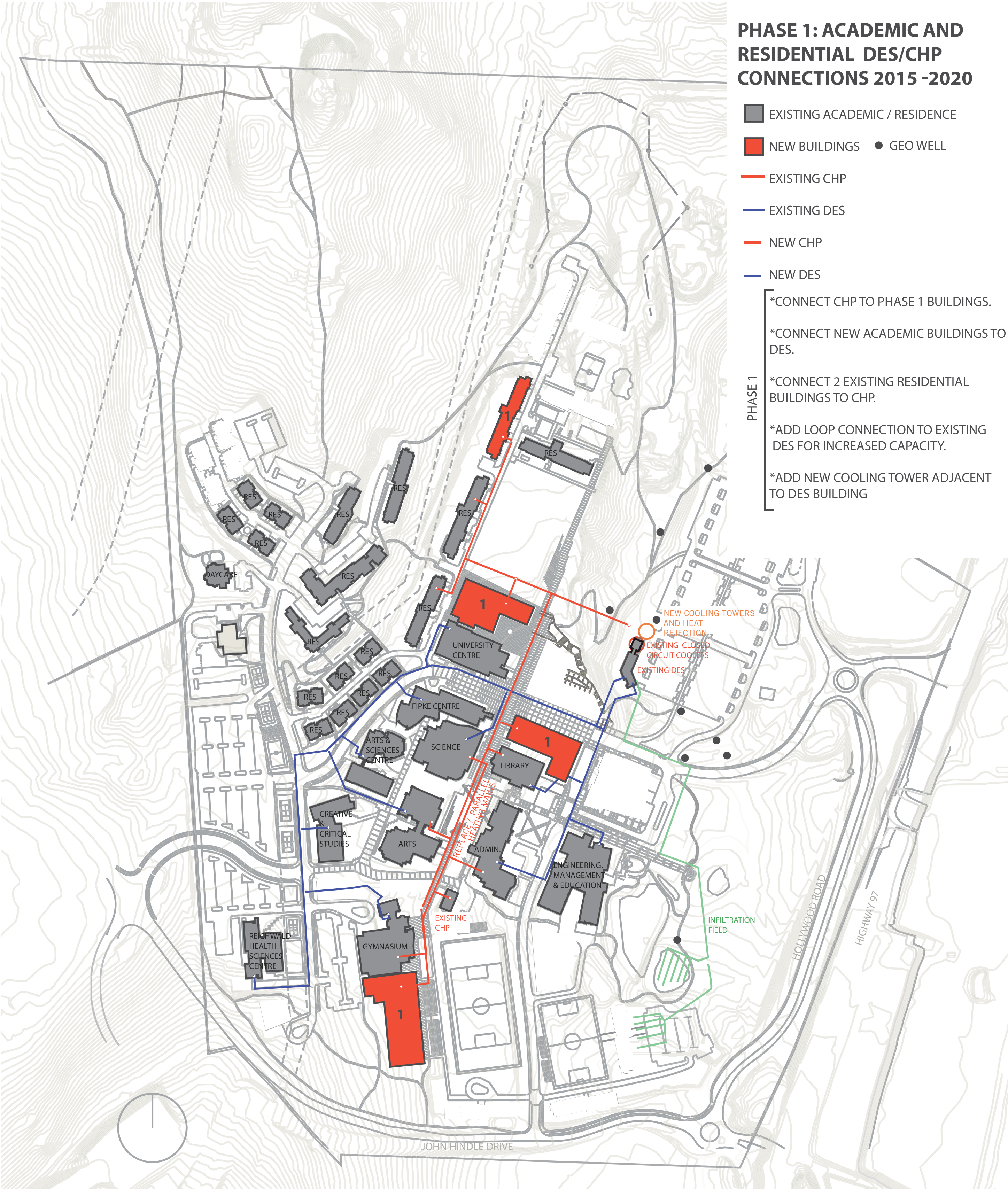


FIGURE 33: PHASE 1 CONCEPTUAL PIPING DIAGRAM FOR CHP AND DES

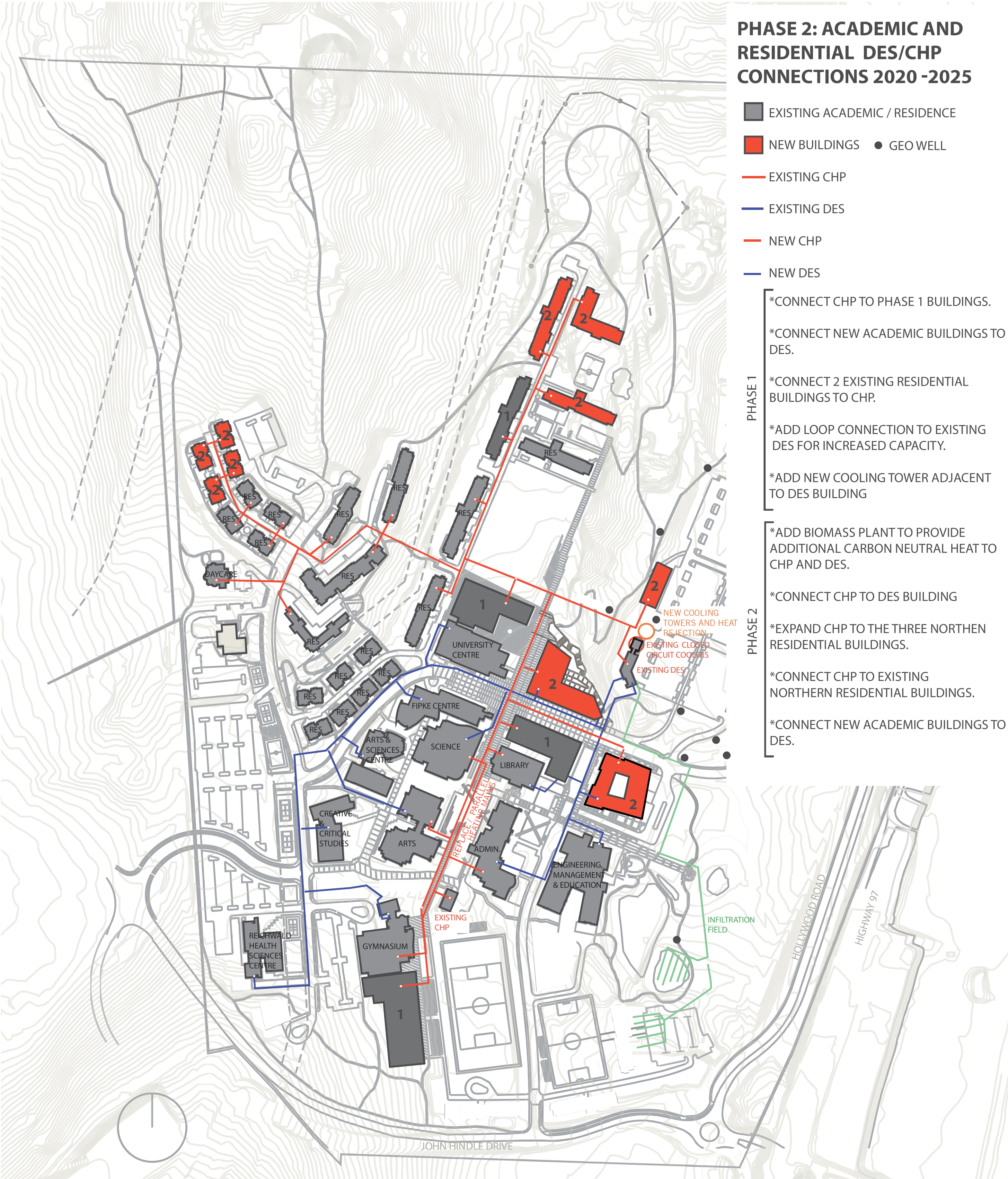
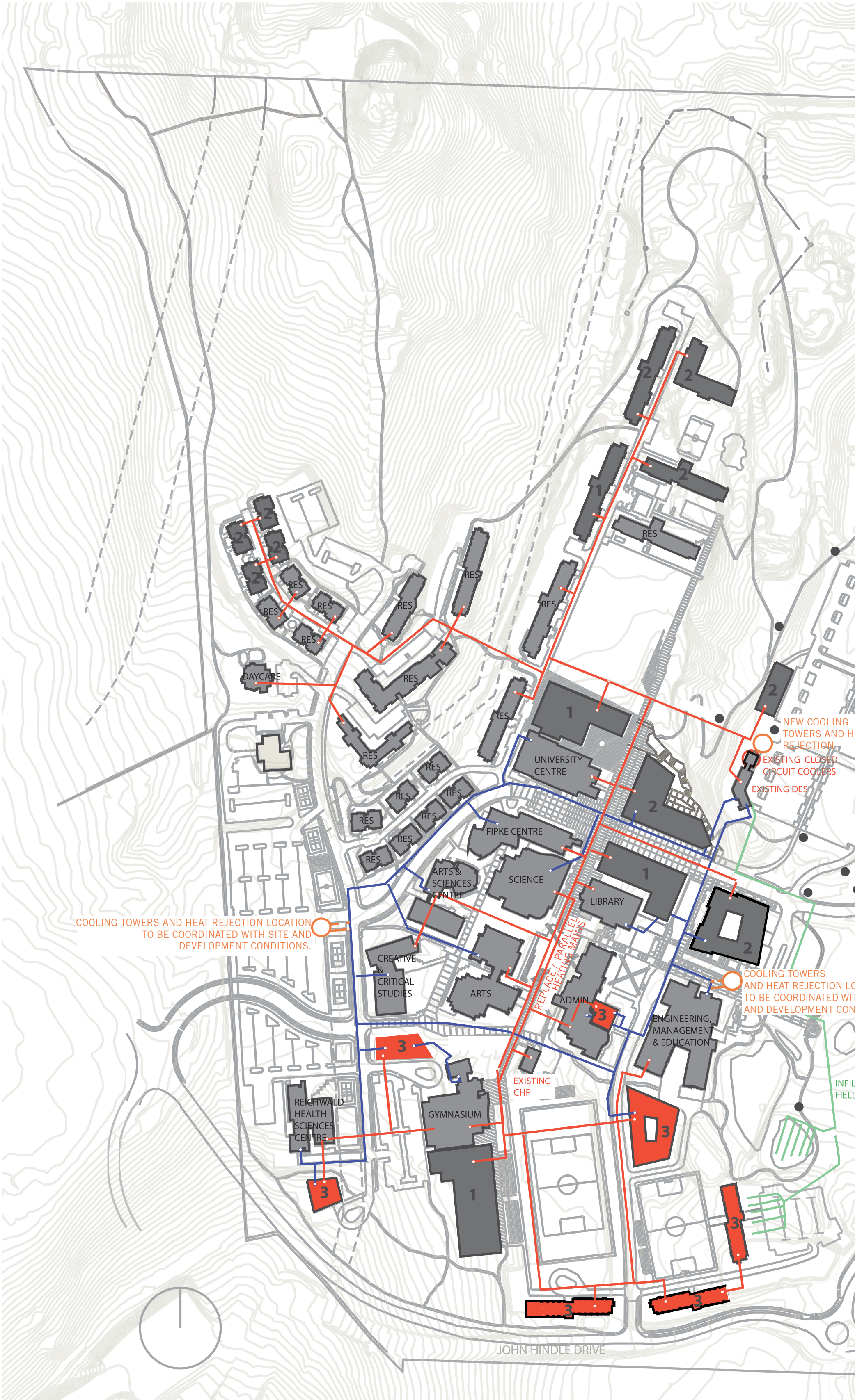


FIGURE 34: PHASE 2 CONCEPTUAL PIPING DIAGRAM FOR CHP AND DES



PHASE 3: ACADEMIC AND RESIDENTIAL DES/CHP CONNECTIONS 2025 - 2030

- EXISTING ACADEMIC / RESIDENCE
- NEW BUILDINGS
- GEO WELL
- EXISTING CHP
- EXISTING DES
- NEW CHP
- NEW DES

PHASE 1

*CONNECT CHP TO PHASE 1 BUILDINGS.

*CONNECT NEW ACADEMIC BUILDINGS TO DES.

*CONNECT 2 EXISTING RESIDENTIAL BUILDINGS TO CHP.

*ADD LOOP CONNECTION TO EXISTING DES FOR INCREASED CAPACITY.

*ADD NEW COOLING TOWER ADJACENT TO DES BUILDING

PHASE 2

*ADD BIOMASS PLANT TO PROVIDE ADDITIONAL CARBON NEUTRAL HEAT TO CHP AND DES.

*CONNECT CHP TO DES BUILDING

*EXPAND CHP TO THE THREE NORTHEN RESIDENTIAL BUILDINGS.

*CONNECT CHP TO EXISTING NORTHERN RESIDENTIAL BUILDINGS.

*CONNECT NEW ACADEMIC BUILDINGS TO DES.

PHASE 3

*CONNECT EXISTING ENGINEERING MANAGEMENT & EDUCATION BUILDING AND NEW SOUTHERN RESIDENTIAL BUILDINGS TO NEW SOUTHERN CHP LOOP.

*EXPAND DES TO PHASE 3 ACADEMIC BUILDINGS.

*CONNECT CHP TO EXISTING ACADEMIC BUILDINGS IN CENTRE OF CAMPUS.

*IN SEVERAL INSTANCES CHP PIPING IS RUN THROUGH BUILDINGS TO REDUCE COST.

*USE DES AS A CONDENSER WATER LOOP.

*ADD TWO NEW COOLING TOWERS TO INCREASE HEAT REJECTION CAPACITY.

*CLOSE AND LOOP DES PIPING

FIGURE 35: PHASE 3 CONCEPTUAL PIPING DIAGRAM FOR CHP AND DES

basic approach is to have a large peak building heating load connected to the modest sized biomass heating system so that the biomass system operates at maximum capacity for the majority of the fall/winter/spring. This results in the significant reduction in GHG emissions along with some operating cost reductions as the biomass fuel is less expensive than natural gas when factoring in carbon tax and carbon offset costs.

At low load summer heating conditions, the biomass plant output can be reduced by modulating or shutting off boiler modules as required. The thermal storage tank installed as part of the biomass plant acts as a buffer tank to allow stable operation of the biomass boilers. This approach will result in significant GHG reductions and provide some financial savings in operating cost.

Phase 3: 2025 to 2030

Phase 3 completes the doubling of the area of the campus buildings (Figure 35). The CHP plant size and piping grid will be expanded to serve the newly constructed buildings and connects the final remaining Academic Buildings as well as Residences.

Additional biomass boilers will be added to meet the load requirements of the new buildings and connections to the remaining existing buildings. Operating experience with the multi-boiler biomass plant will provide guidance in the final sizing of the additional biomass boilers. Should any off-site heating system customers exist in the future, the size of the boiler plant will be adjusted to meet the additional heating load.

Table 32 summarizes the potential GHG reductions realized by implementing a full CHP expansion with a 6MW biomass system.

TABLE 32: CONFIGURATION A—GHG SAVINGS

CONFIGURATION A: FULL CHP EXPANSION WITH 6MW BIOMASS	2030 GHG REDUCTION COMPARED TO BAU	2030 GHG REDUCTION COMPARED TO 2007 BASELINE
Academic Buildings are upgraded with ECMs following original implementation schedule, as per Appendix J. Configuration A: DES is optimized by providing additional heat via CHP. Existing academic and all new buildings are connected to new Biomass/CHP expansion.	79%	46%

Expanding the CHP Distribution Beyond the Campus

With the conversion of the campus hydronic heating system to carbon neutral biomass, there will still be residual GHG emissions due to electricity, peaking gas boiler use, and gas used for cooking. If carbon neutral campus operations for buildings is desired, one approach is to sell carbon neutral heat to off-site customers and use the carbon credits to offset the remaining campus emissions. There are planned industrial and commercial developments to the east of the campus that may be candidates for purchasing the excess heat. A larger heating customer base would allow for sharing of the operating costs for the heating system and provide for capital cost recovery of heating system components that serve off-campus customers.

Alternate Approaches to Expanding District Energy Systems (CHP vs DES)

UBCO commissioned an additional study (April 2016) to consider lower cost alternatives and the impact these systems may have on campus energy and GHG emissions. While Configuration A is the recommended approach to expanding the CHP network and would result in substantial GHG and operational costs savings, the capital cost of the extensive CHP piping network was indicated as a potential financial barrier. This section describes the two alternate configurations assessed. A more robust narrative describing the implications of the alternate configurations and opportunities for improvement are presented in the following section Proposed Heating Options for Building Types for Configuration B and C.

The additional assessment is confined to two alternate configurations listed below, both implement a Phase 2 Biomass heating plant. Unlike the prior analysis, no additional costing analysis was conducted. The basis for these additional configurations are:

1. Configuration B: A DES system to provide heating to most buildings with CHP connection to existing academic buildings with boilers.
2. Configuration C: A full DES system providing heating to all buildings including the retrofit of many existing academic buildings.

Table 33 summarizes the building connection assumptions and a short narrative is provided on the benefits and implications of each configuration. A high level analysis with respect to energy and GHG emissions is presented following each section and summarized in Summary of Carbon Reduction Scenarios. The ECM implementation schedule was revised slightly for this additional study to reflect the implementation of ECMs made to-date. Cooling load is not accounted for in the analysis as the GHG impacts are relatively negligible.

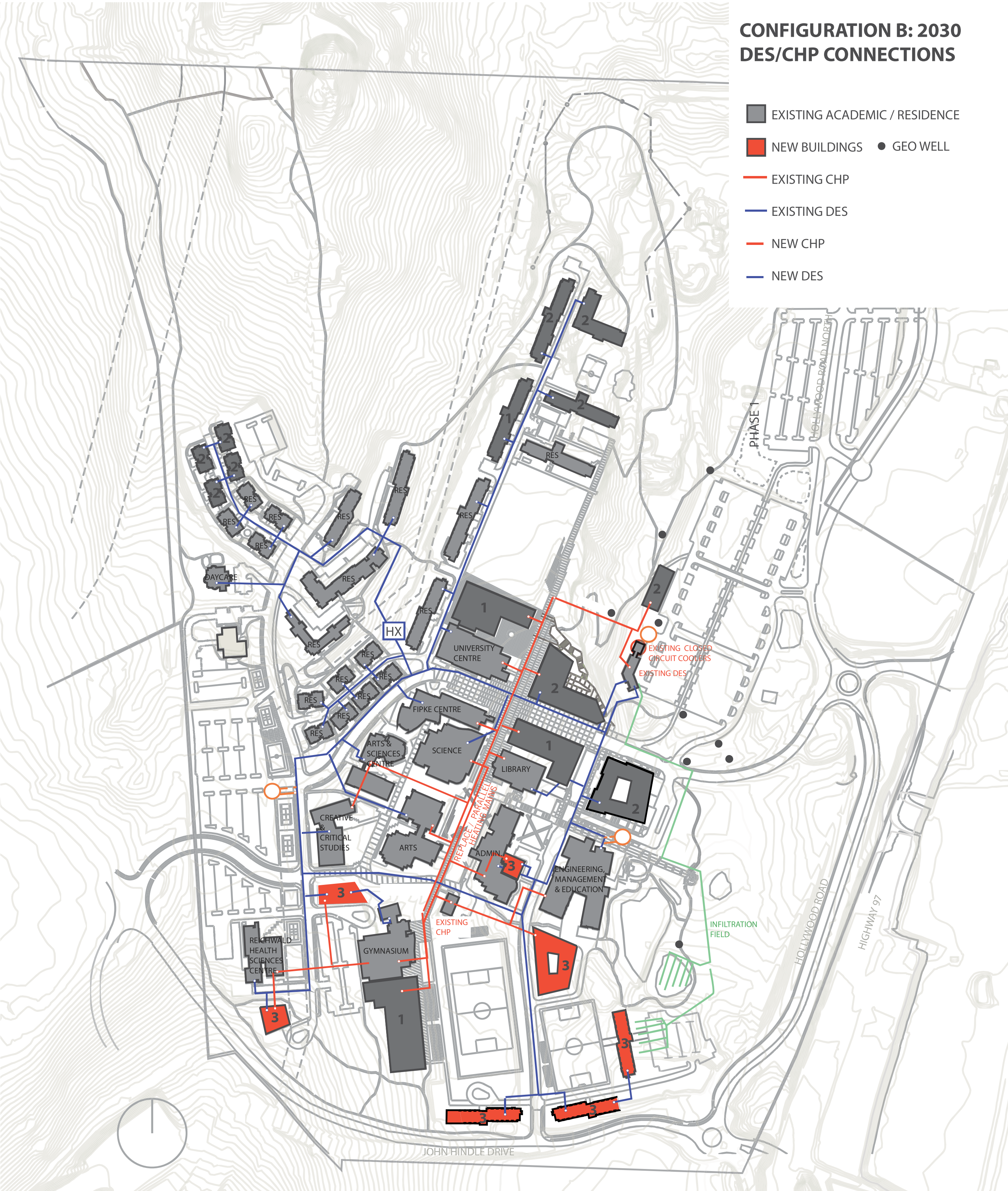


FIGURE 36: CONFIGURATION B: DES FOR COOLING AND HEAT SHARING, CHP FOR PEAK HEATING

TABLE 33: DISTRICT SCALE INFRASTRUCTURE CONFIGURATIONS

		EXISTING	CONFIGURATION A CHP	CONFIGURATION B CHP/DES	CONFIGURATION C DES
Academic Legacy	Science	DES + CHP 3rd Floor: DES + Boilers	Remain 3rd floor: DES + CHP	Remain 3rd floor: DES + CHP	DES Only
	Library	DES + CHP	Remain	Remain	
	Arts	DES + CHP			
	Admin	DES + CHP			
	Creative & Critical Studies	DES + Boilers	DES + CHP	DES + CHP	
	Gym	CHP Gym addition: DES	CHP Gym addition: DES + CHP	CHP Gym addition: DES + CHP	
Academic	University Centre	CHP	DES + CHP Conversion ~2025 after biomass conversion	DES + CHP Conversion ~2025 after biomass conversion	DES Only
	Fipke Centre				
	Arts and Sciences Centre				
	Engineering, Management, and Education				DES + CHP
	Reichwald Health Sciences Centre				
	New Academic	-	CHP	DES + CHP DES or CHP piping adjacent to most buildings	DES Only
Residential	New Residential	-	PTAC HP + CHP	PTAC HP + DES	PTAC HP + DES
	Residential	PTAC + Boilers	PTAC HP + CHP	PTAC HP + DES	PTAC HP + DES
	Residential on all electric	Electric PTAC	PTAC HP + CHP	PTAC HP + DES	PTAC HP + DES

Configuration B: DES for Cooling and Heat Sharing, CHP for Peak Heating

Configuration B is similar to Configuration A for except for two differences:

1. New and existing residential are connected to the DES, eliminating a significant portion of the CHP piping grid expansion. Existing residential are converted to DES at major building refit.

2. All new academic buildings are connected to DES with an option for a CHP connection. The optional CHP connection can be decided on a building-by-building basis as several buildings are in close proximity to CHP and DES lines (see phasing diagram). A dual connection would allow for heat sharing and cooling in addition to CHP for peak heating needs.

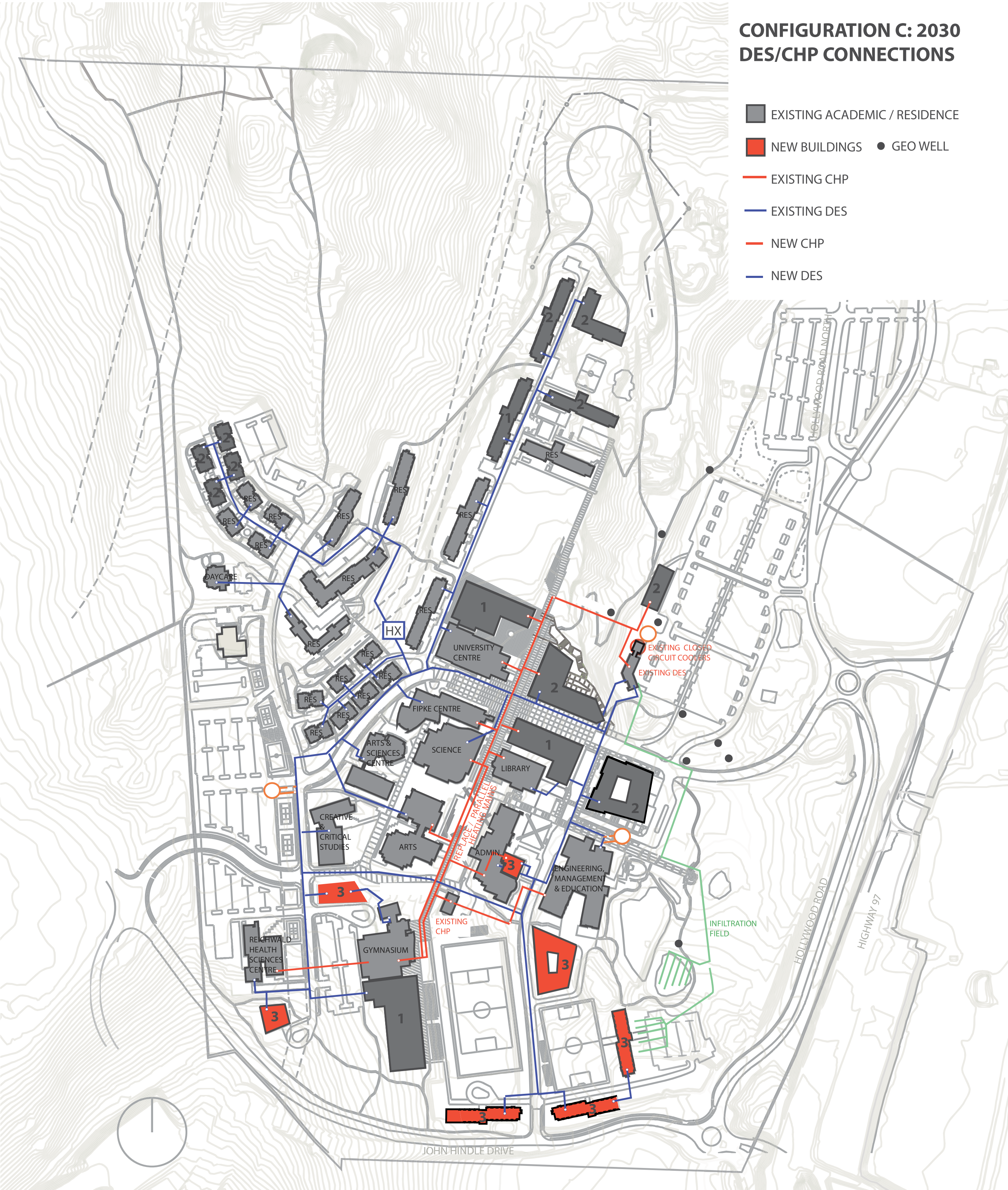


FIGURE 37: CONFIGURATION C: DES FOR HEATING, COOLING AND HEAT SHARING

TABLE 34: CONFIGURATION B—GHG SAVINGS

CONFIGURATION B: DES FOR HEAT SHARING, CHP FOR PEAK HEATING WITH 6MW BIOMASS	2030 GHG REDUCTION COMPARED TO BAU	2030 GHG REDUCTION COMPARED TO 2007 BASELINE
Academic Buildings are upgraded with ECMs following a revised (April 2016) implementation schedule. Configuration B with DES and CHP Expansion to all new Academic and Residential buildings.	75%	45%

Configuration B results in a lower GHG reduction when compared to Configuration A due to the use of gas fired boilers to provide heat via DES and the delayed conversion of existing residential.

Configuration C: DES for Heating, Cooling and Heat Sharing

Configuration C converts the campus to a predominantly DES system for all heating and cooling needs. This configuration requires extensive improvements to the DES and building updates to ensure compatibility with the low temperature system. This configuration will result in a 2030 GHG emission rate above the 2007 baseline.

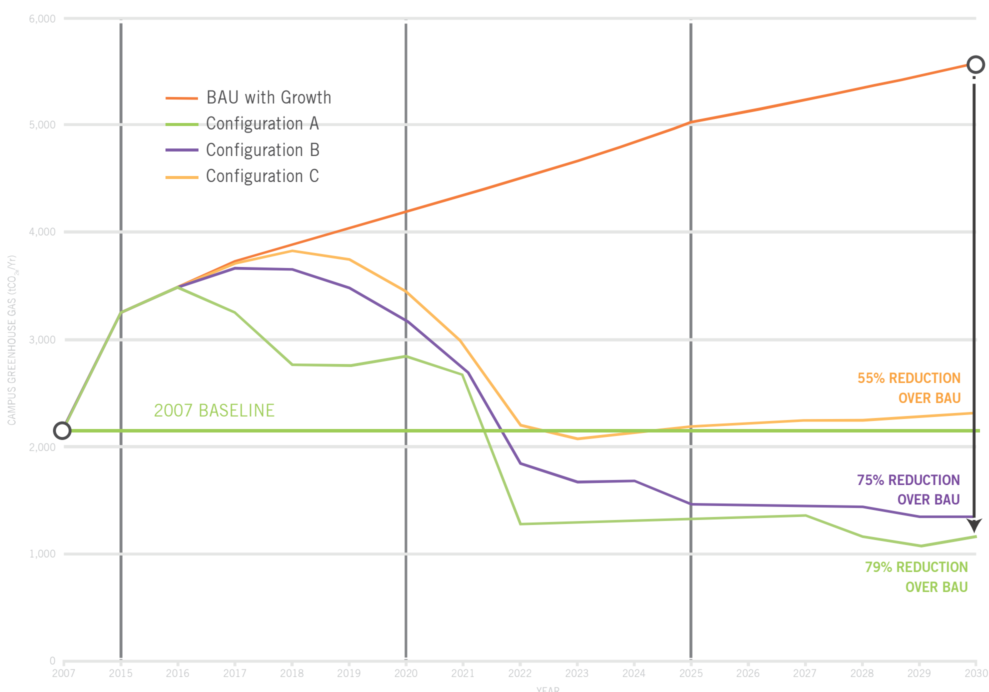


FIGURE 38: SUMMARY OF GHG EMISSIONS FOR DISTRICT SCALE INFRASTRUCTURE CONFIGURATIONS

TABLE 35: CONFIGURATION C—GHG SAVINGS

CONFIGURATION C: DES-ONLY FOR HEATING AND HEAT SHARING	2030 GHG REDUCTION COMPARED TO BAU	2030 GHG REDUCTION COMPARED TO 2007 BASELINE
Academic Buildings are upgraded with ECMs following a revised (April 2016) implementation schedule. Configuration C with DES Expansion to all new Academic and Residential buildings. Conversion of all existing buildings to DES-only.	55%	+15%

Configuration C sees a number of gas fired boilers continuing to operate until after 2030 when they reach boiler end of life replacement or are due for a major building refit. This includes most of the residential (other than Monashee and Similkameen which are ready for refit) and the existing academic buildings that have standalone boilers. By not connecting these buildings to a district energy system before 2030, they continue to contribute significant GHG emissions.

Figure 39 indicates the GHG emissions for the three district scale infrastructure configurations out to the year 2030. It should be noted that the additional increase in emissions from 2016 to 2021 for Configuration B and C, is due to the revised ECM implementation schedule. Table 36 summarizes the 2030 GHG reductions over the 2007 baseline for all three configurations. Configuration C indicates a 2030 GHG emission rate above the 2007 baseline.

TABLE 36: SUMMARY OF CARBON REDUCTION SCENARIOS

DISTRICT SCALE CONFIGURATIONS	2030 GHG REDUCTION COMPARED TO BAU	2030 GHG REDUCTION COMPARED TO 2007 BASELINE
Configuration A with the DES optimized by providing additional heat via CHP. Existing academic and all new buildings are connected to new Biomass/CHP expansion.	79%	46%
Configuration B with DES and CHP Expansion to all new Academic and Residential buildings.	75%	35%
Configuration C with DES Expansion to all new Academic and Residential buildings. Conversion of all existing buildings to DES-only.	55%	+15%

Proposed Heating Options for Building Types for Configurations B and C

UBCO intends to use the *Whole Systems Infrastructure Plan* to inform future 5, 10 and 15 year GHG emissions targets set for the Campus. As these targets are formalized, UBCO should carefully consider the options for the range of heating sources, costs, and related GHG emissions. The following section provides an in depth discussion on the heating options for each building type and the opportunities to advance energy and greenhouse gas savings.

Table 14 as previously presented in the report is repeated here as it is relevant to the selection of heating sources for Configurations B and C. The various operating costs may impact the selection of heating sources for projects such as the new academic or residential buildings.

TABLE 37: OPTIONS FOR 1 MWH OF HEAT FROM VARIOUS SOURCES

HEATING SOURCES	$/1 MWH OUT	GHG KG
Electric Resistance Heat	$73.5	10
Condensing Gas Boiler	$42.6	200
Biomass Boiler	$26.8	0
Building HP (Heat Pump) / Waste Heat	$26.3	3.6
Building HP + Condensing Boiler	$53.6	132
Building HP + Biomass Boiler	$43.5	3.6
Building HP + Large Aquifer HP	$38.1	5.8
Building HP + Biomass Boiler w/ Flue Gas Recovery	$26.3	3.6

As the table above demonstrates, DES heating inherently incurs a higher energy cost due to the operation of the heat pumps. The additional electricity cost, while expensive, is generally more acceptable when the source heat is free. However, the campus currently lacks a large source of waste heat and relies on additional heat from packaged boilers in the GEO building or building-side peaking boilers. A carbon-neutral fuel source will result in lower GHG emissions, however building-side heat pump operations will still incur a higher operating cost (see Table 37). Pursuing a DES expansion without a large source of free heat is considered a risk and detailed studies to identify waste heat sources are recommended.

The following sections describes the availability of different heating sources appropriate for each building typology on campus, options to further reduce GHG emissions, and risks involved with the suggested strategies.

New Academic

The campus heating system piping diagrams of Configuration B and C from Alternative Approaches to Expanding District Energy Systems indicates a connection to the biomass building and connection to the existing CHP piping