22 March 2022

Whitepaper
Zero Carbon Commitment Subcommittee
University of Maine Faculty Senate

Achieving the University of Maine Commitment to Zero Carbon Emissions by 2040

Executive Summary
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I. Introduction

This white paper is meant to help members of the campus community better understand the challenges the university faces in addressing issues arising from the global climate crisis. Among core questions being asked of the campus administration include:

1. What technological approaches are being explored for achieving the campus net-zero carbon commitment by 2040?
2. Which approaches are most likely to achieve the goal by 2040 and be sustainable over time? What are the benefits and drawbacks of each?
3. What are the predicted costs of each of the potentially successful approaches?
4. What will be the means to finance the approach or approaches chosen in order to meet the net-zero carbon commitment by 2040?

This paper addresses some of the same questions through the efforts of volunteer contributions from faculty scientists, researchers, and others. It reviews a range of actions that the university could and/or should take. Feedback from a forthcoming survey of campus community students, faculty, staff, and administrators based on issues discussed in the paper will help the Faculty Senate formulate a set of motions to be forwarded to the campus administration for action.

II. Background and Context

The earth is experiencing an environmental crisis that will have negative economic and social consequences in Maine and in the United States that will soon dwarf the negative consequences of any other crisis experienced in modern human history. Governor Janet Mills makes a convincing case that the climate crisis poses a direct and immediate threat to Maine. However, she views the threat also as a major opportunity for developing clean energy sources, expanding and diversifying the Maine workforce with high paying jobs, and moving us toward energy independence while addressing the challenges brought about by climate change.[1]

[1] https://www.maine.gov/governor/mills/news/speaking-united-nations-governor-mills-announces-maine-will-be-carbon-neutral-2045-2019-09-23

The University of Maine is a charter signatory to the 2007 American College and University Presidents' Climate Commitment,[2] now known as the Carbon Commitment, and has developed a Climate Action Plan[3] with interim emissions reductions goals (20% by 2015, 40% by 2020, and 67% by 2030) to achieve net-zero greenhouse gas (GHG) emissions by 2040.[4]

Although some progress has been made, the University of Maine has experienced only a 10% overall reduction in carbon emissions between 2008 and 2020. We are far behind in achieving our interim emission reduction goals.

> The Faculty Senate strongly supports the University of Maine commitment to purchase a significant percentage of renewable electricity generated by Maine-based solar and hydroelectric generation facilities and also encourages the purchase of wind power.
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> Further, the Faculty Senate supports the University of Maine Energy Project (UMEP) which is a supply-side energy initiative that also includes the evaluation of demand-side energy projects, an electrical infrastructure study and improvements, and a campus steam system study and improvements.
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> Although only an interim step forward, the Faculty Senate also potentially and reservedly supports the use of renewable, sustainable biomass to fuel temporarily the campus steam facilities in order to decrease reliance on fossil fuels for heating.

These three actions under consideration by the University of Maine administration will further decrease carbon and net carbon emissions. They are good steps forward.

However, even with the aforementioned actions, not all UMaine ***electrical*** energy will be sourced from near-zero carbon emission energy generation facilities such as solar, wind, and hydro facilities. Further, while the use of renewable biofuels[5] would substantially reduce our use

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[2] Presidents' Climate Leadership Statement, http://secondnature.org/climate-guidance/the-commitments/#Climate_Leadership_Statement

[3] The University of Maine Climate Action Plan, 2010, http://reporting.secondnature.org/media/uploads/cap/427-cap_1.pdf

[4] Because greenhouse gases consist of several gases, the combination of the specific gases emitted from a facility is typically converted to a "carbon dioxide equivalent (CO_2e)" which is a term for describing different greenhouse gases in a common unit. (e.g., see https://www.era-environmental.com/blog/ghg-emissions-carbon-dioxide-equivalent-co2e)
The terms carbon neutrality, net-zero carbon emissions, net-zero CO_2e emissions, and net-zero greenhouse gas (GHG) emissions may often be used interchangeably in this document. When used in a general sense and for convenience we often use the term **net-zero GHG emissions**.
Under the current energy production environment, even technologies such as solar and wind energy require the expenditure of some GHG emissions in the mining of the materials from which the technologies are created and in manufacturing, transporting, installing and maintaining the capabilities. Thus, to reach net-zero GHG emissions, carbon expended on a project may be neutralized by purchasing equivalent "carbon offsets." The goal of carbon offsets is to counteract the GHG emissions that one cannot avoid causing. Ideally, carbon offset expenditures should be invested in projects that remove an equivalent amount of existing CO_2e from the atmosphere. Still, the ***long-term societal goal is to eliminate carbon emissions all together*** to avoid the need to use carbon offsets. This document sometimes refers to wind, solar, and hydro energy as "non-combustion near-zero carbon emission sources" for energy generation. The combustion supplying or creating these energy resources occurs approximately 90 million miles from Earth on the sun.

[5] Primary biofuels refer to organic materials used primarily for heating purposes and electricity production. Examples include wood chips and pellets typically left in their natural state and burned. Secondary biofuels include processed biomass usually resulting in liquid fuel such as ethanol or biodiesel that are also burned. Extensive research into development of crops and methods for extraction of combustible biofuels that might produce energy more efficiently is ongoing. See https://biofuels-news.com/news/future-trends-in-biofuel/

of fossil fuels for campus ***heating***, even renewable biofuels continue to emit substantial greenhouse gases into the atmosphere through combustion and involve some amount of carbon expenditure in transporting the biofuel to the campus.[6] Further, the university and its students and staff engage in ***ongoing greenhouse gas emitting activities*** not directly controlled by the university (e.g., commuting and business travel).[7] These latter sources are unlikely to decline in carbon intensity until society, as a whole, decarbonizes across all sectors.

All three of these GHG emission categories (i.e., ***Scope 1***: Heating, ***Scope 2***: Electrical, ***Scope 3***: University-Related Travel) need to be addressed to reach net-zero greenhouse gas (GHG) emissions by 2040. Reducing emissions from the last category will likely need to depend on acquisition of ***carbon offsets***[8] if society has not resulted in a transition to electric cars and other reduction methods by that time. Meeting the electrical and heating needs of the campus while maintaining net-zero GHG emissions might be achieved through a range or a combination of renewable energy procurement and energy consumption reduction methods

If the university pursues only its current planned actions, it will still remain well short of its commitment to achieve net-zero GHG emissions by 2040. At the very least, the university must commit to NO increase of its carbon footprint in any of the three GHG emission categories. Further, it should aggressively move well beyond the current planned initiatives for GHG reductions.[9]

III. Scientific Evidence for Urgent Action

A core aspiration of the ***2015 Paris agreement***[10] on climate change was to keep the world within 1.5°C of global warming above pre-industrial levels. At the end of ***COP26 UN Climate Change Conference*** in Glasgow, Scotland in November 2021[11], climate and earth scientists observed that based on the updated provisions agreed to at the conference, the planet will

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[6] Biomass combustion results in net-zero GHG emissions under the condition that the carbon sequestered by new growth equals or exceeds that emitted during burning. Therefore, when near-zero carbon energy generation is unavailable or economically infeasible in the near term, local renewable biomass for campus heating may be an intermediate alternative to near-zero energy sources as part of the mix and progression in replacing fossil fuels. The burning of the renewable biofuel ethanol in vehicles results in substantial CO_2e emissions but is used as an interim partial solution in the transportation sector for reducing fossil fuel emissions until such time as electric vehicles running off of solar, wind, and other near zero-carbon emission sources are widely available and supported by electric vehicle charging infrastructure. In a similar manner, wood may be burned for heating under stringent engineering and contract conditions to temporarily replace fossil fuels during the transition to near zero carbon emission electric heating sources when such an interim investment might make economic sense to achieve the campus net-zero carbon emission goal by 2040. Appendix 2 sets forth the benefits of using a biomass fuel approach for campus heating as well as some drawbacks. Appendix 3 raises further concerns in the use of renewable biomass in achieving net zero carbon emissions and how some concerns might be lessened.

[7] These Scope 3 carbon emissions for the University of Maine are estimated at a continuing rate of approximately 17,000 metric tons per year.

[8] The current cost of carbon offsets in U.S. commercial offset markets range from $5 to $10 per metric ton. However, these prices are very low due to a range of economic and regulation factors and are not at a current level that reflects a 1:1 ratio in that a 1-ton offset actually results in sequestering of a full ton of CO_2e or avoiding the addition of a full ton of CO_2e emissions into the atmosphere. Future prices may rise rapidly or become highly volatile depending upon government regulations. How Do Carbon Offsets Work? (https://www.washingtonpost.com/climate-solutions/2020/09/23/climate-curious-advice/) Carbon offset prices in Europe are already over $60 per ton.

[9] Until UMaine's scope 1, 2, and 3 emissions are in fact zero, it is the pledged responsibility of the university to offset all emissions in line with UMaine's incremental carbon commitment goals. For definitions of Scope 1, 2, and 3 emissions, see UMaine Climate Action Plan Update Spring 2021.

[10] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[11] https://www.un.org/en/climatechange/cop26

almost certainly miss the 1.5 degrees Celsius warming target. The ***climate clock***[12] for reaching this limit is likely now anywhere from approximately seven to eleven years away depending on the scientific studies cited.[13]

According to the more conservative scientific consensus ***Intergovernmental Panel on Climate Change*** reports, the earth is on track to reach 1.5 degrees C warming within the next 9 to 31 years with high confidence.[14] A global rise of 1.5 degrees C is a best-case scenario. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (2021) states that:

- Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years.
- Averaged over the next 20 years, global temperature is expected to reach or exceed 1.5°C of warming
- Unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades, global warming of 1.5°C and even 2°C will be exceeded

For many scientists the goals of both 1.5 and 2 degrees are beginning to look widely out of reach based on the lack of government commitments at Glasgow to stay under these limits.

Why holding to 1.5°C to 2°C is Important: Within 1.5 to 2 degrees of warming, scientists predict that numerous abrupt ecological and climate system disruptions will occur or be put in motion.[15] IPCC Special Reports published in 2018 and 2019 as reported in Nature indicate that tipping points could be exceeded even between 1 and 2 degrees of global warming.[16] Unless deep reductions in greenhouse gases are achieved, a wide range of reported scientific modeling predictions indicate that we are more likely than not to witness a series of looping or tipping point events resulting in a sort of chain reaction accelerating global warming.[17] Because the computer modelling is so complex, there is no scientific consensus in reliably predicting the extent to which and when looping interactions will occur and the conditions under which they will be irreversible for all practical purposes.

In 2013, the Intergovernmental Panel on Climate Change reported that under a worst-case scenario of humans doing nothing to slow climate change, global temperatures may increase by 4 degrees Celsius or more by the year 2100. That is less than eighty years away. "The Earth has not been that warm in millions of years, and such temperature spikes in our planet's history are connected to mass extinction events that killed off a large percentage of species that existed at the time." "There is a genuine possibility that within the coming century, we will hit temperatures that are deeply incompatible with the continued existence of human life."[18]

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[12] https://climateclock.world/science#deadline

[13] There's Still Time to Fix Climate – About 11 Years, Scientific American, Oct 21, 2021, https://www.scientificamerican.com/article/theres-still-time-to-fix-climate-about-11-years/

[14] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., et.al. (eds.)]. Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/

[15] The impacts of climate change at 1.5C, 2C and beyond, https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees/?utm_source=web&utm_campaign=Redirect

[16] Climate tipping points – too risky to bet against. Nature, 27 November 2019, https://www.nature.com/articles/d41586-019-03595-0

[17] For a dramatization and lay person's explanation of tipping points and their potential cascading further warming effects or climate looping phenomena, see Earth Emergency, https://www.pbs.org/video/earth-emergency-6njifx/

[18] https://climate.mit.edu/ask-mit/why-do-some-people-call-climate-change-existential-threat citing Intergovernmental Panel on Climate Change. "Long-Term Climate Change: Projections, Commitments and Irreversibility." In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the

We are already well into the sixth mass global extinction.[19] This one is being caused primarily by humans. Modern homo sapiens has existed on earth for approximately 200,000 years. A mere blink in geologic time. If the accumulating science community projections are correct and humans fail to respond, humanity may be extinct or close to it within the next hundred years. Humans will take a lot of other species with them. Earth will survive but humanity is facing an existential crisis. If even half of the consensus IPCC report findings and the accumulating modeling projections from wide-ranging scientific disciplines are reasonably accurate, these scientifically-based and often conservatively cautious predictions should be taken seriously.

If we listen to the predictions of the scientific community, what might the predictions mean for the future of the campus? Among other things, it probably means that a compulsory carbon market and/or carbon taxes will likely be imposed within years rather than decades. This would make fossil fuel and carbon offset prices very high and volatile. Thus, any major investment in fossil fuel infrastructure on the campus would probably end up being a very poor financial investment in the decades ahead.

Huge challenges create huge opportunities. The U.S. auto industry gets it. It is shifting major segments of its production away from combustion engines to electric vehicles capable of being powered by clean solar, wind, and other near-zero carbon emission energy sources. Our current U.S. president gets it. He is proposing bold environmental goals for the nation with a focus on electric power to be supplied by clean energy sources as well as investments in clean energy research and development. Our current Maine governor gets it. Among other actions, she has incentivized rapid substantial growth in solar and wind energy generation in Maine. The University of Maine needs to follow suit.

IV. State of Maine Leadership

In 2019, Governor Janet Mills signed LD 1679 into law with strong support from the Maine Legislature to create the ***Maine Climate Council***. The law charged this group with developing a Maine climate action plan. The Council and six working groups involving more than 200 Maine people with diverse backgrounds carried out a comprehensive scientific and technical assessment about climate change in Maine. That work resulted in the report titled ***Climate Action Plan, Maine Won't Wait***.[20] The report presents numerous recommendations and transformational economic opportunities for Maine. Many of these should be adopted by and for the University of Maine as well as by other UMS campuses. Among the recommendations highly germane to the university's climate commitment include the development and growth of clean energy sources.

A wide array of practices will need to be implemented by the university to achieve net-zero GHG emissions by 2040. However, one of the more critical recommendations is to immediately cease any planned or proposed actions that will significantly expand the campus carbon footprint. The campus needs to immediately convert such actions to initiatives that will have neutral effects on the carbon footprint or decrease it.

Intergovernmental Panel on Climate Change. 2013. The figures cited reflect projections for the RCP 8.5 emissions pathway, sometimes called a "high emissions" or "business-as-usual" pathway.

[19] Elizabeth Kolbert, The Sixth Extinction: An Unnatural History (2015)

[20] Maine Won't Wait, Climate Action Plan, Maine Climate Council, https://www.maine.gov/future/sites/maine.gov.future/files/inline-files/MaineWontWait_December2020.pdf

A report commissioned by the Maine Climate Council on *Strategy Recommendations to Mitigate Emissions and Support Resilience in Maine Buildings*[21] recommends that procurement rules be amended for state government, the University of Maine, and Maine Community Colleges to achieve low embodied carbon, zero emissions, zero energy, and resilience in new construction by 2025. ***There is no need to wait until 2025.*** All new construction immediately should be designed to achieve net-zero emissions during construction and during operation.[22] Alternatively, sufficient funds should be earmarked for the procurement of carbon offsets to achieve net-zero *GHG* emissions for the life of the structure. Such practices may and should be adopted immediately and before additional new campus construction proceeds in order to allow us to more realistically meet our 2040 Carbon Commitment.

The Maine Climate Action Plan championed by the governor indicates that publicly funded buildings should ***Lead by Example***. "This will save taxpayers money and show how modern design and construction materials, combined with efficient systems and practices, can reduce both emissions and the operating costs of state and local government buildings, schools, universities, and affordable housing."[23]

V. New Construction on the University of Maine Campus

Thus, in constructing any new building or in refurbishing older buildings to serve University of Maine needs:

(a) the unavoidable GHG emissions expended to construct the building should be offset through purchase of carbon offsets, or through the University's own carbon sequestering practices,

(b) the structure should be designed and built using rigorous environmentally responsible best practices such as in selection of climate friendly building materials,

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[21] Strategy Recommendations to Mitigate Emissions and Support Resilience in Maine Buildings, https://www.maine.gov/future/sites/maine.gov.future/files/inline-files/BuildingsInfraHousingWG_FinalStrategyRecommendations_June2020.pdf

[22] See Advanced Energy Design Guide for Small to Medium Office Buildings: Achieving Zero Energy (2019) by ASHRAE, The American Institute of Architects, Illuminating Engineering Society, U.S. Green Building Council, and U.S. Department of Energy. "Zero energy buildings are designed first to significantly reduce energy consumption and then to meet remaining loads with renewable resources, ideally located on site. These buildings are usually connected to the utility grid to receive energy whenever renewable energy production is insufficient to meet required loads and to return energy to the grid when renewable energy production exceeds the loads." (Page 1)."The cost to obtain zero energy has dropped from over 20% of the project budget in 2009 to less than 4% of the project budget on some recent zero energy projects. This reduction is due to advances in energy conservation technologies, the reduced costs of these technologies, and the reduced costs of renewable generation systems. Meanwhile, estimated building construction costs on the same projects ranged from plus to minus 8% of the projected bid costs. This means that the cost to add zero energy is often within the expected window for bid results." (Page 15 and Fig. 2-2) "As this Guide shows, zero energy office buildings can also have lower maintenance costs. Many energy-efficiency strategies result in less operational time for mechanical and electrical equipment. Reducing the strain on this equipment yields reduced maintenance costs. The most effective systems are simpler and smarter." (Page 4)

[23] Lead by Example Report, 2021, https://www.maine.gov/future/sites/maine.gov.future/files/inline-files/Lead%20By%20Example_2021.pdf. Further, the use of wood-based building materials, such as mass timber and wood fiber insulation, have lower embodied carbon than other more traditional building materials, such as steel and concrete. "Embodied carbon" includes all of the carbon emitted to create the material or product including that emitted from energy used to extract and transport raw materials as well as emissions from manufacturing processes. The use of wood-based materials also supports the Maine economy.

provisioning of low energy lighting, heating, and cooling systems, and use of energy efficient construction and weatherization,[24]

(c) the energy supplied for electricity and heating for the expected life of the building should come from non-combustion near-zero carbon emission energy sources[25] or the costs of sequestering unavoidable CO_2e emissions from energy use over the life of the building should be covered by the initial building construction budget, and

(d) best practices must be rigorously followed in the accounting of carbon emissions and carbon emission offsets.

By following these principles, building projects may require some increased funding for initial construction and energy infrastructure accommodations.[26] Yet often the increase is minimal and may even be less expensive. Even if more expensive initially, in the long-term, energy costs should be much more stable and lower as the negative financial effects of climate change grow. In addition, the governor's office and the legislature may be willing to support state funding or bond initiatives for "showcase" projects that clearly demonstrate the ability to address climate change challenges while growing Maine's work force, stimulating the economy, supporting innovation in arriving at solutions, and providing new opportunities for clean energy businesses in Maine.

Most industrial zero-carbon infrastructure visions for the future envision conversion to electric supply of energy distributed across networks to meet demand using wind, solar, and any additional near-zero carbon emission sources (e.g., hydro, hydrogen, etc.). Electric heating in buildings using filaments is far less energy efficient than electric heating through liquid circulation systems. The high temperatures required for steam heat circulation result in much more energy expenditure as compared to water circulation heating and cooling systems. As a result, one strong option for campus new construction and building refurbishments is to deploy water heating and cooling circulation systems powered by electric ground-source heat pump systems (also known as geothermal heat pumps).[27]

Heat pumps may be deployed on a building-by-building basis but also could be designed to support a heat pump network connecting clusters of buildings or all campus buildings over time. All pumps would eventually be powered by near-zero carbon generated electricity. At the very least, even if using carbon offsets for a specific building project to temporarily achieve net-zero carbon emissions, all new facilities should be built to be "zero-carbon ready." By example, a new building might be built with a water heating system utilizing a heat exchanger with steam supplied from the campus steam plant that burns renewable biofuels. Thus, future conversion to full electric for the building would be built into the design. The best long-term option

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[24] **LEED** (Leadership in Energy and Environmental Design) Certification focuses on green construction and green design of a building, but the certification does not have a rating for after the project is complete. It's possible the tenants of a LEED-certified building are using more energy or water than tenants in other buildings, despite design efforts to reduce usage. While LEED certification at the silver level or above should be pursued for each building, the primary focus of this document is on sustainable solutions to reduce the building's long-term carbon footprint.

[25] The campus might supply its own clean energy plant such as through one or more non-combustion near-zero carbon emission sources (example: solar or wind energy facilities). However, the university might also contract for long-term electric service from one or many Maine-based businesses to supply near-zero carbon emission electric energy and thus help grow the green energy private business sector in Maine.

[26] Appendix 1 provides in illustrative computation of predicted energy use and CO_2e emissions for a building recently constructed on the University of Maine campus. In alignment with the literature cited in footnote 22, the cost to add net-zero energy accommodations would likely have been very minimal when compared to the overall cost of constructing this major new building and within the standard bidding approximation factor of plus or minus 8%.

[27] See https://www.energy.gov/eere/geothermal/geothermal-heat-pumps.

environmentally to achieve the 2040 commitment would likely be to convert to full electric energy supplied by non-combustion near-zero energy sources for all new construction, aggressively convert existing buildings to full electric as quickly as possible, expand on-campus power generation using renewable biofuels to deal with the peaks and valleys of solar and wind power supply as well as provide emergency power backup for the future, and maintain steam heat using biomass or other renewable biofuels to serve buildings not yet converted.

VI. Refurbishing, Replacing, or Phasing Out the University of Maine Steam Plant

Currently, burning of fossil fuels in the University of Maine Central Steam Plant provides heating for most buildings on campus. It also generates a small amount of electricity supplying less than 5% of the campus demand. Numerous technical options exist for achieving net zero carbon emissions for campus heating by 2040. Some of these are listed below:

Progressive Conversion to All Electrical Power Supplied by Solar and Wind: Extending from the previous discussion, the first option would be to convert most campus buildings over time to allow them to be heated, cooled and powered by energy supplied by wind and solar farms. All new construction as well would be based on energy needs being met by these or similar future non-combustion near-zero carbon emission sources. Solar and wind energy systems during their operation do not directly produce air pollutants or greenhouse gases. The GHG emissions produced in the mining, manufacture, transport, installation, operation, and disposal of solar panels and wind systems is a very small fraction of that required for similar production and support operations of fossil fuel energy generation. Solar and wind energy are proven technologies for reliably delivering electricity with near-zero carbon emissions during operation. Geothermal heat pump systems are as well highly reliable and proven technologies for transferring energy from the earth for heating and cooling buildings with zero carbon emissions during operation assuming that the pumps are powered by non-combustion near-zero energy sources.[28]

These proven technologies are not without their challenges. For example, a geothermal heat pump approach might need a backup heat source for the coldest days of the year. Clean energy geothermal for core heating of campus buildings supplemented by clean energy

[28] For those unfamiliar with the concepts of heat pumps and geothermal heating, we offer the following brief description:

Heat pumps are devices powered by electricity that gather heat energy from one place and transfer it to another. Although variations exist, a ground source electric driven heat pump mechanically circulates thermally conductive liquid solution (e.g., water) through underground horizontal or vertical pipe loops. After absorbing the ground's thermal energy, the solution goes back into the heat pump and exchanges its heat energy with liquid refrigerant inside the heat pump. That refrigerant is then turned into a vapor and compressed. The act of compressing the vapor increases its temperature. This allows even outside air-based heat pumps to work in very cold weather. Once the vapor is hot enough, it enters a heat exchanger which transfers the heat, typically to the air. That warm air is then circulated throughout a building using standard air ductwork. Distribution of the heat through low temperature hot water circulating throughout a building using radiators might typically be used in new construction for a major building.

After a certain point, the weather may become too cold for too long in very cold climates such that there aren't enough BTUs in the ground's thermal energy to raise the temperature to the desired level in a building. Thus, resort to heating through a back-up system is required. By example, electric water heating powered by clean energy might be one option used during peak demands

Due to to a reversing valve, heat pumps are able to change the flow of refrigerant and thus also cool buildings. Geothermal systems provide a proven technology that is widely considered one of the most energy efficient heating and air conditioning system available. These ultra-efficient heating and air conditioning systems save energy, reduce carbon emissions, and increase comfort. They may be driven in entirety by solar, wind, and other non-combustion near-zero carbon emission electric energy sources.

electric water heating during peak demands is one typical means used to address this demand. If the campus used its own solar and wind farms there would also be times when the sun and wind would be insufficient to meet immediate campus electrical demands. This is typically solved by buying and drawing on clean electric energy across a public power network as the campus is already doing for a substantial portion of its electric power supply. Another option to deal with electric supply ups and downs would be to generate electric power through its own electric turbines powered by biomass combustion or renewable liquid/gas biofuel combustion. On-campus electric power generation is already being supported but with fossil fuels and on a much smaller scale than would be needed to support electric backup capacity. One advantage of backup power generation through dependence on renewable biofuels is that such power generation is currently classified and is far more likely to continue to be classified as "renewable" under federal programs than the combustion of biomass solely for heating purposes.

Conversion to Renewable Biofuels to meet Most Near-Term Heating Needs: Another option that would eliminate the burning of fossil fuels on campus in the near term would be to convert the current steam plant or build a new one to burn renewable biofuels. Burning waste or other wood as a renewable biofuel still creates pollution on the campus and counting it as a renewable energy resource as deployed in practice in other large-scale operations has been problematic and controversial.[29] Further, the definitions of net-zero carbon emissions, renewability, and carbon neutrality are currently inconsistent, unclear, and have shifting legal definitions among state and regional jurisdictions. The US Environmental Protection Agency (EPA) Revised Renewable Fuel Standard (RFS2) does NOT currently include a pathway for the combustion of woody biomass for use as a heating fuel.[30] While such use is under consideration by the USDA and advocated by many in the forest industry, it is not yet known if such a pathway will be approved by the EPA and, if so, when. Nor is it known what potentially stringent conditions might be imposed in the burning of biomass for heating in order to qualify under RFS2. Burning of biomass for heat in the context of an electric power and heat co-generation plant might have a greater chance of being defined as renewable.

The burning of biomass solely for heat is accepted under some state and regional definitions as renewable energy assuming that certain requirements are met. (See Appendix 2). This may be sufficient for the campus particularly if looking at the burning of biomass for heat as a temporary twenty-year transition investment. The burning of renewable biomass and liquid or gas renewable biofuels (current and to be developed) might have a greater possibility of being defined federally as renewable if justified as backup electric power supply for handling the peaks and valleys of campus core use of solar and wind power supporting heat pumps. That is, the biofuel combustion might then be viewed as an integral part of an overall renewable and carbon neutral clean energy system,

Conversion to Renewable Biofuels to meet Long-Term Heating Needs: A third option would be to convert the steam plant or build a new one to burn renewable biofuels and count on this as the long-term renewable energy net-zero emission solution for most campus heating. This approach has significant advantages but also potential major disadvantages in meeting the campus zero-carbon emission commitment. This has many of

[29] See Appendix 2.
[30] Unnasch. S. and L. Buchan (2021). Life Cycle Analysis of Renewable Fuel Standard Implementation for Thermal Pathways for Wood Pellets and Chips, Life Cycle Associates Report LCA.6161.209.2021, Prepared for Technology Transition Corporation, p. vii

the same challenges as documented in the second option above. The best biofuel solution, if pursued, might be to build a new heating plant to serve as a showcase example of how a campus-wide system might be converted to use and enforce very high renewable energy and pollution control standards while providing the ability to use the cheapest renewable biofuel option of the day (solid, glass, liquid) as biofuel technologies advance over time. The greatest advantage of this approach is minimal upfront costs in achieving net-zero carbon emission goals compared to most other approaches. In the long-term, this may not be a good investment depending on the rate of escalating severity of the climate crisis and regulatory reactions.

For this third option, the facility should:

- Use the highest standards established such as by using residual waste from only lands certified by the Forest Stewardship Council (FSC) (ie.g, lands certified by the Sustainable Forestry Initiative (SFI) allow clear cuts of up to 120 acres),
- impose rigorous annual renewability accounting procedures that ensure at least I to 1 carbon sequestering through new growth for every ton of carbon leaving the campus smokestack,
- accomplish annual audits that among other issues additionally account for all carbon emissions offsite and onsite for transportation and processing of the biomass or other renewable biofuel,
- require and enforce stiff penalties for source material lands not kept in sustainable forestry for 50 years after residual from them has been used by the university as biofuel,
- contractually impose stiff penalties for cutting of full tree swaths of forest to meet the university's combustion demand rather than using residual waste product from forestry cut for other societal purposes,
- ensure the highest standards for pollution controls in the combustion process, and
- impose similar implementation and contractual obligations.

The campus's sustainability reputation should be maintained as a highly valued asset for attracting students and research and development funds. If it deploys a biomass or biofuels combustion installation it should be a stellar best-practices solution that can be pointed to as a positive exemplar by other universities. The campus should not open itself to critique for questionable sustainability claims in regard to its practices.

The above campus heating options are among many that might be considered. Consult Appendices 2 and 3 for concerns and arguments on both sides of the biomass combustion issue.

As mentioned earlier, what would the university's consulting experts predict as to costs for each of these approaches that have promise in meeting the net-zero carbon commitment by 2040? What would be the potential means to finance each approach?

Direct energy generation from the sun and wind for heating and electrical demands appears to be the best current long-term solution in actually achieving a net zero-carbon commitment for any major institution such as a university. Investment in electric infrastructure is required to support the direct use of solar, wind and hydro energy. Thus, if an interim biomass solution is pursued, any institution set on actually achieving net zero carbon emission goals will also likely need to start a process of constructing new buildings and converting existing buildings to use non-combustion near-zero carbon energy sources.

VII. A University Vision for Future Growth and Sustainability

Proposition: Within 10 years, the University of Maine will be well known as a destination campus for students from across the nation and the globe that want to make a difference. Why? Because the University of Maine and UMS are preparing and engaging students collaboratively across all disciplines in addressing the world's most pressing current and emerging societal challenges. Across and among its many scholarly domains, whether in regard to acquiring education and skills for the workforce of tomorrow, engaging in undergraduate and graduate research experiences, or advancing and critically analyzing new knowledge and innovations, all students are engaged in helping to address the next emerging crises affecting Maine, the nation, and the world. The University of Maine remains up-to-date and always relevant in responding to critical societal needs. Across and among all of its colleges and programs the University of Maine by 2030 has already focused considerable combined energies to comprehensively address the technological, social, economic, and environmental challenges of climate change. It is not only talking the talk, but walking the walk by being the first land grant university in the nation to achieve net-zero carbon emissions. It has become a magnet for students, researchers, educators, and industry partners that are interested in working collaboratively and from multiple perspectives in helping the nation respond to the climate crisis. Opportunities have expanded for graduates across all of our disciplines as students develop as researchers and leaders in what is becoming the future of all sustainable institutions.

With the current Governor of Maine and President of the United States marshaling and directing resources toward similar visions for the state and nation, the timing is right for action by the University of Maine and the University of Maine System.

VIII. Summary

For over a decade, the University of Maine has continued to emit greenhouse gas emissions each and every year well beyond that which would have been emitted if it had been making consistent progress toward its Carbon Commitment of net-zero GHG emissions by 2040. The university is falling far short. The regularly published national progress report by the University of Maine shows that we have actually increased carbon emissions to back over 60,000 metric tons of CO_2e in a recent reporting year rather than decreasing emissions.[31] We have moved in the wrong direction.[32]

We, the faculty of the University of Maine, as represented by the duly elected members of the Faculty Senate, affirm that we believe in science and the climate science conclusions reached and published by our own faculty and their national and international peers. They inform us that we are already at the beginning of a climate crisis the likes of which humanity has never witnessed. We believe that the University of Maine has much to offer and should take a leadership role in addressing the societal and scientific challenges of tomorrow. A first and important step is to honestly assess our performance toward and step up our progress in meeting our professed Carbon Commitment. As Governor Mills has indicated, the situation presents a golden opportunity for Maine to come out as a leader in addressing the climate crisis

[31] University of Maine CO_{2e} Progress Report, https://reporting.secondnature.org/institution/detail!1906##1906
[32] There was indeed a decrease for 2021 but this was due primarily to the move to online teaching as a result of the pandemic.

while at the same time gaining huge economic, infrastructure, and well-being benefits. The University of Maine can be a shining exemplar in making envisioned benefits happen and provide hope, inspiration, and prosperity for future generations.

IX. Faculty Senate Motions

The Faculty Senate hereby approves the following motions:

- <motions will be developed after receiving campus community feedback>
- TBA
- TBA

Numerous motions have been made in past years by the Faculty Senate and student governments directed to the University of Maine Administration and the UMS Board of Trustees that addressed the need to keep on track in achieving zero carbon emission commitments and to divest from any forms of investment in the fossil fuel industry. For over a decade, those motions have resulted in little to no substantive progress through a succession of administrators.[33] It is time for the Faculty Senate to become more actively engaged.

[33]See, for instance, approved 2015 Faculty Senate Divestment Resolution. While the UMS Board of Trustees continues to avoid fossil fuel divestment, State of Maine Legislature bill LD99 now bans public investments in fossil fuels. "The bill requires the $17 billion Maine Public Employee Retirement System (PERS) to divest $1.3 billion from fossil fuels within five years, and orders the state Treasury to do the same with all state funds." https://www.ai-cio.com/news/maine-becomes-first-state-to-pass-fossil-fuel-divestment-bill/ See also https://legislature.maine.gov/legis/bills/display_ps.asp?LD=99&snum=130, Enacted, Jun 16, 2021, Governor's Action: Signed, Jun 16, 2021. Multiple Faculty Senate zero-carbon emission motions have also been passed.

Appendix 1

Computation of Energy Use and CO_2e Emissions for a University Laboratory Building

Industrial building energy modelers are normally employed to accurately calculate the energy expended to construct a large building and to provide the building with heat, electricity, and maintenance services on a yearly basis over the life of the building. Based on the energy sources to be used, they also compute the expected *CO_2e emissions.* The following paragraphs very roughly estimate the CO_2e emissions for a building recently constructed on the University of Maine campus and the costs to bring it down to net-zero emissions over the life of the building.

1. Building Use: Operational Long-term Energy Consumption and Greenhouse Gas Costs
Very roughly, "Laboratories in the U.S. are energy-intensive facilities that use anywhere from 30 to 100 kilowatt-hours (kWh) of electricity and 75,000 to 800,000 Btu of natural gas per square foot annually. Actual use varies with such factors as the age of the facility, the type of research done there, and the climate zone in which the lab is located. In a typical laboratory, lighting and space heating account for approximately 74% of total energy use." (Reference: https://ouc.bizenergyadvisor.com/article/laboratories).

Thus, for a recent four-floor steel, concrete, and brick university building with 110,000 square feet of floor space, the energy consumption per year might range approximately as follows:

Low Energy Estimate for Building	High Energy Estimate for Building
Electricity: 30 kWh/sf/year x 110,000 sf = 3,300,000 kWh/yr	Electricity: 100 kWh/sf/year x 110,000 sf = 11,000,000 kWh/yr
Heating (assuming natural gas): 75,000 Btu/sf/year x 110,000 sf = 8,250,000,000 Btu/year	Heating (assuming natural gas): 800,000 Btu/sf/year x 110,000 sf = 88,000,000,000 Btu/year

Let's assume these numbers represent the entirety of the annual energy use for the building.

UMaine Energy Use Emissions Factors:
Electricity = 0.000236929 (MT CO_2e/kwh)
UMaine uses the Iso-New England electrical grid average with a correction factor applied to account for residuals.
Natural Gas = 0.053166722 (MT CO_2e /MMBTU)
The Central Steam Plant runs primarily on two Natural Gas Boilers with a third boiler running on #6 Fuel Oil during only the coldest days of winter.
#6 Fuel Oil = 0.474436451 (MT CO_2e /Barrel (42 gallons per Barrel))
The #6 oil-fired boilers are only fired up during the coldest days of winter, the rest of the year the Steam Plant runs on Natural Gas.

Let's also roughly assume that UMaine annual CO_2e emissions for the energy needs of the new 110,000 sq ft laboratory building are generated only by electricity drawn from the New England electric grid and only natural gas burned in the UMaine steam plant.

Low CO_2e Emissions Annual Estimate	High CO_2e Emissions Annual Estimate
Electricity: 3,300,000 kWh/yr x 0.000236929 (MT CO_2e/kwh) = 782 MT (metric tons) CO_2e per year	Electricity: 11,000,000 kWh/yr x 0.000236929 (MT CO_2e/kwh) = 2,606 MT (metric tons) CO_2e
Heating (assuming natural gas):	Heating (assuming natural gas):

8,250,000,000 Btu/year x 0.053166722 (MT CO_2e /MMBTU) x (1MMBTU/1,000,000 Btu) = 439 MT (metric tons) CO_2e per year	88,000,000,000 Btu/year x 0.053166722 (MT CO_2e /MMBTU) x (1MMBTU/1,000,000 Btu) = 4,678 MT (metric tons) CO_2e per year
TOTAL = 1,221 MT (metric tons) CO_2e per year	TOTAL = 7,284 MT (metric tons) CO_2e per year

The UMaine campus as-a-whole produces approximately 60,000 metric tons per year of CO_2e so this recent single building alone is likely increasing the yearly emissions of the campus somewhere between 2% and 12%. We would guess it to be on the higher end of this scale. However, a professional building energy modeler would need to be employed to make a much more concise estimate.

Let us assume that this new building produces 5,000 MT (metric tons) CO_2e per year. Let us also assume the carbon offset investment costs over a life span for this building for say 50 years will be at a predicted annual average price of say $10 per MT. Using these assumptions (5000 MT/yr x 50 yr x 10 $/MT) the initial cost to fund the building should be increased by about $2.5 million dollars. This amount would of course cover only the annual CO_2e offset costs and not the yearly energy costs. All of these numbers are highly speculative and subject to wide variations depending on the specific building, the specific fuels used, the volatility of the carbon offset market, the cost to actually sequester the CO_2e amount versus the market price for offsets, time value of money, and a host of additional factors that could be best approximated by a specialist.

2. Construction: Embodied Short-term Energy Consumption and Greenhouse Gas Costs
Operational carbon is that released over the life of a building whereas embodied carbon is released during the year the building is constructed. Embodied carbon includes the energy to create the building materials as well as the energy expended in the construction process. Using a very simplistic calculator for embodied carbon for a 110,000 sf building with 4 stories above grade, a landscape disturbance no greater than the first story floor plan, and averaging between steel versus concrete building construction, the computed embodied CO_2e for this project based on estimates from previous projects is probably between 3,231 metric tons and 4,881 metric tons (http://www.buildcarbonneutral.org/). Thus, the embodied carbon released to construct the project might be about 4,000 MT (metric tons). In the initial construction year let us assume a $10 per MT cost of sequestering unavoidable CO_2e, the initial cost to fund the building should be increased by another $40,000 dollars. Again, such a number is highly speculative and could best be approximated by a building energy modeler.

3. Total Carbon Offset Costs for a Single University Building
The goal of making some rough computations here is to indicate through an example for a single building the likely costs (plus or minus perhaps a factor of 5) to achieve net-zero carbon emissions for a single building project. The construction budget for the university building described above was about $75 million dollars.

As indicated above, the carbon offset costs incurred to initially construct a university lab/classroom/office building of this size might be about $40,000. The costs to handle the offsets over the life of the building would be approximately $2.5 million. Together these costs would raise the fundraising goal for the building by somewhat over $2.5 million dollars. Although our rough estimates are speculative, this is less than 3.3% of the $75 million cost of the building. Anything under 5% would certainly appear to be a very reasonable onus for building advocates to bear. (See footnote 21).

Appendix 2
The Case for Using Wood as a Renewable Energy Biofuel on the University of Maine Campus

Prepared by UMaine Office of Sustainability

Renewable Biomass for UMaine Heating

The state of Maine has working forests that have been regularly harvested for hundreds of years. To ensure a sustainable supply of wood product source materials, Maine’s working forests are managed for a range of tree species and stand structures, which allows them to provide an ongoing supply of woody biomass in addition to a multitude of additional ecosystem services such as biodiversity, clean water, clean air, and recreation. Such management promotes the healthy composition, density, and growth of natural regeneration.

There is more forest biomass today than at any other time in Maine's recent history and this will likely increase due to ongoing sustainable management efforts. Approximately 89% of the state is forested and of that, ~50% is third-party certified by the Forest Stewardship Council (FSC) or the Sustainable Forestry Initiative (SFI). Maine’s working forest biomass is considered renewable over a multi-decadal timeframe (~35 to 80-years, varying with latitude, tree species, and use) providing it is sustainably managed to promote healthy regeneration. Additionally, Maine’s sustainably managed forests will be more resilient to disturbance considering the changing environmental conditions we see happening today and anticipate will continue in future.

Residual biomass is produced as a by-product of timber harvesting operations for lumber and pulpwood. Driven by consumer demand for sustainable products and various state and federal regulations, many pulp and lumber operations in Maine depend primarily on FSC and SFI certified source material to remain competitive. As a result, the associated residual biomass is also sustainably certified. Local surveys have shown that ~500,000 green tons of residual biomass are produced annually within a 50-mile radius of the UMaine campus.

Residual biomass from Maine’s sustainably managed forests is a potentially attractive fuel source for heating the UMaine campus. The UMaine Central Steam Plant currently burns fossil natural gas and #6 fuel oil to meet the campus thermal load. If the university were to build a new biomass fueled central steam plant using residual biomass as primary fuel, its resulting GHG emissions profile would be an order of magnitude smaller than it is currently.

While the burning of biomass does release carbon into the atmosphere, the regrowth of Maine’s sustainably managed forest would take that carbon back out of the atmosphere.
Fossil fuels never pay off their carbon debt, they have a permanently negative carbon impact. It is worth noting that the carbon balance from burning sustainably certified residual biomass is not zero, even after the trees have fully regrown, because energy is used during the harvesting, processing, and transportation of the resource. Studies show that under a typical scenario, it takes ~2.1 gallons of diesel fuel to fell, skid, chip, and transport one green ton of biomass fuel (actual use will vary by harvest type, equipment used, distance to market and other factors).

For air emission reporting purposes to state and federal agencies, UMaine is required to report onsite combustion emissions (also known as stack emissions or burner-tip emissions), not offsite affiliated emissions. As a result, the diesel fuel used to harvest and process residual biomass would not be counted in UMaine's official GHG emissions profile. When a Life Cycle Assessment (LCA) of these systems is conducted, offsite affiliated emissions are included. However, studies typically show that the life-cycle GHG emissions from residual biomass energy systems are more than an order of magnitude less than those from equivalent natural gas systems (see Appendix A for LCA reference list).

The biomass plant that UMaine is currently considering would be designed and constructed to use biomass as the primary fuel. However, a UMaine biomass plant would still require the capability to use additional gas/liquid fuels for operational redundancy and reliability, and in order to supplement biomass during periods of high steam demand. Thus, supplemental boilers will be needed to meet capacity. The supplemental boilers are currently modeled to utilize natural gas but can also be designed to use a range of gas/liquid fuels including renewable fuels.

For carbon accounting purposes, if UMaine builds a new biomass fueled central steam plant, it could use existing sustainably-harvested renewable residual biomass. This biomass, obtained from ongoing commercial and industrial forest harvesting operations, would offset ~25,000 metric tons of fossil-based CO2e emissions (see Figure 1a). Of the ~500,000 green tons of residual biomass available annually within a 50-mile radius of the UMaine campus, a potential UMaine biomass plant would use ~40,000 green tons. While using biomass as primary fuel, additional GHG emissions reductions could be achieved by burning renewable fuel(s) instead of natural gas for secondary fuel. Any remaining GHG emissions (e.g., from electrical consumption, fleet fuels, etc.) may be offset using carbon offsets.

Thermal Renewable Energy Certificates

Renewable Energy Certificates (RECs) are tradable commodities that represent the environmental and other non-power attributes of renewably generated electricity. RECs are used to demonstrate compliance with state renewable portfolio standards (RPS) which are designed to increase development and production of energy from renewable resources by imposing mandated targets for retail sales of renewable generation. One REC is produced for every Megawatt Hour (MWh) of renewable electricity generated. A Thermal Renewable Energy Certificate (TREC) is a REC that represents an amount of thermal energy equivalent to a unit of electricity. A TREC of one MWh represents 3,412,000 British thermal units of thermal energy.

Maine Governor Janet Mills signed legislation to reform and update Maine's RPS. The new law (LD 1494), titled "An Act To Reform Maine's Renewable Portfolio Standard", substantially updates Maine's RPS by requiring that competitive electricity suppliers in Maine obtain TRECs reflecting an increasing amount of output from renewable thermal energy resources. The new provision is intended to incentivize installation of efficient heating and cooling systems throughout Maine. Under the Act, competitive electricity suppliers in Maine must purchase TRECs in an amount equivalent to 0.4% of the suppliers' retail electricity sales in 2021, increasing 0.4% annually to reach 3.6% of their retail electricity sales in 2030. Eligible thermal resources include heat, steam, hot water, or other forms of thermal energy beginning operation after June 30, 2019 and generated in accordance with applicable energy performance standards established by the Maine Public Utilities Commission (MPUC). UMaine's thermal energy from wood will qualify for TRECs under existing rules.

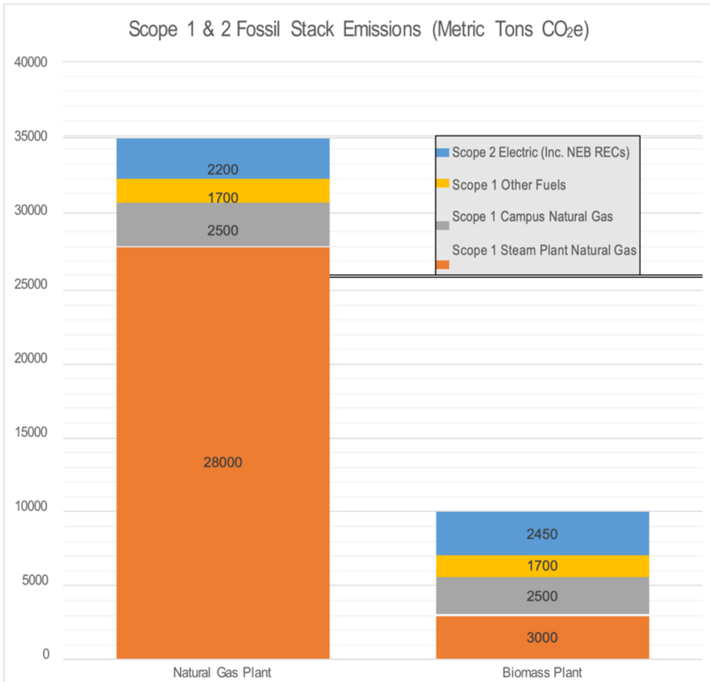
The market price for TRECs will be established by market dynamics and capped by an Alternative Compliance Payment of $25, as determined by the MPUC. The statewide TREC demand is expected to be three times the number of TRECs that UMaine could generate in the

Figure 1. Conceptual UMaine GHG emissions profiles: comparison of a fossil natural gas fueled central steam plant versus a new biomass fueled central steam plant.

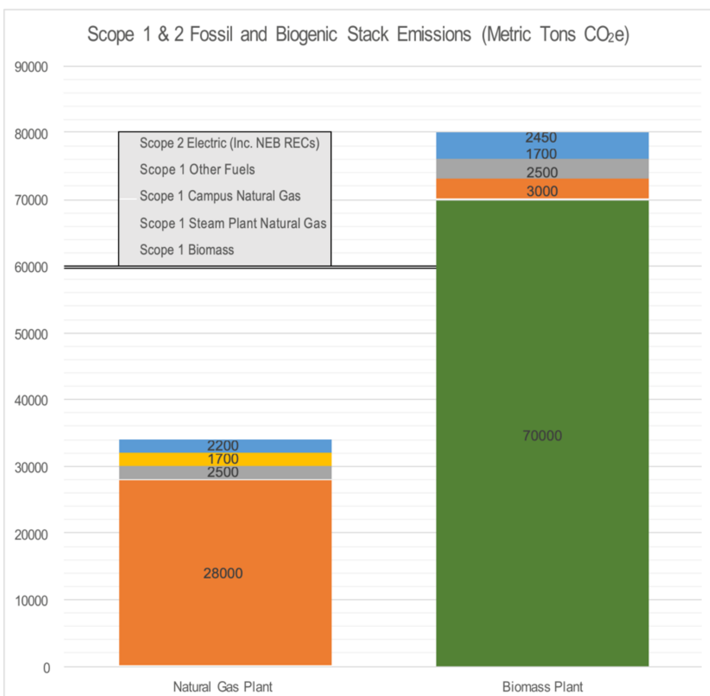
a) Scope 1 & 2 fossil emissions.

b) Scope 1 & 2 fossil and biogenic emissions (note scale change between a & b)

(a)



(b)



first year of a UMaine biomass plant's operation. Subsequent TREC demand is projected to increase to five times what UMaine could generate by 2030. At this time there are no large-scale biomass thermal projects with applications before the MPUC and outside of UMaine there are very few large heating-only entities that could utilize the TREC program. An independent TREC pricing assessment (conducted as part of the UMEC project conceptual engineering study) modeled the following TREC price ranges: a high value of $23/MWh, an expected value of $18/MWh, and low value of $10/MWh.

A UMaine renewable biomass plant would produce ~135,000 TRECs with a value of ~$2,500,000 annually (assuming a TREC price of ~$18/MWh) and the university would have the option of selling or retiring the TRECs. If UMaine was to retire (i.e. keep) said TRECs, the biomass fuel would retain its renewable status and the associated GHG emissions from the biomass would not be counted towards UMaine's carbon footprint. However, if TRECs are sold, the biomass fuel that generated them would no longer be considered renewable and the associated GHG emissions from the biomass (~70,000 metric tons CO2e, see Figure 1b) would then need to be offset to maintain UMaine's Carbon Commitment (net-zero scope 1 GHG emissions by 2030).

Clearly, TRECs represent a potentially significant financial revenue stream for a future UMaine biomass plant. It would be in the financial interest of the university to sell TRECs until the cost of necessary carbon offsets (to meet our Carbon Commitment goals) equals the market value of the TRECs. In this scenario, TREC and carbon offset cost parity occurs when TRECs are worth $18/MWh and carbon offsets cost $31.18/ton. The TRECs would be retired for any carbon cost above that threshold. However, it is worth bearing in mind that the value of TRECs will fluctuate according to market conditions. For example, if the TREC value was $10/MWh, then the TRECs would be retired when the carbon offset rate was $17.32/ton or higher. If the TREC value was $23/MWh, then the TRECs would be retired when the carbon offset rate was $39.85/ton or higher.

Additional Biomass Plant Considerations

Below is a brief list of the pros and cons of a potential UMaine biomass fueled central steam plant:

Pros:

1. Progress towards UMaine's 2040 Carbon Commitment goal
    a. A UMaine biomass plant could burn existing renewable sustainably-harvested residual biomass from ongoing commercial and industrial forest harvesting operations, thus eliminating ~90% of the scope 1 fossil emissions from the Central Steam Plant
2. Minimize annual energy costs
    a. Biomass fuel costs less per unit of energy than natural gas. Furthermore, future natural gas prices are expected to increase at a higher rate than biomass fuel prices
3. Predictable and stable long term energy costs
    a. Historically, biomass fuel prices are more stable than natural gas prices
4. Less reliance on carbon offsets to meet UMaine's 2040 Carbon Commitment goal
    a. Emissions from sustainably harvested residual biomass are renewable and therefore have minimal long-term carbon footprint impact
5. Maine economic impact

   a. Residual biomass fuel can be locally sourced, processed, and delivered by Maine- based companies
   b. Purchasing locally sourced biomass would contribute millions of dollars per year into the local working forest economy
6. UMaine educational & research impact
   a. A biomass plant supports academic courses specific to multiple UMaine programs including engineering, economics, ecology, and climate science.
7. Financial impact of potential revenue from sale of TRECs
   a. While carbon offset prices remain below certain thresholds, a UMaine biomass plant would provide the ability to sell TRECs to increase return on investment for the UMEC project

Cons:

1. Initial capital expenditure
   a. Biomass plants require greater initial investment (compared to an equivalent natural gas plant) due to the infrastructure required to store, handle, process, and deliver the biomass fuel to the boilers and the infrastructure required after the fuel is used (precipitator and ash disposal)
2. Complexity and maintenance
   a. Biomass plants have many more moving pieces compared to natural gas plants and thus require more maintenance
3. Local environmental/air impact
   a. Biomass burning has higher particulate emissions compared to natural gas
   b. These pollutants can be significantly reduced and nearly eliminated with appropriate technology
4. Footprint and aesthetics
   a. Biomass plants are larger than natural gas plants, and have more visible equipment (e.g. emission control, ash collection, etc.)
   b. The size of the primary UMaine biomass plant could be minimized by having a remote fuel unloading and storage facility
5. Noise
   a. Solid fuel handling equipment creates more noise than natural gas delivery systems
   b. Solid fuel processing noise could be largely relocated to a remote fuel processing facility
6. Fuel delivery truck traffic
   a. Solid fuel must be delivered to the plant
   b. During cold winter months, when UMaine campus steam demand is at its peak with two biomass boilers operating at full fire, 8 biomass fuel delivery trucks per day will be required to maintain operation

Life Cycle Assessment Reference List

Bird, N., Cowie, A., Cherubini, F., & Jungmeier, G. 2011. Using a Life Cycle Assessment Approach to Estimate the Net Greenhouse Gas Emissions of Bioenergy. IEA Bioenergy:ExCo:2011:03.

Cherubini, F., Bird, N.D., Cowie, A., Jungmeier, G., Schlamadinger, B., & Woess-Gallasch, S. 2009. Energy- and greenhouse gas-based LCA of biofuel and bioenergy systems: key issues, ranges and recommendations. Resources Conservation and Recycling. 53(8), 434–447. doi:10.1016/j.resconrec.2009.03.013

Cherubini, F. & Stromman, A.H. 2011. Life Cycle Assessment of Bioenergy Systems: State of the Art and Future Challenges. Bioresource Technology, 102, 437-451. doi:10.1016/j.biortech.2010.08.010

Dinca, C., Badea, A., & Apostol, T. 2010. Life cycle impact assessment of fossil fuels. UPB Scientific Bulletin, Series C: Electrical Engineering, Vol. 71, No. 1, pp.115–126.

Elsayed, M.A., Matthews, R., & Mortimer, N.D. 2003. Carbon and Energy Balances for a Range of Biofuel Options. In: R. R. Unit (Ed.), Sheffield Hallam University, Sheffield, UK. p. 71.

Heath, G.A., O'Donoughue, P., Arent, D.J., & Bazilian, M. 2014. Harmonization of initial estimates of shale gas life cycle greenhouse gas emissions for electric power generation. Proc. Natl. Acad. Sci. Unit. States Am. 111(31), E3167–E3176. doi:10.1073/pnas.1309334111

Hongke, H., Li, D., Kui, W., Junming, X., & Weiguo, L. 2021. An updated framework for climate change impact assessment of bioenergy and an application in poplar biomass. Applied Energy. 299(117323). doi:10.1016/j.apenergy.2021.117323

Liu, W., Yu, Z., Xie, X., von Gadow, K., & Peng, C. 2017. A critical analysis of the carbon neutrality assumption in life cycle assessment of forest bioenergy systems. Environmental Reviews. 26(1), 93-101. doi:10.1139/er-2017-0060

Petersen Raymer, A.K. 2006. A comparison of avoided greenhouse gas emissions when using different kinds of wood energy. Biomass and Bioenergy. 30, 605– 617. doi:10.1016/j.biombioe.2006.01.009

Righelato, R. & Spracklen, D.V. 2007. Carbon mitigation by biofuels or by saving and restoring forests? Science. 317(5840), p. 902. doi:10.1126/science.1141361

World Energy Council. 2004. Comparison of Energy Systems Using Life Cycle Assessment. Special Report of the World Energy Council. London, UK. p. 67.

Xu, H., Latta, G., Lee, U., Lewandrowski, J., & Wang, M. 2021. Regionalized Life Cycle Greenhouse Gas Emissions of Forest Biomass Use for Electricity Generation in the United States. Environ. Sci. Technol. 55, 14806−14816. doi:10.1021/acs.est.1c04301

Appendix 3
Drawbacks of Using Wood as a Renewable Energy Biofuel on the University of Maine Campus

NOTE: This appendix has yet to be edited for errors and omissions and expanded to include additional items raised by physical, social, and climate scientists, engineers, economists, and additional UMaine faculty members and administrators that served as reviewers of the whitepaper.

In addition to the drawbacks itemized in Appendix 2, …

While in theory, biofuels could be deployed to result in net-zero carbon emissions, the current track record in the use of wood biofuels in practice has been highly controversial.[34] Among the critiques raised include that even though burning wood emits far more CO_2e from a smokestack than burning oil or gas, the adverse warming effects of wood burning and its increases in emissions over fossil fuels is not offset until decades later. <Is this true for a working forest in active production for over 50 years?>. An increase in facilities burning wood over fossil fuels will increase actual CO_2e emissions for decades. Further, there is no binding governmental or industrial oversight that ensures that forests grow back or that the growth will actually offset the carbon load already emitted into the atmosphere. It is common practice to replant hardwood forests with fast-growing pines for biomass production which actually decreases the carbon density of wooded areas. The pellet production industry routinely insists that it uses only the wood bits not used for other purposes (i.e., waste) yet the definition of waste is extremely loose and full logs are often used in the pellet production process. All of this results in a "gaming" of the renewable energy accounting system for biomass. Further, wood biomass is far less energy dense than most fossil fuel alternatives and has high variability in the biomass material. This makes its burning less efficient and often dirtier than fossil fuels.

It should be noted that these drawbacks in current practices are drawn from references critical of the wood pellet industry in an international context. This does not negate the existence of similar concerns that would need to be addressed in the burning of wood waste in a large-scale operation such as might be proposed for the University of Maine.

Because it takes so long under current technology to start up, increase, and shut down the burning of wood biomass, a backup source of heat generation is still needed to deal with startup and peak loads. Thus, an ongoing dependency on alternative fuel burning typically continues in such operations. This might be supplied by a liquid or gas renewable biofuel but campus intentions are not yet known.

Regardless of its potential drawbacks, if a wood burning interim solution is pursued for the University of Maine steam plant to decrease near-term net-zero carbon emissions for the campus, the critiques of the use of wood as a renewable resource should be addressed by any campus implementation. Stringently drafted contracts with high penalties for violation should restrict wood suppliers to use only waste wood not suitable for other primary purposes (e.g., pulp and lumber), the waste must be acquired from only FSC Certified sustainable wood parcels or cast-off waste from lumber mills that saw wood primarily from certified sustainable growers,

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[34] See: The Millions of Tons of Carbon Emissions that Don't Officially Exist (https://www.newyorker.com/news/annals-of-a-warming-planet/the-millions-of-tons-of-carbon-emissions-that-dont-officially-exist) and How Burning Wood Pellets in Europe is Harming the U.S. South (https://climate.to/ten-years-to-1-5c-how-climate-anxiety-is-affecting-young-people-around-the-world-podcast/)

and the carbon sequestering through new growth each year must verifiably offset the carbon emitted that year from the steam plant. If land from which biofuel has been obtained is no longer used as *working forest* in the future such as through land use change, then contractually enforceable penalties should be payable to the university in an amount sufficient to purchase carbon offsets to achieve carbon neutrality for the land in question for the remainder of the 50 years. Further, the trucking of wood waste to the campus for burning (i.e., many large truckloads each and every day year around) and removal of ash must be included in the CO2e emission computations. Truck deliveries should occur other than at times when classes are in session and enforced by contract. In addition to CO2e emissions, smoke from the burning of wood contains particulate matter and other pollutants that should be stringently controlled and/or recaptured through appropriate design, regular testing, and maintenance requirements.

Use of near-zero carbon emission energy sources such as solar or wind do not raise this plethora of concerns. Solar and wind energy systems during their operation do not directly produce air pollutants and greenhouse gases nor do they require the continued transport operations, data tracking, and enforcement burdens that biomass burning involves. As such, wood burning and biomass burning in general is not a substantial nor viable generalizable solution for addressing carbon emissions for the nation. However, wood burning might be assessed for consideration in a state such as Maine where waste wood is abundant, nearby, and perhaps could be economically viable in meeting some short-term fossil fuel reduction goals. A better biofuel option might be to redesign the steam plant or build a new one to be able to use a range of biofuel options (solid, gas, liquid) so that when biofuel technologies advance over time the university may switch to cleaner, cheaper and easier to transport net-zero GHG emission biofuels as needed. Further, the plant should probably be designed as a co-generation facility supplying both heat and electricity to increase the likelihood of meeting federal rules regarding renewability and to serve as a long-term backup electric power source to address potential varying supplies of solar and wind energy in the future.

The question remains whether the campus should invest limited campus financial resources first and foremost in incremental achievement of the long-term zero-carbon commitment goal of 2040 by advancing electrification and non-combustion near-zero carbon emission energy infrastructure. Or should the campus instead invest currently available financial resources to achieve some interim net-zero carbon reduction goals in the next decade through wood burning in order to provide breathing space for achieving the long-term commitment? Several detailed financial analyses incorporating many predictions about future costs would better position decision-making. Yet the need for a decision in moving forward is great even in the face of many uncertainties.