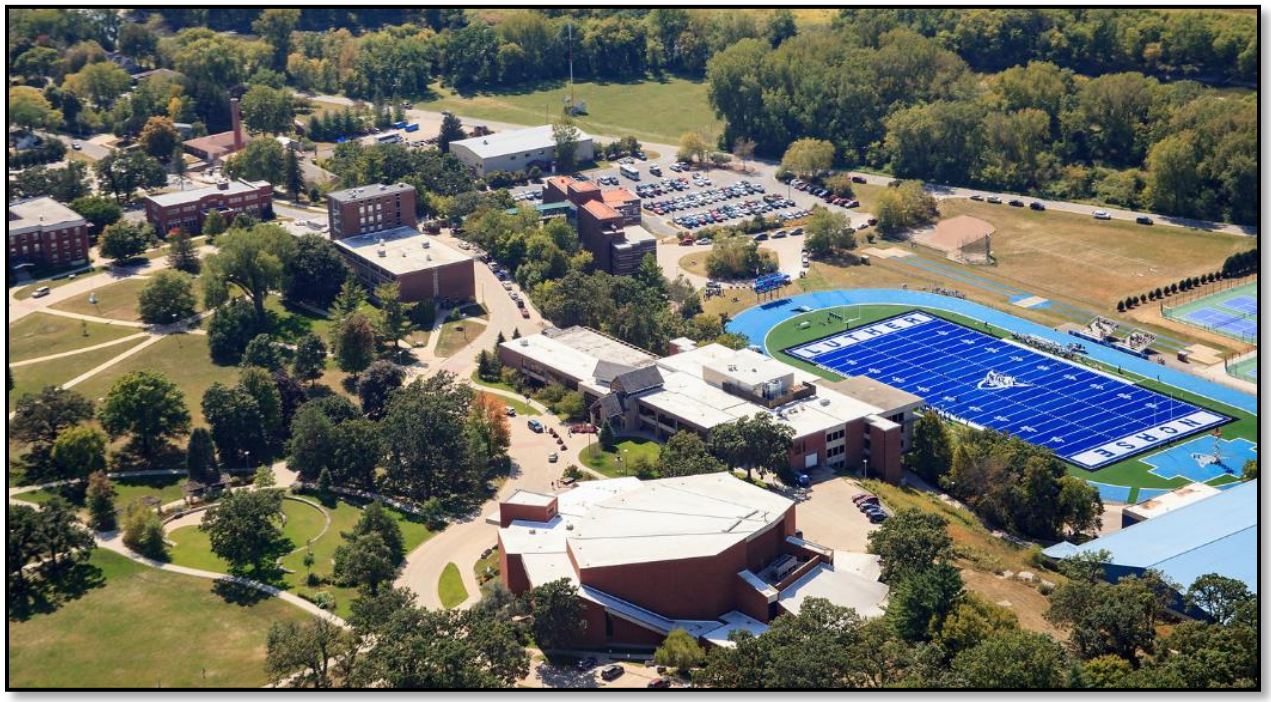
LUTHER COLLEGE
Energy Master Plan



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Executive Summary

MEP Associates has conducted an Energy and Utility Master Planning and Engineering Study for Luther College's Decorah, Iowa Campus. The goal of this study is to develop an energy master plan that articulates a pathway, including detailed systems design, to achieve carbon neutral energy systems by 2030, improve resiliency to power outages in the immediate future, manage campus electrical demand, leverage market incentives, and maintain comfort and reliability. The campus electrical plug, lighting and process loads are beyond the scope of this study. Since 2003, Luther College has successfully reduced these electrical loads by 36%.

A Business-As-Usual (BAU) case was developed to show both the costs and level of carbon emissions for the existing campus and thermal energy systems should no major changes be made.

The analysis focused on three potential options aimed at reducing energy and carbon emissions. All Options include a transition from the existing district steam system to a district Low Temperature Hot Water (LTHW) system with a ground source heat pump energy plant and a district chilled water (CHW) system. Each Option includes a detailed, year by year roadmap for implementation, coordinated with the current facility planning for renovations and additions. Options evaluated include:

1. Option B: 1,200 ton ground-source heat pump system
2. Option D: 450 ton ground-source heat pump system
3. Option D w/ Solar Thermal: Option D with a roof mounted solar thermal array

The annual energy use and carbon footprint were modeled for the BAU case and each Option. Cost estimates for building conversions, new geothermal energy plants, geothermal exchange fields and new campus heating and cooling distribution utilities were developed. Operations and maintenance costs for existing equipment was developed and coordinated with Luther College facilities staff. A Life Cycle Cost Analysis (LCCA) was performed for all options comparing the net present value of capital costs, utility costs, operations and maintenance expenses, a voluntary social carbon tax and a cost of carbon offsets over a 50 year study period.

Option B represents the largest carbon emissions reduction, with a 67.2% overall carbon emissions reduction and a 99% natural gas carbon emissions reduction. While the carbon emissions from burning natural gas are almost entirely avoided, the increased use of grid-purchased, carbon-intensive electricity results in only a 62.7% overall reduction. Option B provides the largest carbon emissions reduction for the campus thermal systems, however it has the lowest net present value savings compared to the BAU. As the electric utility continues its commitment to renewable energy sources and carbon emissions reductions, future grid purchased electricity will have less carbon emissions.

Option D has the highest net present value savings compared to the BAU and represents the best financial performance of all options evaluated. Option D provides a lower carbon emissions reduction, with a 55.2% overall carbon emissions reduction and a 69.7% natural gas carbon emissions reduction. Option D with solar thermal further reduces the campus natural gas carbon emissions by 72.3%.

As the original goal for this study was to achieve carbon neutrality, Option B would allow for near carbon neutrality for the campus heating and cooling systems if it were possible to source electricity from renewable energy systems. Should funding for Option B not be available, and especially if it is not possible to source green power, then Option D still presents a significant reduction in overall carbon emissions, with less capital investment. Both Options include a similar phased approach over 10 years, which will allow for lessons learned from previous phases to inform the subsequent phase, offering the opportunities for adjustments between options, as the financial climate may change.

List of Abbreviations

ACCH	Air Cooled Chiller
BAU	Business as Usual
CHP	Combined Heat and Power
CHW	Chilled Water
COP	Coefficient of Performance
DX	Direct Expansion (refrigerant based)
GHG	Greenhouse Gas
GHX	Geothermal Heat Exchanger
GSF	Gross Square Foot
HTHW	High Temperature Hot Water (160-180°F)
kBTU	Thousand British Thermal Units
LTHW	Low Temperature Hot Water (120 – 140°F)
LCCA	Life Cycle Cost Analysis
MWh	Mega Watt Hour
PPA	Power Purchase Agreement
REC	Renewable Energy Credit
RTU	Roof Top Unit
SGCC	Study Group on Climate Change
SCC	Social Cost of Carbon
TES	Thermal Energy Storage
WWCH	Water-cooled Chiller
WWHP	Water to Water Heat Pump

Introduction

Luther College has hired MEP Associates to perform Energy and Utility Master Planning and Engineering Services for their Decorah, Iowa Campus. The goal of this study is to develop and present recommended energy and utility master planning options that would enable Luther College to significantly reduce carbon emissions for their heating and cooling systems by 2072. The options analyzed have been compared to their Business As Usual (BAU) reference case to inform capital investment, operations and maintenance costs, energy use and carbon emissions reductions.

Existing Systems

Campus Buildings

Luther College is comprised of 38 buildings and almost 1,500,000 SF. Included in this study are 25 buildings, and 1,398,000 SF. Buildings remote to the central campus that would present a logistical and financial challenge to connect to a centralized heating and cooling system, such as the Baker Village, have been excluded from this study. Refer to Appendix A for a complete list of buildings included in this scope of work.

Campus Heating

Luther College operates a central steam plant located at the Korsrud Heating Plant building, originally built in 1946. The centralized steam system includes three Cleaver-Brooks boilers operating at 60 psi. Two of the boilers are 1,000 hp water tube boilers. The third boiler is a 600 hp fire tube boiler, installed in 2004, that includes an economizer, oxygen control, and other energy savings controls. The central steam system relies on natural gas with #6 fuel oil as a backup, which is permitted by the State for one of the water tube boilers. The central steam plant is capable of generating 55,000 #/hr of steam. The peak average daily steam load in the central steam plant within the past three years was 27,000 #/hr.

The central plant distributes medium pressure steam at 60 psi mainly through tunnels to 21 buildings on campus. For the buildings connected to the district steam network, some are heated directly by the steam and some convert the steam to hot water which is then circulated through the buildings. The remaining buildings on campus not connected to the central steam plant have stand-alone heating systems such as boilers, heat pumps and furnaces. The campus steam distribution is shown below in Figure 1.

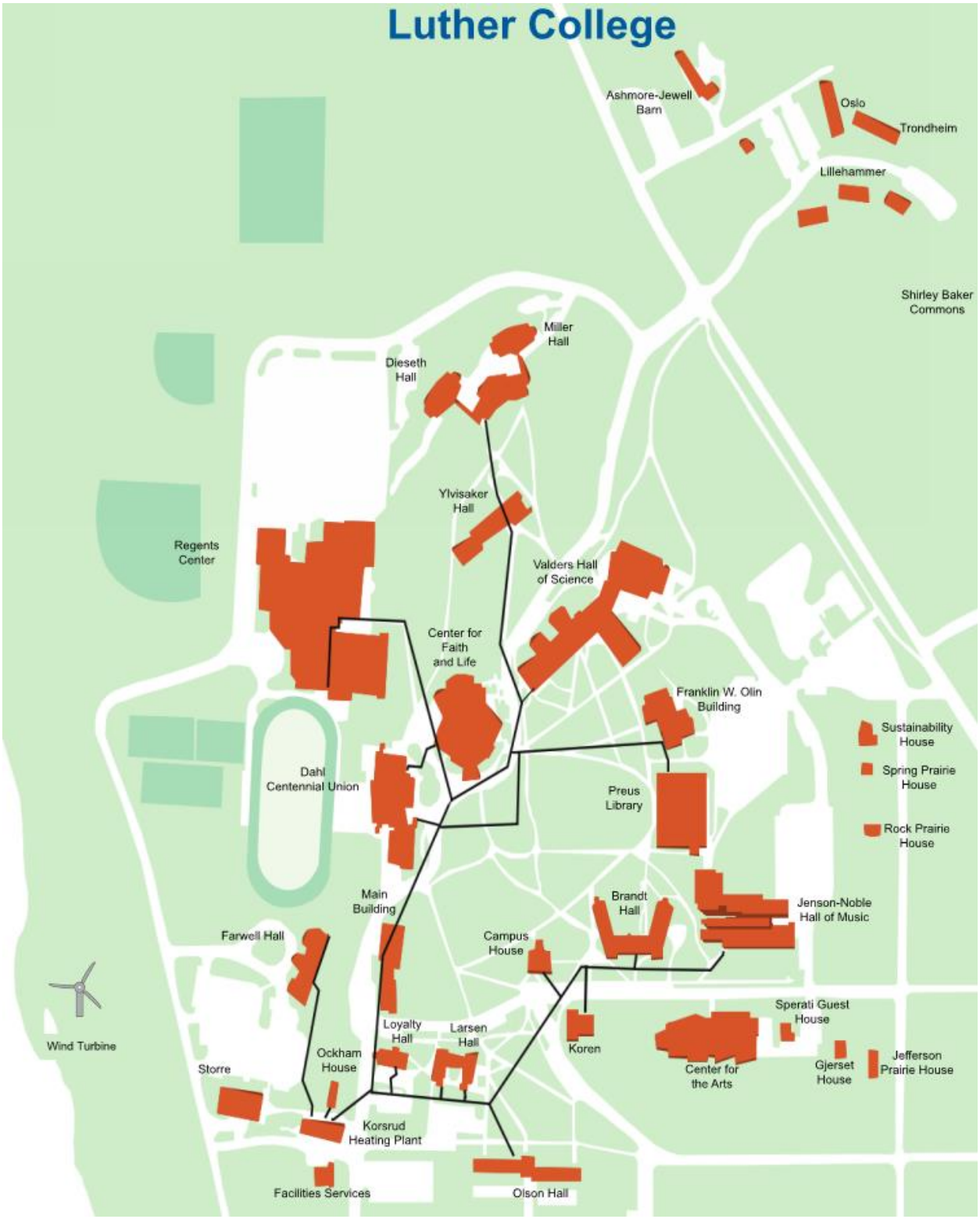


Figure 1: Campus Steam Distribution

Campus Cooling

Most cooling on campus is done via stand-alone water chillers, with two major distributed CHW systems. The Miller and Dieseth residence halls share a Trane 350-ton rotary-screw chiller, located in the Brunsdale Lounge building. Preus Library and Olin Hall share a Daikin/McQuay 300-ton centrifugal chiller. Both chilled water systems do not have cooling towers and instead a utilize a once through city water system for heat rejection. There is no distributed chilled water utility piping on campus, beyond what exists at Miller / Dieseth and Preus / Olin. Multiple stand-alone air and water cooled chillers located at individual buildings provide cooling. The chiller locations and approximate capacities are indicated in Table 1 below. The installed chilled water capacity from these chillers is approximately 2,000 tons and includes 400 tons of excess capacity.

Table 1. Campus Chiller Summary

Campus Chiller Summary		
Building	Type	Capacity (Tons)
Miller/Dieseth	City Water	350
Sampson Hoffman	Water-cooled	280
Valders	Water-cooled	190
Preus	City Water	300
Dahl	Air Cooled / Water-cooled	300
Farwell	Air Cooled	200
Main	Air Cooled	128
CFL	Air Cooled	180
Koren	Air Cooled	40
Total Campus Chiller Capacity	-	1,968
Approximate Campus Chiller Cooling Load	-	1,600

Other buildings on campus utilize DX style systems, including packaged roof top units (RTUs), for cooling. Some older refrigeration equipment still in use on campus utilize R-22 refrigerant. The total tonnage of campus cooling capacity, including air and water-cooled chillers, packaged RTUs and other DX equipment, is estimated at 2,720 tons.

Geothermal

Ground-source heat pumps provide heating and cooling for the Center for the Arts and Baker Village. The Center for the Arts (CFA) consists of 160 tons of water to air, ground source heat pumps and 40 tons of water to water, ground source heat pumps. The CFA geofield includes of 88 boreholes at a depth of 275'. As noted above, Baker Village is not included in the scope of this study.

Domestic Hot Water

Dieseth, Miller, Brandt, Ylvisaker, Larsen, Olson, Regents Center, Farwell, Dahl Centennial Union, Olin and Valders utilize steam from the central steam plant for domestic water heating via steam to hot water heat

exchangers. Dieseth, Miller, Ylvisaker, Larsen, and Olson have back up electric elements for use when the steam is off. The remaining buildings on campus utilize electric, storage type water heaters for domestic water heating.

Stand-Alone Systems

Heating

There are 8 buildings, totaling approximately 101,00 GSF, that are not connected to the central steam plant. These buildings are heated using natural gas or electricity via boilers and air handlers.

Cooling

The majority of cooling on campus is provided through individual stand-alone systems. There is no centrally distributed chilled water utility piping on campus, beyond what exists at Miller / Dieseth and Preus / Olin. Buildings are cooled with either a local air or water cooled chilled water system, a direct expansion (DX) system, RTUs or similar, or through-the-wall type air conditioners.

Campus Electrical Systems

Based on data from 2018, Luther College annually purchases about 13,000 MWh with a peak demand average of about 2.9 MW over the previous 5 years leading up to 2018. In the last three years Luther College has been exposed to increasingly frequent, disruptive, and costly power outages that have caused damage to its wind turbine and other large electrical devices (motors, contactors and VFD's) on campus. On-site solar generates electricity for Baker Village (net zero), the President's residence, Sustainability House, and the campus distribution grid. These solar arrays have been funded via a variety of financial arrangements, including Luther College ownership, equipment lease, and a third-party Power Purchase Agreement (PPA). The campus has 2 MW of solar PV generation, 1.6 MW wind generation and 370 kW of Lithium Ion battery storage.

Luther College currently purchases RECs from a local wind turbine to offset a 2,000 MWh of the campus's electrical consumption. Luther College also owns a 1.6 MW wind turbine. The power generated by the wind turbine is brought back to campus via an underground power line and is currently sold to Luther College's electric utility partner, Alliant Energy. The related RECs are retained by the College and used to offset electricity purchases and reduce Luther College's campus carbon footprint. These average 3,300 MWh per year.

Campus Utility Energy Master Plan

Business as Usual (BAU) Forecast

The BAU forecast forms the foundation for a comparison of the relative costs and benefits of the alternative cases included in this study. It includes a forecast of energy consumption and cost, operations and maintenance expenses, energy system capital expenditures, and GHG emissions. The BAU forecast is based on historical energy performance at Luther College and has been forecasted through the end of 2070 using a variety of assumptions outlined below. The relative performance of the BAU and alternative cases will be GHG emissions over time compared to the goals established by Luther College. The utility energy master plan will focus on Scope 1 emissions associated with the combustion of fossil fuels on campus and Scope 2 emissions associated with purchased electricity.

The BAU case will outline the historic and forecasted GHG emissions and energy consumption for the campus through 2050. The annual heating and cooling load profile for the campus BAU case is included in Figure 2 below.

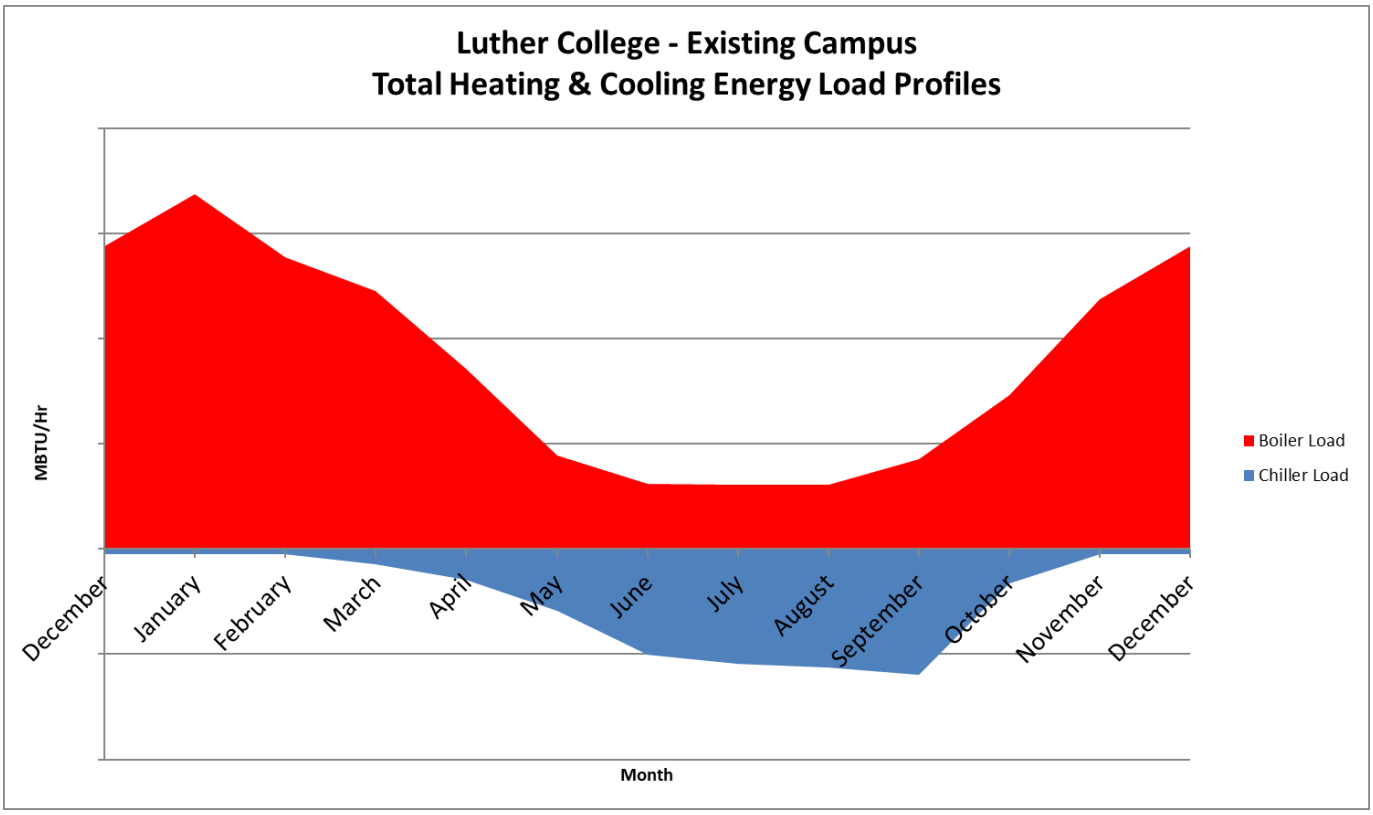


Figure 2: BAU Thermal Profile

The BAU implementation plan for year 2031 is included in Figure 3 below, including major projects tentatively planned by year. A detailed year by year phasing BAU road map is included in Appendix B.

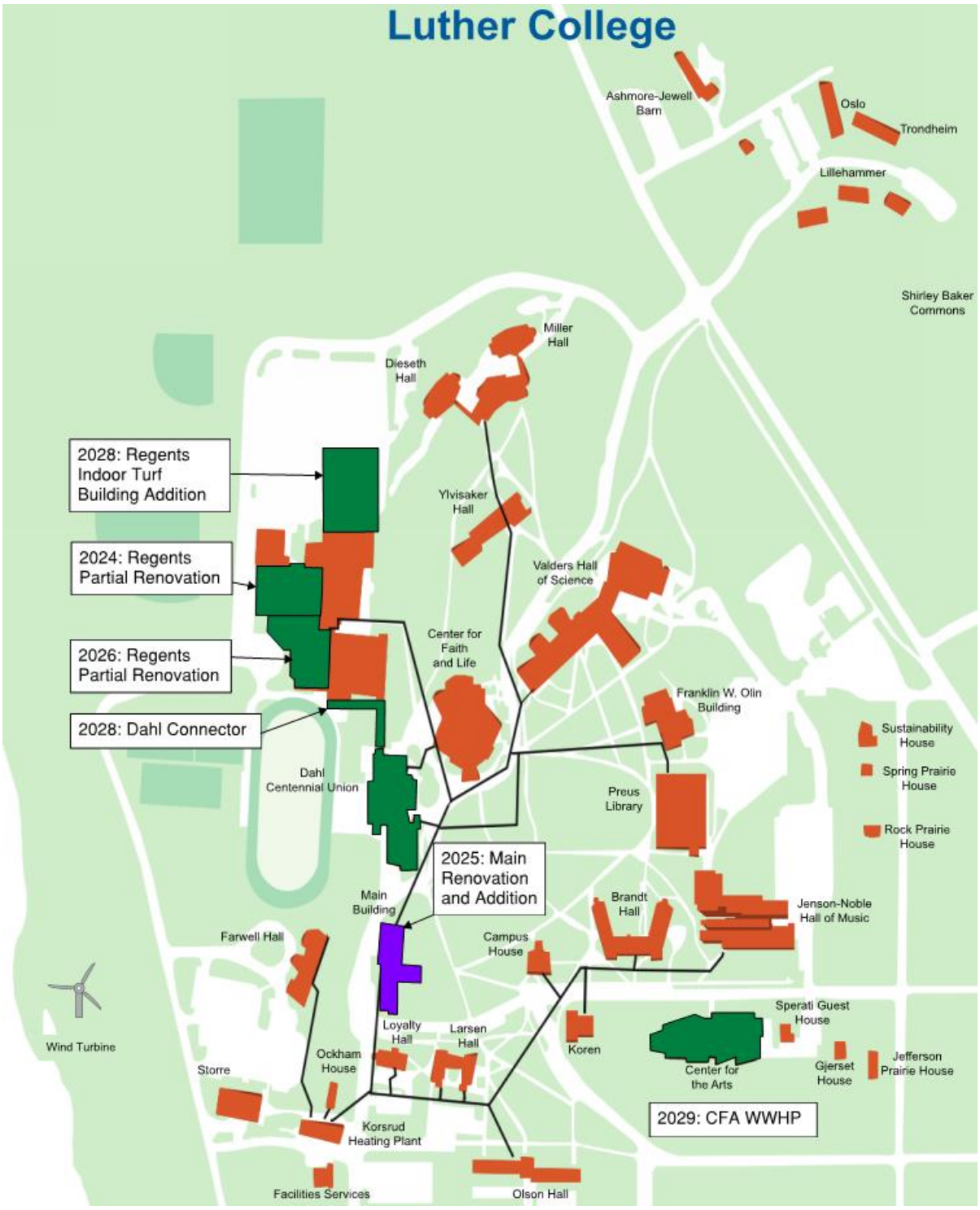


Figure 3: BAU Facilities Plan by Year

The BAU implementation plan is outlined in Table 2 below, including planned renovations and additions to campus buildings during the current planning phase.

Table 2: BAU Implementation Plan by Year

Year	Tentatively Planned Renovations & Additions	Energy Plant & Geofield Installations
2022	-	-
2023	-	-
2024	Regents (partial renovation)	-
2025	Main (renovation & addition)	-
2026	Regents (partial renovation)	-
2027	-	-
2028	Regents - Indoor Turf Building (addition) Dahl Centennial Connector (addition)	-
2029	CFA	New WWHP at CFA (150 Ton)
2030	-	-
2031	-	-

Energy and GHG Emissions

Campus carbon emissions from 2003 to 2020 are shown below in Figure 4. Between 2003 and 2020, the carbon emissions were reduced by 31%. During this period, the natural gas carbon emissions remained relatively consistent while the electricity carbon emissions were significantly reduced.

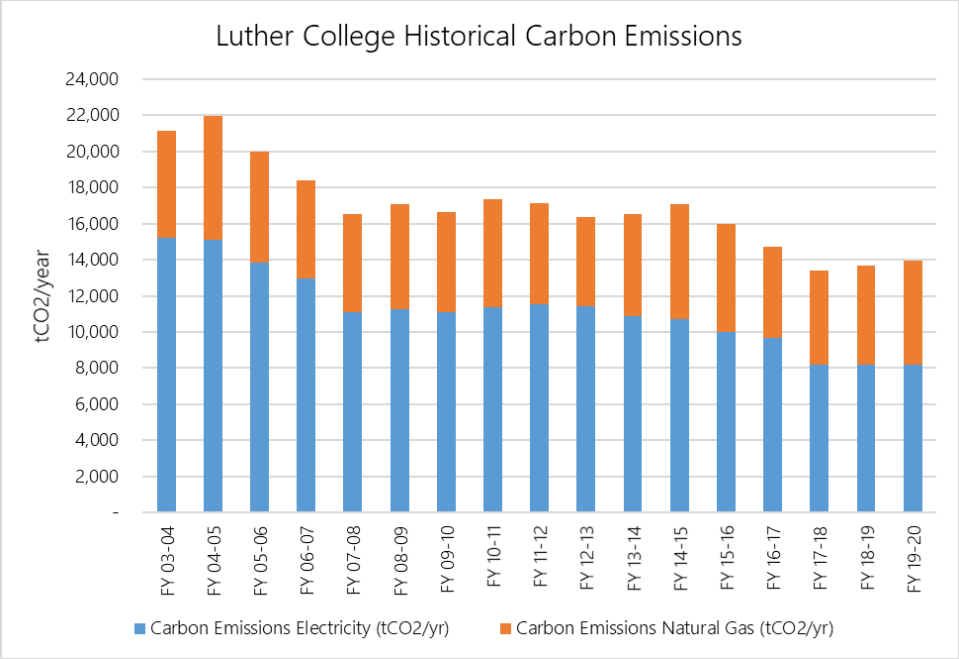


Figure 4: Campus Historical GHG Emissions

Campus energy use from 2007 to 2020 are shown below in Figure 5 and Figure 6. Since 2003, electricity usage has decreased by 36%, while natural gas usage has been inconsistent and has varied by about 10% from the average usage.

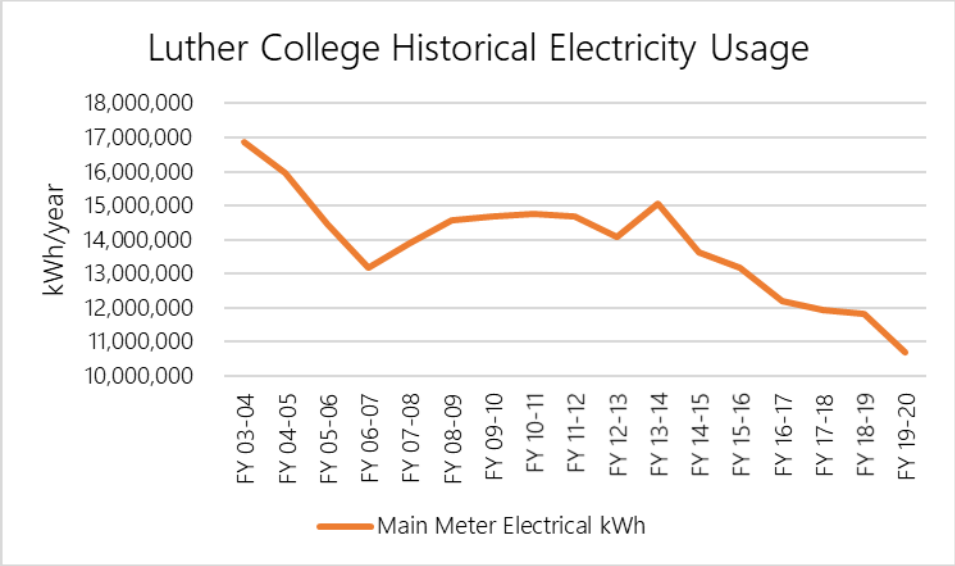


Figure 5: Historical Electricity Usage

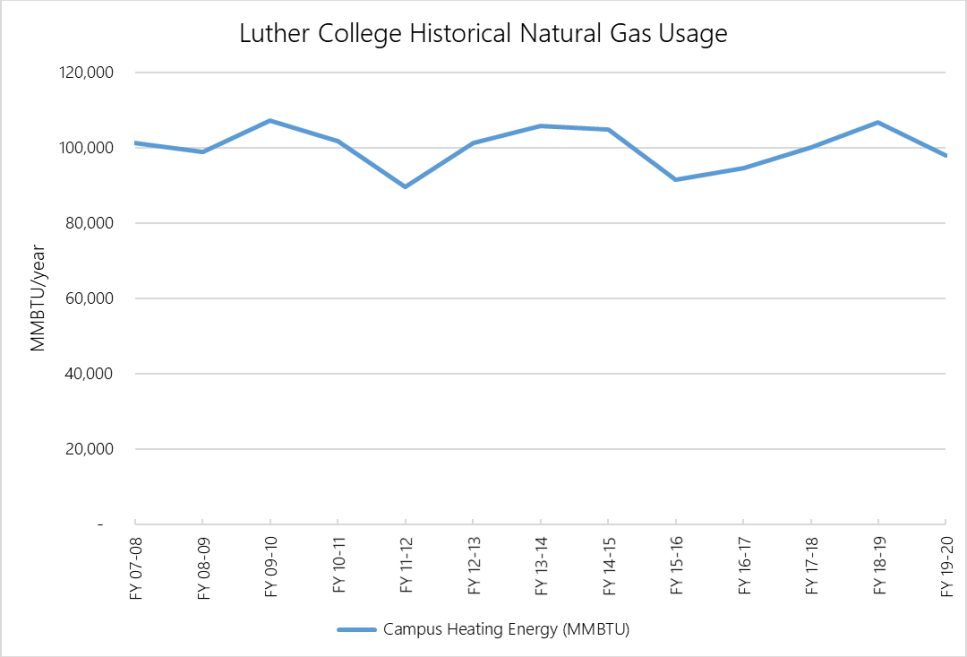


Figure 6: Historical Natural Gas Usage

The predicted energy use, carbon footprint and utility costs for the BAU case today (2020) and at the end of the current facility planning period (2032) are summarized below in

Table 3. These energy use and carbon emission predictions inform the campus operations and provide the performance baseline for comparison of energy master planning options evaluated. All costs are in today's dollars. The carbon emissions factors used to calculate the campus carbon footprint are included in Table 4 below. The carbon emissions factor for electricity is currently 1.24 lb/KWH, as the electrical grid continues to move towards renewable energy sources, the carbon emission factor for purchased electricity will continue to reduce over time. This factor could potentially be reduced to as low as zero, as electrical utilities commit to 100% renewable energy sources.

Table 3: Campus Energy Use & Carbon Emissions for HVAC Systems

	Existing BAU Systems (2020)	Existing BAU Systems (2032 - 2070)
Elec (kWh/yr)	2,042,722	2,329,008
NG (Therm/yr)	945,963	1,009,073
Elec Utility ($/yr)	$168,570	$192,195
NG Utility ($/yr)	$378,385	$403,629
Total Utility ($/yr)	$546,955	$595,824
Energy (MBTU/yr)	101,566,114	108,853,873
Carbon Emissions - Elec (t CO2/yr)	1,071	1,223
Carbon Emissions - NG (t CO2/yr)	5,020	5,355
Total Carbon Emissions (t CO2/yr)	6,091	6,578

Table 4: Carbon Emission Factors

Utility CO2 Emissions Factors	
Electricity (lb CO2/KWH)	Natural Gas (lb CO2/Therm)
1.24	11.70

City Water Use

The water cooled chillers at Dieseth / Miller and Olin / Preus utilize city water for heat rejection, in a single pass configuration. A conventional water cooled chiller would be coupled with a condenser water system including a cooling tower for heat rejection. The single pass configuration consumes more water than a conventional condenser water system, as city water is continuously dumped down the drain instead of being cooled and recirculated. Metering information from Luther College has identified how much water is being used annually by these city water, single pass chillers. A cost for the difference in city water use between a conventional condenser water system and these single pass chillers has been included in the BAU case.

Capital Expenditures

The BAU phasing roadmap was carried out to the year 2031. This year was chosen as it is the extent of the current campus facilities planning with regards to major campus renovations and additions. Beyond 2031, any potential campus additions and renovations were considered too undefined for incorporation into the BAU case and the LCCA. A detailed year by year phasing road map for the BAU is included in Appendix B. The known campus renovations and additions include:

- Regents – extensive renovation throughout
- Regents – addition of the new Indoor Turf Building
- Dahl Centennial - connector addition
- Main – addition and extensive renovation throughout

A redesign of the Center for the Arts (CFA) was also included in the BAU, incorporating the replacement of the existing air to water heat pumps with a 4-pipe fan coil unit system served by a central 150 ton water to water heat pump (WWHP). The CFA redesign was based on the age of the existing air to water heat pumps, installed in 2001, and the college's ongoing the maintenance requirements of these units.

In addition to correcting operations and maintenance issues at CFA, the installation of a 150 WWHP will allow for the incorporation of the existing 88 geofield bores and the existing CFA WWHP to feed into the proposed campus low temperature hot water and chilled water distribution network outlined below in Options B and D.

Capital expenditures for the BAU case also considered the replacement of HVAC systems associated with heating. If the HVAC equipment was already beyond its useful life or would be by 2031, these replacement costs were included in the BAU as a capital expense. In addition, as the study spans 50 years, we included another equipment replacement cost for 2070. Replacement costs for HVAC systems that would be impacted

by LTHW building conversions were considered, providing a baseline cost comparison for the master plan scenarios. A summary of the HVAC replacement costs by building are provided in Table 5.

Table 5: BAU Capital Cost Summary for Existing Buildings

Building	Initial HVAC Replacement	50 year HVAC Replacement
Ylvisaker Hall	$680,000	$680,000
Miller Hall	$90,000	$280,000
Dieseth Hall	$90,000	$280,000
Brunsdale Lounge	$120,000	$760,000
Regents Center	$760,000	$1,060,000
Center for Faith & Life (CFL)	$350,000	$820,000
Valders Hall of Science	$220,000	$1,550,000
Sampson Hoffland Laboratories	$20,000	$2,540,000
Franklin W. Olin	$510,000	$510,000
Preus Library	$10,000	$560,000
Jenson-Noble Hall of Music	$470,000	$600,000
Brandt Hall	$810,000	$1,160,000
Center for the Arts (CFA)	$3,350,000	$3,470,000
Koren Hall	$80,000	$150,000
Dahl Centennial Union	$30,000	$1,290,000
Farwell Hall	$0	$930,000
Loyalty Hall	$10,000	$390,000
Larsen Hall	$570,000	$570,000
Olson Hall	$530,000	$530,000
Ockham House	$20,000	$50,000
Korsrud Heating Plant	$1,100,000	$1,100,000
Facilities Services	$110,000	$110,000
Total	$9,930,000	$19,390,000

The Korsrud heating plant costs include replacement of the existing steam boilers twice during the study period. The majority of the steam and steam condensate distribution piping installed in tunnels throughout the campus has already or will exceed its useful life during the 50-year analysis period covered by this energy master plan. We have included a $3M capital expenditure for the phased replacement of the campus steam distribution network over three years, from 2030 to 2033.

Operations & Maintenance

MEP and Luther College Facilities Services staff developed the operations and maintenance expenses related to the current HVAC equipment installed on campus. These expenses include maintaining the central steam plant and steam distribution systems, the distributed chilled water equipment and packaged DX HVAC equipment (e.g. rooftop units) throughout the campus. The BAU case includes an annual operation and maintenance expenses of $450,584. The annual maintenance costs were determined using the type and capacity of equipment on campus. A summary of the maintenance costs is included below in Table 6. These maintenance costs were applied to both the BAU and the Options evaluated, where the equipment listed is applicable. A summary of maintenance costs by year and equipment type is included in Appendix C.

Table 6: Operations and Maintenance Expenses

Annual Maintenance Cost Estimates	
System	Cost
Water-cooled Chiller System	$70/Ton
Air Cooled Chiller System, Air Source Heat Pump System	$50/Ton
Direct Expansion RTU System	$25/Ton
City Water Chiller System	$70/Ton
Water to Water Heat Pump System	$70/Ton
High Efficiency Condensing Boiler (>12,000 MBH)	$5,200

The existing steam plant requires specifically trained and licensed full-time employees to operate and maintain the boilers and ancillary equipment, as well as the steam and condensate return distribution system. Additional maintenance includes monitoring and maintaining the chemical treatment, patching distribution piping in tunnels, maintaining steam traps and condensate pumps - both in the heating plant and throughout the steam distribution systems. Salary included in the annual maintenance costs does not include fringe benefits or costs to maintain steam operators licensing.

BAU Energy & Carbon Performance

The predicted energy use and carbon emissions for the campus BAU case over the current facility planning period from 2022 to 2031 are summarized in Table 7 below. Beyond 2032, with no additional capital planning projects or major renovations planned for the campus, the annual energy and carbon projections remain the same from year 2032 to the end of the 50 year study period, 2072. The monetary values included in the table are all in today's dollars.

Table 7: BAU Energy & Carbon Summary by Year

	Years		
	2022-2024	2025-2027	2028-2031
Elec KWH/yr	2,042,722	2,075,782	2,329,008
NG Therm/yr	945,963	956,767	1,009,073
Elec Utility $/yr	$168,570	171,298	192,195
NG Utility $/yr	$378,385	382,707	403,629
Total Utility $/yr	$546,955	554,005	595,824
Energy MBTU/yr	101,566,114	102,759,267	108,853,873
Carbon Emissions Electricity (t CO2/yr)	1,071	1,089	1,223
Carbon Emissions Natural Gas (t CO2/yr)	5,020	5,078	5,355
Total Carbon Emissions (t CO2/yr)	6,091	6,167	6,578

Master Plan Scenarios

Summary of Level 1 Analysis (Options A-D)

The Level 1 Option Screening phase, conducted in 2019, included four major options evaluating technologies and solutions based on initial capital cost estimates, energy savings, and carbon reduction. Options investigated under the Level 1 stage were centered around the following design elements:

- Elimination of the steam boilers
- Removal of the existing steam distribution network
- Installation of a new low temperature hot and chilled water distribution network connecting all buildings in order to maximize simultaneous heating and cooling capacity
- Installation of new WWHPs and supplementary high efficiency low temperature hot water boilers in a new energy plant located adjacent to the new Indoor Turf Building
- The new hot and chilled water distribution networks coupled with the energy plant provide heating and cooling redundancy and increase resiliency.
- Incorporation of the new 150 ton WWHP and 88 bore geo system located at CFA
- Reuse of existing campus cooling and geothermal assets where applicable to reduce the size of new central plant equipment
- Conversion of single pass, city water chillers at Preus / Olin & Dieseth / Miller to a traditional water-cooled chiller plant with the addition of a condenser water systems, including cooling towers

Options evaluated in the level 1 options screening phase included:

- Option A: 1,800 ton geothermal w/ (1) 14,000 MBH boiler
- Option B: 1,200 ton geothermal w/ (2) 13,000 MBH high efficiency boilers
- Option C: 760 ton geothermal w/ (3) 10,000 MBH high efficiency boilers
- Option D: 450 ton geothermal w/ (3) 12,000 MBH high efficiency boilers

Options B and D from this initial analysis performed better than options A and C in terms of energy and carbon reduction, capital investment and simple payback, and were selected as the two options for advanced LCCA, to be conducted in this Level 2 phase: Options Analytics.

Level 2 Options Analytics

The Level 2 Options Analytics evaluated performance metrics and costs across several options. The final options evaluated in comparison with the projected BAU reference case are summarized below:

- Reference Case: Represents the current BAU campus operations
- Option B: Represents a complete conversion from steam to a LTHW district heating network, an expansion of the central cooling, and a 1,200 ton ground-source heat pump system

- Option D: Represents a complete conversion from steam to a LTHW district heating network, an expansion of the central cooling, and a 450 ton ground-source heat pump system
- Option D with solar thermal: Option D with solar thermal incorporates a solar thermal array into the above described Option D

For all options, the campus conversion is implemented in annual phases through 2031, aligned with the current campus facilities planning and the BAU.

Option B

Overview

Option B includes a campus conversion from steam to a LTHW district heating network, an expansion of the central cooling network, and an expansion of the ground-source heat pump system. Heating and cooling capacity from the new geothermal energy plant will replace existing, less efficient systems, such as DX, roof top units (RTUs) and air cooled chillers. Single pass, water cooled chillers at Preus / Olin and Dieseth / Miller will be demolished and their capacity replaced by the new geothermal energy plant. Option B implementation will occur over a 10 year period, staring in 2022 and ending in 2031. The campus conversion implementation plan includes new LTHW and chilled water utilities distribution throughout campus, building conversions from steam to LTHW, planned renovations and additions, a new energy plant and geofield construction. The final building conversion phasing plan for Option B 2031 is included in Figure 7 below, including building conversions, renovations, additions and new projects by year. A detailed year by year phasing road map is included in Appendix B. The Option B implementation plan is further outlined in Table 8 below.

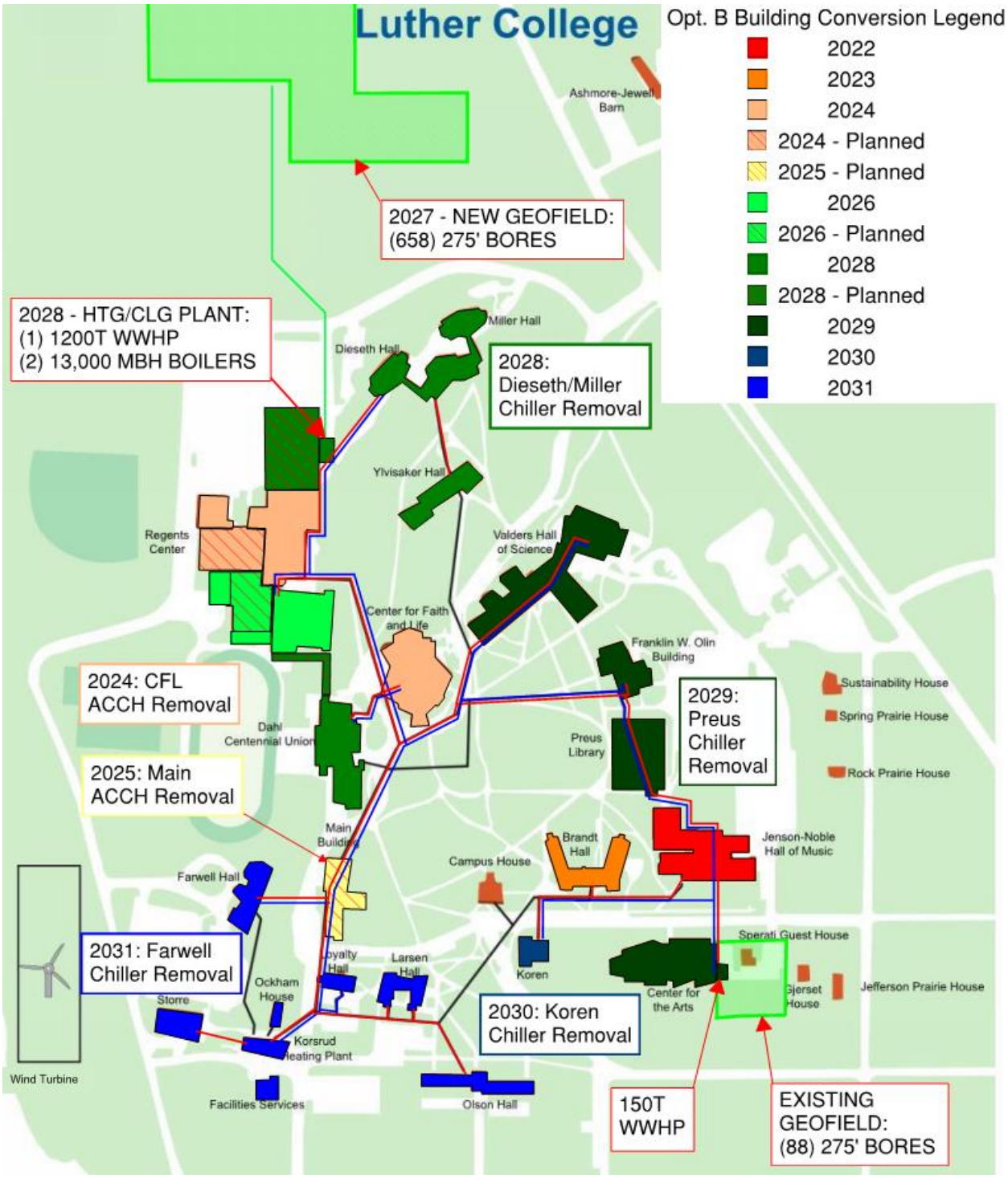


Figure 7: Option B Building Conversions by year

Table 8: Option B Implementation Plan by Year

Year	Building Conversions	Planned Renovations & Additions	Energy Plant & Geofield Installations
2022	Jenson-Noble	-	-
2023	Brandt	-	-
2024	CFL Regents (partial)	Regents (partial renovation)	CFL – ACCH removal (200 Ton)
2025	Main	Main (renovation & addition)	Main ACCH removal (128 Ton)
2026	Regents (partial)	Regents (partial renovation)	-
2027	-	-	New Geofield
2028	Dahl / Centennial Brunsdale Dieseth Miller Ylvisaker	Regents – Indoor Turf Building (addition) Dahl Centennial Connector (addition)	New Energy Plant (1,200 Ton WWHP + 26,000 MBH Boilers) Dieseth / Miller WCCH removal (350 Ton)
2029	Olin Preus Sampson Hoffland Valders	CFA (redesign)	New WWHP at CFA (150 Ton) Preus / Olin WCCH removal (300 Ton)
2030	Koren	-	Koren ACCH removal (40 Ton)
2031	Facilities Services* Farwell Korsrud Larsen Loyalty Okham Olson Storre	-	Farwell – ACCH removal (200 Ton)

*heating only

Building Conversions

For compatibility with the future campus LTHW distribution system for heating, all campus buildings utilizing steam will require a heating system conversion, including the removal of mechanical equipment served by steam, and replacement with equipment sized to meet the building heating loads at the LTHW design temperature. Option B building conversion costs also include the removal of the city water, single pass chillers at Preus / Olin & Dieseth / Miller, with replacement capacity provided by the new geothermal energy

plant. A total of 22 buildings and 1.38 million GSF will be converted from steam to LTHW heating systems at a cost of $12.2M. The building conversions will be completed in the phased approach outlined in the above implementation plan and aligned with currently planned building renovations. The building conversion costs are summarized below in Table 9.

Table 9: Option B Building Conversion Cost Summary

Building	Area (Sq. Ft.)	Total Cost
Ylvisaker Hall	46,065	$891,859
Miller Hall	84,083	$313,552
Dieseth Hall	82,287	$313,552
Brunsdale Lounge	7,680	$216,804
Regents Center	231,900	$701,769
Center for Faith & Life (CFL)	74,639	$890,267
Valders Hall of Science	103,232	$902,136
Sampson Hoffland Laboratories	71,997	$1,243,213
Franklin W. Olin	50,369	$472,166
Preus Library	102,523	$240,197
Jenson-Noble Hall of Music	48,539	$612,293
Brandt Hall	71,189	$1,216,982
Center for the Arts (CFA)	59,825	$-
Koren Hall	17,158	$192,481
Dahl Centennial Union	118,096	$1,006,661
Farwell Hall	76,681	$604,006
Loyalty Hall	14,835	$290,206
Larsen Hall	40,540	$798,682
Olson Hall	39,267	$799,656
Ockham House	4,000	$81,911
Korsrud Heating Plant	10,870	$209,983
Facilities Services	16,339	$187,572
Total	1,372,114	$12,185,946

Hybrid Heating and Cooling

Water to water heat pump systems perform most efficiently operating in simultaneous heating and cooling applications. When coupled with ground source heat exchangers, WWHPs can provide very efficient heating or cooling, with a high Coefficient of Performance (COP). A heat pump COP indicates the equipment efficiency and a higher COP translates to better efficiency. Ground source heat pump systems perform most efficiently with a balanced yearly load profile. For a ground source system, a balanced yearly load profile occurs when the heat that is stored in the ground during the summer equals the heat removed from the ground in the winter. In order to achieve a balanced load profile, a portion of the total heating and cooling loads will need to be provided by new hot water boilers and existing electric chillers. This use of supplemental heating and cooling sources is known as a "hybrid heating and cooling" approach. With hybrid heating and cooling, the heat pump system, including the ground source heat exchangers, is sized for the balanced yearly load, and does not need to be sized for the campus peak heating and cooling. As the cost of

the geothermal systems represent a large capital expenditure, they need to be correctly sized to meet the balanced load profile and supplemented with hybrid heating and cooling systems. The ground source heat pumps systems, including their operation under simultaneous loads, provide heating and cooling for a large percentage of the year with lower energy costs and carbon emissions compared to fossil fuel boilers and electric chillers.

For Option B, the WWHP system, including simultaneous and geothermal operating modes, provide the majority of the campus heating and cooling. The WWHP system is sized for 60% of the peak cooling load and provides 98.9% of the total annual heating and cooling energy. The annual heating and cooling load profile for Option B is included in Figure 8 below.

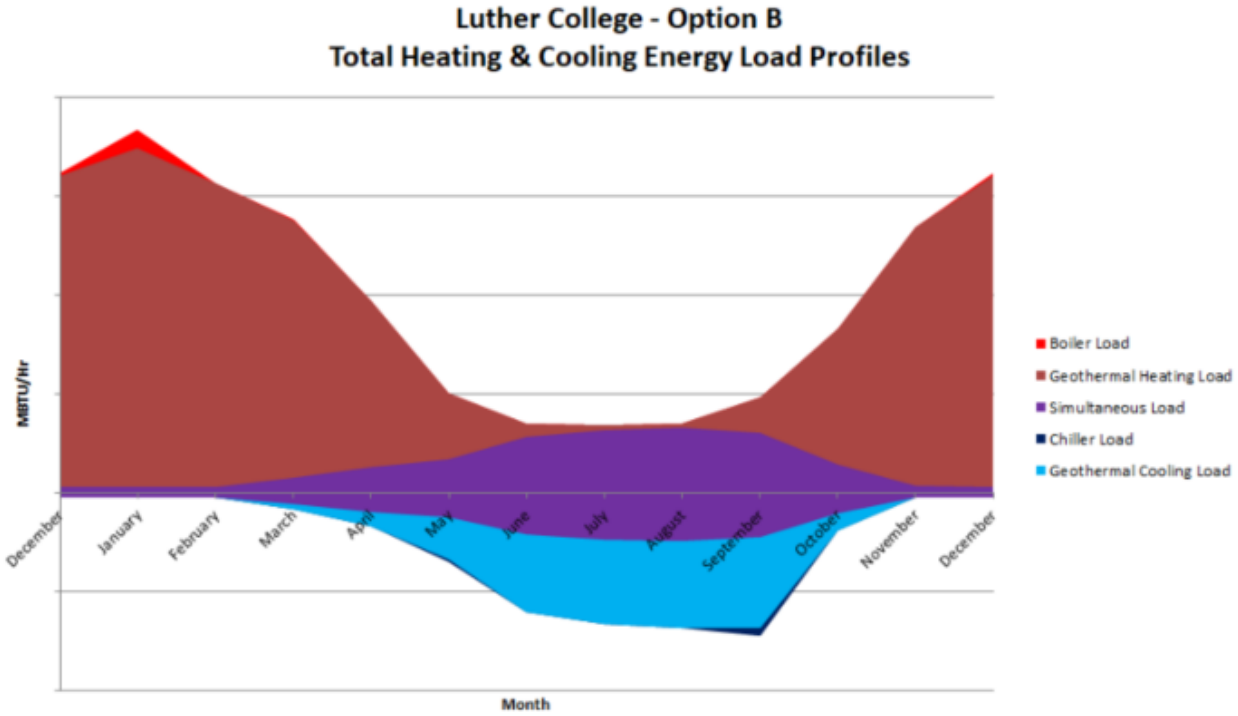


Figure 8: Option B Thermal Profile

Geothermal Energy Plant

The Option B new geothermal energy plant consists of a 1,200 ton, modular WWHP and (2) 13,000 MBH high efficiency condensing boilers. The WWHP will be coupled with a new geofield consisting of 658 ground loop heat exchangers, 275' deep. The geofield will be located north of campus, in the recreation fields north of the soccer field. Underground supply and return geothermal piping connect the geofield to the new energy plant at the Regents Addition / Indoor Turf Building.

The new energy plant equipment, including ground-source heat pumps, high efficiency condensing boilers, pumps and all ancillary equipment will be located adjacent to the new Indoor Turf Building. The geofield is scheduled to be installed in 2027, one year before the new energy plant and Indoor Turf Building addition in

2028. Once the new energy plant is online, the high efficiency condensing boilers will begin to replace the existing steam boilers. When the final phase of building conversions to LTHW are complete in 2031, the steam boilers can be taken offline.

Campus Utilities Estimated Cost

Option B costs include the design and construction of utilities for hot water and chilled water distribution piping, geofield utility piping and heat exchangers, energy plant equipment and building conversions. A summary of costs for Option B are included in Table 10 below.

Table 10: Option B Capital Costs

Year	Utilities	Geofield	Energy Station	Building Conversions	Design Fees	Total
2022	$2,064,743	-	-	$2,291,940	$348,535	$4,705,217
2023	-	-	-	$1,216,982	$97,359	$1,314,340
2024	$2,550,448	-	-	$1,241,151	$303,328	$4,094,928
2025	$362,218	-	-	-	$28,977	$391,195
2026	-	-	-	$350,884	$28,071	$378,955
2027	-	$8,267,469	-	-	$661,398	$8,928,867
2028	$1,184,999	-	$3,174,385	$2,742,428	$568,145	$7,669,957
2029	$2,207,604	-	-	$2,857,712	$405,225	$5,470,541
2030	$334,016	-	-	$192,481	$42,120	$568,616
2031	$2,530,489	-	-	$2,972,015	$440,200	$5,942,704
Total (Through 2031)	$11,234,517	$8,267,469	$3,174,385	$13,865,593	$2,923,357	$39,465,321

City Water Use

For Option B, the water cooled chillers at Dieseth / Miller and Olin / Preus, utilizing city water for heat rejection, will remain in operation until 2028 and 2029. An annual cost for the city water use for these single pass chillers has been included in this analysis until their removal.

Operations & Maintenance

Option B includes an initial annual operation and maintenance expense of $447,460 for 2022. The annual operations and maintenance costs for Option B significantly decrease to $178,170 after the existing steam plant is taking offline in 2031. The annual maintenance costs are based on the type and capacity for all equipment on campus for any given year during the study period. A summary of the maintenance costs is included above in Table 6. A summary of maintenance costs by year and equipment type are included in Appendix C.

Option B Energy & Carbon Performance

The predicted energy use and carbon emissions for Option B over the current facility planning period from 2022 to 2031 are summarized in Table 11 below. The monetary values included in the table are all in today's dollars. All escalation factors are summarized and applied in the Life Cycle Cost Analysis section below. Beyond 2032, with no additional capital planning projects or major renovations planned for the campus, the annual energy and carbon projections remain the same from year 2032 to the end of the study period, 2072, except for the planned reduction in carbon dioxide emissions at the electrical utility company. Alliant Energy, the electric utility that serves Luther College, has committed to at least 55% reduction in carbon dioxide emissions by 2050 for the electricity they generate. As the electric utility grid becomes greener, the carbon emissions associated with electricity use will be reduced.

Table 11: Option B Energy & Carbon Summary by Year for HVAC Systems

	Year							
	2022-2023	2024	2025	2026-2027	2028	2029	2030	2031-2032
Elec KWH/yr	1,997,017	1,935,785	1,963,893	1,952,715	5,790,559	6,953,519	7,025,579	8,057,955
NG Therm/yr	935,363	945,963	956,767	956,767	438,693	130,480	120,330	9,340
Elec Utility $/yr	$164,798	$159,745	$162,064	$161,142	$477,849	$573,819	$579,765	$664,959
NG Utility $/yr	$374,145	$378,385	$382,707	$382,707	$175,477	$52,192	$48,132	$3,736
Total Utility $/yr	$538,943	$538,130	$544,771	$543,849	$653,326	$626,011	$627,897	$668,695
Energy MBTU/yr	100,350,139	101,201,248	102,377,502	102,339,363	63,626,650	36,773,435	36,004,244	28,427,698
Carbon Emissions Electricity (t CO2/yr)	1,047	1,014	1,029	1,023	3,086	3,720	3,759	4,324
Carbon Emissions Natural Gas (t CO2/yr)	4,964	5,020	5,078	5,078	2,328	692	639	50
Total Carbon Emissions (t CO2/yr)	6,011	6,034	6,107	6,101	5,414	4,412	4,398	4,374

Option B results in a 67.2% overall carbon emissions reduction and a 99% natural gas carbon emissions reduction when compared to the BAU case. The carbon emissions for Option B compared to the BAU case are summarized in Table 12 below.

Table 12: Option B Carbon Savings vs. BAU

	Existing BAU Systems 2020	Option B -New Geothermal Systems 2072	% Reduction
Carbon Emissions Electricity (t CO2/yr)	1,071	1945	-81.7%
Carbon Emissions Natural Gas (t CO2/yr)	5,020	50	99%
Total Carbon Emissions (t CO2/yr)	6,091	1,995	67.2%

Option D

Overview

Option D includes a campus conversion from steam to a LTHW district heating network, an expansion of the central cooling network, and an expansion of the ground-source heat pump system at a smaller scale than Option B. Heating and cooling capacity from the new geothermal energy plant will replace existing, less efficient systems, such as DX, roof top units (RTUs), while existing air and water-cooled chillers will remain. Single pass, water-cooled chillers at Preus / Olin and Dieseth / Miller will be converted to traditional water-cooled systems with cooling towers. Option D implementation will occur over the same 10 year period, staring in 2022 and ending in 2031. The campus conversion implementation plan includes new LTHW and chilled water utilities distribution throughout campus, building conversions from steam to LTHW, planned renovations and additions, a new energy plant and geofield construction.

The final building conversion phasing plan for Option D 2031 is included in Figure 9 below, including building conversions, renovations, additions and new projects by year. A detailed year by year phasing road map is included in Appendix B. The Option D implementation plan is further outlined in Table 13 below.

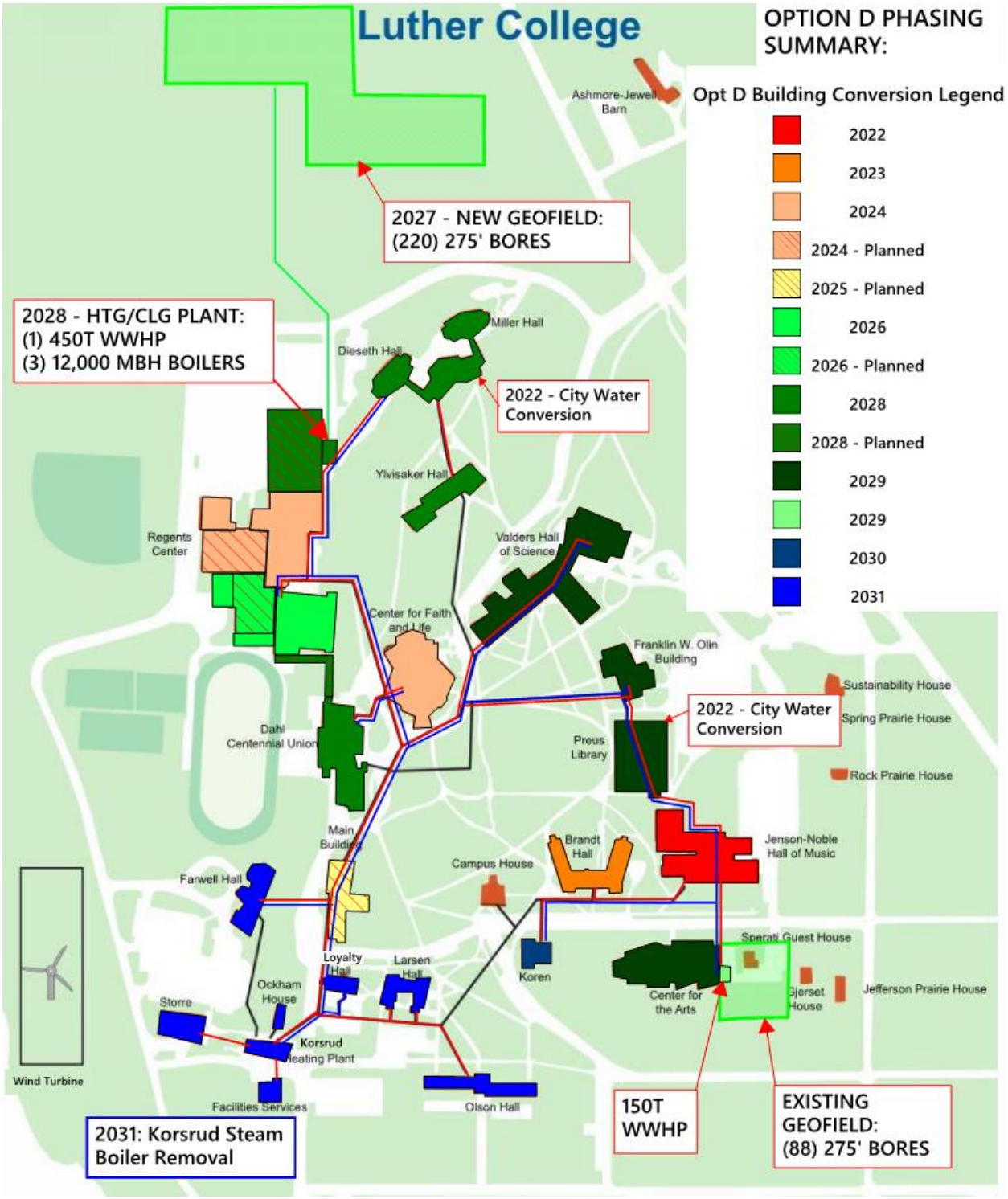


Figure 9: Option D Building conversions by year

Table 13: Option D Implementation Plan by Year

Year	Building Conversions	Planned Renovations & Additions	Energy Plant & Geofield Installations	City Water Chiller Conversions
2022	Jenson-Noble	-	-	Dieseth / Miller Preus / Olin
2023	Brandt	-	-	-
2024	CFL Regents (partial)	Regents (partial renovation)	-	-
2025	Main	Main (renovation & addition)	-	-
2026	Regents (partial)	Regents (partial renovation)	-	-
2027	-	-	New Geofield	-
2028	Dahl / Centennial Brunsdale Dieseth Miller Ylvisaker	Regents - Indoor Turf Building (addition) Dahl Centennial Connector (addition)	New Energy Plant (450 Ton WWHP + 36,000 MBH Boilers)	-
2029	Olin Preus Sampson Hoffland Valders	CFA (redesign)	New WWHP at CFA (150 Ton)	-
2030	Koren	-	-	-
2031	Facilities Services* Farwell Korsrud Larsen Loyalty Okham Olson Storre	-	-	-

*heating only

Building Conversions

Option D includes building conversions for a total of 22 buildings and 1.38 million GSF at a cost of $13.8M. The building conversions will be completed in the phased approach outlined above and aligned with

currently planned building renovations. Option D building conversion costs are summarized below in Table 14.

Table 14: Option D Building Conversion Cost Summary

Building	Area (Sq. Ft.)	Total Cost
Preus City Water Chiller Conversion	-	$657,123
Brunsdale City Water Chiller Conversion	-	$1,022,523
Ylvisaker Hall	46,065	$891,859
Miller Hall	84,083	$313,552
Dieseth Hall	82,287	$313,552
Brunsdale Lounge	7,680	$186,354
Regents Center	231,900	$701,769
Center for Faith & Life (CFL)	74,639	$826,434
Valders Hall of Science	103,232	$902,136
Sampson Hoffland Laboratories	71,997	$1,243,213
Franklin W. Olin	50,369	$472,166
Preus Library	102,523	$204,263
Jenson-Noble Hall of Music	48,539	$616,556
Brandt Hall	71,189	$1,216,982
Center for the Arts (CFA)	59,825	$-
Koren Hall	17,158	$192,481
Dahl Centennial Union	118,096	$1,006,661
Farwell Hall	76,681	$625,811
Loyalty Hall	14,835	$290,206
Larsen Hall	40,540	$798,682
Olson Hall	39,267	$799,656
Ockham House	4,000	$81,911
Korsrud Heating Plant	10,870	$209,983
Facilities Services	16,339	$187,572
Total	1,372,114	$13,761,444

Building conversion costs between Options B and D are very similar however with some key differences in demolition scope and existing chilled water capacity to remain. In Option B, demolition costs are slightly higher, as more existing cooling systems are demolished and replaced by the WWHP energy plant. Where existing building chillers are not demolished, and are connected to the central CHW distribution, costs are included for replacement chilled water pumps sized for the new distribution system. Option D relies more on these existing chillers and as a result includes new equipment estimates slightly higher than Option B.

Hybrid Heating and Cooling

The hybrid heating and cooling concept remains the same for Option D. For Option D, the WWHP system, including simultaneous and geothermal operating modes, provide a portion of the campus heating and cooling. The WWHP system is sized for 26.6% of the peak cooling load and provides 67.6% of the total

annual heating and cooling energy. The annual heating and cooling load profile for Option D is included in Figure 10 below.

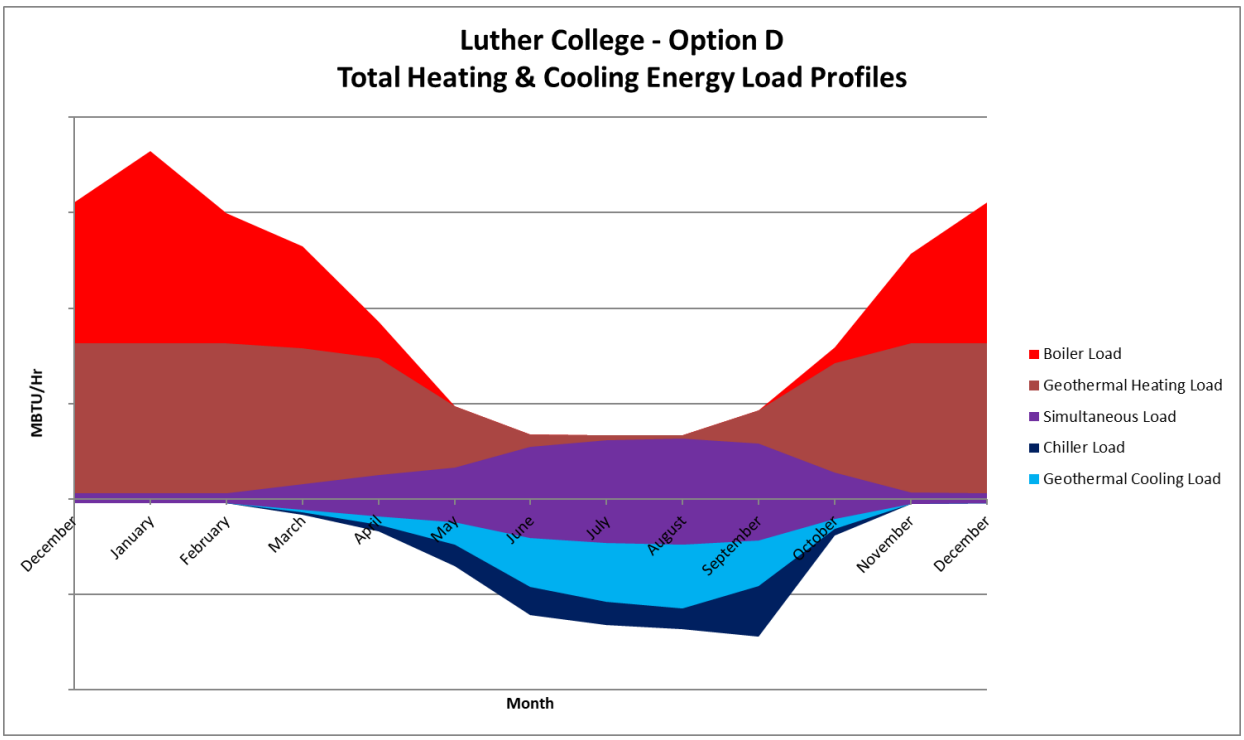


Figure 10: Option D Thermal Profile

Geothermal Energy Plant

The new geothermal energy plant for Option D is similar to Option B, however with a smaller geothermal energy plant component and larger boiler capacity. The Option D geothermal energy plant consists of a 450 ton, modular WWHP and (3) 12,000 MBH high efficiency condensing boilers. The WWHP will be coupled with a new geofield consisting of 220 ground loop heat exchangers, 275' deep. Option D relies more on maintaining the existing chillers and connecting these currently stand-alone assets to a centralized CHW distribution network.

Campus Utilities

Option D will require the same new LTHW, CHW and geothermal utility piping distribution systems as Option B, with some minor differences in pipe sizing and phasing.

Estimated Cost

Option D costs include the design and construction of utilities for hot water and chilled water distribution piping, geofield utility piping and heat exchangers, energy plant equipment and building conversions. A summary of costs for Option D are included in Table 15 below.

Table 15: Option D Capital Costs

Year	Utilities	Geofield	Energy Station	Building Conversions	Design Fees	Total
2022	$2,286,388	-	-	$2,296,203	$366,607	$4,949,198
2023	-	-	-	$1,216,982	$97,359	$1,314,340
2024	$2,128,332	-	-	$1,177,318	$264,452	$3,570,103
2025	$362,218	-	-	-	$28,977	$391,195
2026	-	-	-	$350,884	$28,071	$378,955
2027	-	$3,122,102	-	-	$249,768	$3,371,870
2028	$1,569,512	-	$2,471,229	$2,711,978	$540,217	$7,292,936
2029	$2,211,100	-	-	$2,821,778	$402,630	$5,435,509
2030	$334,016	-	-	$192,481	$42,120	$568,616
2031	$2,409,313	-	-	$2,993,820	$432,251	$5,835,384
Total (Through 2031)	$11,300,879	$3,122,102	$2,471,229	$13,761,444	$2,452,452	$33,108,106

Operations & Maintenance

Option D includes an initial annual operation and maintenance expense of $447,460 for 2022. The annual operations and maintenance costs for Option D significantly decrease to $196,833 after the existing steam plant is taking offline in 2031. Option D maintains more of the existing chilled water systems than Option B. A summary of the maintenance costs is included above in Table 6. A summary of maintenance costs by year and equipment type are included in Appendix C.

Option D Energy & Carbon Performance

The predicted energy use and carbon emissions for Option D over the current facility planning period from 2022 to 2031 are summarized in Table 16 below. Similar to Option B, the annual energy and carbon projections remain the same from year 2032 to 2072, as there are no planned capital projects beyond 2031.

Table 16: Option D Energy & Carbon Summary by Year for HVAC Systems

	Year							
	2022-2023	2024	2025	2026-2027	2028	2029	2030	2031-2032
Elec KWH/yr	2,036,380	1,935,785	1,967,115	1,956,004	4,371,279	5,589,614	5,601,232	5,762,232
NG Therm/yr	945,963	945,963	956,767	956,767	494,135	316,928	314,042	286,236
Elec Utility $/yr	168,046	$159,745	$162,330	$161,413	$360,727	$461,266	$462,225	$475,511
NG Utility $/yr	378,385	$378,385	$382,707	$382,707	$197,654	$126,771	$125,617	$114,495
Total Utility $/yr	546,432	$538,130	$545,037	$544,120	$558,381	$588,038	$587,842	$590,006
Energy MBTU/yr	101,544,476	101,201,248	102,388,496	102,350,585	67,335,987	50,764,549	50,515,561	48,284,382
Carbon Emissions Electricity (t CO2/yr)	1,068	1,014	1,031	1,025	2,318	2,977	2,984	3,071
Carbon Emissions Natural Gas (t CO2/yr)	5,020	5,020	5,078	5,078	2,622	1,682	1,667	1,519
Total Carbon Emissions (t CO2/yr)	6,088	6,034	6,109	6,103	4,940	4,659	4,651	4,590

Option D results in a 52.4% overall carbon emissions reduction and a 69.7% natural gas carbon emissions reduction when compared to the BAU case. The carbon emissions for Option D compared to the BAU case are summarized in Table 17 below.

Table 17: Option D Carbon Savings vs. BAU

	Existing BAU Systems 2020	Option B -New Geothermal Systems 2072	% Reduction
Carbon Emissions Electricity (t CO2/yr)	1,071	1,382	-29%
Carbon Emissions Natural Gas (t CO2/yr)	5,020	1,519	69.7%
Total Carbon Emissions (t CO2/yr)	6,091	2,901	52.4%

Option D with Solar Thermal

Overview

Option D with solar thermal is the same as Option D with the addition of an 80 panel solar thermal array located on the roof the Aquatic Center at Regents Hall. Roof mounted solar hot water heating panels generate heat year round that will reduce the demand on the on the campus central heating plant. Combined with the geothermal systems, the heat generated by the solar thermal array can eliminate the need to fire the boilers during summer months. The solar thermal array is expected to generate over 6,000,000 MBH of heating energy annually, 7.6% of the total campus heating load.

The solar thermal array will consist of roof mounted solar water heating panels, supply and return distribution piping connecting the array to the new energy plant, pumps, controls and ancillary equipment. The solar thermal array is scheduled to be installed in 2028, the same year as the energy plant.

The building conversion phasing plan for Option D with solar thermal for 2028 is included in Figure 11 below, including building conversions, renovations, additions and new projects by year.

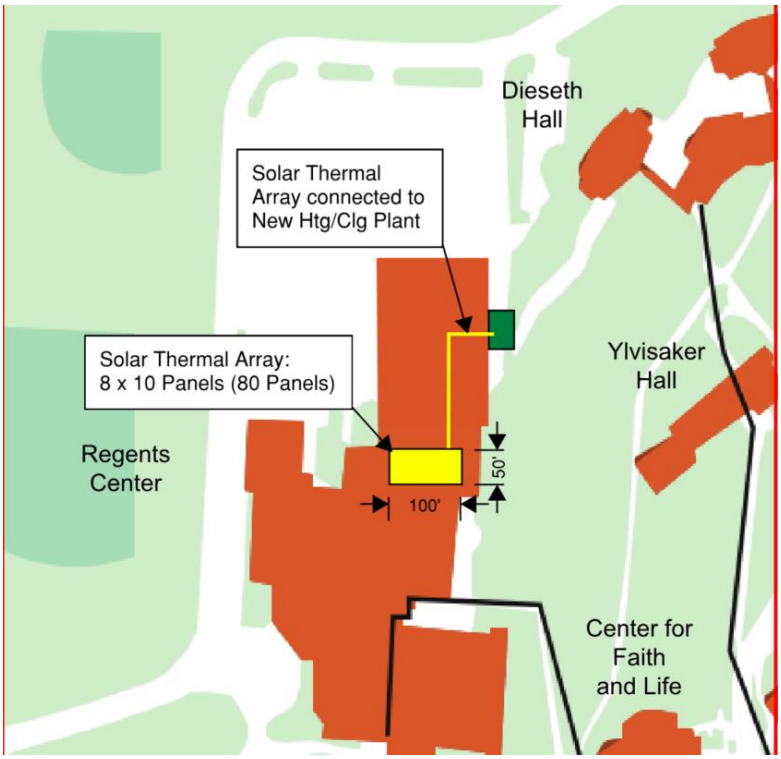


Figure 11: Option D w/ Solar Thermal 2028 Phasing

Building Conversions

The building conversion strategy and costs under Option D with solar thermal are the same as Option D.

Hybrid Heating and Cooling

The hybrid heating and cooling concept under Option D with solar thermal is the same as Option D. The annual heating and cooling load profile for Option D is included in Figure 12 below.

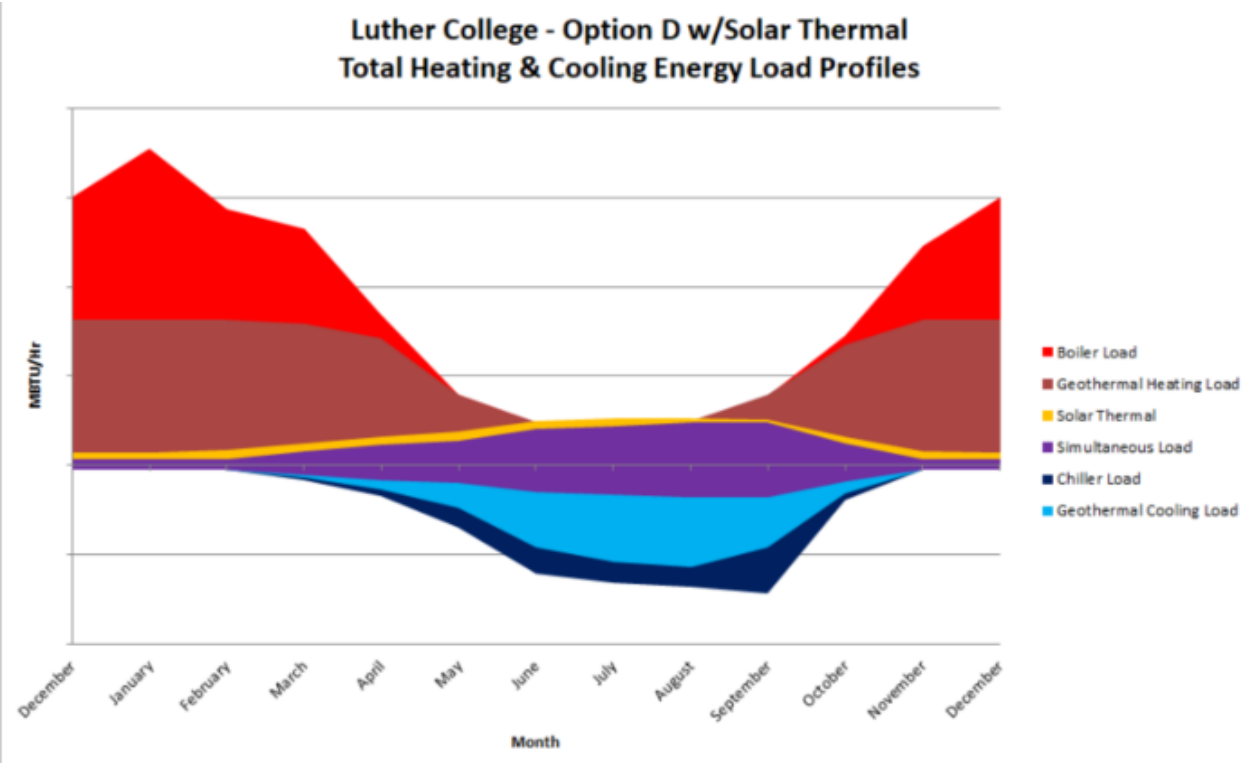


Figure 12: Option D w/ Solar Thermal Thermal Profile

Geothermal Energy Plant

The geothermal energy plant strategy under Option D with solar thermal is the same as Option D.

Campus Utilities

The campus utilities for option D with solar thermal are the same as Option D, plus the additional piping required to connect the solar thermal array on the roof of the Regents Center to the new energy plant. These piping costs are carried in the solar thermal capital costs, as the array location on the Regents Center adjacent to the new energy plant will likely not require any direct buried or tunnel installed piping.

Estimated Cost

Option D with solar thermal costs are the same as Option D plus solar thermal array costs, including distribution piping, pumps and ancillary equipment. A summary of costs for Option D with solar thermal are included in Table 18 below.

Table 18: Option D w/ Solar Thermal Capital Costs

Year	Utilities	Solar Thermal	Geofield	Energy Station	Building Conversions	Design Fees	Total
2022	$2,286,388	-	-	-	$2,296,203	$366,607	$4,949,198
2023	-	-	-	-	$1,216,982	$97,359	$1,314,340
2024	$2,128,332	-	-	-	$1,177,318	$264,452	$3,570,103
2025	$362,218	-	-	-	-	$28,977	$391,195
2026	-	-	-	-	$350,884	$28,071	$378,955
2027	-	-	$3,122,102	-	-	$249,768	$3,371,870
2028	$1,569,512	$778,437	-	$2,471,229	$2,711,978	$602,492	$8,133,647
2029	$2,211,100	-	-	$-	$2,821,778	$402,630	$5,435,509
2030	$334,016	-	-	$-	$192,481	$42,120	$568,616
2031	$2,409,313	-	-	$-	$2,993,820	$432,251	$5,835,384
Total (Through 2031)	$11,300,879	$778,437	$3,122,102	$2,471,229	$13,761,444	$2,514,727	$33,948,817

Operations & Maintenance

Option D with solar thermal annual operation and maintenance expenses are the same as Option D, with the minor addition of costs associated with the thermal array, associated pumps and ancillary equipment, estimated at approximately $1,200 per year. A summary of the maintenance costs is included above in Table 6. A summary of maintenance costs by year and equipment type are included in Appendix C.

Option D with Solar Thermal Energy & Carbon Performance

The predicted energy use and carbon emissions for Option D with solar thermal over the current facility planning period from 2022 to 2031 are summarized in Table 19 below. Similar to Options B and D, the annual energy and carbon projections remain the same from year 2032 to 2072, as there are no planned capital projects beyond 2031.

Table 19: Option D w/ Solar Thermal Energy & Carbon Summary by Year for HVAC Systems

	Year							
	2022-2023	2024	2025	2026-2027	2028	2029	2030	2031-2032
Elec KWH/yr	2,036,380	1,935,785	1,967,115	1,956,004	4,134,314	5,385,677	5,398,670	5,578,623
NG Therm/yr	945,963	945,963	956,767	956,767	475,707	293,041	289,950	262,224
Elec Utility $/yr	168,046	$159,745	$162,330	$161,413	341,172	444,437	445,509	460,359
NG Utility $/yr	378,385	$378,385	$382,707	$382,707	190,283	117,216	115,980	104,889
Total Utility $/yr	546,432	$538,130	$545,037	$544,120	531,455	561,654	561,489	565,249
Energy MBTU/yr	101,544,476	101,201,248	102,388,496	102,350,585	61,677,002	47,680,035	47,415,240	45,256,624
Carbon Emissions Electricity (t CO2/yr)	1,068	1,014	1,031	1,025	2,190	2,867	2,874	2,971
Carbon Emissions Natural Gas (t CO2/yr)	5,020	5,020	5,078	5,078	2,525	1,555	1,539	1,392
Total Carbon Emissions (t CO2/yr)	6,088	6,034	6,109	6,103	4,715	4,422	4,413	4,363

Option D with solar thermal results in a 55.2% overall carbon emissions reduction and a 72.3% natural gas carbon emissions reduction when compared to the BAU case. The carbon emissions for Option D with solar thermal compared to the BAU case are summarized in Table 20 below.

Table 20: Option D w/ Solar Thermal Carbon Savings vs. BAU

	Existing BAU Systems 2020	Option B -New Geothermal Systems 2072	% Reduction
Carbon Emissions Electricity (t CO2/yr)	1,071	1,337	-24.8%
Carbon Emissions Natural Gas (t CO2/yr)	5,020	1,392	72.3%
Total Carbon Emissions (t CO2/yr)	6,091	2,729	55.2%

Alternative Systems / Options Considered

CHP & Biomass

Burns & McDonnell investigated the feasibility of a Combined Heat and Power (CHP) system, including biomass fuel options, to serve the campus heating and electrical demand. After considering the geothermal plant options included in this report, there would be insufficient thermal loads left on campus to justify a CHP system. In addition, it was determined that burning biomass does not align with the Luther College's carbon reduction philosophy.

Ambient Loop

In addition to the options summarized above, an ambient geothermal water loop system was also investigated. An ambient geothermal water system utilizes of distribution network of ambient geothermal water, connected to satellite WWHPs, which are then connected to individual buildings, or groups of buildings. An ambient system can reduce capital costs for new utility piping installation as only one set of supply and return pipes need to be installed, instead of two sets of supply and return pipes, HWS/R and CHWS/R. However, a network of satellite WWHP plants, with the requisite redundancies at each site, creates stranded capacity; the WWHP plants cannot share excess capacity amongst themselves. Ultimately, it was determined that an ambient loop was not suitable for the campus due to the following:

- Stranded capacity at satellite WWHP plants
- Due to layout of campus buildings, full utility savings could not be realized
- Increased cost for the space to house new satellite WWHP plants
- Individual plant redundancy requirements

Life Cycle Cost Analysis (LCCA)

Assumptions

The relative economic and environmental performance of each option was evaluated using a Life-Cycle Cost Analysis (LCCA) model. The LCCA model used the discount and escalation rates included in Table 21. The forecast period is 50 years with the first forecast year being 2022 and the final forecast year being 2072.

Table 21: LCCA Discount and Annual Escalation Rates

LCCA Rate Information	
Inflation Rate	2.41%
Real Discount Rate	5.00%
Natural Gas Escalation Rate	3.44%
Electric Escalation Rate	1.60%
Nominal Discount Rate	7.54%

Each option was compared to the BAU Reference Case using the Net Present Value of all future cash flows throughout the forecast period. The LCCA model discounts all future cash flows to 2022 dollars using a 5.0% real discount rate, as agreed upon with Luther College. The inflation rate of 2.41% represents the average yearly inflation rate provided by the US Bureau of Labor Statistics from 1990 to 2020. Escalation rates for natural gas and electricity were determined using the Department of Energy's Energy Escalation Rate Calculator (EERC) version 2.0-20. The EERC determines escalation rates for a specified period based on the Energy Information Administration (EIA) energy price projections by state.

Social Cost of Carbon (Carbon Tax)

The LCCA includes a voluntary, annual carbon tax of $75 per ton of CO_2 emissions. The dollar per ton tax included in this LCCA is a simplified approach to capturing this potential cost of operations. A carbon tax is a fee on the carbon content of fossil fuels. A carbon tax would drive up the cost of fossil fuels, potentially making low or zero-carbon investments market competitive. Outside of the United States, many countries have enacted a carbon tax. Within the United States, Oregon, Washington, California and New England are currently considering a carbon tax or Emissions Trading Systems (ETS). A carbon tax would directly set the price of carbon by defining a tax rate on emissions. An ETS, or cap-and-trade system, would cap total emissions levels and allow those with low emissions to sell their excess emissions capacity to higher emitters. The trading systems would establish a market price for greenhouse gas emissions. The economic implications of taxing pollution are well understood, but political viability remains the primary challenge, making it difficult to determine what value to use in this analysis. The World Bank State and Trends of Carbon Pricing 2018 published the current nominal carbon tax rates by countries that have implemented carbon pricing initiatives, ranging from $25/ton (UK, Spain, Denmark) to $140/ton (Sweden). The $75/ton used in this study aims to approximate an average carbon cost.

Purchased Carbon Offsets

The LCCA includes the cost of purchasing carbon offsets to negate any CO_2 emissions released by the campus thermal energy systems. A carbon offsets can take the form a certificates which represents the reduction of a ton of carbon dioxide emissions. This reduction is achieved through the funding of projects which remove or avoid carbon emissions such as renewable energy projects and carbon capture projects. The price of carbon offsets varies significantly from $1 to $50 per ton based on geographic location and carbon standards under which they were created. For this project, a carbon offset price of $15 per ton is used. This price is based off actual pricing from the latest California Cap and Trade Program historical settlement prices dated August 2020.

Capital Costs

Capital costs for the BAU case include replacement of HVAC systems over the study period. For the Options, capital costs include new utility piping, geothermal exchange fields, geothermal energy station and building conversions. Figure 13 below illustrates the comparative flow of capital costs throughout the forecast period.

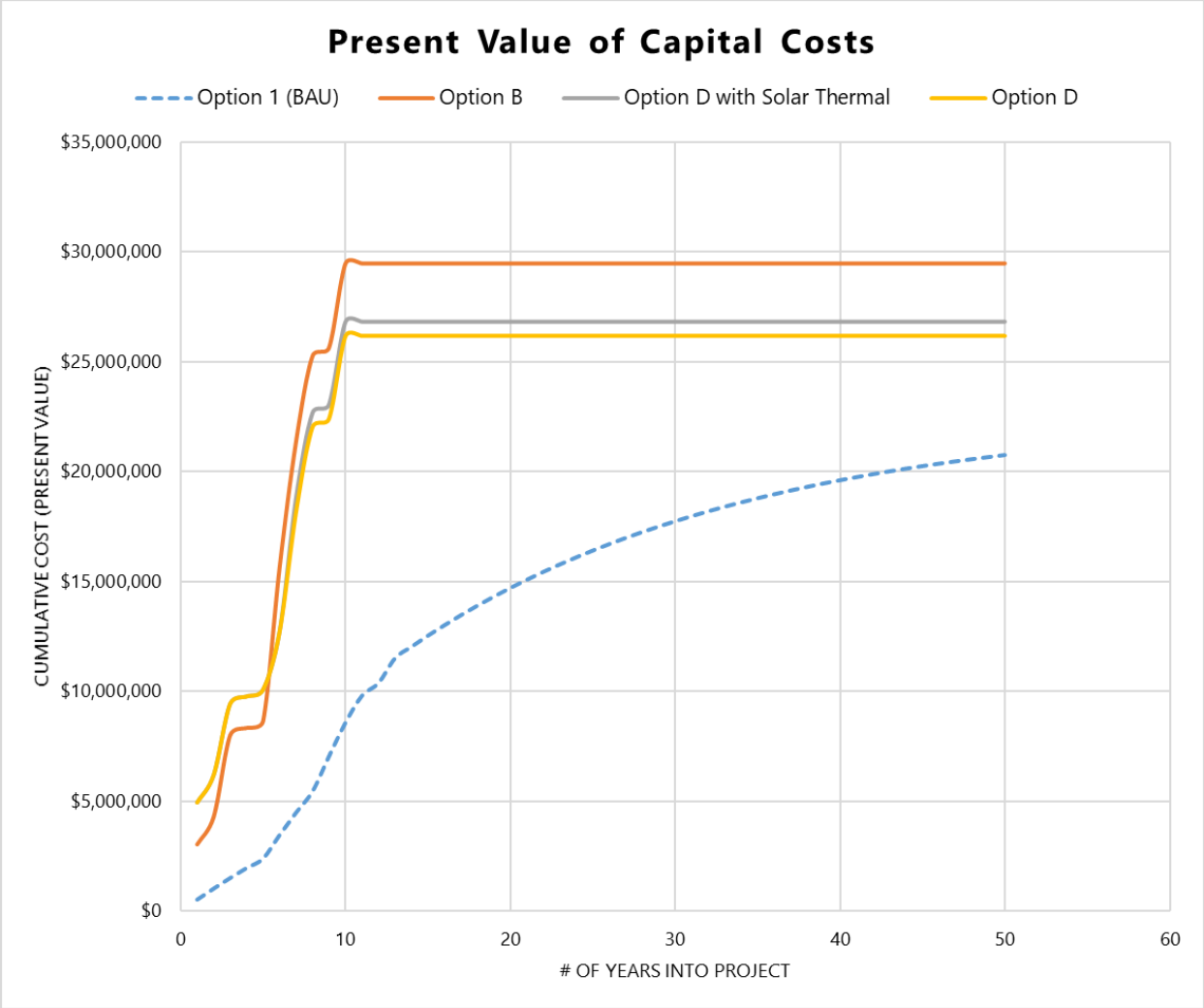


Figure 13: Capital Costs by Option

Utility Costs

Purchased Fuel Pricing

According to the information provided by Luther College, the average price for natural gas was $0.40 per Therm for Fiscal Year 2019, including commodity and distribution. A 3.44% escalation per year was used for natural gas in the LCCA, resulting in a 2072 natural gas price approaching $2.32 per Therm. The assumed natural gas price forecast is shown in Figure 14 below.

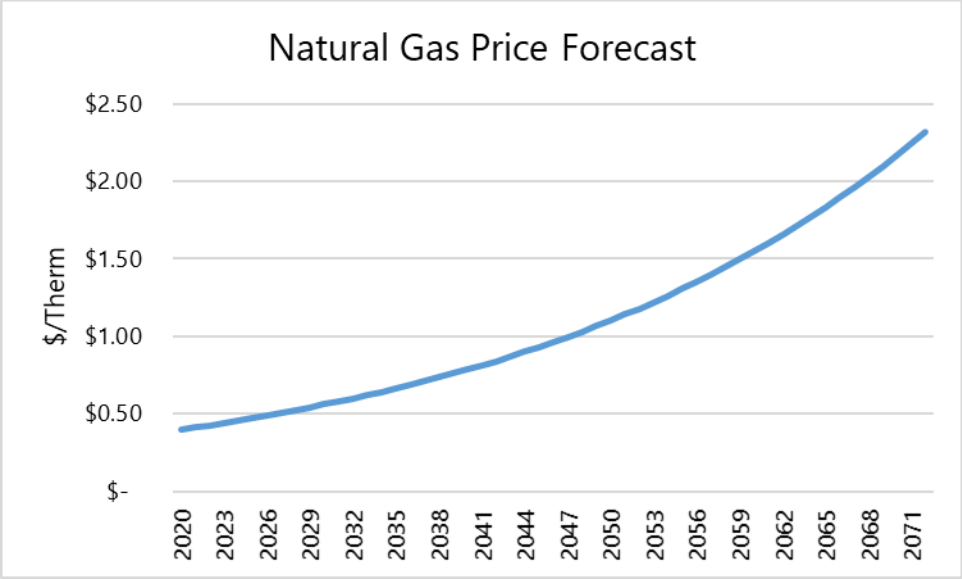


Figure 14: Purchased Fuel Cost Forecast

Purchased Electricity Pricing

According to the information provided by Luther College, the average price of $0.08 per kWh for electricity purchased in Fiscal Year 2019. This analysis assumes 1.6% per year escalation through 2072, resulting in a 2072 purchased electricity price exceeding $0.19 per kWh. The assumed price forecast is shown in Figure 15 below.

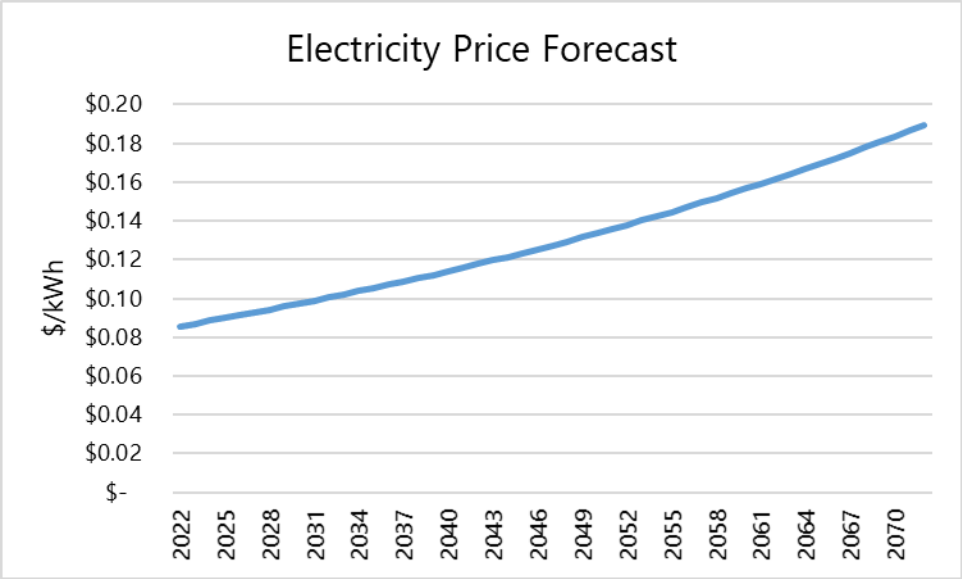


Figure 15: Electricity Cost Forecast

Relative Economic and GHG Performance

A summary of costs and the present value comparison of each option to the BAU case is included below in Table 22 and Figure 16.

Table 22: Economic Comparison Options vs. BAU

50 Year Life Cycle - Economic Comparison				
Option:	BAU	Option B	Option D	Option D w/ Solar Thermal
Electric Utility Cost	$3,127,885	$8,465,358	$6,380,549	$6,196,100
Gas Utility Cost	$8,910,367	$2,336,735	$4,109,341	$3,947,534
Total Utility Costs	$12,038,252	$10,802,093	$10,489,890	$10,143,634
Investment / Capital Costs	$20,742,732	$29,464,074	$26,182,202	$26,809,554
Maintenance Costs	$8,637,123	$5,509,515	$5,703,097	$5,719,704
City Water Costs	$1,618,856	$513,110	$0	$0
NG Social Carbon Costs	$7,538,057	$2,777,261	$4,046,228	$3,929,398
Elec Social Carbon Costs	$1,267,517	$3,040,737	$2,343,358	$2,280,408
Carbon Offset Costs	$1,143,890	$551,079	$662,816	$626,860
50 Year Life Cycle Cost	$52,986,426	$52,657,870	$49,427,591	$49,509,558
50 Year Savings	-	$328,556	$3,558,835	$3,476,868

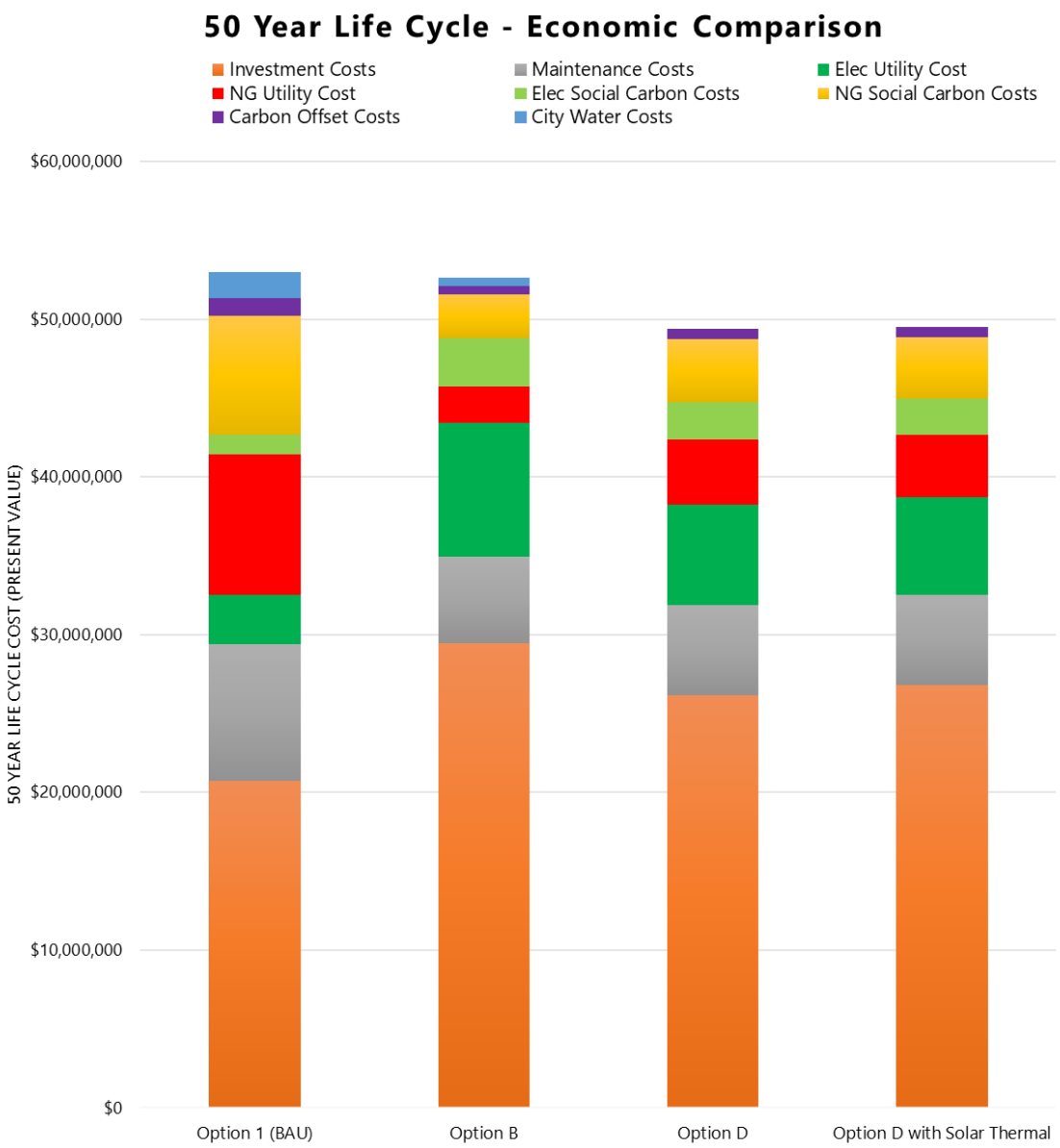


Figure 16: Present Value Comparison

The present value of cashflow for the BAU case and each Option is shown in Figure 17 below. Compared to the BAU case, the break even point for Option D is year 36 (2057). The breakeven point for Option D with solar thermal is also year 36 (2057) while the break even point for Option B occurs in year 48 (2069).

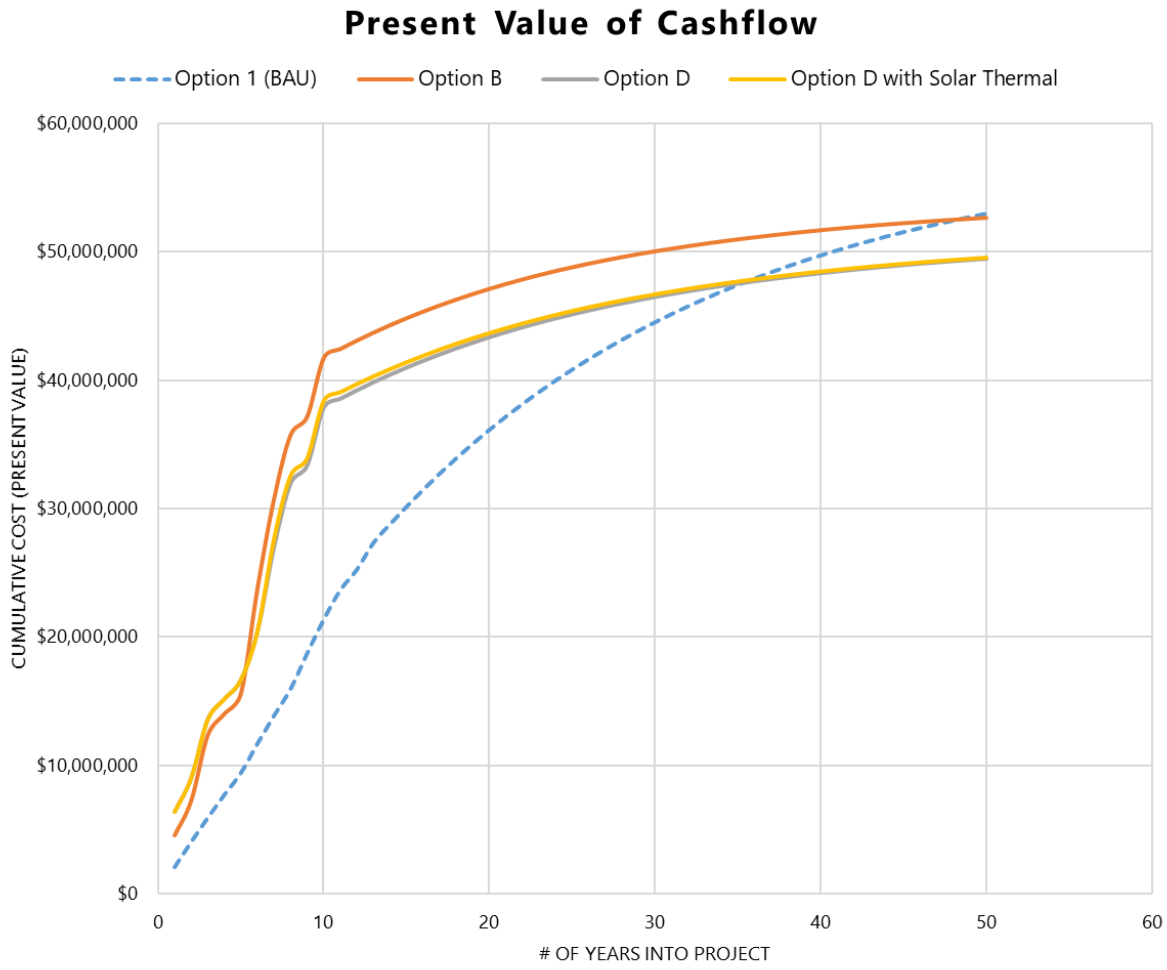


Figure 17: Net Present Value Cashflow

The resulting carbon emissions for the BAU case and each option are detailed in Figure 18. While all options evaluated provide significant carbon reductions compared to the BAU case, Option B results in the largest carbon emissions reduction. The additional purchased carbon offsets that would be required to reach Luther College's goal of carbon neutral campus energy systems are shown starting in the year 2030. The below projections assume a 'Greening' of the electrical grid and that the electrical grid will convert to 55% renewable energy sources by year 2050.

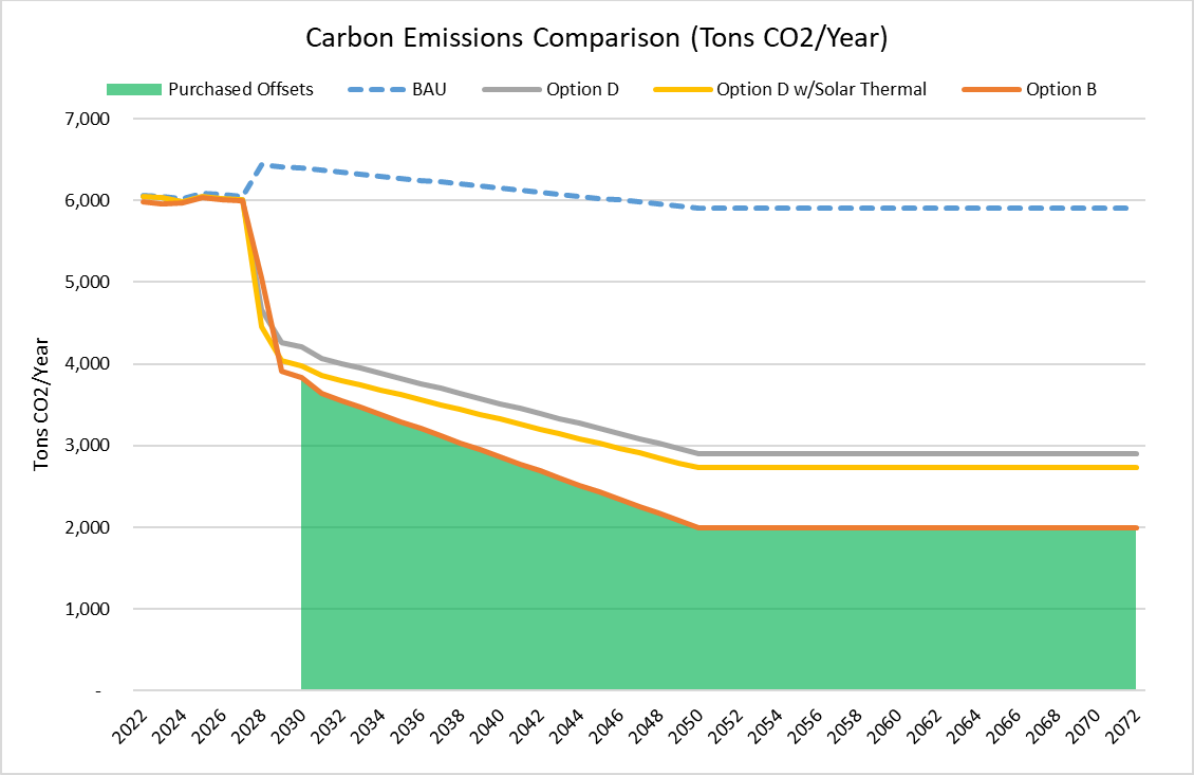


Figure 18: Carbon Emissions Forecast

Sensitivity Analysis

The relative economic performance is dependent on key assumptions, including utility escalation rates for natural gas and electricity, that have an inherent level of uncertainty over the 50 year study period. Utility rates are market driven and subject to somewhat unpredictable variability. Similarly, variability is expected for a carbon tax, as the specific requirements and implementation of this emerging monetary disincentive are not yet known. The financial results presented in this study will be impacted if utility rates fluctuate beyond the assumed forecasting and if an implemented carbon tax is higher or lower than what has been assumed. To understand the impact of significant utility rate and carbon tax fluctuations beyond the current forecast, a sensitivity analysis was conducted, applying a ±20% uncertainty.

The following ten scenarios where evaluated and compared against the original net present value results:

- +20% Electricity
- -20% Electricity
- +20% Natural Gas
- -20% Natural Gas
- +20% Elec & -20% Gas
- -20% Elec & +20% Gas
- +20% Elec & +20% Gas
- -20% Elec & -20% Gas
- +20% Elec & -20% Gas & -20% Carbon
- -20% Elec & +20% Gas & +20% Carbon

From the sensitivity analysis, the financial performance of each Option improves as the electrical rates escalate slower than modeled, and natural gas and carbon taxes rates escalate faster than modeled. As electrical rate escalation increases faster than modeled and natural gas rates increase slower than modeled, the financial performance for all options decreases, however Option D and Option D with solar thermal net present values still outperform the BAU reference case. The best- and worst-case scenario results from the sensitivity analysis are included below in Table 23.

Table 23: Sensitivity Analysis Results

Sensitivity Analysis – Scenario Results	Option B	Option D	Option D w/ Solar Thermal
Best NPV (-20% Elec & +20% Gas & +20% Carbon)	$3,879,081	$6,449,614	$6,327,162
Original NPV	-$264,255	$3,077,761	$2,959,838
Worst NPV (+20% Elec & -20% Gas)	-$2,646,476	$1,467,023	$1,353,628

The effects of a higher natural gas escalation rate were also investigated. With the natural gas escalation rate doubled from 3.44% to 6.88% the break even point for Option D occurs in year 29 (2050) instead of year 36

(2057). The escalation rate comparison and results from this analysis are included below in Figure 19 and Figure 20.

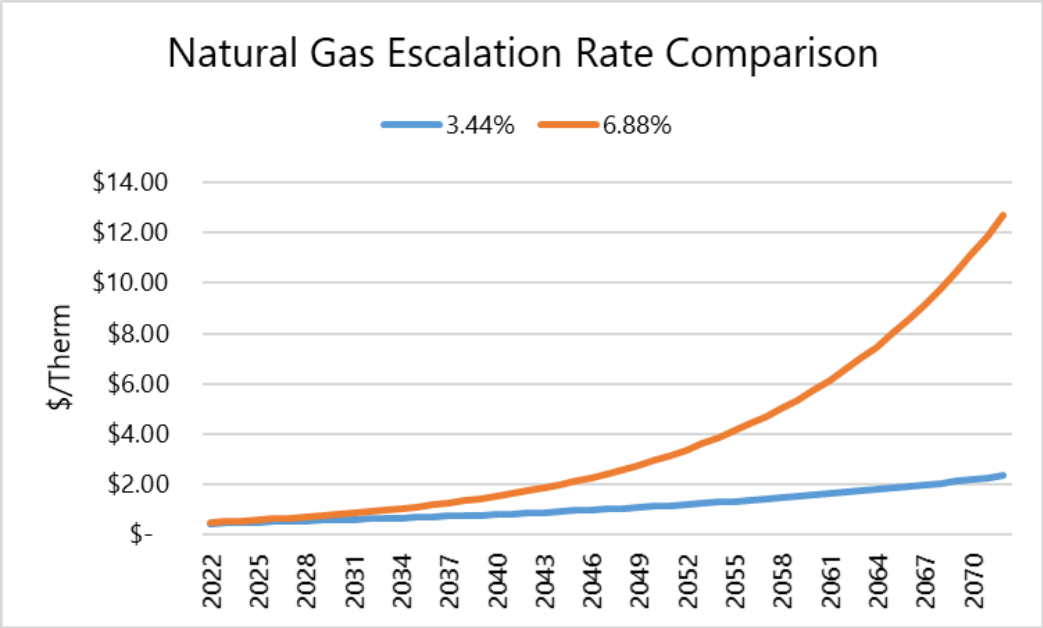


Figure 19: Natural Gas Escalation Rate Comparison

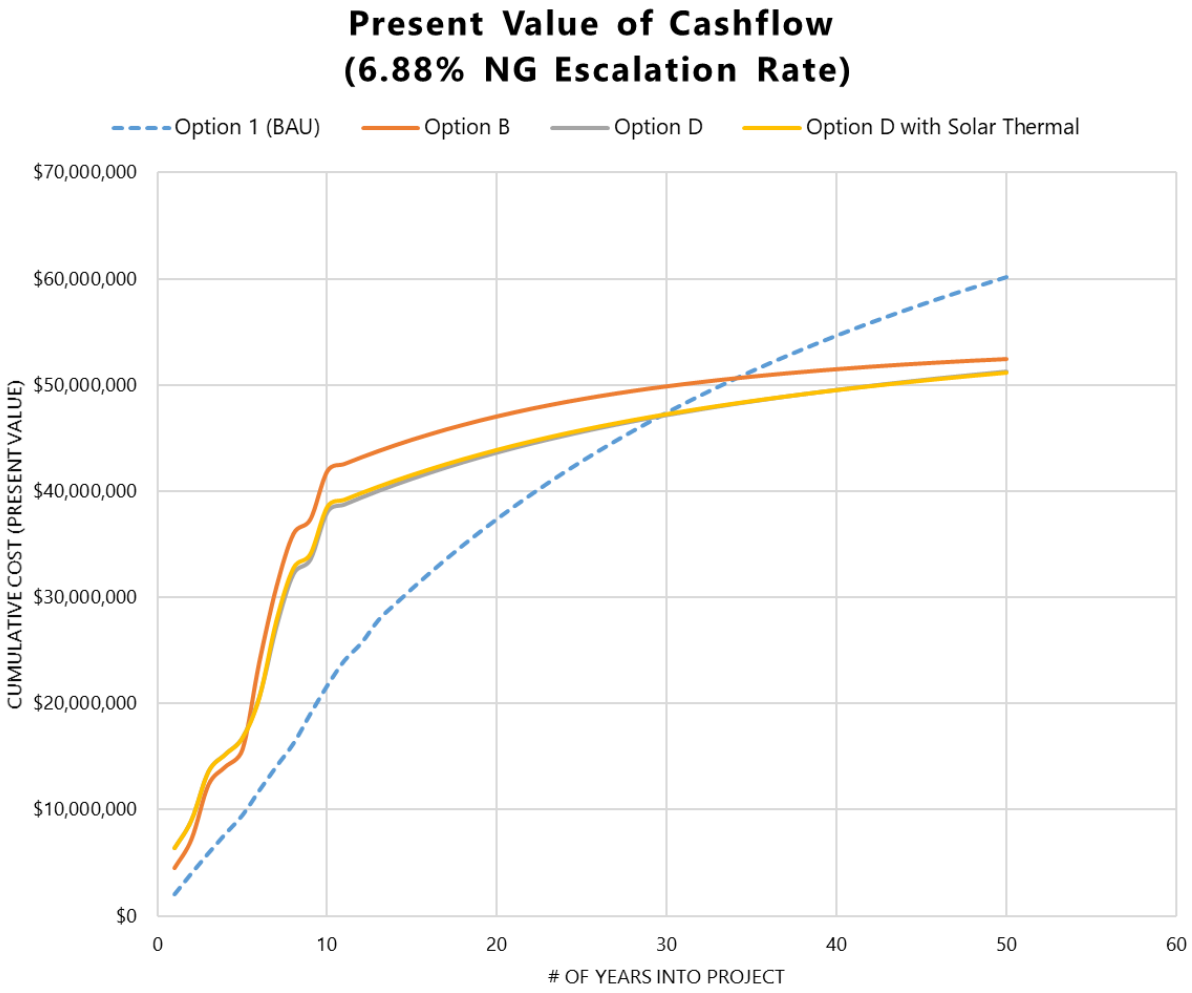


Figure 20: Present Value of Cashflow Nat. Gas Escalation Rate at 6.88%

The effect of a higher initial natural gas price was also investigated. If the initial gas price for year 1 (2022) increases to $0.80/therm, double the current cost, and the natural gas escalation rate remains at a constant 3.44% the break-even point for Option D occurs in year 27 (2048) instead of year 36 (2057). The results from this analysis are included below in Figure 21.

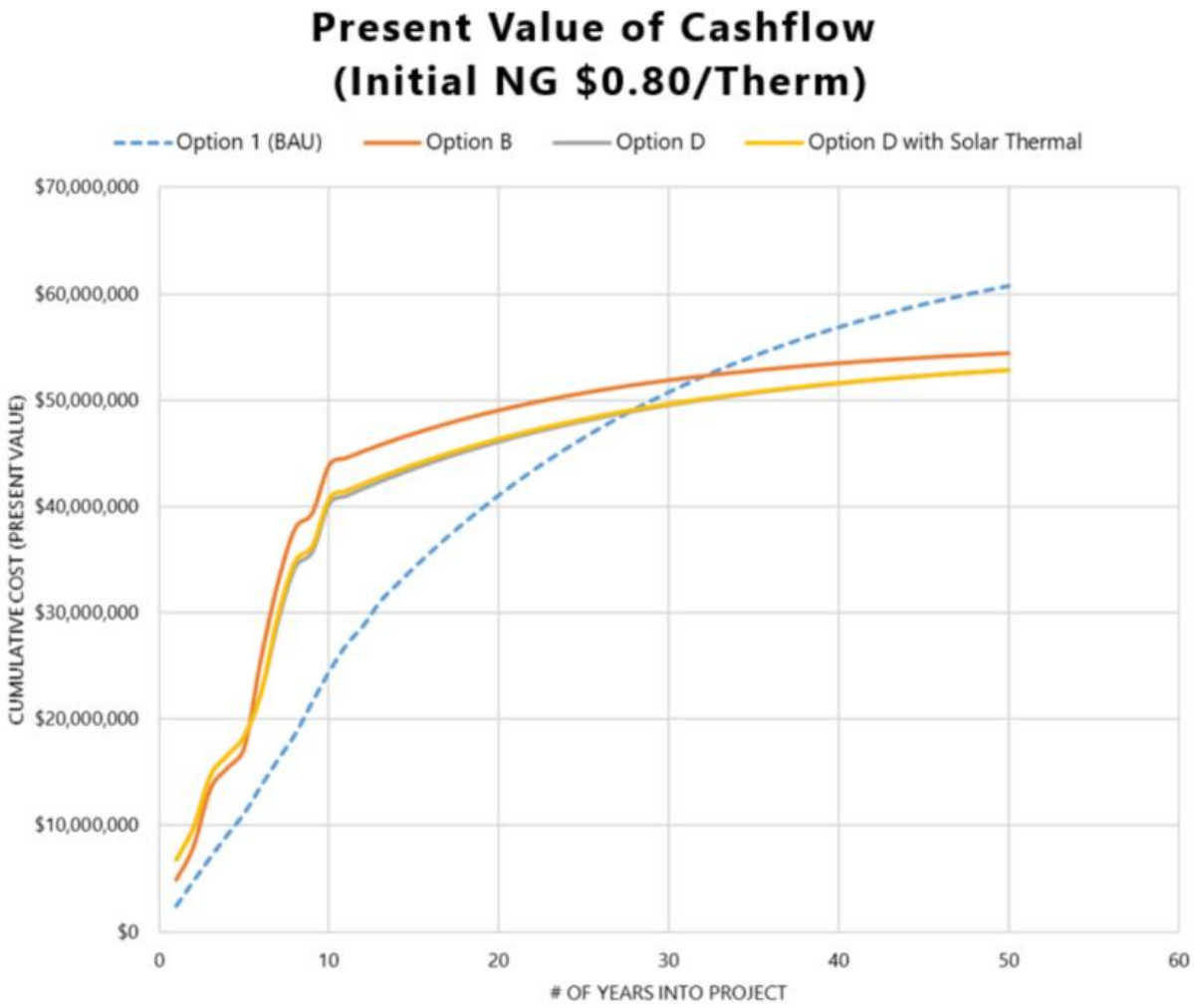


Figure 21: Present Value of Cashflow Initial Nat. Gas Price of $0.80/therm

The 50 Year savings in present value dollars for each of the natural gas price alternatives is compared in the Table 24 below.

Table 24: Comparison of Natural Gas Price Alternatives

50 Year Savings Comparison for Alternate Natural Gas Prices			
NG Alternative	Option B	Option D	Option D with Solar Thermal
BAU	$ (264,255)	$3,126,799	$ 2,959,838
6.88% Escalation Rate	$ 7,783,981	$8,959,535	$ 8,986,874
$0.80/Therm	$ 6,309,377	$7,927,825	$ 7,922,671

Conclusion

Option D has the highest net present value compared to the BAU and represents the best financial performance of all options evaluated. Although Option B has the lowest net present value savings when compared to the BAU, it represents the largest carbon emissions reduction, at 67.2%, and avoids 99% of natural gas carbon emissions. The carbon emissions from burning natural gas are almost entirely avoided, and considering the electrical grid will eventually convert 100% renewable energy sources, Option B provides a clear roadmap for achieving a campus thermal systems that are near carbon neutral.

As the original goal for this study was to achieve carbon neutrality, Option B would allow for near carbon neutrality for the campus heating and cooling systems. Should funding for Option B not be available, considering the lower net present value savings over the BAU, Option D still present a significant reduction in carbon emissions with less capital investment. Both Options include a similar phased approach over 10 years, which will allow for lessons learned from previous phases to inform the subsequent phase, offering the opportunities for adjustments between options, as the financial climate may change.

The water based campus energy distribution systems utilized in both Options B and D allow for a high level of flexibility to adapt with appropriate hybrid options as market, technology, policy and environmental conditions evolve.

Appendix:

Appendix A: Building Summary

Appendix B: Phasing Maps

B1. BAU
B2. Option B
B3. Option D
B4. Option D w/ solar thermal (2028)

Appendix C: Maintenance Cost Summary

C1. BAU
C2. Option B
C3. Option D
C4. Option D w/ solar thermal

Appendix D: LCCA Annual Cost Summary Tables

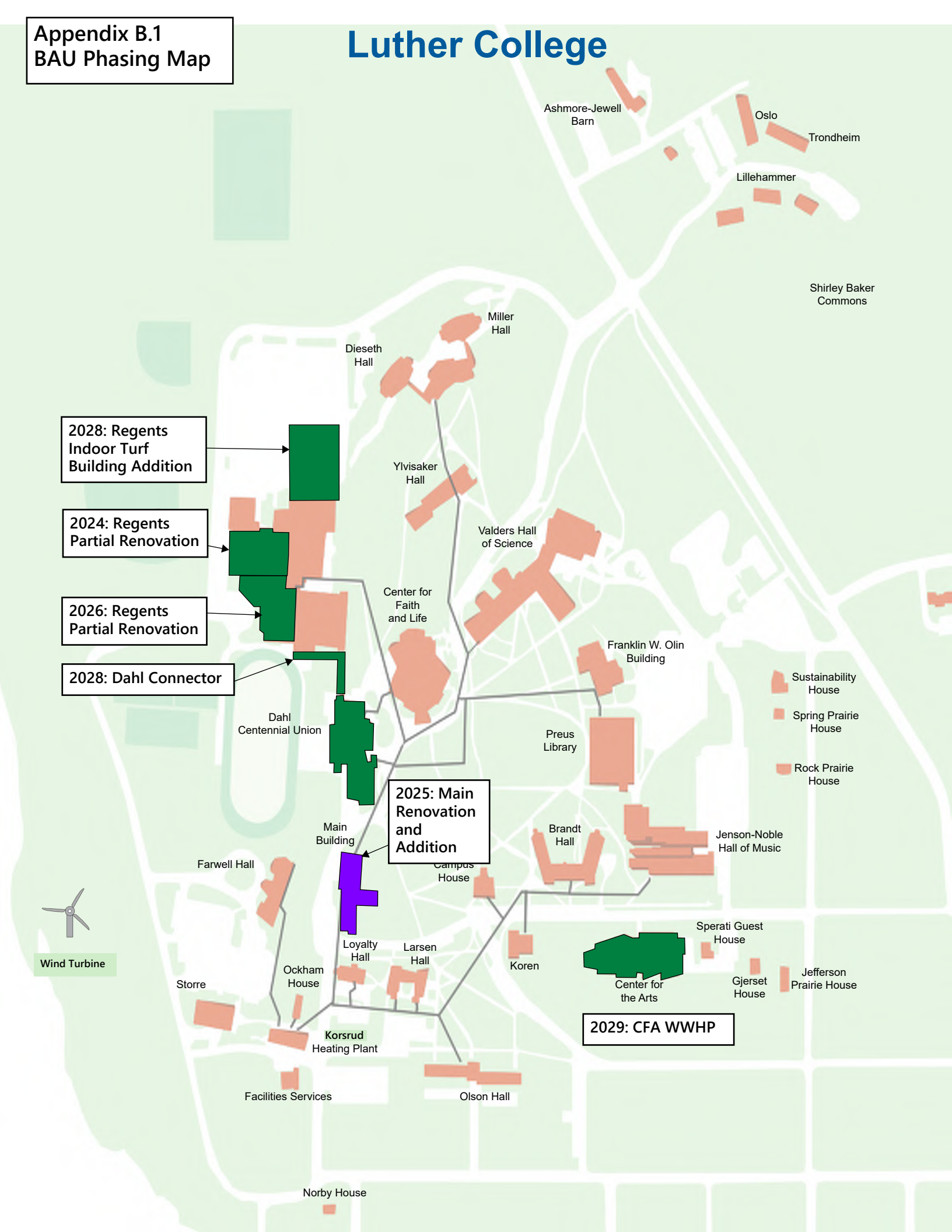
D1. BAU
D2. Option B
D3. Option D
D4. Option D w/ solar thermal

Appendix A
Building Summary

Campus Buildings Included in Study				
Number	**Building Name**	**Description**	**Year Built**	**Gross Sq.Ft.**
1	Brandt Hall	Residence Hall	1957	71,189
2	Brunsdale Lounge	Residence Lounge	1966	7,680
3	Centennial Union	Student Life	1960	118,096
4	Center for Faith and Life	Academic	1975	74,639
5	Center For the Arts	Academic (Arts)	2002	59,825
6	Dieseth Hall	Residence Hall	1966	82,287
7	Farwell Hall	Residence Hall	1999	76,681
8	Franklin Olin Hall	Academic	1994	50,369
9	Jenson Hall	Academic (Music)	1980	33,311
10	Jenson Noble Addition	Academic (Music)	2001	15,228
11	Koren	Academic classroom	1921	17,158
12	Korsrud Heating Plant	Facilities Operation (Boiler Plant)	1946	10,870
13	Larsen Hall	Residence Hall	1907	40,540
14	Loyalty Hall	Administrative	1916	14,835
15	Main	Administrative/Academic	1952	46,932
16	Maintenance Building/Facilities Services	Facilities Operations	1965	5,627
17	Miller Hall	Residence Hall	1966	84,083
18	Ockham (Korsrud Annex)	Admin	1947	4,000
19	Olson Hall	Residence Hall	1954	39,267
20	Preus Library	Academic	1969	102,523
21	Regents Center	Athletic	1963	205,402
22	Sampson Hoffland (Valders)	Academic (Science)	2001	71,997
23	Storre Theatre	Academic (Drama)	1974	16,339
24	Valders Hall of Science	Academic (Science)	1999	103,212
25	Ylvisaker Hall	Residence Hall	1963	46,065
			Total GSF	1,398,155

Appendix B.1
BAU Phasing Map

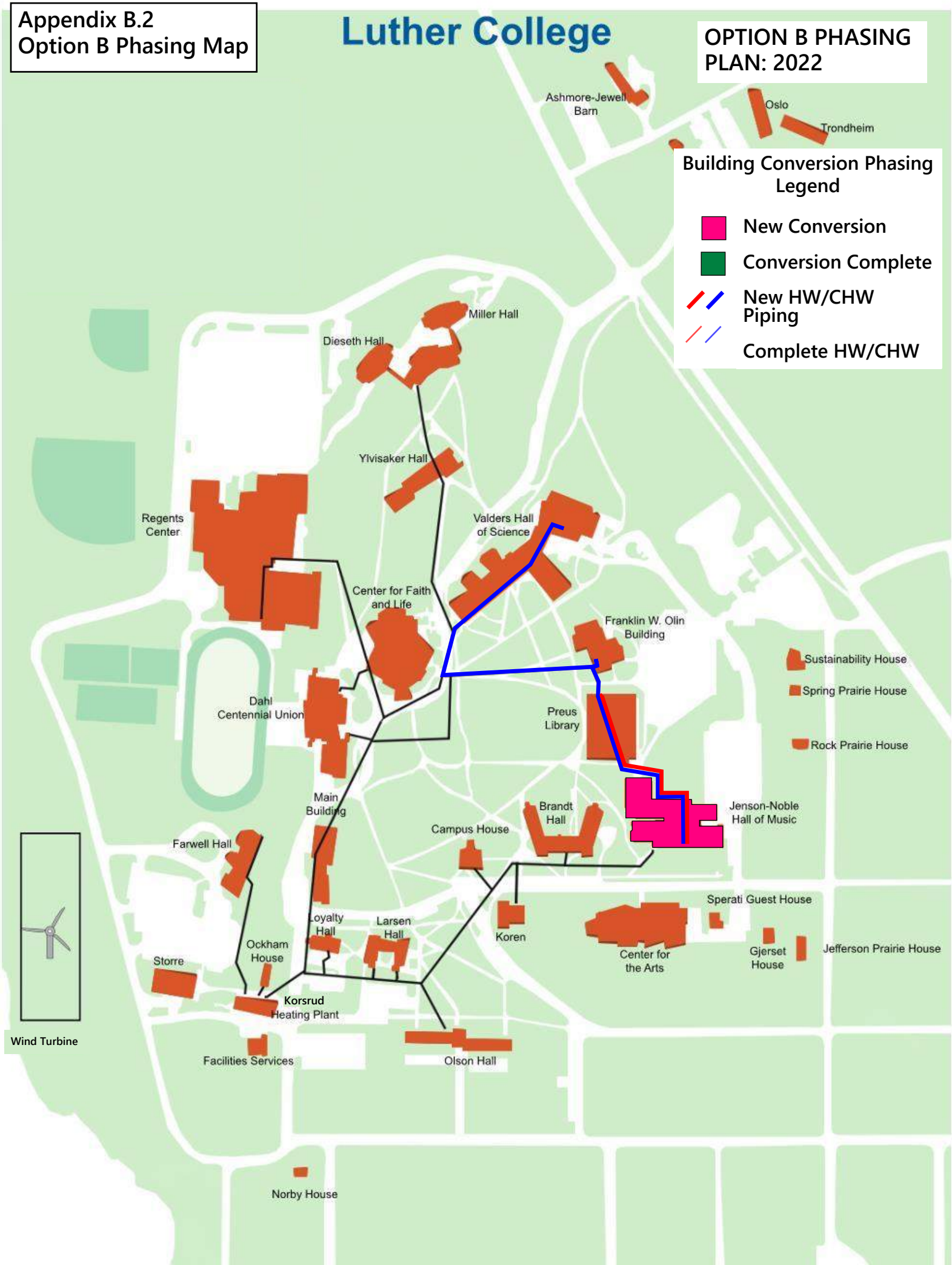
Luther College

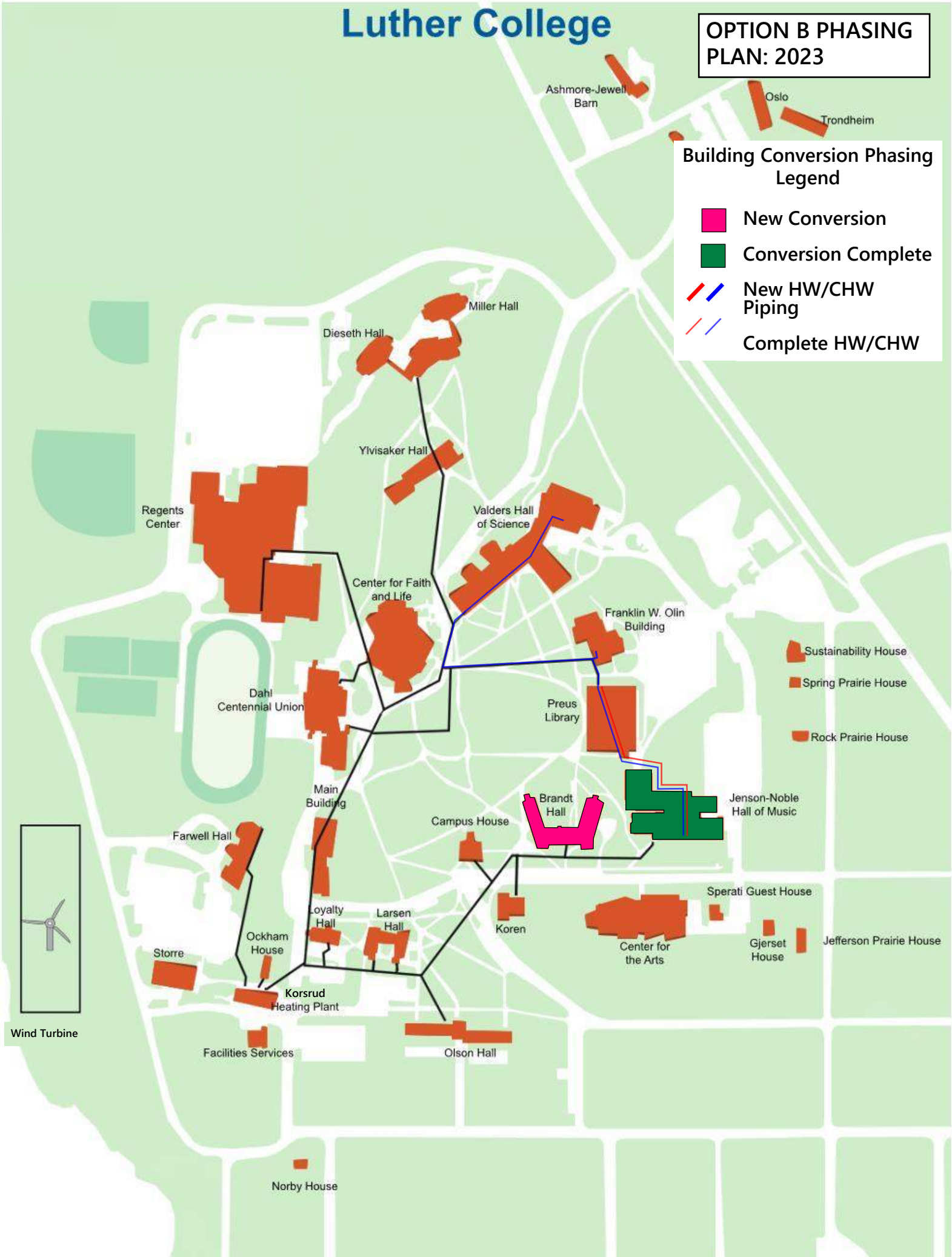


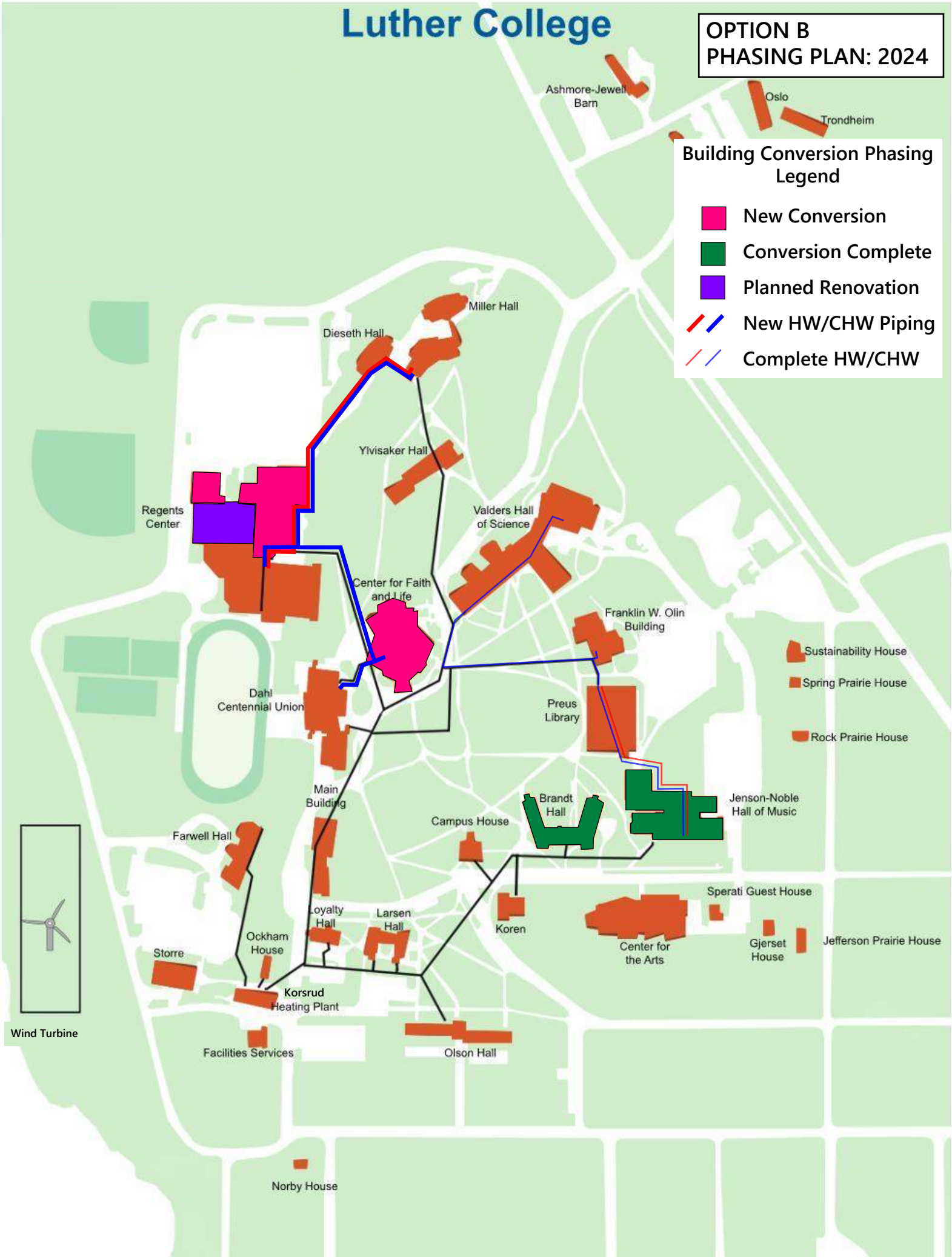
Appendix B.2
Option B Phasing Map

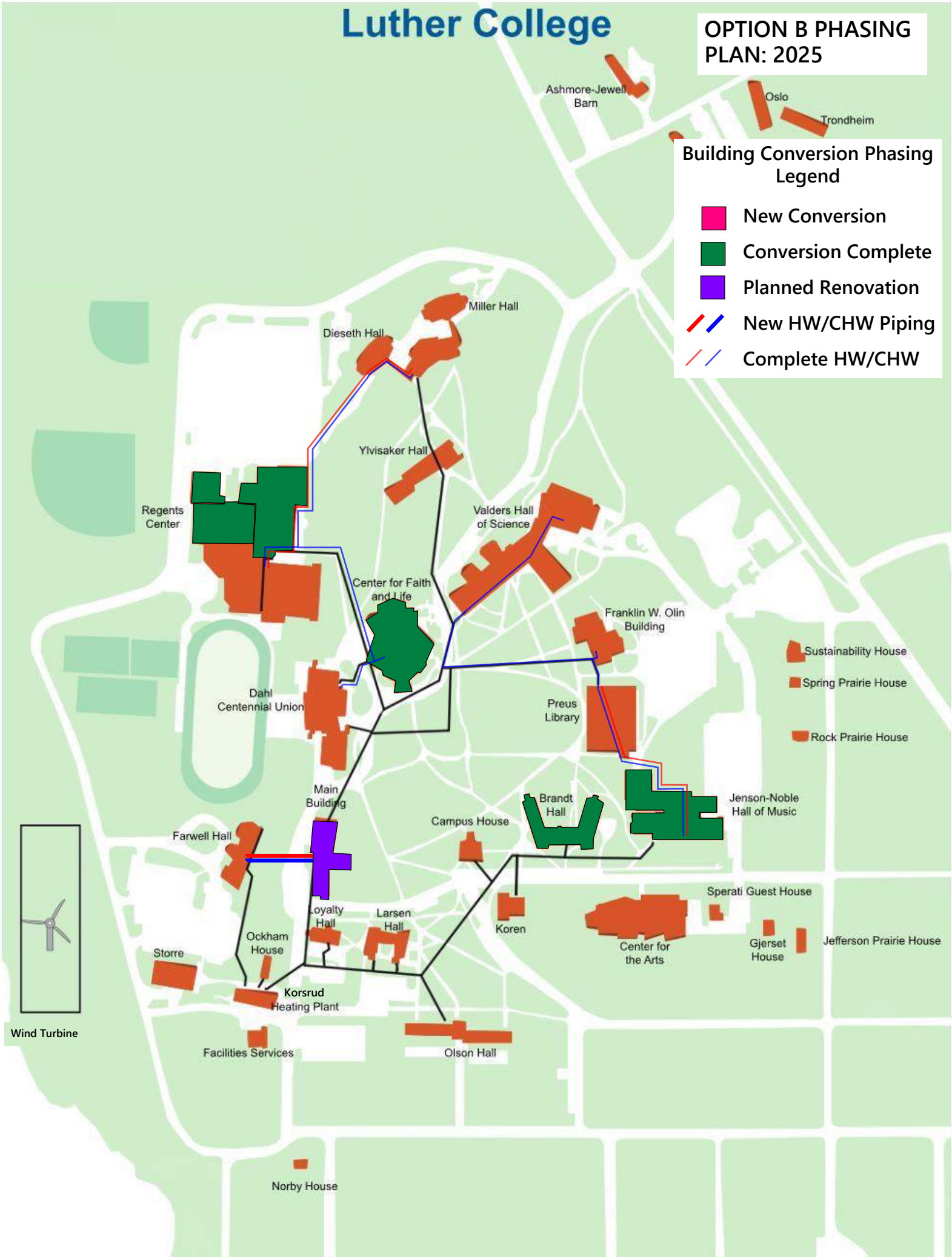
Luther College

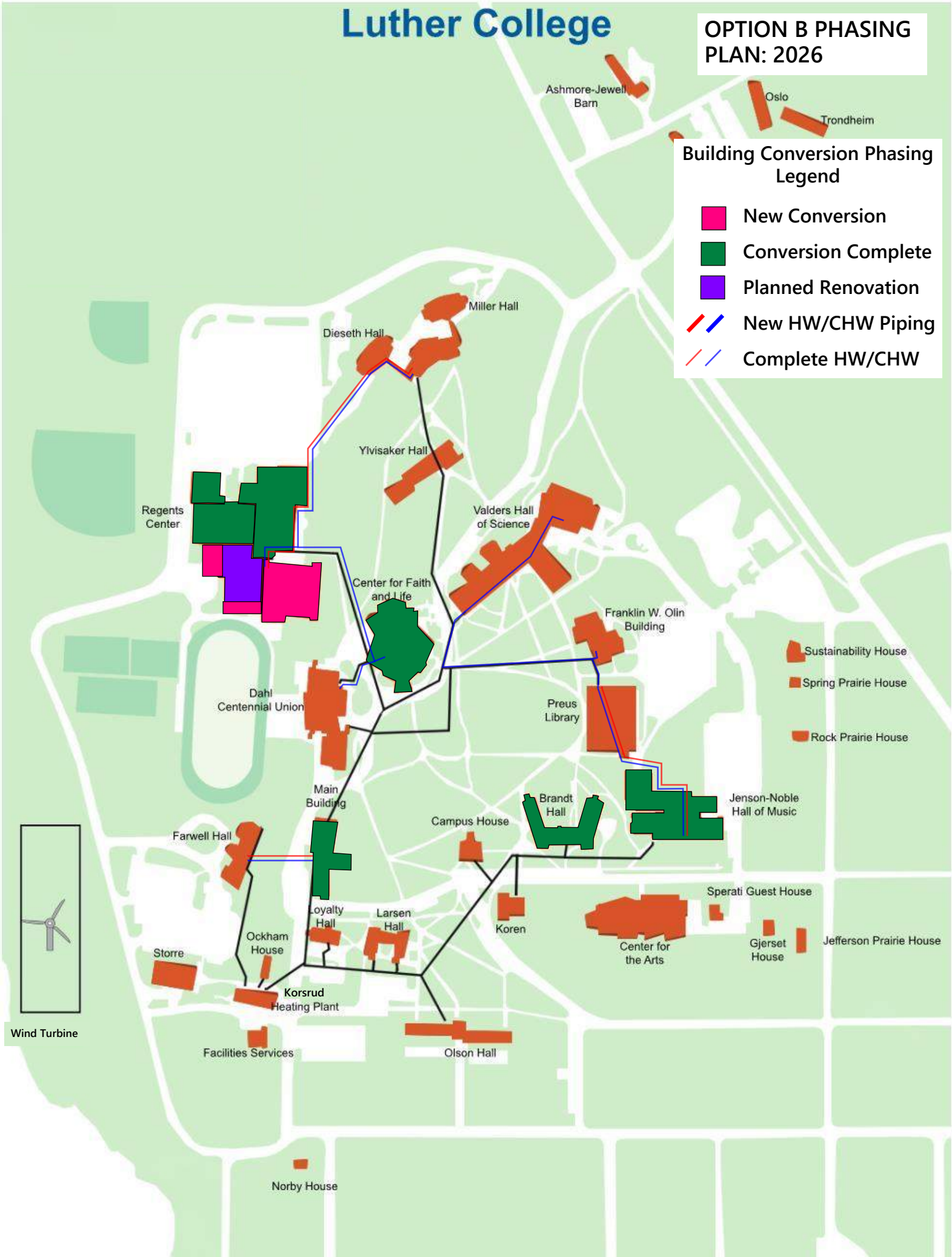
OPTION B PHASING PLAN: 2022




Luther College
OPTION B PHASING PLAN: 2023
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
New HW/CHW Piping
Complete HW/CHW
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine


Luther College
OPTION B
PHASING PLAN: 2024
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW Piping
Complete HW/CHW
Ashmore-Jewell Barn
Oslo
Trondheim
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine


Luther College
OPTION B PHASING PLAN: 2025
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW Piping
Complete HW/CHW
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine


Luther College
OPTION B PHASING PLAN: 2026
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW Piping
Complete HW/CHW
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
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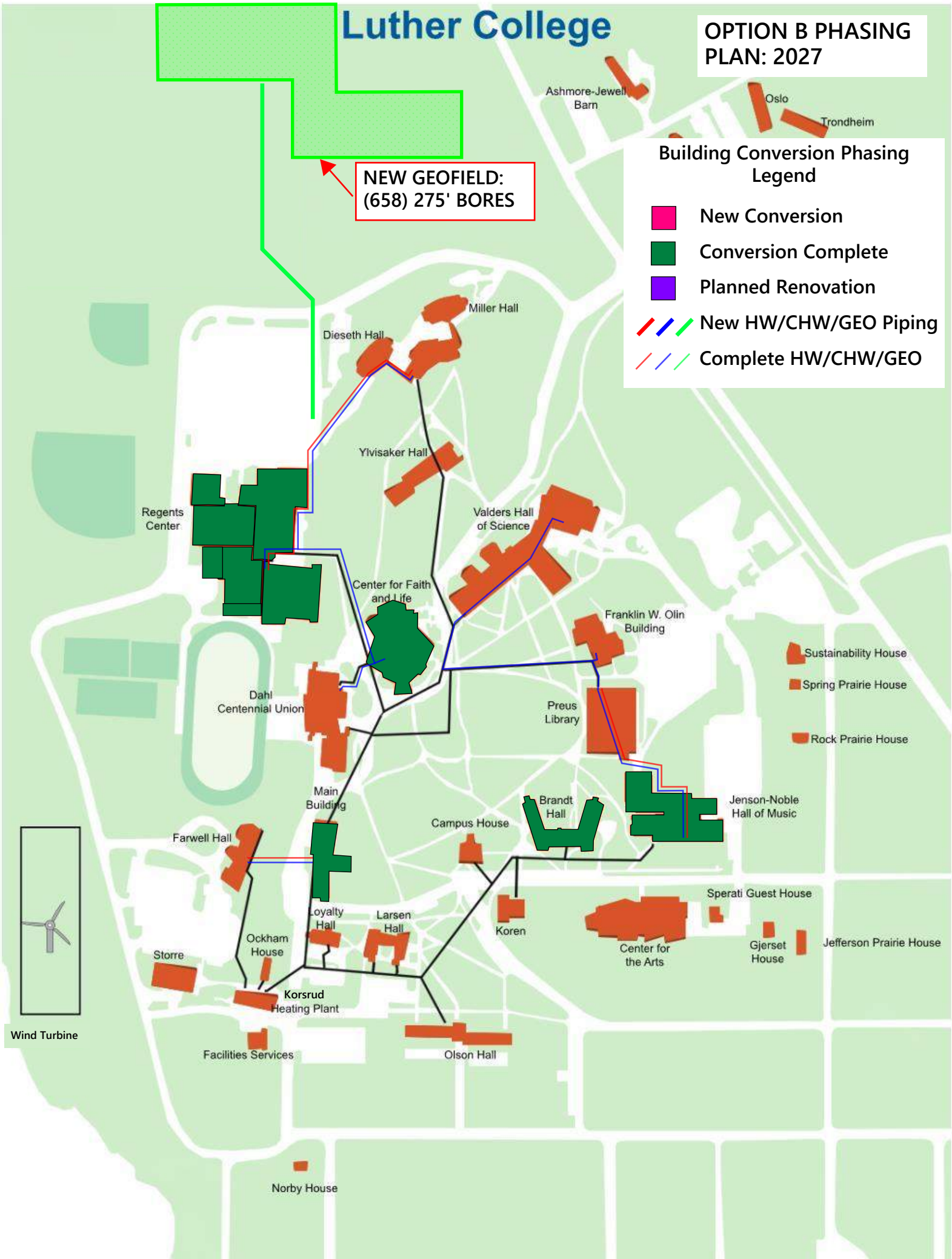
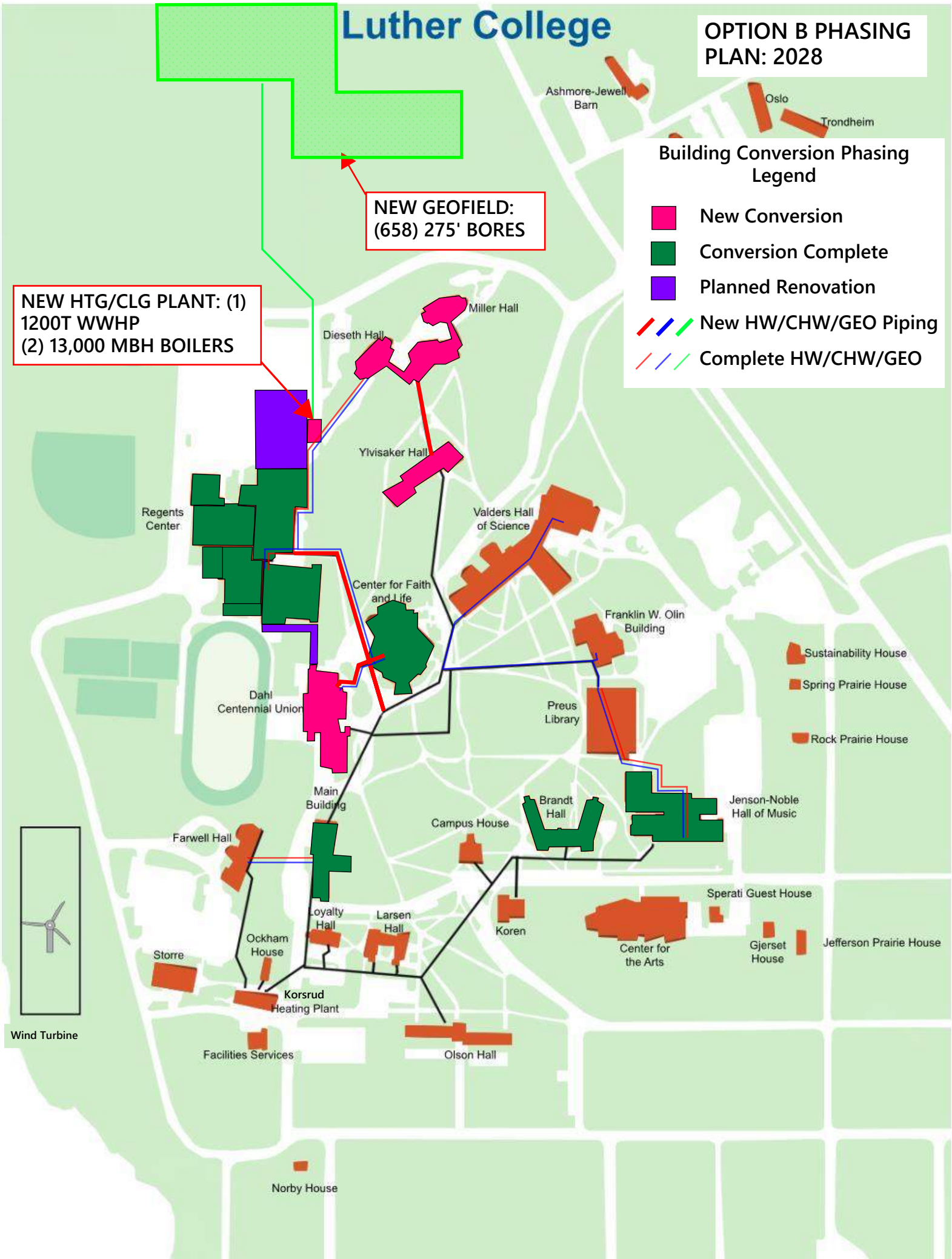
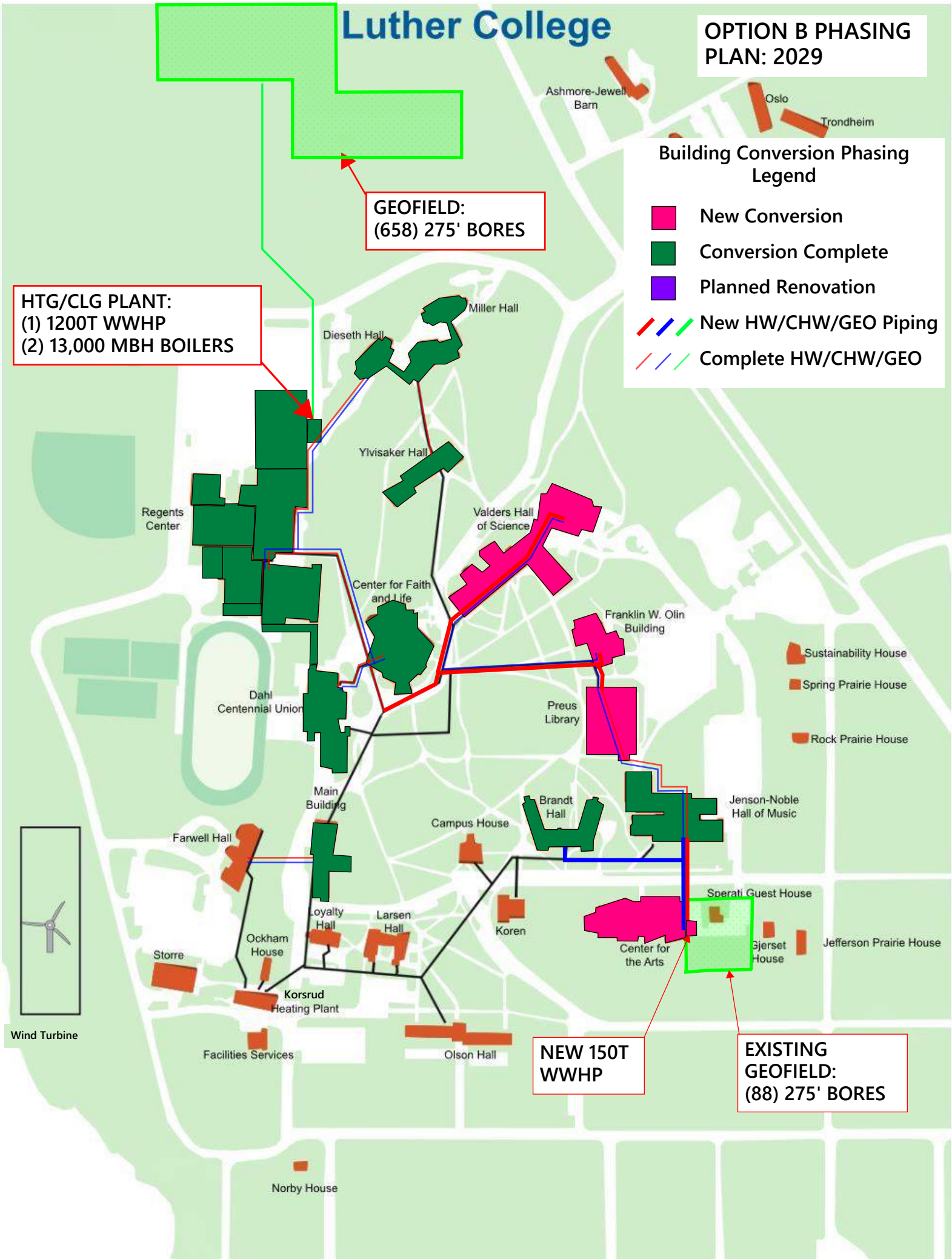
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine


Luther College
OPTION B PHASING PLAN: 2027
NEW GEOFIELD: (658) 275' BORES
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
Ashmore-Jewell Barn
Oslo
Trondheim
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Loyalty Hall
Larsen Hall
Koren
Sperati Guest House
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine


Luther College
OPTION B PHASING PLAN: 2028
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
NEW GEOFIELD: (658) 275' BORES
NEW HTG/CLG PLANT: (1) 1200T WWHP (2) 13,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Loyalty Hall
Larsen Hall
Koren
Sperati Guest House
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine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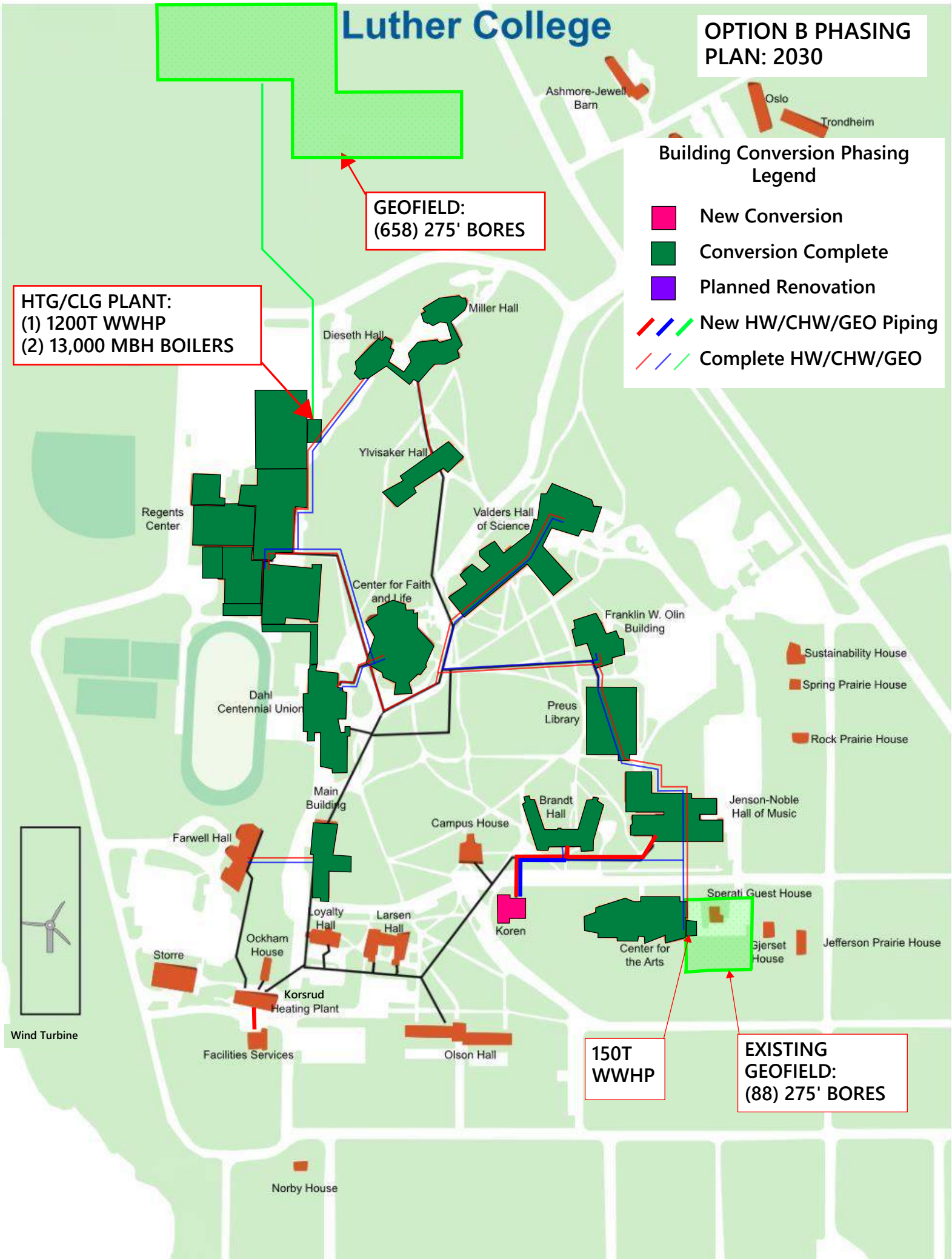
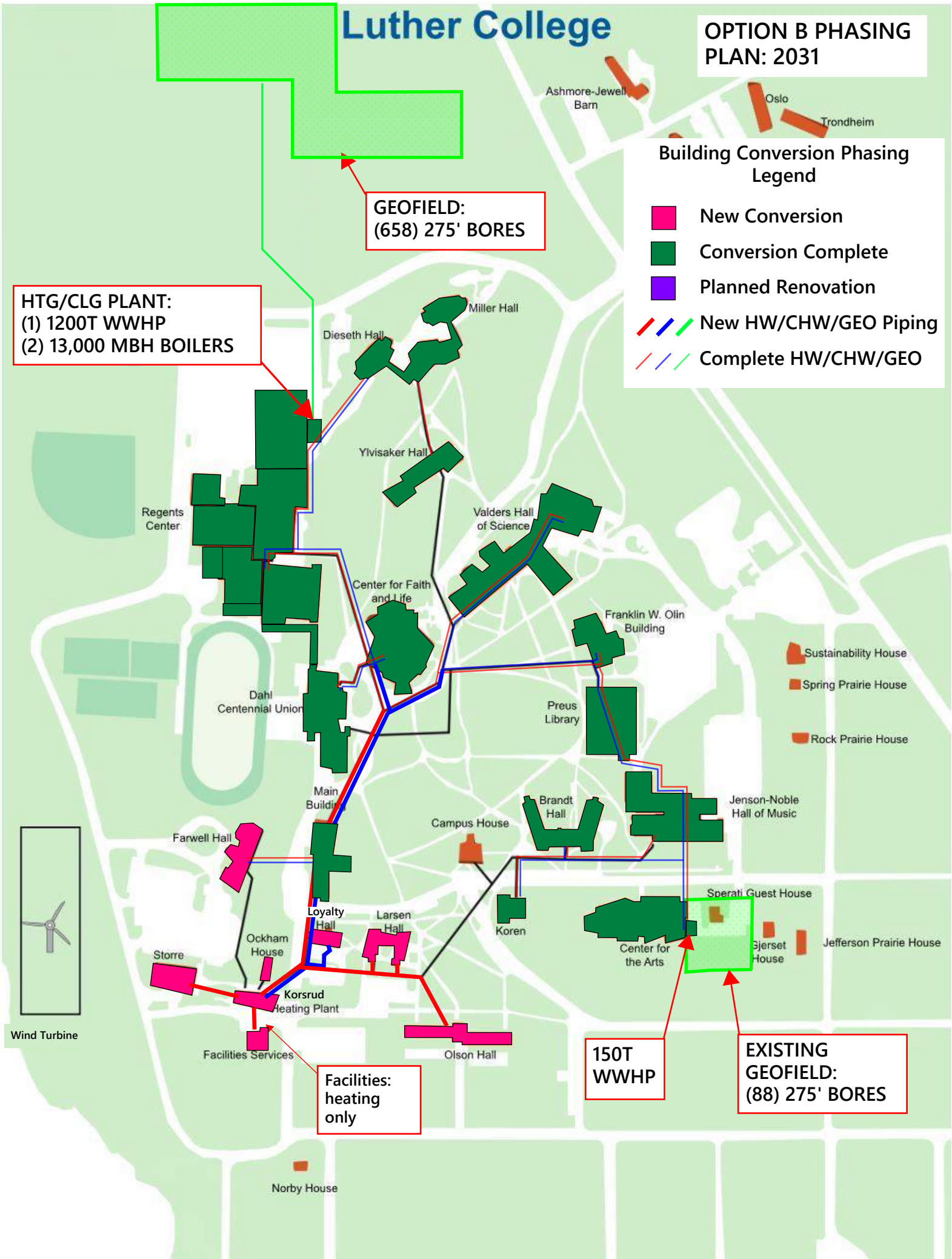
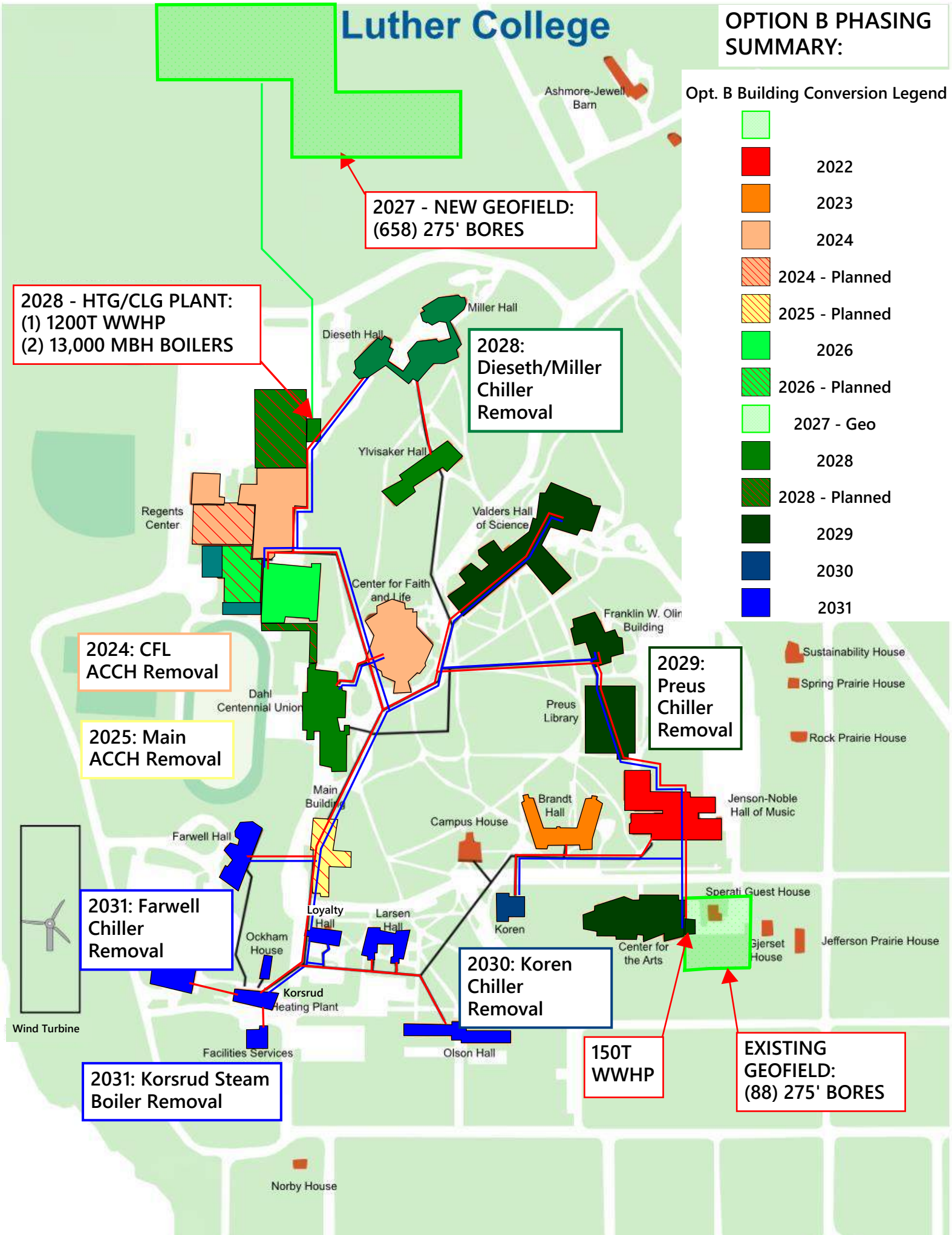
OPTION B PHASING PLAN: 2029
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
GEOFIELD: (658) 275' BORES
HTG/CLG PLANT: (1) 1200T WWHP (2) 13,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Ockham House
Storre
Center for the Arts
Gjerset House
Jefferson Prairie House
Korsrud Heating Plant
Facilities Services
Olson Hall
Wind Turbine
NEW 150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Norby House


Luther College
OPTION B PHASING PLAN: 2030
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
GEOFIELD: (658) 275' BORES
HTG/CLG PLANT: (1) 1200T WWHP (2) 13,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Ockham House
Storre
Center for the Arts
Gjerset House
Jefferson Prairie House
Korsrud Heating Plant
Facilities Services
Olson Hall
Wind Turbine
150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Norby House

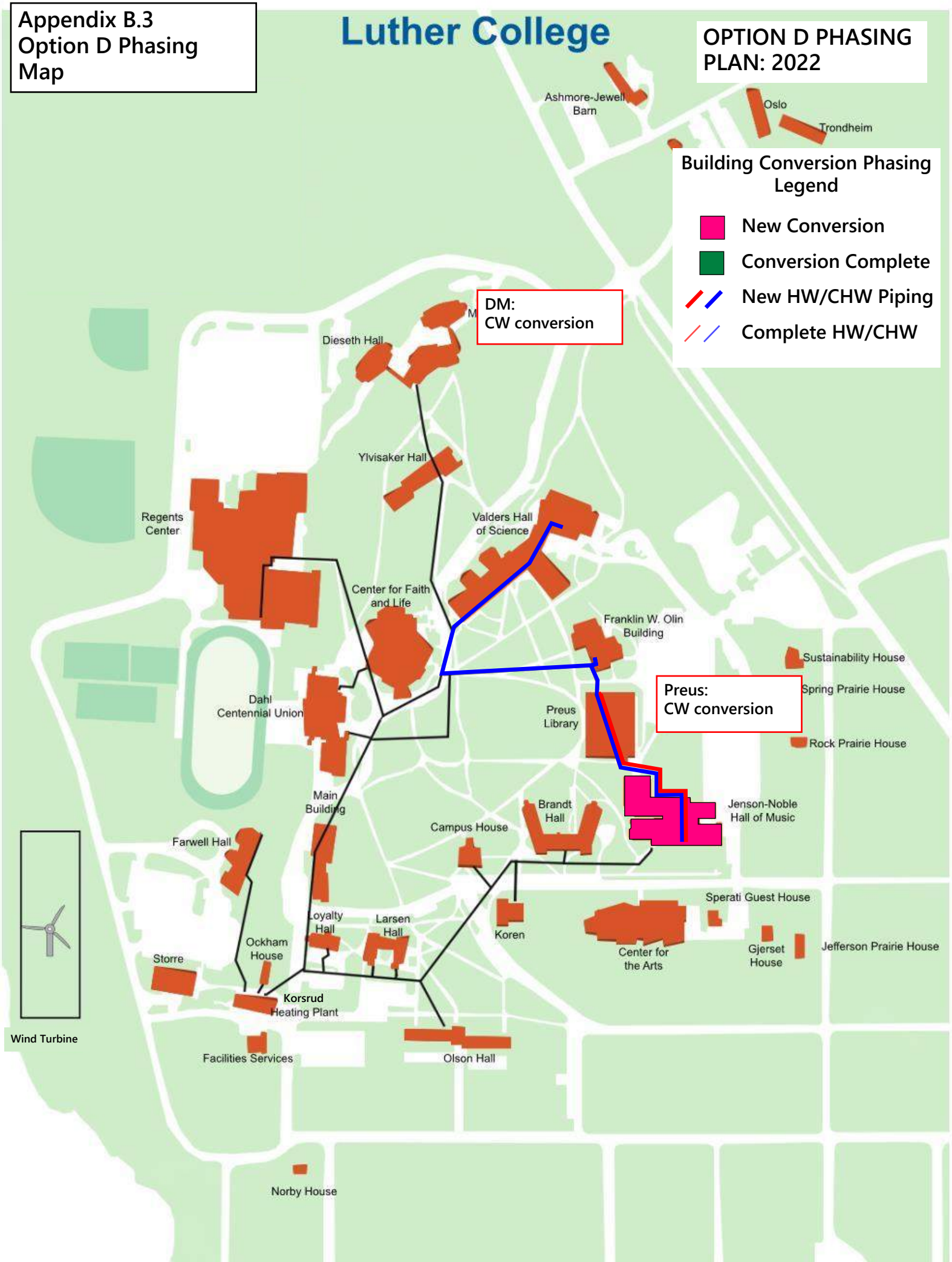

Luther College
OPTION B PHASING PLAN: 2031
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
GEOFIELD: (658) 275' BORES
HTG/CLG PLANT: (1) 1200T WWHP (2) 13,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Loyalty Hall
Larsen Hall
Koren
Sperati Guest House
Ockham House
Storre
Center for the Arts
Gjerset House
Jefferson Prairie House
Korsrud Heating Plant
Facilities Services
Olson Hall
Wind Turbine
Norby House
150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Facilities: heating only

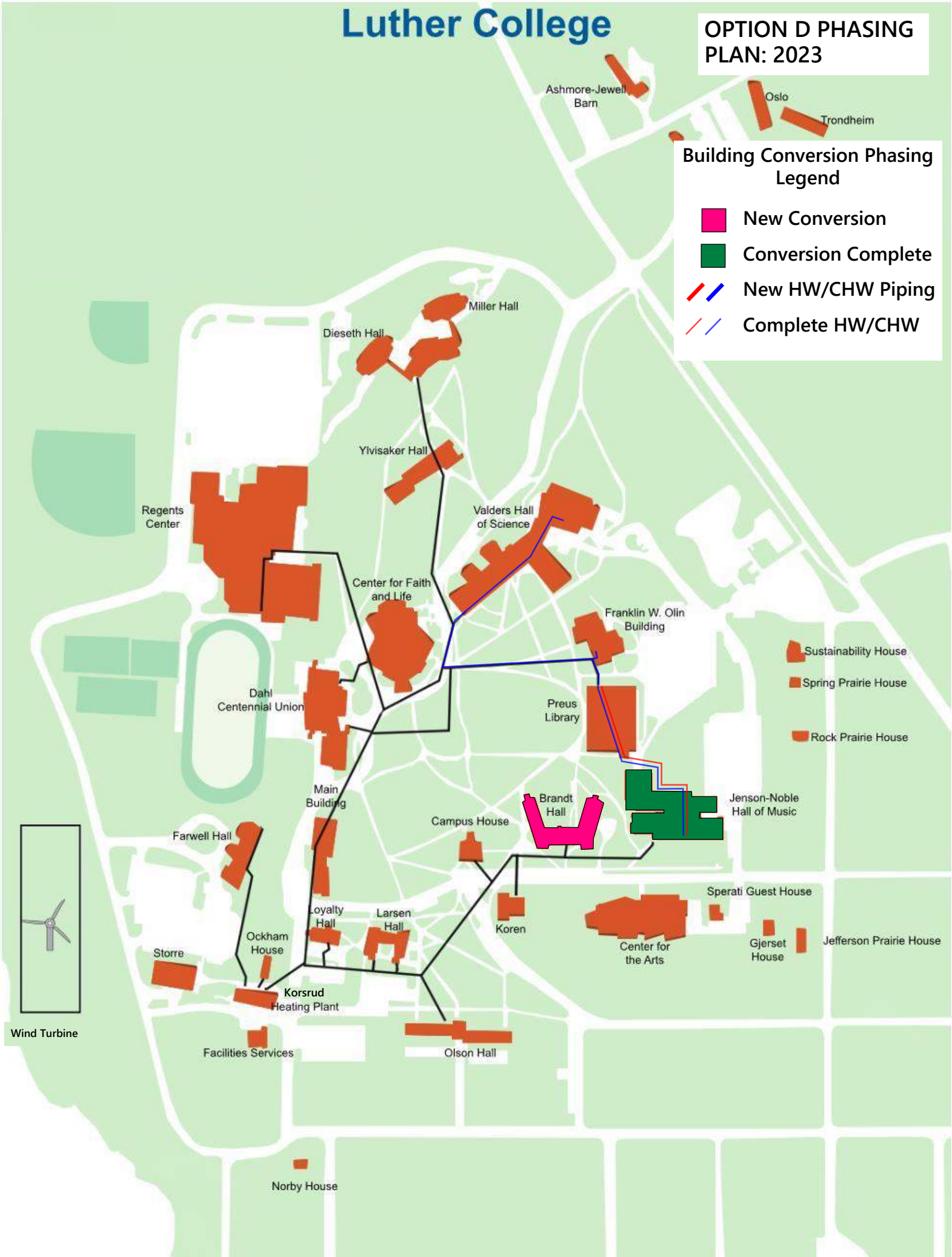

Luther College
OPTION B PHASING SUMMARY:
Opt. B Building Conversion Legend
2022
2023
2024
2024 - Planned
2025 - Planned
2026
2026 - Planned
2027 - Geo
2028
2028 - Planned
2029
2030
2031
2027 - NEW GEOFIELD: (658) 275' BORES
2028 - HTG/CLG PLANT: (1) 1200T WWHP (2) 13,000 MBH BOILERS
2028: Dieseth/Miller Chiller Removal
2024: CFL ACCH Removal
2025: Main ACCH Removal
2029: Preus Chiller Removal
2031: Farwell Chiller Removal
2030: Koren Chiller Removal
2031: Korsrud Steam Boiler Removal
150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Ashmore-Jewell Barn
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Dahl Centennial Union
Preus Library
Sustainability House
Spring Prairie House
Rock Prairie House
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Loyalty Hall
Larsen Hall
Ockham House
Korsrud Heating Plant
Facilities Services
Koren
Center for the Arts
Sperati Guest House
Gjerset House
Jefferson Prairie House
Olson Hall
Wind Turbine
Norby House

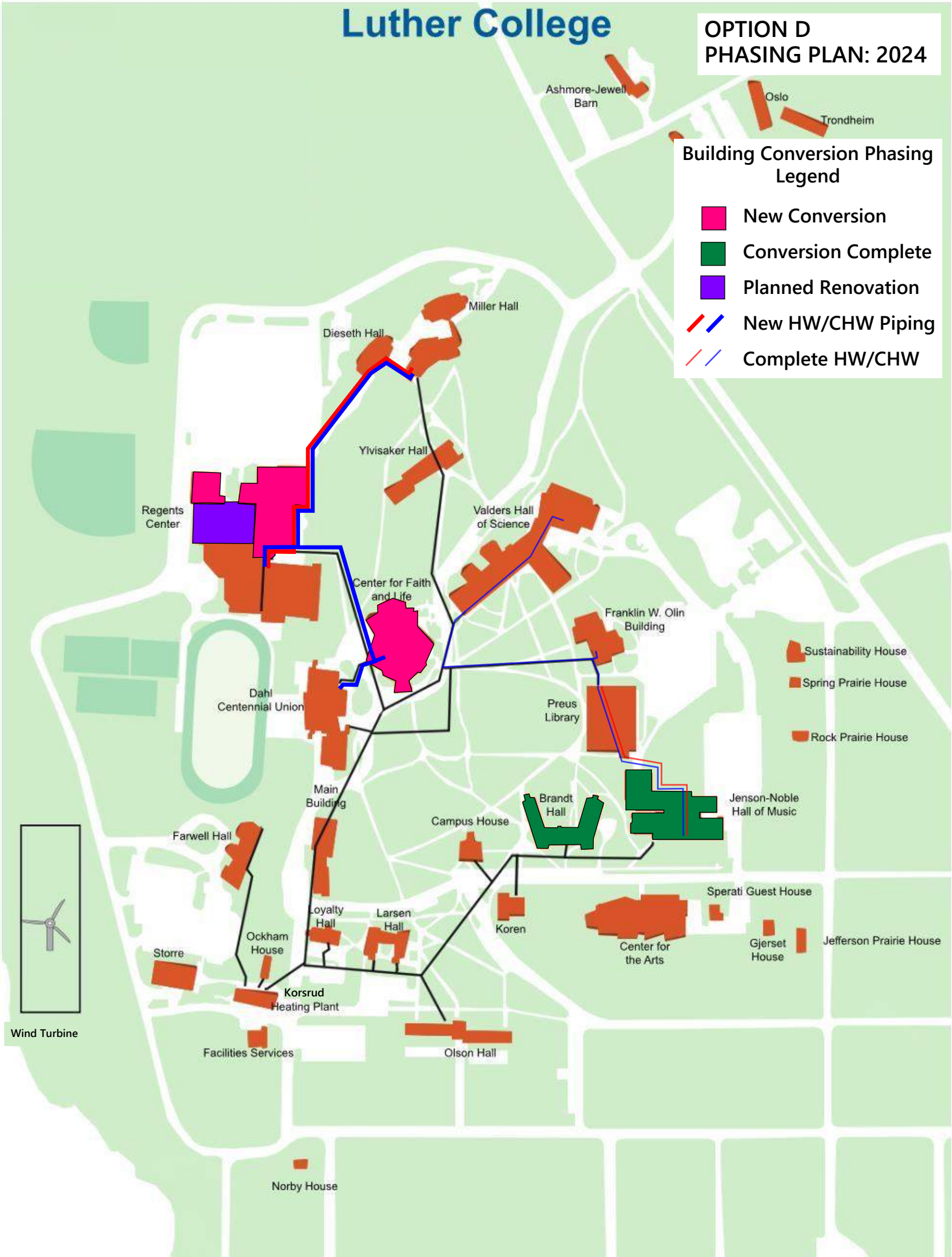
Appendix B.3
Option D Phasing Map

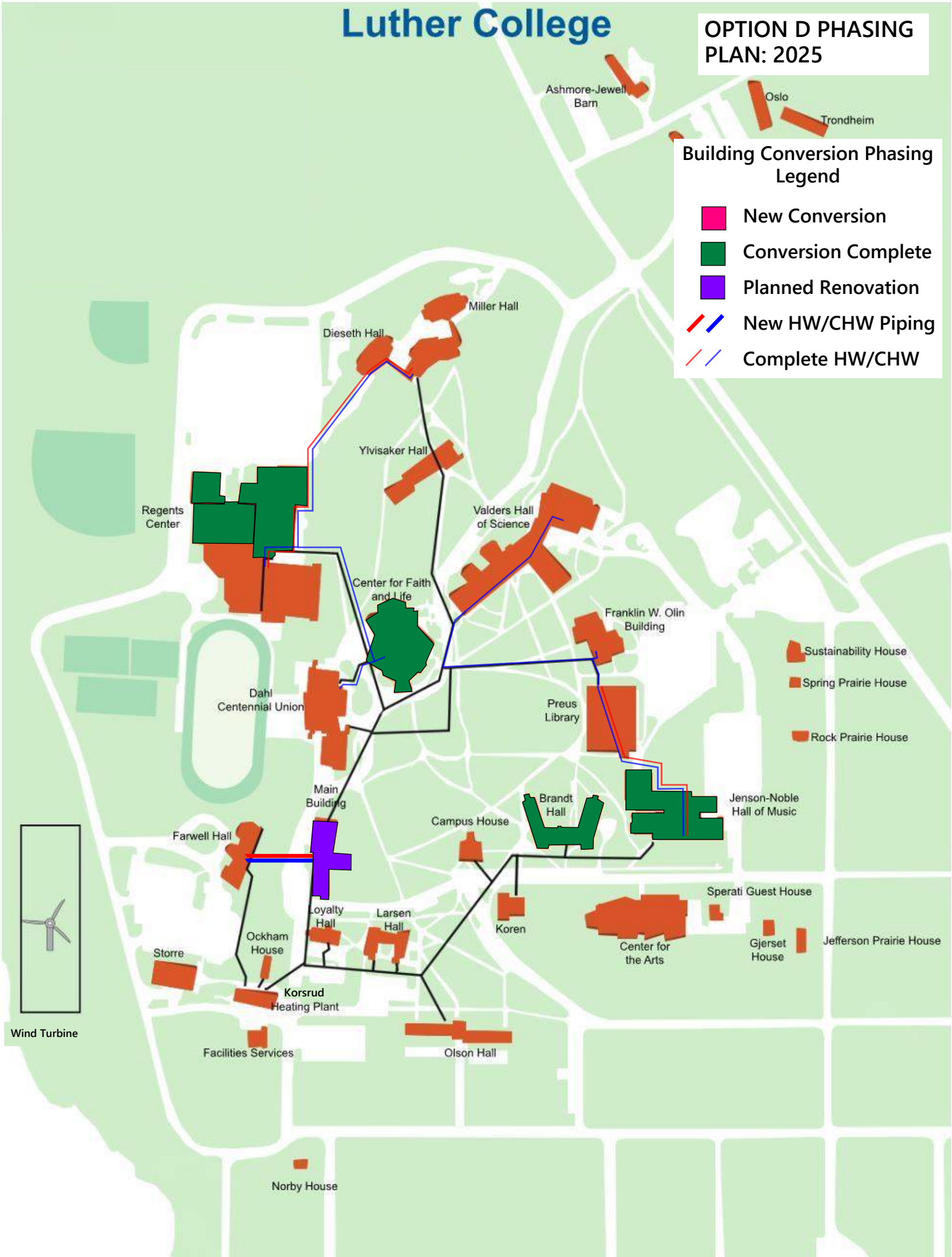
Luther College

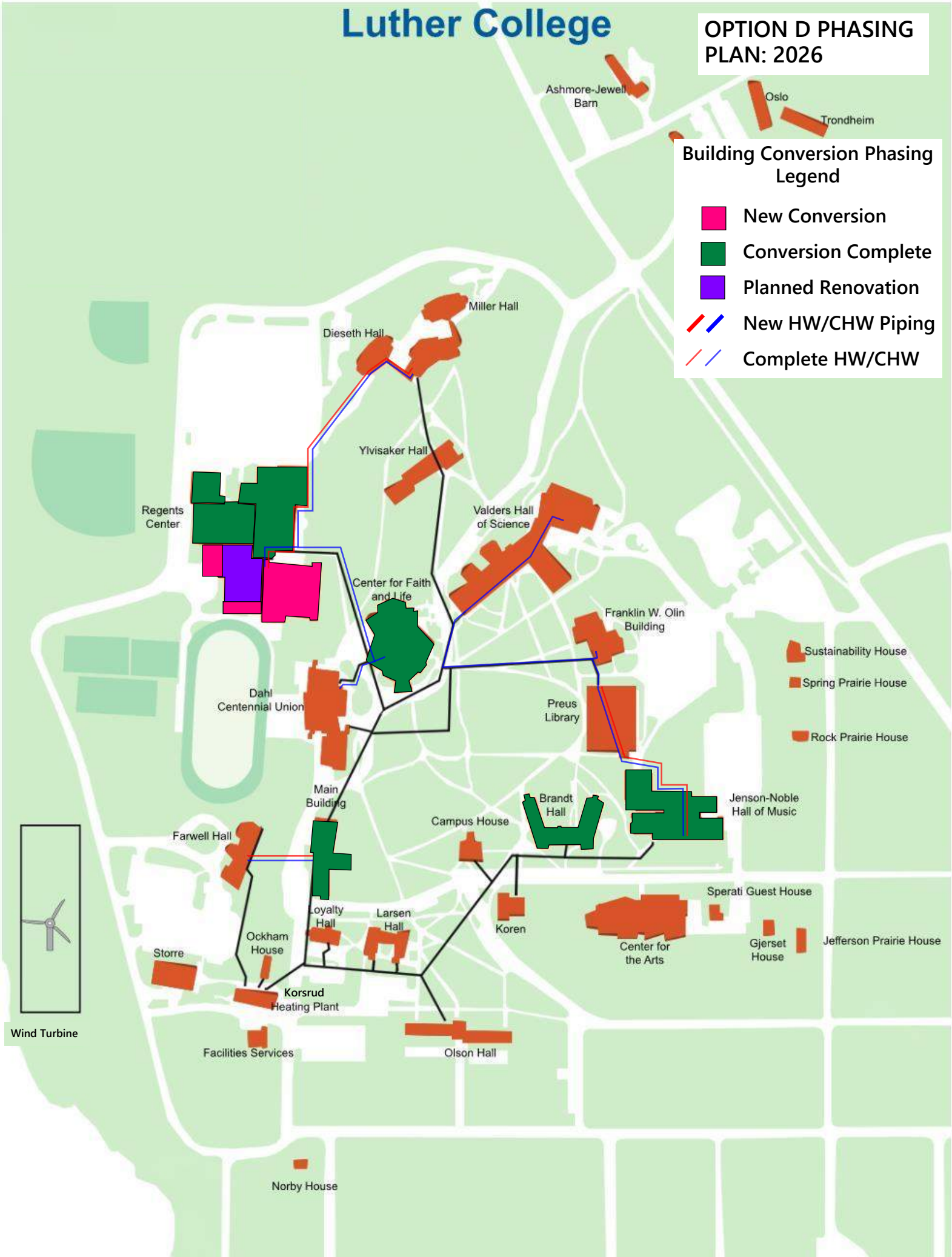
OPTION D PHASING PLAN: 2022

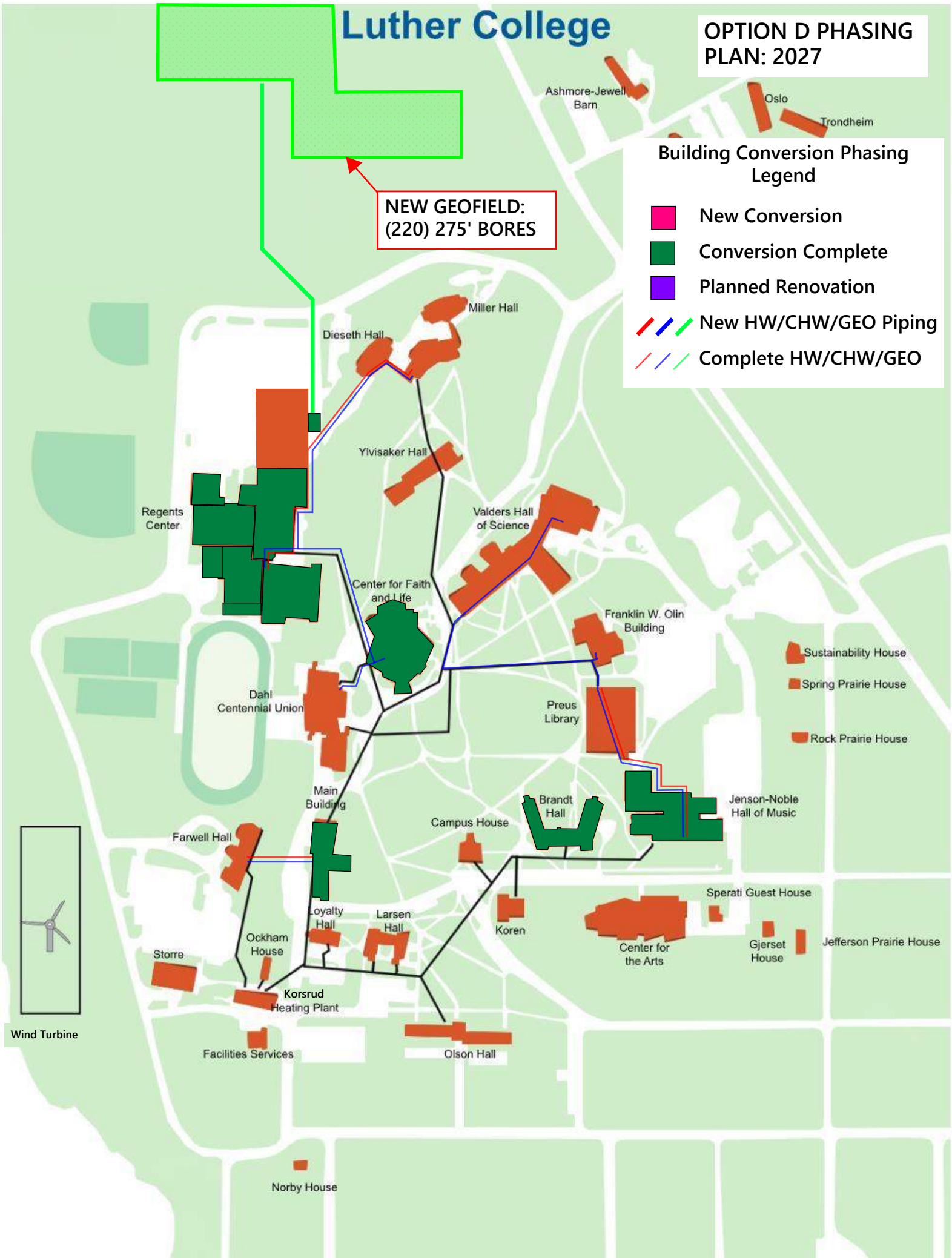


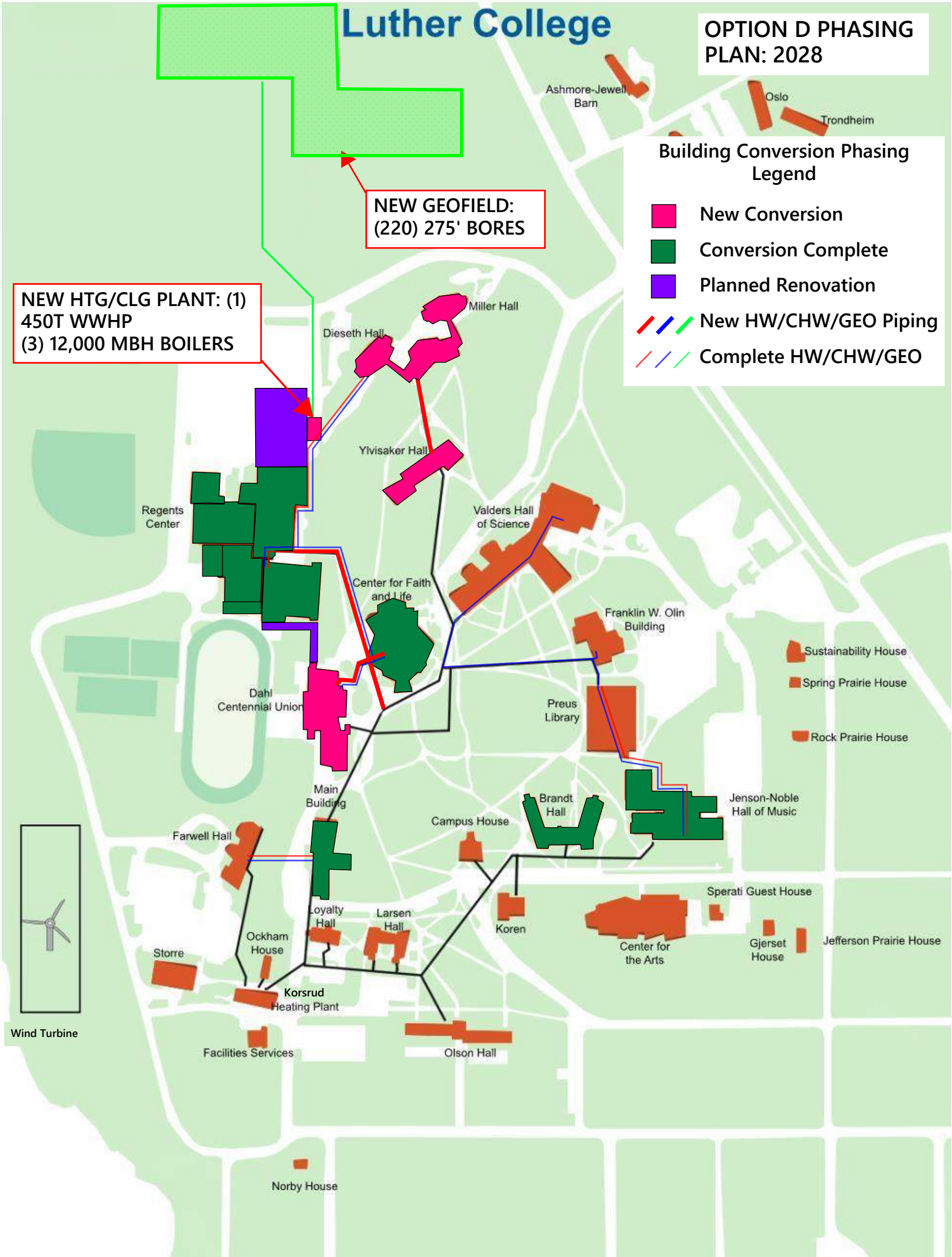

Luther College
OPTION D PHASING PLAN: 2023
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
New HW/CHW Piping
Complete HW/CHW
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine

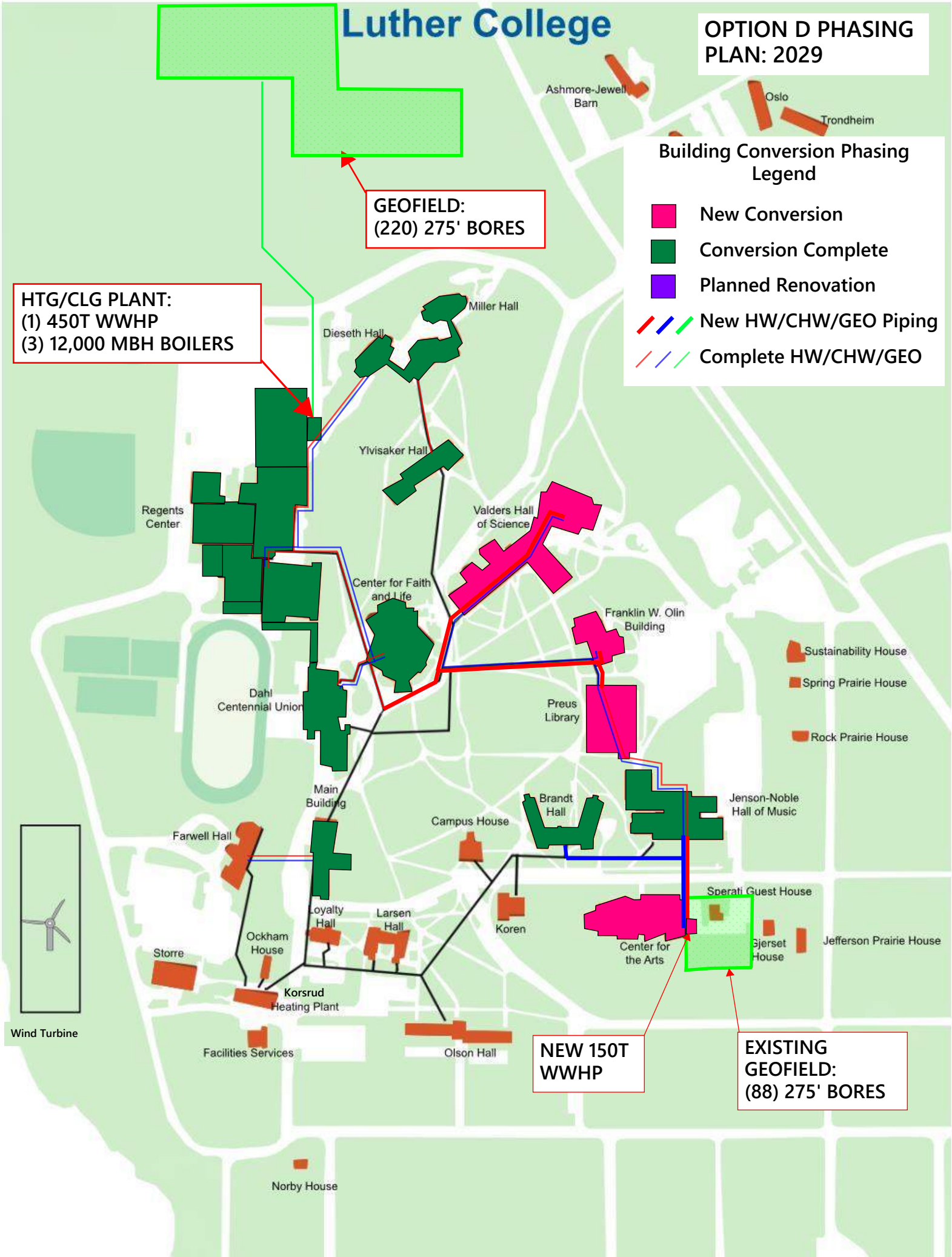

Luther College
OPTION D
PHASING PLAN: 2024
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW Piping
Complete HW/CHW
Ashmore-Jewell Barn
Oslo
Trondheim
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine

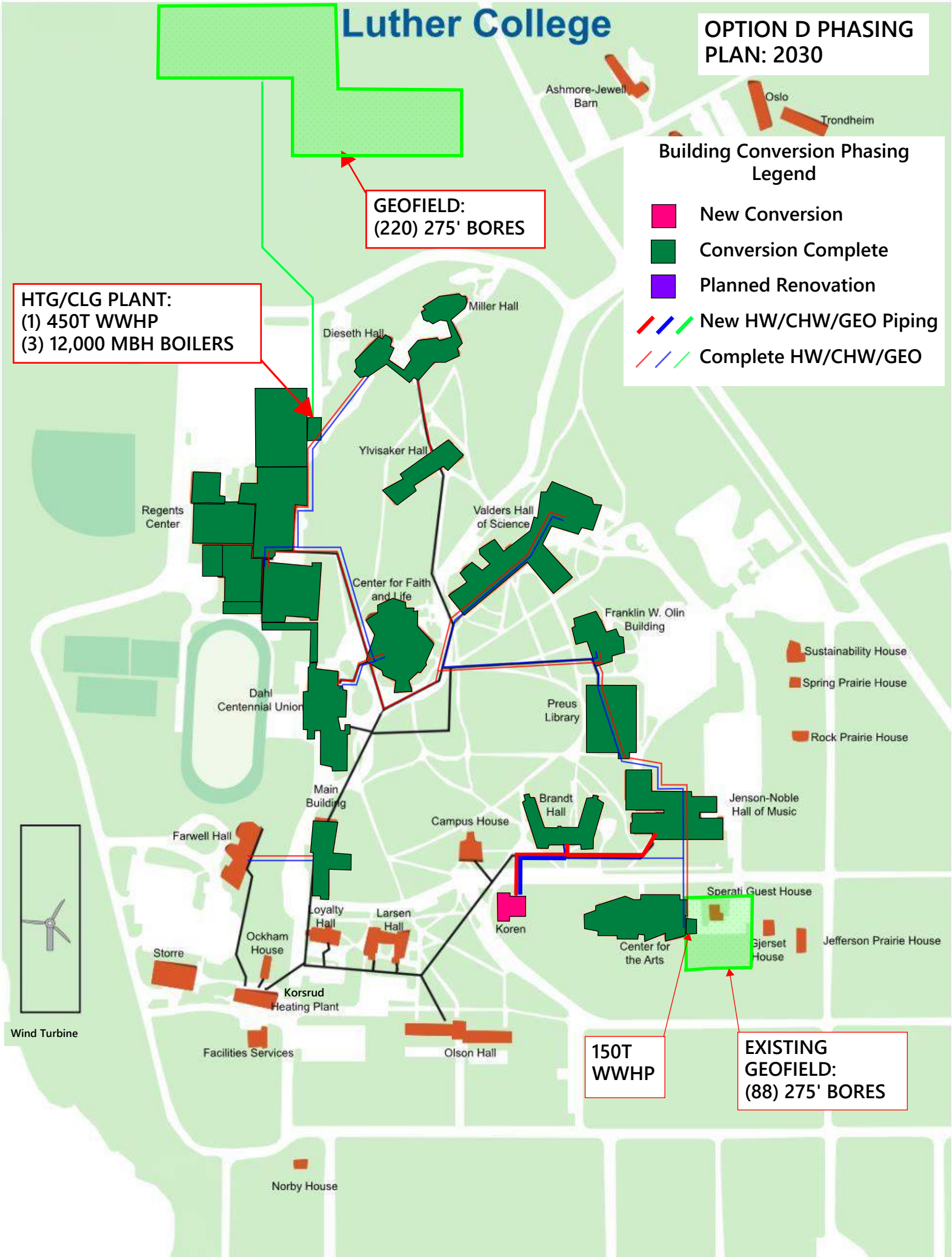

Luther College
OPTION D PHASING PLAN: 2025
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW Piping
Complete HW/CHW
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine

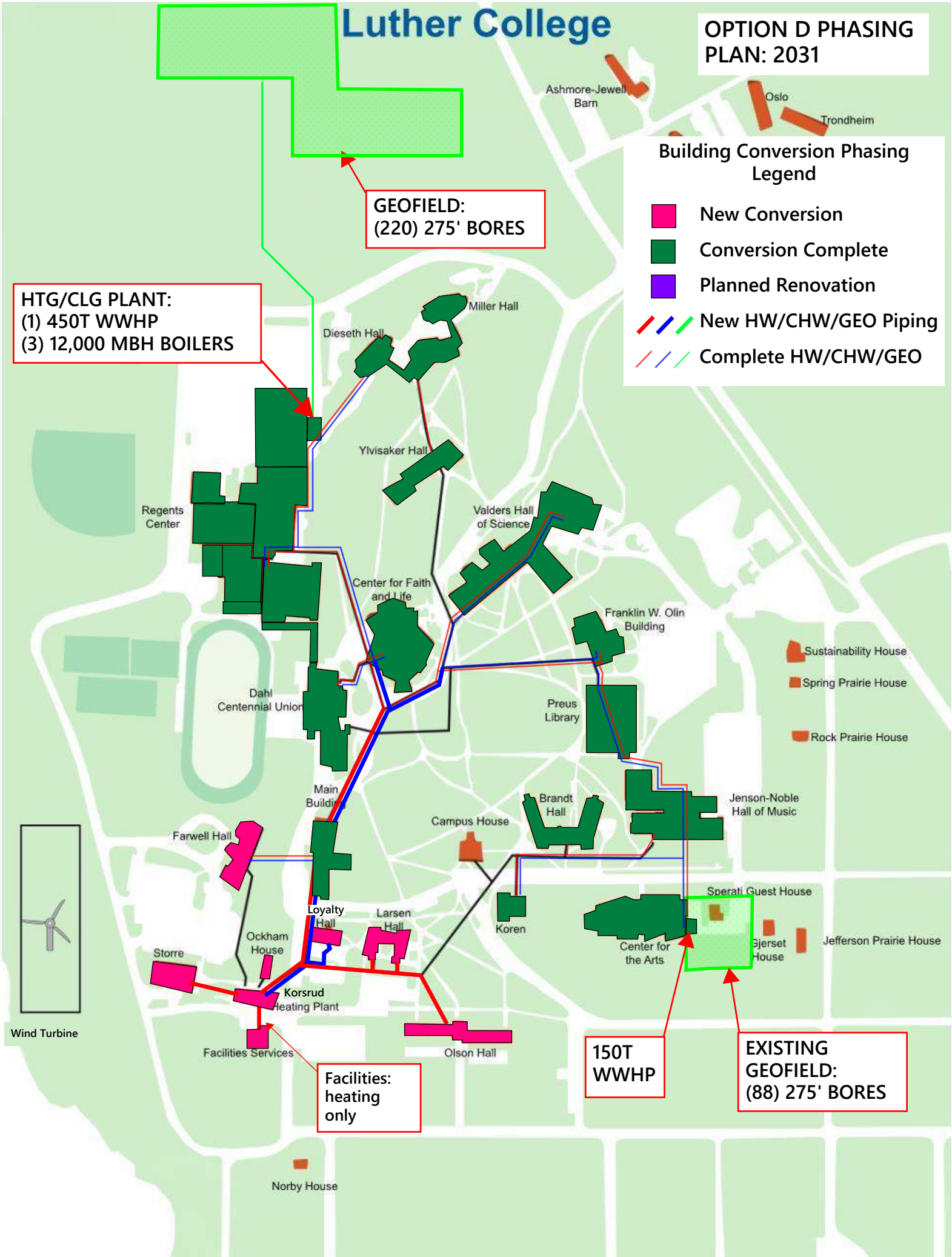

Luther College
OPTION D PHASING PLAN: 2026
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW Piping
Complete HW/CHW
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine

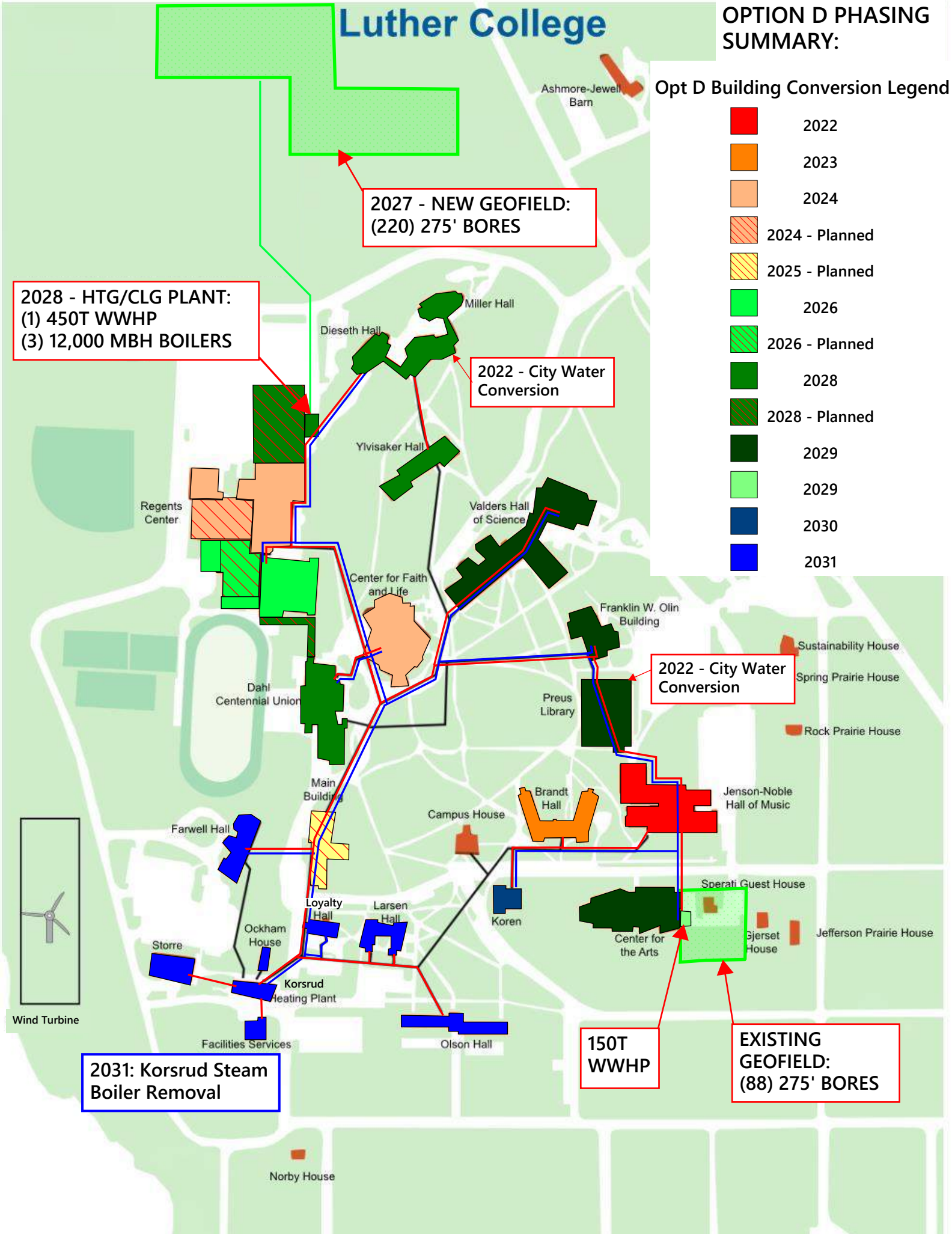

Luther College
OPTION D PHASING PLAN: 2027
NEW GEOFIELD: (220) 275' BORES
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
Ashmore-Jewell Barn
Oslo
Trondheim
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine

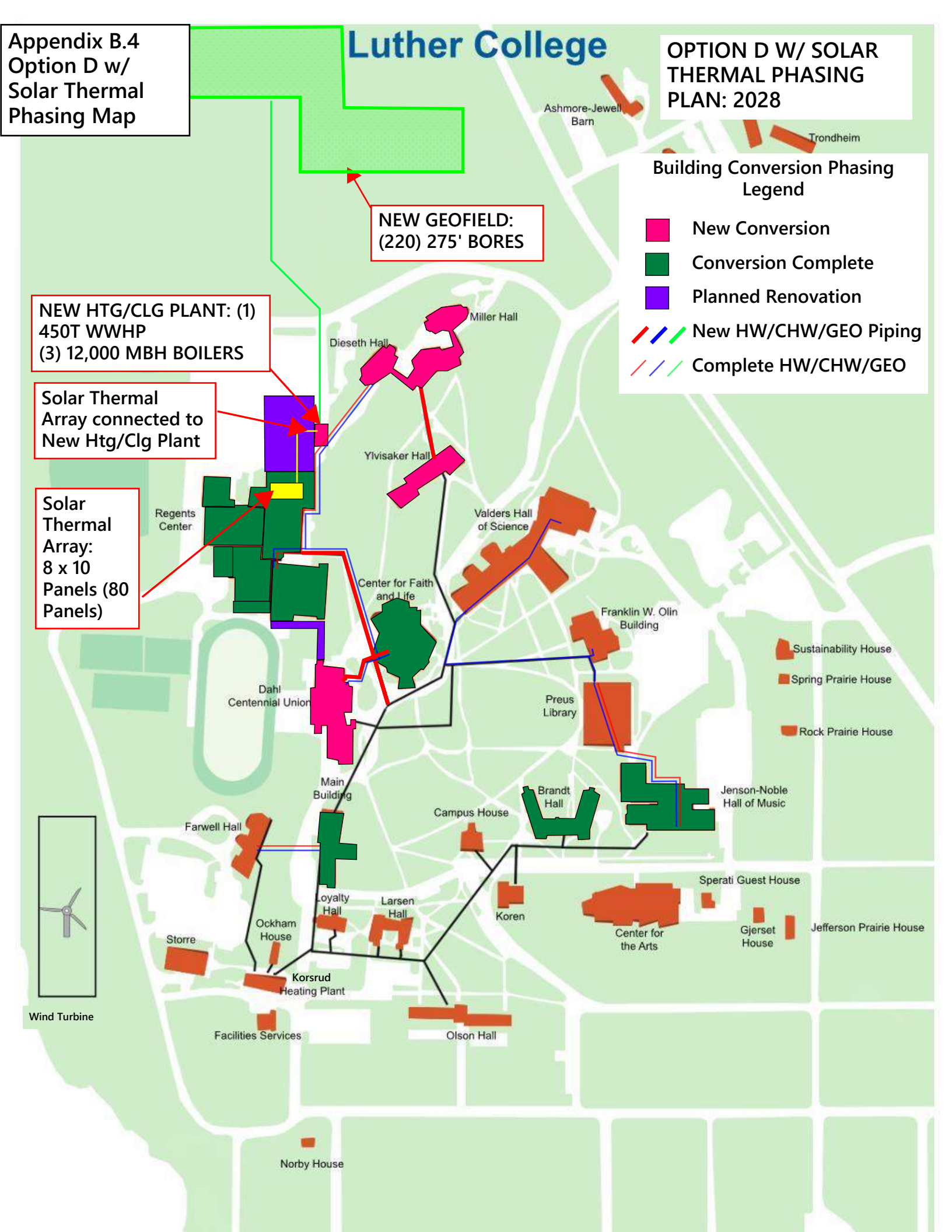

Luther College
OPTION D PHASING PLAN: 2028
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
NEW GEOFIELD: (220) 275' BORES
NEW HTG/CLG PLANT: (1) 450T WWHP (3) 12,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Center for the Arts
Gjerset House
Jefferson Prairie House
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Norby House
Wind Turbine


Luther College
OPTION D PHASING PLAN: 2029
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
GEOFIELD: (220) 275' BORES
HTG/CLG PLANT: (1) 450T WWHP (3) 12,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Ockham House
Storre
Center for the Arts
Gjerset House
Jefferson Prairie House
Korsrud Heating Plant
Facilities Services
Olson Hall
Wind Turbine
NEW 150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Norby House


Luther College
OPTION D PHASING PLAN: 2030
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
GEOFIELD: (220) 275' BORES
HTG/CLG PLANT: (1) 450T WWHP (3) 12,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty Hall
Larsen Hall
Koren
Ockham House
Storre
Center for the Arts
Gjerset House
Jefferson Prairie House
Korsrud Heating Plant
Facilities Services
Olson Hall
Wind Turbine
150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Norby House


Luther College
OPTION D PHASING PLAN: 2031
Ashmore-Jewell Barn
Oslo
Trondheim
Building Conversion Phasing Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
GEOFIELD: (220) 275' BORES
HTG/CLG PLANT: (1) 450T WWHP (3) 12,000 MBH BOILERS
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Loyalty Hall
Larsen Hall
Koren
Sperati Guest House
Ockham House
Storre
Korsrud Heating Plant
Center for the Arts
Gjerset House
Jefferson Prairie House
Wind Turbine
Facilities Services
Olson Hall
Facilities: heating only
150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Norby House


Luther College
OPTION D PHASING SUMMARY:
Opt D Building Conversion Legend
2022
2023
2024
2024 - Planned
2025 - Planned
2026
2026 - Planned
2028
2028 - Planned
2029
2029
2030
2031
2027 - NEW GEOFIELD: (220) 275' BORES
2028 - HTG/CLG PLANT: (1) 450T WWHP (3) 12,000 MBH BOILERS
2022 - City Water Conversion
2022 - City Water Conversion
2031: Korsrud Steam Boiler Removal
150T WWHP
EXISTING GEOFIELD: (88) 275' BORES
Wind Turbine
Ashmore-Jewell Barn
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents Center
Valders Hall of Science
Center for Faith and Life
Franklin W. Olin Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl Centennial Union
Preus Library
Main Building
Brandt Hall
Jenson-Noble Hall of Music
Campus House
Farwell Hall
Loyalty Hall
Larsen Hall
Ockham House
Storre
Korsrud Heating Plant
Facilities Services
Olson Hall
Koren
Sperati Guest House
Center for the Arts
Gjerset House
Jefferson Prairie House
Norby House


Appendix B.4
Option D w/
Solar Thermal
Phasing Map
Luther College
OPTION D W/ SOLAR
THERMAL PHASING
PLAN: 2028
Ashmore-Jewell
Barn
Trondheim
Building Conversion Phasing
Legend
New Conversion
Conversion Complete
Planned Renovation
New HW/CHW/GEO Piping
Complete HW/CHW/GEO
NEW GEOFIELD:
(220) 275' BORES
NEW HTG/CLG PLANT: (1)
450T WWHP
(3) 12,000 MBH BOILERS
Solar Thermal
Array connected to
New Htg/Clg Plant
Solar
Thermal
Array:
8 x 10
Panels (80
Panels)
Miller Hall
Dieseth Hall
Ylvisaker Hall
Regents
Center
Valders Hall
of Science
Center for Faith
and Life
Franklin W. Olin
Building
Sustainability House
Spring Prairie House
Rock Prairie House
Dahl
Centennial Union
Preus
Library
Main
Building
Brandt
Hall
Jenson-Noble
Hall of Music
Campus House
Farwell Hall
Sperati Guest House
Loyalty
Hall
Larsen
Hall
Koren
Ockham
House
Storre
Center for
the Arts
Gjerset
House
Jefferson Prairie House
Korsrud
Heating Plant
Wind Turbine
Facilities Services
Olson Hall
Norby House

Appendix C.1
Maintenance Costs

BAU Maintenance

	Capacity (MBH or Tons)	2022-2072
Steam Generation System Total	87045.4	$281,000
Water Cooled Chiller Total	720	$50,400
Air Cooled Chiller Total	923	$43,025
DX total	288.5	$8,213
City Water Clg	650	$45,500
Existing Geo (WSHP)	160	$22,447
	Annual Maintenance Cost:	$450,584
	Total 50yr Maintenance Cost:	$22,529,208

Building/System	Capacity (MBH or Tons)
Jenson - DX	125
Brandt - DX	15
Ctr Faith and Life - ACCH	180
Regents N - DX	65
Centenniel Union - DX	40
Main Bldg - ACCH	128
Main Bldg - DX	25
Regents S - DX	30
Centenniel Union - WCCH	250
Centenniel Union - ACCH	50
Dieseth/Miller - City Cooled CH	350
Ylvisaker - DX	20
Ctr For Arts - ASHP	40
Ctr For Arts - WSHP	160
Ctr For Arts - DX	50
Ctr For Arts - Geo heat	1928
Franklin Olin/Preus - City Cooled CH	300
Valders/Sampson - WCCH	470
Koren - ACCH	200
Farwell - ACCH	200
Loyalty Hall - DX	32
Korsrud/Ockam - Window AC	7
Larsen - DX	20
Olson - DX	17
Storre - DX	7.5

Appendix C.2

Option B Maintenance- (1) 1,200T WWHP & (2) 13,000 MBH Boilers

	Capacity (MBH)	Capacity (Tons)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031-2072
Steam Generation System Total	87,045		$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	
Water Cooled Chiller Total		720	$50,400	$50,400	$50,400	$50,400	$50,400	$50,400	$50,400	$50,400	$50,400	$50,400
Air Cooled Chiller Total		923	$39,900	$39,900	$39,900	$39,900	$39,900	$39,900	$28,400	$26,400	$16,400	$0
DX total		289	$8,213	$8,213	$6,588	$6,588	$5,838	$5,838	$4,838	$3,588	$3,213	$500
City Water Clg		650	$45,500	$45,500	$45,500	$45,500	$45,500	$45,500	$21,000	$0	$0	$0
Existing Geo (WSHP)		160	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447
Boiler Total	26,000								$10,324	$10,324	$10,324	$10,324
New Geothermal Total (WWHP)		1200 (2028) then 1350 (2029)							$84,000	$94,500	$94,500	$94,500
		Annual Maintenance Cost	$447,459	$447,459	$445,834	$445,834	$445,084	$445,084	$502,408	$488,658	$478,283	$178,171
		Total 50 Year Maintenance Cost	$11,451,101									

Appendix C.3

Option D Maintenance - (1) 450T WWHP & (3) 12,000 MBH Boilers

	Capacity (MBH)	Capacity (Tons)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031-2072
Steam Generation System Total	67,750		$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	
Water Cooled Chiller Total		720	$50,400	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900
Air Cooled Chiller Total		923	$39,900	$39,900	$39,900	$39,900	$39,900	$39,900	$37,400	$35,400	$25,400	$19,000
DX total		289	$8,213	$8,213	$6,588	$6,588	$5,838	$5,838	$4,338	$3,088	$2,713	$0
City Water Clg		650	$45,500	$0	$0	$0	$0	$0	$0	$0	$0	$0
Existing Geo (WSHP)		160	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447
Boiler Total	36,000								$15,486	$15,486	$15,486	$15,486
New Geothermal Total (WWHP)		450 (2028) then 600 (2029)							$31,500	$42,000	$42,000	$42,000
		Annual Maintenance Cost	$447,459	$447,459	$445,834	$445,834	$445,084	$445,084	$488,070	$495,320	$484,945	$194,833
		Total 50 Year Maintenance Cost	$12,133,230									

Appendix C.4

Option D w/Solar Thermal Maintenance - (1) 450T WWHP & (3) 12,000 MBH Boilers

	Capacity (MBH)	Capacity (Tons)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031-2072
Steam Generation System Total	67,750		$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	$281,000	
Water Cooled Chiller Total		720	$50,400	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900	$95,900
Air Cooled Chiller Total		923	$39,900	$39,900	$39,900	$39,900	$39,900	$39,900	$37,400	$35,400	$25,400	$19,000
DX total		289	$8,213	$8,213	$6,588	$6,588	$5,838	$5,838	$4,338	$3,088	$2,713	$0
City Water Clg		650	$45,500	$0	$0	$0	$0	$0	$0	$0	$0	$0
Existing Geo (WSHP)		160	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447	$22,447
Boiler Total	36,000								$15,486	$15,486	$15,486	$15,486
New Geothermal Total (WWHP)		450 (2028) then 600 (2029)							$31,500	$42,000	$42,000	$42,000
Solar Thermal	1,880								$1,200	$1,200	$1,200	$1,200
		Annual Maintenance Cost	$447,459	$447,459	$445,834	$445,834	$445,084	$445,084	$489,270	$496,520	$486,145	$196,033
		Total 50 Year Maintenance Cost	$12,186,030									

Appendix D.1
LCCA Summary Tables

Luther College - Option 1 (BAU)											
Year	Year Count	Electric Utility Cost PC ($)	Gas Utility Cost PC ($)	Investment Cost PC ($)	Maintenance Cost PC ($)	City Water Cost PC ($)	Carbon Tax NG PC ($)	Carbon Tax Electricity PC ($)	Total PC ($)	Total FC ($)	Total PV ($)
2022	1	$168,570	$378,385	$528,469	$450,584	$84,453	$376,519	$80,328	$2,067,309	$2,067,309	$2,067,309
2023	2	$168,570	$378,385	$528,469	$450,584	$84,453	$376,519	$79,123	$2,066,104	$2,118,504	$1,970,047
2024	3	$168,570	$378,385	$528,469	$450,584	$84,453	$376,519	$77,918	$2,064,899	$2,171,017	$1,877,405
2025	4	$168,570	$378,385	$528,469	$450,584	$84,453	$376,519	$76,714	$2,063,694	$2,224,883	$1,789,161
2026	5	$168,570	$378,385	$528,469	$450,584	$84,453	$376,519	$75,509	$2,062,489	$2,280,139	$1,705,105
2027	6	$171,298	$382,707	$1,362,634	$450,584	$84,453	$380,819	$75,521	$2,908,015	$3,290,980	$2,288,561
2028	7	$171,298	$382,707	$1,362,634	$450,584	$84,453	$380,819	$74,296	$2,906,791	$3,372,176	$2,180,695
2029	8	$171,298	$382,707	$1,362,634	$450,584	$84,453	$380,819	$73,071	$2,905,566	$3,455,435	$2,077,948
2030	9	$192,195	$403,629	$2,362,634	$450,584	$84,453	$401,638	$80,725	$3,975,859	$4,838,241	$2,705,621
2031	10	$192,195	$403,629	$2,362,634	$450,584	$84,453	$401,638	$79,349	$3,974,483	$4,957,020	$2,577,790
2032	11	$192,195	$403,629	$1,993,000	$450,584	$84,453	$401,638	$77,973	$3,603,472	$4,609,534	$2,229,109
2033	12	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$76,139	$2,601,638	$3,422,275	$1,538,993
2034	13	$192,195	$403,629	$2,013,000	$450,584	$84,453	$401,638	$74,304	$3,619,803	$4,864,801	$2,034,390
2035	14	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$72,469	$2,597,968	$3,593,109	$1,397,291
2036	15	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$70,635	$2,596,134	$3,681,814	$1,331,453
2037	16	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$68,800	$2,594,299	$3,772,791	$1,268,744
2038	17	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$66,965	$2,592,464	$3,866,098	$1,209,015
2039	18	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$65,131	$2,590,630	$3,961,798	$1,152,122
2040	19	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$63,296	$2,588,795	$4,059,954	$1,097,931
2041	20	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$61,461	$2,586,960	$4,160,634	$1,046,311
2042	21	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$59,627	$2,585,126	$4,263,903	$997,139
2043	22	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$57,792	$2,583,291	$4,369,831	$950,300
2044	23	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$55,957	$2,581,456	$4,478,490	$905,681
2045	24	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$54,123	$2,579,622	$4,589,953	$863,175
2046	25	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$52,288	$2,577,787	$4,704,294	$822,683
2047	26	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$50,453	$2,575,952	$4,821,592	$784,109
2048	27	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$48,619	$2,574,118	$4,941,926	$747,359
2049	28	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$46,784	$2,572,283	$5,065,378	$712,348
2050	29	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$44,949	$2,570,448	$5,192,032	$678,993
2051	30	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$5,321,975	$647,214
2052	31	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$5,459,048	$617,362
2053	32	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$5,599,771	$588,899
2054	33	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$5,744,245	$561,760
2055	34	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$5,892,573	$535,883
2056	35	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$6,044,862	$511,210
2057	36	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$6,201,220	$487,682
2058	37	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$6,361,761	$465,248
2059	38	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$6,526,600	$443,856
2060	39	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$6,695,857	$423,456
2061	40	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$6,869,653	$404,003
2062	41	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$7,048,115	$385,452
2063	42	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$7,231,372	$367,761
2064	43	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$7,419,559	$350,889
2065	44	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$7,612,811	$334,799
2066	45	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$7,811,270	$319,454
2067	46	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$8,015,083	$304,819
2068	47	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$8,224,397	$290,861
2069	48	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$8,439,366	$277,549
2070	49	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$8,660,150	$264,851
2071	50	$192,195	$403,629	$993,000	$450,584	$84,453	$401,638	$43,115	$2,568,614	$8,886,910	$252,740
50 Year Total		*$9,428,910*	*$19,992,473*	*$53,195,517*	*$22,529,208*	*$4,222,650*	*$19,893,860*	*$2,845,726*	*$132,108,345*	*$259,262,508*	*$51,842,536*

Appendix D.2
LCCA Summary Tables

Luther College - Option B											
Year	Year Count	Electric Utility Cost PC ($)	Gas Utility Cost PC ($)	Investment Cost PC ($)	Maintenance Cost PC ($)	City Water Cost PC ($)	Carbon Tax PC NG ($)	Carbon Tax PC Elec ($)	Total PC ($)	Total FC ($)	Total PV ($)
2022	1	$164,798	$374,145	$3,025,571	$447,459	$84,453	$376,519	$80,328	$4,553,274	$4,553,274	$4,553,274
2023	2	$164,798	$374,145	$1,314,340	$447,459	$84,453	$376,519	$79,123	$2,840,838	$2,911,935	$2,707,878
2024	3	$159,745	$378,385	$4,094,928	$445,834	$84,453	$372,300	$76,155	$5,611,800	$5,891,443	$5,094,676
2025	4	$162,064	$382,707	$391,195	$445,834	$84,453	$372,300	$74,977	$1,913,531	$2,063,882	$1,659,691
2026	5	$161,142	$382,707	$378,955	$445,084	$84,453	$376,519	$71,512	$1,900,372	$2,102,235	$1,572,067
2027	6	$161,142	$382,707	$8,928,867	$445,084	$84,453	$380,819	$71,404	$10,454,476	$11,794,183	$8,201,721
2028	7	$477,849	$175,477	$7,669,957	$502,408	$84,453	$380,819	$69,842	$9,360,805	$10,788,379	$6,976,551
2029	8	$573,819	$52,192	$5,470,541	$488,658	$0	$380,819	$68,690	$7,034,720	$8,281,182	$4,979,943
2030	9	$579,765	$48,132	$568,616	$478,283	$0	$174,611	$203,730	$2,053,137	$2,446,374	$1,368,051
2031	10	$664,959	$3,736	$5,942,704	$178,171	$0	$51,935	$241,343	$7,082,847	$8,722,902	$4,536,155
2032	11	$664,959	$3,736	$0	$178,171	$0	$47,894	$239,666	$1,134,426	$1,375,833	$665,335
2033	12	$664,959	$3,736	$0	$178,171	$0	$3,717	$269,171	$1,119,754	$1,383,686	$622,242
2034	13	$664,959	$3,736	$0	$178,171	$0	$3,717	$262,685	$1,113,268	$1,402,067	$586,325
2035	14	$664,959	$3,736	$0	$178,171	$0	$3,717	$256,199	$1,106,782	$1,420,583	$552,437
2036	15	$664,959	$3,736	$0	$178,171	$0	$3,717	$249,713	$1,100,296	$1,439,229	$520,468
2037	16	$664,959	$3,736	$0	$178,171	$0	$3,717	$243,227	$1,093,810	$1,458,002	$490,308
2038	17	$664,959	$3,736	$0	$178,171	$0	$3,717	$236,741	$1,087,324	$1,476,898	$461,859
2039	18	$664,959	$3,736	$0	$178,171	$0	$3,717	$230,255	$1,080,838	$1,495,913	$435,023
2040	19	$664,959	$3,736	$0	$178,171	$0	$3,717	$223,769	$1,074,352	$1,515,043	$409,712
2041	20	$664,959	$3,736	$0	$178,171	$0	$3,717	$217,283	$1,067,866	$1,534,282	$385,839
2042	21	$664,959	$3,736	$0	$178,171	$0	$3,717	$210,797	$1,061,380	$1,553,627	$363,325
2043	22	$664,959	$3,736	$0	$178,171	$0	$3,717	$204,311	$1,054,894	$1,573,073	$342,093
2044	23	$664,959	$3,736	$0	$178,171	$0	$3,717	$197,825	$1,048,408	$1,592,612	$322,072
2045	24	$664,959	$3,736	$0	$178,171	$0	$3,717	$191,339	$1,041,921	$1,612,240	$303,194
2046	25	$664,959	$3,736	$0	$178,171	$0	$3,717	$184,853	$1,035,435	$1,631,952	$285,394
2047	26	$664,959	$3,736	$0	$178,171	$0	$3,717	$178,366	$1,028,949	$1,651,739	$268,613
2048	27	$664,959	$3,736	$0	$178,171	$0	$3,717	$171,880	$1,022,463	$1,671,596	$252,793
2049	28	$664,959	$3,736	$0	$178,171	$0	$3,717	$165,394	$1,015,977	$1,691,515	$237,879
2050	29	$664,959	$3,736	$0	$178,171	$0	$3,717	$158,908	$1,009,491	$1,711,489	$223,822
2051	30	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,731,510	$210,572
2052	31	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,764,840	$199,585
2053	32	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,798,841	$189,175
2054	33	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,833,527	$179,310
2055	34	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,868,913	$169,963
2056	35	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,905,013	$161,106
2057	36	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,941,843	$152,712
2058	37	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$1,979,417	$144,759
2059	38	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,017,752	$137,222
2060	39	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,056,864	$130,079
2061	40	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,096,769	$123,311
2062	41	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,137,483	$116,896
2063	42	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,179,025	$110,817
2064	43	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,221,412	$105,056
2065	44	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,264,661	$99,596
2066	45	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,308,791	$94,422
2067	46	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,353,821	$89,517
2068	47	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,399,770	$84,869
2069	48	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,446,658	$80,464
2070	49	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,494,504	$76,289
2071	50	$664,959	$3,736	$0	$178,171	$0	$3,717	$152,422	$1,003,005	$2,543,329	$72,331
50 Year Total		*$29,868,440*	*$2,703,766*	*$37,785,674*	*$11,451,102*	*$591,171*	*$3,436,033*	*$8,330,354*	*$94,166,540*	*$133,091,910*	*$52,106,791*

Appendix D.3
LCCA Summary Tables

Luther College - Option D											
Year	Year Count	Electric Utility Cost PC ($)	Gas Utility Cost PC ($)	Investment Cost PC ($)	Maintenance Cost PC ($)	City Water Cost PC ($)	Carbon Tax PC NG ($)	Carbon Tax PC Elec ($)	Total PC ($)	Total FC ($)	Total PV ($)
2022	1	**$168,046**	**$378,385**	**$4,949,198**	**$447,459**	**$0.00**	**$376,519**	**$80,328**	$6,399,936	$6,399,936	$6,399,936
2023	2	**$168,046**	**$378,385**	**$1,314,340**	**$447,459**	**$0.00**	**$376,519**	**$79,123**	$2,763,873	$2,833,128	$2,634,594
2024	3	**$159,745**	**$378,385**	**$3,570,103**	**$445,834**	**$0.00**	**$376,519**	**$77,252**	$5,007,838	$5,257,959	$4,546,865
2025	4	**$162,330**	**$382,707**	**$391,195**	**$445,834**	**$0.00**	**$376,519**	**$76,057**	$1,834,643	$1,979,133	$1,591,539
2026	5	**$161,413**	**$382,707**	**$378,955**	**$445,084**	**$0.00**	**$376,519**	**$72,582**	$1,817,261	$2,010,791	$1,503,684
2027	6	**$161,413**	**$382,707**	**$3,371,870**	**$445,084**	**$0.00**	**$380,819**	**$72,593**	$4,814,487	$5,439,477	$3,782,634
2028	7	**$360,727**	**$197,654**	**$7,292,936**	**$488,070**	**$0.00**	**$380,819**	**$71,014**	$8,791,220	$10,139,018	$6,556,627
2029	8	**$461,266**	**$126,771**	**$5,435,509**	**$495,320**	**$0.00**	**$380,819**	**$69,843**	$6,969,529	$8,217,738	$4,941,790
2030	9	**$462,225**	**$125,617**	**$568,616**	**$484,945**	**$0.00**	**$196,679**	**$152,975**	$1,991,057	$2,387,821	$1,335,307
2031	10	**$475,511**	**$114,495**	**$5,835,384**	**$194,833**	**$0.00**	**$126,146**	**$193,154**	$6,939,522	$8,574,407	$4,458,933
2032	11	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$124,997**	**$190,206**	$1,100,042	$1,365,374	$660,277
2033	12	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$191,174**	$1,089,943	$1,382,321	$621,628
2034	13	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$186,568**	$1,085,336	$1,406,657	$588,244
2035	14	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$181,961**	$1,080,729	$1,431,418	$556,651
2036	15	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$177,354**	$1,076,123	$1,456,610	$526,753
2037	16	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$172,748**	$1,071,516	$1,482,242	$498,460
2038	17	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$168,141**	$1,066,910	$1,508,321	$471,686
2039	18	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$163,535**	$1,062,303	$1,534,856	$446,348
2040	19	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$158,928**	$1,057,696	$1,561,853	$422,371
2041	20	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$154,321**	$1,053,090	$1,589,323	$399,681
2042	21	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$149,715**	$1,048,483	$1,617,272	$378,209
2043	22	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$145,108**	$1,043,876	$1,645,710	$357,890
2044	23	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$140,502**	$1,039,270	$1,674,645	$338,662
2045	24	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$135,895**	$1,034,663	$1,704,087	$320,466
2046	25	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$131,288**	$1,030,057	$1,734,044	$303,248
2047	26	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$126,682**	$1,025,450	$1,764,526	$286,955
2048	27	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$122,075**	$1,020,843	$1,795,542	$271,537
2049	28	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$117,469**	$1,016,237	$1,827,102	$256,947
2050	29	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$112,862**	$1,011,630	$1,859,216	$243,141
2051	30	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$1,891,894	$230,077
2052	31	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$1,934,572	$218,780
2053	32	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$1,978,289	$208,046
2054	33	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,023,073	$197,847
2055	34	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,068,953	$188,155
2056	35	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,115,957	$178,945
2057	36	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,164,115	$170,192
2058	37	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,213,456	$161,874
2059	38	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,264,014	$153,969
2060	39	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,315,818	$146,456
2061	40	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,368,903	$139,315
2062	41	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,423,303	$132,527
2063	42	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,479,053	$126,075
2064	43	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,536,188	$119,943
2065	44	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,594,745	$114,113
2066	45	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,654,763	$108,571
2067	46	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,716,280	$103,302
2068	47	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,779,338	$98,293
2069	48	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,843,976	$93,531
2070	49	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,910,238	$89,003
2071	50	**$475,511**	**$114,495**	**$0.00**	**$194,833**	**$0.00**	**$113,930**	**$108,255**	$1,007,024	$2,978,167	$84,698
50 Year Total		***$21,761,174***	***$7,427,596***	***$33,108,106***	***$12,133,230***	***$0.00***	***$7,916,137***	***$6,144,814***	***$88,491,057***	***$133,835,626***	***$48,764,775***

Appendix D.4
LCCA Summary Tables

Luther College - Option D with Solar Thermal											
Year	Year Count	Electric Utility Cost PC ($)	Gas Utility Cost PC ($)	Investment Cost PC ($)	Maintenance Cost PC ($)	City Water Cost PC ($)	Carbon Tax PC NG ($)	Carbon Tax PC ($)	Total PC ($)	Total FC ($)	Total PV ($)
2022	1	$168,046	$378,385	$4,949,198	$447,459	$0.00	$376,519	$80,328	$6,399,936	$6,399,936	$6,399,936
2023	2	$168,046	$378,385	$1,314,340	$447,459	$0.00	$376,519	$79,123	$2,763,873	$2,833,128	$2,634,594
2024	3	$159,745	$378,385	$3,570,103	$445,834	$0.00	$376,519	$77,252	$5,007,838	$5,257,959	$4,546,865
2025	4	$162,330	$382,707	$391,195	$445,834	$0.00	$376,519	$76,057	$1,834,643	$1,979,133	$1,591,539
2026	5	$161,413	$382,707	$378,955	$445,084	$0.00	$376,519	$72,582	$1,817,261	$2,010,791	$1,503,684
2027	6	$161,413	$382,707	$3,371,870	$445,084	$0.00	$380,819	$72,593	$4,814,487	$5,439,477	$3,782,634
2028	7	$341,172	$190,283	$8,133,647	$489,270	$0.00	$380,819	$71,014	$9,606,205	$11,079,988	$7,165,126
2029	8	$444,437	$117,216	$5,435,509	$496,520	$0.00	$380,819	$69,843	$6,944,345	$8,188,242	$4,924,053
2030	9	$445,509	$115,980	$568,616	$486,145	$0.00	$189,344	$144,541	$1,950,136	$2,338,579	$1,307,770
2031	10	$460,359	$104,889	$5,835,384	$196,033	$0.00	$116,638	$185,974	$6,899,277	$8,524,708	$4,433,088
2032	11	$460,359	$104,889	$0.00	$196,033	$0.00	$115,408	$183,198	$1,059,888	$1,314,598	$635,722
2033	12	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$184,967	$1,050,620	$1,331,407	$598,732
2034	13	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$180,510	$1,046,163	$1,354,717	$566,523
2035	14	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$176,053	$1,041,706	$1,378,429	$536,045
2036	15	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$171,596	$1,037,249	$1,402,550	$507,204
2037	16	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$167,139	$1,032,792	$1,427,086	$479,912
2038	17	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$162,682	$1,028,335	$1,452,046	$454,087
2039	18	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$158,225	$1,023,878	$1,477,436	$429,650
2040	19	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$153,768	$1,019,421	$1,503,263	$406,526
2041	20	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$149,310	$1,014,964	$1,529,537	$384,646
2042	21	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$144,853	$1,010,507	$1,556,263	$363,941
2043	22	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$140,396	$1,006,050	$1,583,450	$344,350
2044	23	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$135,939	$1,001,593	$1,611,107	$325,813
2045	24	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$131,482	$997,136	$1,639,241	$308,272
2046	25	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$127,025	$992,679	$1,667,861	$291,674
2047	26	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$122,568	$988,222	$1,696,975	$275,970
2048	27	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$118,111	$983,765	$1,726,593	$261,110
2049	28	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$113,654	$979,308	$1,756,722	$247,049
2050	29	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$109,197	$974,851	$1,787,372	$233,745
2051	30	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$1,818,553	$221,157
2052	31	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$1,859,392	$210,278
2053	32	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$1,901,221	$199,941
2054	33	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$1,944,065	$190,120
2055	34	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$1,987,952	$180,789
2056	35	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,032,907	$171,921
2057	36	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,078,960	$163,496
2058	37	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,126,139	$155,489
2059	38	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,174,474	$147,880
2060	39	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,223,994	$140,649
2061	40	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,274,731	$133,776
2062	41	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,326,718	$127,245
2063	42	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,379,987	$121,037
2064	43	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,434,573	$115,137
2065	44	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,490,509	$109,529
2066	45	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,547,832	$104,198
2067	46	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,606,580	$99,130
2068	47	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,666,789	$94,313
2069	48	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,728,499	$89,733
2070	49	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,791,750	$85,379
2071	50	$460,359	$104,889	$0.00	$196,033	$0.00	$104,372	$104,740	$970,394	$2,856,583	$81,240
50 Year Total		*$21,086,850*	*$7,007,223*	*$33,948,817*	*$12,186,030*	*$0.00*	*$7,516,954*	*$5,959,526*	*$87,705,399*	*$131,500,803*	*$48,882,698*