluating current and emerging best practices regarding the adoption, implementation, and long-term efficacy of building code policies to improve sustainable building performance outcomes with a focus on achieving carbon emission reduction targets for new construction.

The scope of this analysis will be centered around four areas of building design and construction that have the potential to contribute significantly to carbon emission reductions. These are:

- Energy
- Water
- Site, and
- Materials.

Additionally, a range of secondary dimensions will be considered including, but not limited to, prescriptive versus performance-based criteria, initial costs compared with payback periods, specification standards and post construction commissioning, operations and maintenance and code targets for new construction. To do so, the building standards analysis team will undertake a comparative analysis of current national and international best practices and summarize policies and practices in consideration, globally, for improvements to current standards.

The proposed recommendations will furthermore consider several cultural and logistical dimensions specific to the current oversight of construction, facilities and operations at the University of Michigan's campuses and how to ensure the successful adoption of new building standards.

APPENDIX J

Campus Culture and Communication

Faculty Leads: Samer Ali and Joseph Trumpey

Proposed Scope of Work

The CCC Team will evaluate existing campus sustainability structures and recommend new strategies to build cultural capacity, raise awareness, educate the community about carbon neutrality, enhance personal investment in sustainability initiatives, and drive overall behavioral change towards a more sustainable UM. Current UM systems and strategies will be evaluated as well as benchmarking of peer institutions and other relevant organizations.

Initial goals include the following:

- make recommendations to improve or create a new organization that builds culture. Special attention will be paid to the UM DEI initiative as a model.
- benchmark key carbon neutrality/sustainability cultural initiatives at peer organizations
- identify key moments in the UM calendar that captures large cohorts of the UM community, such as orientations for incoming students, faculty, and staff where Carbon Neutral goals can be easily conveyed and participation encouraged
- make a recommendation on a university-wide required course / mini-course / online training regarding carbon neutrality/sustainability
- host town hall meetings where stakeholders can learn and share perspectives
- stage new media campaigns, hosting new list serves, chalking, art contests, as well as Twitter account "takeovers" and live micro-blogging
- recommend specific arts engagement, exhibits, and performances with the UMMA, Penny Stamps, UMS.
- evaluate and devise behavioral incentives
- recommend ways to collaborate with existing campus stakeholders

Priority: Facilitating behavior change as the highest priority. We will work with other IATs to determine specific high-impact behaviors, such as those pertaining to travel, energy, and food. We will identify best practices for engaging all members of the broad UM community including faculty, staff, students, alumni, visitors, and patients. Based on precedent, collaboration and conversation will serve as an effective method of transforming consciousness and culture.

Initial Direction and Approaches: The CCC Team will establish benchmarks and understand current environmental practices and opinions. To gain that understanding we will study data and findings from the Sustainability Cultural Indicators Program (SCIP) and personally interview key persons involved with current sustainability initiatives on campus. We are also conducting precedent research to understand models of cultural and behavioral change at peer institutions.

Stakeholders: The CCC Team will intersect with a wide array of UM stakeholders including: Student Life (Housing, MDining), student organizations, Office of Campus Sustainability, Planet Blue, Greek Life, Alumni Association, Athletics, the Humanities Institute, UMS, relevant faculty, and staff. We have also requested the participation of a representative from the Office of Diversity, Equity and Inclusion to ensure that environmental justice undergirds our work and conversation about sustainability and carbon neutrality at UM.

APPENDIX K

Energy Consumption Team

Faculty Lead: Thomas Lyon

Proposed Scope of Work

There will be 3 main stages of the project:

1. Understanding current University policies, guidelines, incentive structures, and performance.
    a. Topics will include
        i. Building energy consumption
        ii. Investments in energy efficiency
        iii. Transportation energy consumption
        iv. Community awareness about campus sustainability impacts and options, which can make use of the Sustainability Cultural Indicators Program (SCIP).
    b. Research will begin by creating a baseline measure of energy consumption, efficiency and greenhouse gas emissions. It is my understanding that the University already conducts such an assessment for Scope 1 and Scope 2 emissions, but Scope 3 emissions are not accounted for, so this will require further research, which will likely be shared across multiple teams.
    c. We will interview key facilities and operations managers in units across the campus, using Andy Berki in the Office of Campus Sustainability as a guide to finding the correct individuals. We will continue by reading all energy-related University policies and guidelines, (both formal and informal) that we can identify, and gathering comprehensive data on campus-related energy consumption and efficiency performance, including Scope 3 emissions.
    d. We will seek to identify explicit and implicit policies regarding investments in energy efficiency. Are there explicit payback periods imposed on new investments in energy efficiency? Are there "guidelines" for payback periods that are informal norms but not official policies? Are those guidelines applied inconsistently across different sorts of investments? Are there problems with "split incentives" that are created by existing UM policies?
    e. We will need to make we understand what our current policies and practices imply about the implicit discount rates UM is using in energy investment decisions.

2. Gathering information about best practices at other universities and non-university organizations
    a. Andy Berki, Manager of the Office of Campus Sustainability, can help us to gather information on what the other 13 Big 10 schools are doing, as well as what the so-called "Ivy League +" Listening Group has been learning about the impact of internal carbon taxes and other policies.
    b. For example, Yale has experimented with an internal carbon tax and we should learn from their experience. We should likewise learn from Harvard's $12 million Green Revolving Fund, which provides capital for high-performance campus design, operations, maintenance, and occupant behavior projects.
    c. It will be important to reach beyond the academy to private sector, NGO, and gov't entities as well.

3. Developing a set of specific recommendations for UM, making use of multiple criteria for evaluation, including

a. Internal economic gains, both as total net present value (NPV) and return on investment (ROI)
b. Overall gains when incorporating a social cost of carbon (SCC). We will consider a range of plausible values of SCC.
c. Difficulties of implementing and enforcing alternative policies. This will include explicit consideration of the behavioral changes that may be required for successful implementation. In order to assess the difficulties involved, we will seek to identify the stakeholders that will be affected by each potential recommendation, and solicit their input on challenges that might be anticipated. We will plan to start with individual interviews and progress, as needed, to either focus groups or larger-scale surveys.
d. Environmental justice concerns that might arise from alternative recommendations. These will also be assessed using interviews, focus groups and surveys as needed.

Potential for UM solutions to set examples that produce spillover benefits beyond the university campus.

APPENDIX L

External Collaboration Team

Faculty Co-Leads: Andy Hoffman and Trish Koman

Proposed Scope of Work

- To evaluate opportunities for collaborations focused on scaling and replicating high-impact solutions, the External Collaboration Team will (a) coordinate with other PCCN IAT Teams and to identify and prioritize external partners with which to collaborate for emissions reduction project development, review and implementation and (b) identify and prioritize additional external partners that are critical for the success of the University's Carbon Neutrality efforts. In this way, this team will act as both a catalyst partner for the other more topic-focused PCCN IAT teams and a boundary-spanning function to highlight additional communities and partners that should be engaged to anchor carbon neutrality more firmly within our communities and contribute to long-lasting beneficial relationships. We will strategically seek to establish new ties and take advantage of external ties which are already established through other units within the University with the goal of supporting the carbon neutrality emissions reductions and assessment of replicability and scaling.

- The key priorities will be four-fold: (1) to assure that the proper skills, knowledge and support are brought into the Carbon Neutrality effort to assure success of the various components of this project (e.g., buildings, food, commuting, and operations), both on the University of Michigan campuses (Ann Arbor, Flint and Dearborn) and their local and regional communities, (2) to create an inclusive process that allows impacted and vulnerable communities to be aware of this effort and have voice in its implementation (this will consider environmental justice and economic equity considerations), (3) to flesh out collaboration opportunities and identify potential obstacles which can be overcome, and (4) to create an environment in which all relevant stakeholder's concerns and objections are addressed and accounted for throughout the project in order to ensure the delivery of viable proposed solutions for the overall long-term success of the project; thus, taking into account the complex social, political, technical and economic landscapes in which the University acts and operates.

- One unique challenge for this team will be to coordinate with other PCCN IAT teams and other PCCN initiatives as they develop their methods and reports. Each of the IAT teams will presumably be reaching to external groups as well, and a key challenge will be to coordinate this effort and maximize insights gathered for scalability and replicability. The initial analysis will seek to identify both short-term and long-term relevant stakeholders for the overall objectives of the PCCN initiative and its various sub-components. After that first step is complete, a second round of analysis will consider other parties that are missing from this analysis. Once identified, and communicated to the various teams, initial outreach will seek to establish contact, interest and possible avenues for collaboration. For this to succeed, this team requires some form of open on-going communication with the other IAT teams and broader university constituents in the PCCN initiative.

- Another area of emphasis for scaling and replication will be forming networks with other Universities. Our team will coordinate with the PCCN on university consortia as well as seek other ways in which the University already has relationships with other colleges and universities. Because of the global nature of this work, we will seek to make the U-M solutions accessible to the other communities through our networks and maximize the impact of PCCN. By April 2020, the External Collaboration team will deliver a proposed framework of strategies, solutions and best practices for the PCCN to consider moving forward in regards to encouraging and welcoming stakeholder input, managing affected party relations and forming valuable partnerships, and scaling and replicability of high-impact solutions in order to facilitate the future lasting success of the project. We anticipate a report that depicts both in graphical and narrative forms the most impactful approaches to achieve PCCN goals, metrics to be used, and the network of relevant external constituents to the efforts of the PCCN (e.g., local communities, subject matter experts, alumni, corporations, government, non-governmental organizations). Ultimately, this effort will include an array of possible outcomes presented from the team's research, which will provide the PCCN with various options to adjust the scope of collaboration through an analysis of associated impact factors. The External Collaboration team will recognize areas in which the PCCN may have the ability to create a national or international impact among other highly regarded institutions, and identify opportunities where leadership and innovation in environmental stewardship would be beneficial for the University of Michigan to examine and act upon.

APPENDIX M

Internal Analysis Team Charter
Composition and Process

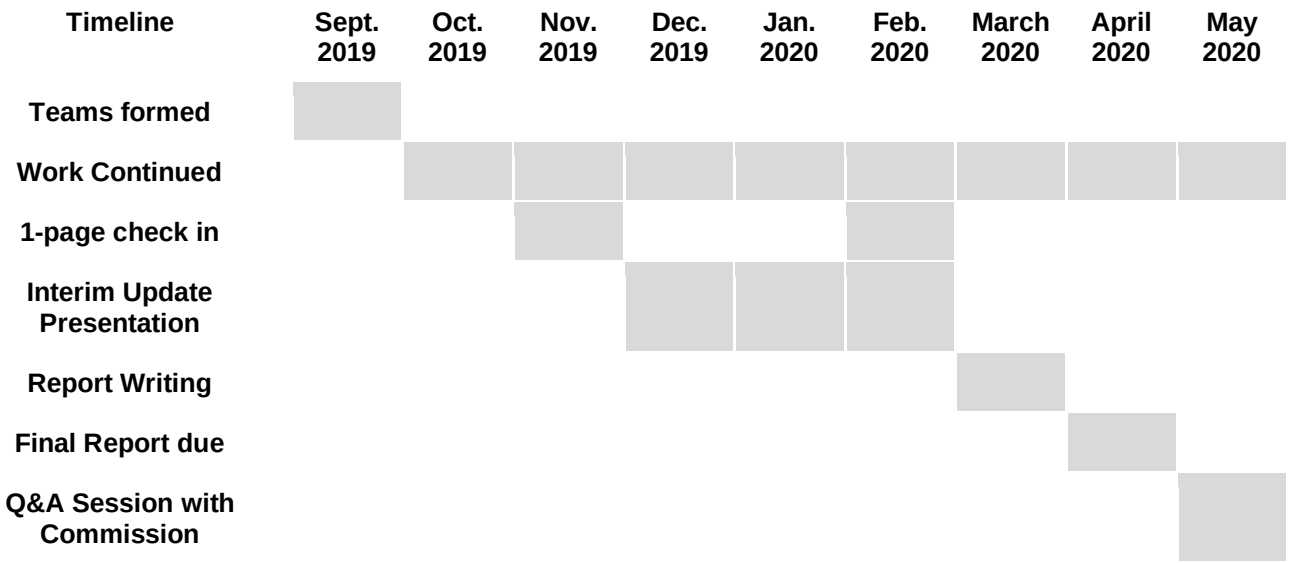
Internal Analysis Teams will:

- comprise approximately 10 faculty, staff, and students
- be led by an UM faculty member with relevant subject expertise, and will collaborate closely with a senior UM staff member(s) with relevant responsibilities and expertise
- be staffed by UM students with relevant knowledge and training across multiple fields of study
- include UM staff with relevant knowledge and responsibilities
- include a PCCN staffer as a formal liaison to the Commission
- seek advice from UM faculty and other sources with relevant expertise
- identify and consult with external subject matter experts, representatives of affected groups, and other stakeholders who bring important perspectives to the Commission
- consult with UM budget and finance experts as required

Regarding process, each internal analysis team will:

- meet regularly (e.g., bi-weekly) throughout the project timeline
- submit requests for data/information from UM units to PCCN staff as needed
- submit requests for specialized external studies to the PCCN co-chairs and Administrative Director
- provide regular progress updates to the Commission, receive feedback and guidance, and meet with them as needed

Internal Analysis Work Timeline



Faculty leads will be responsible for:

- determining the skills and experience requirements for student staffers, and selecting students with relevant knowledge and training across multiple levels and fields of study
- monitoring the progress and productivity of student team members throughout the project timeline
- leading the team towards solutions within the project scope
- assisting students with expertise and resources to perform analyses of the topic assigned to the internal analysis teams
- ensuring the M-Box internal analysis team folder is updated with recent work, documents and progress reports on a monthly basis
- meeting with the PCCN co-chairs as requested
- delivering required products on schedule

PCCN Personnel will be responsible for:

- managing the student hiring process (e.g., posting jobs, screening for minimum qualifications, etc.)
- approving student time on a bi-weekly basis (note: student appointments will be in the Graham Institute)
- sharing student time reports with the faculty leads to ensure accuracy
- ensuring the M-Box internal analysis team folder is updated with relevant work, documents and requested data on a monthly basis
- providing meeting space as required
- facilitating outreach with advisory panels and external experts and stakeholders

Deliverables

Project Start-up Report (August 18)

The purpose of the start-up reports is to inform the Commission of the faculty leads' proposed scope of their internal analysis teams, to assist in hiring well-qualified student interns to staff each team, and to ensure each team includes U-M staff with relevant knowledge and responsibilities. Each report will include the following:

1. *Proposed Scope of Work*
    - A brief narrative of the scope of the project that addresses the following questions:
        - How is the faculty lead interpreting and defining the scope?
        - What key priorities for analysis has the faculty lead identified?
        - Are there any significant changes to the brief scope listed in the introduction of this document that need to be addressed?
        - What initial directions will the analysis go, and what approaches will used?
        - Who are some of the key stakeholders that will need to be involved?
    - Note: Following Commission review and approval, each team's scope of work will be included in the Commission's Fall 2019 progress report
2. *Student Staffing Requirements*
    - A brief narrative listing the skills, training, expertise and experience the faculty lead would like to staff their internal analysis team.
    - These could include technical skills, soft skills, specializations, or specific certifications and experiences.

- These requirements will be incorporated into the student job description prior to posting (attached).

3. *Key U-M Staff Roles/Individuals needed to make team successful*
   - A list of key U-M staff members, or staff roles if specific individuals are not known, who will be essential to the success of the team's research.
   - These staff members will act as key collaborators and advisors to the team to inform research and analysis with key data, information, and knowledge throughout the process.
   - PCCN staff will assist faculty leads in identifying and securing participation of key staff.

APPENDIX N, Roster of Participation

Commission Members and Support Staff	UM Campus	Primary Unit	Student
Stephen Forrest*	UM Ann Arbor	College of Engineering, LS&A	
Jennifer Haverkamp*	UM Ann Arbor	Graham Sustainability Institute	
Henry Baier	UM Ann Arbor	Facilities and Operations	
Andrew Berki	UM Ann Arbor	Facilities and Operations	
Valeria Bertacco	UM Ann Arbor	Office of the Provost	
T. Anthony Denton	UM Ann Arbor	Health System	
Brandon Hofmeister	External	Consumers Energy	
Gregory Keoleian	UM Ann Arbor	School for Environment and Sustainability	
Larissa Larsen	UM Ann Arbor	Taubman College	
Jonathan Overpeck	UM Ann Arbor	School for Environment and Sustainability	
Barry Rabe	UM Ann Arbor	Ford School of Public Policy	
Camilo Serna	External	DTE Energy	
Anna Stefanopoulou	UM Ann Arbor	College of Engineering	
Missy Stults	External	City of Ann Arbor	
Lisa Wozniak	External	Michigan League of Conservation Voters	
Logan Vear**	UM Ann Arbor	College of Engineering	X
Austin Glass**	UM Ann Arbor	College of Engineering	X
Andrew Horning	UM Ann Arbor	Graham Sustainability Institute	
Lydia Whitbeck	UM Ann Arbor	Graham Sustainability Institute	
Liz Barry	UM Ann Arbor	Office of the President	

Carbon Accounting Sub Group	UM Campus	Primary University Unit	Student
Gregory Keoleian	UM Ann Arbor	School for Environment and Sustainability	
Austin Glass	UM Ann Arbor	College of Engineering	X
Catie Hausman	UM Ann Arbor	Ford School of Public Policy	
Kenneth Keeler	UM Ann Arbor	Facilities and Operations	
Eric Kort	UM Ann Arbor	College of Engineering	
Geoff Lewis	UM Ann Arbor	School for Environment and Sustainability	
Daniel Raimi	UM Ann Arbor	Ford School of Public Policy	

Social Justice Sub Group	UM Campus	Primary University Unit	Student
Larissa Larsen	UM Ann Arbor	Taubman College	
Roshan Krishnan	UM Ann Arbor	School for Environment and Sustainability	X
Dim Mang	UM Ann Arbor	College of Literature, Science, and the Arts	X
Daphne Onsay	UM Ann Arbor	School for Environment and Sustainability	X
Ifeoluwa Owolabi	UM Ann Arbor	Taubman College	X

Vehicle Fleet Electrification Sub Group	UM Campus	Primary Unit	Student
Anna Stefanopoulou	UM Ann Arbor	College of Engineering	
Andrew Berki	UM Ann Arbor	Facilities and Operations	
Stephen Dolen	UM Ann Arbor	Facilities and Operations	
Austin Glass	UM Ann Arbor	College of Engineering	X
Brandon Hofmeister	External	Consumers Energy	
Gregory Keoleian	UM Ann Arbor	School for Environment and Sustainability	
William McAllister	UM Ann Arbor	Facilities and Operations	
Camilo Serna	External	DTE Energy	
Missy Stults	External	City of Ann Arbor	

Heat and Power Infrastructure External Analysis	UM Campus	Primary University Unit	Student
James Adams	UM Ann Arbor	Utilities	
Andrew Berki	UM Ann Arbor	Office of Campus Sustainability	
Sam Brooks	External	Integral Group	
Justin Chin	External	Integral Group	
Greg Kats	External	Integral Group	
Kenneth Keeler	UM Ann Arbor	Office of Campus Sustainability	
Jennie Kim	External	Integral Group	
Sara Lappano	External	Integral Group	
Vladimir Milkler	External	Integral Group	
Kevin Morgan	UM Ann Arbor	Office of Campus Sustainability	
Shreshth Nagpal	External	Integral Group	
Tom Prince	UM Ann Arbor	Utilities	
Dan Stanish	UM Ann Arbor	Operational Support	
Mike Swanson	UM Ann Arbor	Utilities	

Bio sequestration Internal Analysis Team	UM Campus	Primary University Unit	Student
Heather Dawson	UM Flint	College of Arts and Sciences	
Rebecca Tonietto	UM Flint	College of Arts and Sciences	
Nicole Blankertz	UM Flint	College of Arts and Sciences	X
Hannah Mosiniak	UM Ann Arbor	School for Environment and Sustainability	X
Lara O'Brien	UM Ann Arbor	School for Environment and Sustainability	X
Caleb Short	UM Flint	College of Arts and Sciences	X
Chenyang Su	UM Ann Arbor	School for Environment and Sustainability	X
Cyrus Van Haitsma	UM Ann Arbor	School for Environment and Sustainability	X

Building Standards Internal Analysis Team	UM Campus	Primary University Unit	Student
Jen Maigret	UM Ann Arbor	Taubman College	
Shuhaib Nawawi	UM Ann Arbor	College of Engineering	X
McHugh Carroll	UM Ann Arbor	Taubman College	X
Hannah Irish	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Mitch Mead	UM Ann Arbor	Taubman College	X
Nicole Rusk	UM Ann Arbor	Taubman College	X
Kay Wright	UM Ann Arbor	Taubman College	X

Campus Culture and Communication Internal Analysis Team	UM Campus	Primary University Unit	Student
Samer Ali	UM Ann Arbor	College of Literature, Sciences, and the Arts	
Joseph Trumpey	UM Ann Arbor	Penny W Stamps School of Art and Design	
Meg Czerwinski	UM Ann Arbor	School of Nursing	X
Ben Ingall	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Lisa Maillard	UM Ann Arbor	School for Environment and Sustainability	X
Chris Merchant	UM Ann Arbor	School for Environment and Sustainability	X
Madeline Peery	UM Ann Arbor	College of Literature, Sciences, and the Arts	X

Commuting Internal Analysis Team	UM Campus	Primary University Unit	Student
Jonathan Levine	UM Ann Arbor	Taubman College	
Griffin Barron	UM Ann Arbor	College of Engineering	X
Samuel Maves	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Abas Shkembi	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Gwyndolyn Sofka	UM Ann Arbor	School for Environment and Sustainability	X
James Wooldridge	UM Ann Arbor	Taubman College	X

Energy Consumption Policies Internal Analysis Team	UM Campus	Primary University Unit	Student
Thomas Lyon	UM Ann Arbor	Ross School of Business	
Jessica Carlin	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Lyanda Dudley	UM Ann Arbor	College of Engineering	X
Taylor Lind	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Larson Lovdal	UM Ann Arbor	College of Engineering	X

External Collaboration Internal Analysis Team	UM Campus	Primary University Unit	Student
Andrew Hoffman	UM Ann Arbor	Ross School of Business	
Trish Koman	UM Ann Arbor	School of Public Health	
Gopichand Alla	UM Dearborn	College of Engineering & Computer Science	X
Amelia Brinkerhoff	UM Ann Arbor	Ross School of Business / SEAS	X
Zoie Chang	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Wenjie Liu	UM Ann Arbor	Ford School of Public Policy	X
Erin O'Shaughnessy	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Mara Page	UM Ann Arbor	Rackham Graduate School	X
Joseph Samulski	UM Dearborn	College of Engineering & Computer Science	X
Anya Shapiro	UM Ann Arbor	Ross School of Business / SEAS	X

Food Internal Analysis Team	UM Campus	Primary University Unit	Student
Andrew Jones	UM Ann Arbor	School of Public Health	
Lesli Hoey	UM Ann Arbor	Taubman College	
Caroline Baloga	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Sarah Bellaire	UM Ann Arbor	School for Environment and Sustainability	X
Rebecca Harley	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Marc Jaruzel	UM Ann Arbor	Ford School of Public Policy	X
Nathalie Lambrecht	UM Ann Arbor	Rackham Graduate School	X

University Travel Internal Analysis Team	UM Campus	Primary University Unit	Student
John Williams	UM Ann Arbor	Medical School	
Ming Xu	UM Ann Arbor	School for Environment and Sustainability	
Hyo Sub Choi	UM Ann Arbor	Rackham Graduate School	X
William Chown	UM Ann Arbor	College of Literature, Sciences, and the Arts	X

Jiangzhou Fu	UM Ann Arbor	Rackham Graduate School	X
Nate Hua	UM Ann Arbor	School for Environment and Sustainability	X
You Lyu	UM Ann Arbor	Rackham Graduate School	X
Monica Yen	UM Ann Arbor	Rackham Graduate School	X

Student Advisory Panel	UM Campus	Primary University Unit	Student
Austin Glass	UM Ann Arbor	College of Engineering	X
Logan Vear	UM Ann Arbor	College of Engineering	X
Sophie Alphonso	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Sabrina Butcher	UM Ann Arbor	School for Environment and Sustainability	X
Grant Faber	UM Ann Arbor	School for Environment and Sustainability	X
Kristen Hayden	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Marc Jaruzel	UM Ann Arbor	Ford School of Public Policy	X
Virginia Lafever	UM Ann Arbor	School of Public Health	X
Mitch Mead	UM Ann Arbor	College of Literature, Sciences, and the Arts	X
Jake North	UM Ann Arbor	College of Engineering	X
Christian Noyce	UM Ann Arbor	Ross School of Business / SEAS	X
Gregory Phillips	UM Ann Arbor	Ross School of Business	X
Liana Smale	UM Ann Arbor	Penny W Stamps School of Art and Design	X
Noah Weaverdyck	UM Ann Arbor	Rackham Graduate School	X

Total Direct Participation				
UM Campus	**Primary University Unit**	**Faculty**	**Staff**	**Student**
UM Flint	College of Arts and Sciences	2	0	2
UM Ann Arbor	College of Engineering	3	0	7
UM Dearborn	College of Engineering and Computer Science	0	0	1
UM Ann Arbor	College of Literature, Science, and the Arts	1	0	14
UM Ann Arbor	Facilities and Operations	0	10	0
UM Ann Arbor	Ford School of Public Policy	3	0	2
UM Ann Arbor	Graham Sustainability Institute	1	2	0
UM Ann Arbor	UM Medicine and Medical School	1	1	0
UM Ann Arbor	Office of the President	0	1	0
UM Ann Arbor	Penny W Stamps School of Art and Design	1	0	1
UM Ann Arbor	Rackham Graduate School	0	0	7

UM Ann Arbor	Ross School of Business	2	0	4
UM Ann Arbor	School for Environment and Sustainability	3	1	13
UM Ann Arbor	School of Nursing	0	0	1
UM Ann Arbor	School of Public Health	2	0	1
UM Ann Arbor	Taubman College	4	0	6
	Totals	**23**	**15**	**59**

Internal Analysis Team Specific Direct Participation			
UM Campus	**Primary University Unit**	**Faculty**	**Student**
UM Flint	College of Arts and Sciences	2	2
UM Ann Arbor	College of Engineering	0	4
UM Dearborn	College of Engineering and Computer Science	0	2
UM Ann Arbor	College of Literature, Science, and the Arts	1	11
UM Ann Arbor	Ford School of Public Policy	0	2
UM Ann Arbor	UM Medicine and Medical School	1	0
UM Ann Arbor	Penny W Stamps School of Art and Design	1	0
UM Ann Arbor	Rackham Graduate School	0	6
UM Ann Arbor	Ross School of Business	2	2
UM Ann Arbor	School for Environment and Sustainability	1	10
UM Ann Arbor	School of Nursing	0	1
UM Ann Arbor	School of Public Health	2	0
UM Ann Arbor	Taubman College	3	5
	Total	**13**	**45**
		Graduates	**Undergraduates**
		27	**18**