Climate Change Impact on Utility of District Heating in New Development Context

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Abstract

In Southwest British Columbia climate change of any degree is expected to lead to the increased need for cooling systems in buildings. This presents cities such as Vancouver with a new challenge in building design, as the existing paradigm dictates that cooling is not necessary for achieving comfort in buildings. This project will investigate the impact of introducing cooling systems to new development in a Marine climate. A high-density development that is nearing construction will serve as the test subject for urban energy simulations under present and future climate conditions. A morphed weather file for the district is used to represent climate change in line with a radiative forcing of 8.5 W m^{-2} by the end of the century. This paper will conclude by identifying several pathways for the development that achieve comfort, minimize carbon emissions, and are economical.

Introduction

The most recent and comprehensive report on climate change estimated that human-driven warming is *likely* in the range of 0.8°C to 1.2°C (Masson-Delmotte et al., 2018). This level of warming is close to the IPCC determined safe warming limit of 1.5°C, a barrier that the planet will *likely* surpass within the next three decades, unless carbon emissions are reduced at a rapid rate. Globally, there is a need for immediate and complete emissions reductions, along with the equally pressing need to adapt to the emerging conditions presented by climate change. This study investigates the utility of district heating for a new construction in a region with low-carbon electricity and a shifting heating-cooling season relationship.

New Cooling Paradigm

Marine climates in the region of North America commonly known as the "Pacific Northwest" have, until very recently, not experienced climate conditions that warranted the use of mechanical cooling in buildings in order to achieve comfort. Marine climates, in this region, do from time to time experience warm season temperatures during which buildings would benefit from cooling systems, but these have until very recently not been a considerable enough factor to prompt developers and architects to include space cooling systems in their designs. Instead, they have relied on operable windows and prevailing marine winds, to justify the ability for a building to be kept cool under warm conditions. However, as climate change raises temperatures even slightly this norm is changing. In 2018, a survey by the British Columbia Hydro and Power Authority (BC Hydro), a provincial electric utility, revealed that the adoption of air conditioning units in homes has increased from 10% of homes surveyed to 34%, between 2001 and 2017. This may be partially attributed to rising wealth and changes in personal standards of comfort. The survey data also reveals that there was an increase in the use of portable A/C from 5% to 16% in the same time period. These portable A/C units are adopted in existing buildings that cannot be modified for central air conditioning, which raises the suspicion that traditional cooling methods are no longer providing comfort in warm conditions.

This new cooling paradigm has begun to infiltrate new development throughout the region as developers see the need to provide mechanical cooling to meet the expectations of a growing community of buyers from hot-humid climates (Connolly, 2018). The introduction of cooling devices has the potential to disrupt previous modes of delivering thermal comfort.

Economic impact of cooling technology

A warmer climate is likely to place buildings at risk of overheating, particularly as they are under stricter performance standards, but also designed using weather boundary conditions that are representative of only typical and past conditions (Bhandari et al., 2012; Crawley et al. 2015; Moazami et al. 2019). Accepting that cooling will become a part of design in this region, the introduction of mechanical cooling technologies (i.e. heat pumps) presents an opportunity to couple heating and cooling into one efficient, electric unit. Whereas heat pumps may have been cost prohibitive when considered solely for heating, this study will show that they become economically efficient when coupled with providing cooling services.

The introduction of a cooling load to the existing electricity grid has the potential for increased carbon emissions. In the regional context of this study, the carbon implications are mitigated by an existing hydroelectric grid.

Table 1: This table describes the key variables that were altered between scenarios as well as describes the naming convention used to differentiate the scenarios. Ds = District Heat, Dc = Decentralized Cooling, NC = No Cooling, DsC = District Cooling, DeC = Decentralized Cooling, SP = Standard Performance, HP = High Performance,

	Scenario 1 S1_Ds_NC_SP	Scenario 2 S2_Ds_DsC_SP	Scenario 3 S3_Ds_DeC_SP	Scenario 4 S4_De_NC_SP	Scenario 5 S5_De_DeC_SP	Scenario 6 S6_Ds_NC_HP	Scenario 7 S7_Ds_DsC_HP)	Scenario 8 S8_Ds_DeC_HP	Scenario 9 S9_De_NC_HP	Scenario 10 S10_De_DeC_HP
Cooling	portable	ASHP	ASHP	portable	ASHP	portable	ASHP	ASHP	portable	ASHP
Description	not modeled	water/air	air/air	not modeled	air/air	not modeled	water/air	air/air	not modeled	air/air
COP	2.6	3.0	2.8	2.6	2.8	2.6	3	2.8	2.6	2.8
Emission	room air	central A/C	central A/C	room air	central A/C	room air	central A/C	central A/C	room air	central A/C
Heating	ASHP	ASHP	ASHP	baseboard	ASHP	ASHP	ASHP	ASHP	baseboard	ASHP
COP	3.4	3.4	3.4	100%	3.0	3.4	3.4	3.4	1	3
Emission	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)	floor (40/35)
DHW	ASHP	ASHP	ASHP	tankless	ASHP	ASHP	ASHP	ASHP	tankless	ASHP
Description	district	district	district	electric	water/water	district	district	district	electric	water/water
eff/COP	3.4	3.4	3.4	95%	3.0	3.4	3.4	3.4	95%	3
Control			room control					room control		
Ventilation			mechanical only					mechanical ventilation with demand control and economizer		
Temp (in/out)			(60/10)					(60/10)		
WWR			60%					40%		
ACH(50Pa)			2.0					0.6		
Roof(U)			0.200					0.110		
Absorptance			0.600					0.400		
Wall(U)			0.36					0.2		
Absorptance			0.60					0.40		
Floor(U)			0.36					0.15		
Window(U)			2.55					0.6		
Transmittance			0.75					0.29		
Shading			0.08					0.08		

Study Context

This study simulates the energy performance of a new development in a Marine Climate Zone. The Planned Development, totalling 159,925 sqm. of primarily residential units is scheduled for construction within the next few years and will consist of midrise construction as well as podiums with towers built to a maximum height of 34 stories. The development makes up 12% of the total load of an existing district heating scheme. Figure 1 shows the distribution of the district heating system across four planned developments (N1-N4). For the purposes of simplifying the simulation space, only the Planned Development (N2) is considered. How the actual district heating system was scaled down is described in the methodology section.

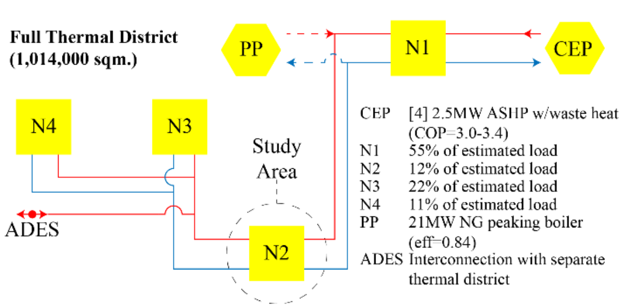


Figure 1: A diagram of the actual district heating system. The study is concerned with "N2" which is 12% of the estimated total load upon buildout.

This district heating system will, at completion, service 1.1 million sqm. of primarily residential space from a central heating plant that will integrate heat pumps with a waste heat rejector from a large waste heat producer nearby. The waste heat is considered low grade heat, improving the overall efficiency of the heat pumps in the Central Energy Plant (CEP) only slightly, from a Coefficient of Performance (COP) of 2.7 to a COP of 3.4, as described in Figure 2.

The planned development is considered the baseline scenario in this study. Nine additional scenarios were developed to test the influence of fuel type, heating and cooling service type, and climatic conditions on the development's carbon emissions, total annualized cost, and overall efficiency in supplying comfortable conditions to occupants. This study will consider the following two research questions.

1. Is district energy, that is somewhat reliant on natural gas infrastructure, the most viable option to supply low-carbon energy in an area with low-carbon electricity?
2. In considering the potential impacts of a warmer climate where might building systems shift in a Marine climate and how does this impact the utility of district heating?

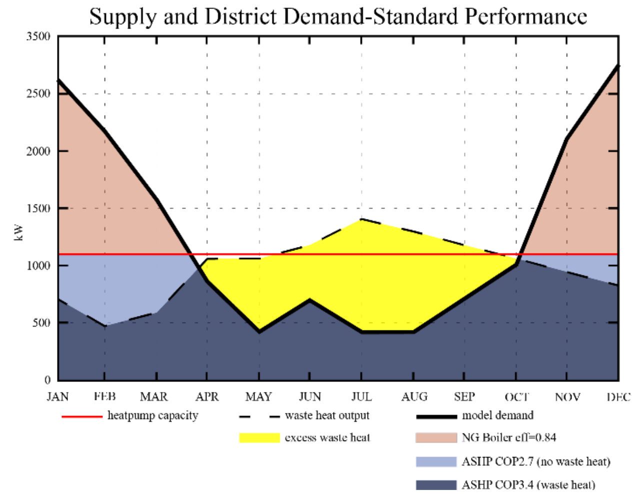


Figure 2: The model demand as it relates to the availability of waste heat and the capacity of the heat pumps.

Methods

Spatial Model

The field of urban energy modelling and simulation has grown in recent years as municipal governments look for ways to match density and growth targets with energy consumption and emissions goals (Reinhart and Cerezo Davila, 2016). This project utilizes a toolset created for urban energy simulation in the context of district heating and cooling, proposed by Fonseca and Schlueter in 2015, now known as the City Energy Analyst (CEA) (Fonseca et al., 2016). The CEA exists in a Python 2.7 environment and is developed as an open-source tool for urban energy analysis. The toolset consists of multiple models for building demand forecasting, district energy analysis, renewables potential, building Life Cycle Assessment, multi-objective optimization, and sensitivity analysis. The authors use the toolset as the central data management structure and simulation engine, with several project-specific workflow addendums.

The input for the spatial model is shown in Figure 3. The CEA interprets building footprints stored in a 2-D shapefile, extruding them based on the height feature stored in the shapefile's attribute table. This is efficient, but has shortcomings with certain typologies, such as podium towers. In this case towers were brought down to the ground and the podium footprint was drawn around the tower (see buildings 5 and 11 in Figure 3).

Scenario Development

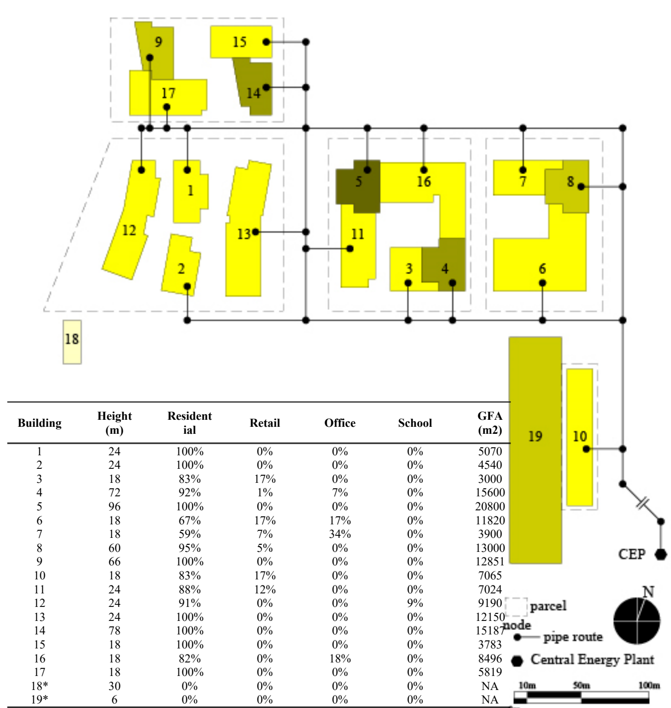
Scenario 1 represents the baseline, which is the development as it has been planned. The key variables considered are the type of heating system, the type of cooling system (if present), and the performance standards and codes the development is designed to meet.

Scenarios 1 through 5 were developed to model different types of heating and cooling systems, some based on a thermal district and some with only decentralized services. These "Standard Performance" scenarios reflect the expected standard of performance following existing code (UBC Panning, 2018). The "High Performance" scenarios, 6 through 10, deviate from the Standard Performance scenarios, in that they reflect a construction and architectural approach more aligned with passive and high-performance buildings. Table 1 describes the parameters being changed across the scenarios.

The assumptions surrounding the efficiency levels of the various heating and cooling options were taken from preliminary plans for the development's district heating system (CPCN Application, 2014).

Future Climate Weather Files

Three rounds of dynamic building performance simulation were performed using the CEA on each scenario to provide a long-term idea (90-year) of how the development may perform under a climate change scenario of unmitigated carbon emissions (Riahi et al., 2011). This scenario, commonly known as Representative Concentration Pathway 8.5 (RCP85), projects a world in which carbon emissions have continued to rise through to the end of the century leading to rampant warming. The three simulation rounds represent three climatic periods the *2020s* (2011-2040), the *2050s* (2041-2070), and the *2080s* (2071-2100). These periods are held in boundary condition weather files produced using a morphing process, first published by Belcher et al. in 2005. The temperature (TAS) and relative humidity (RHS) adjusted TMY weather files are product of



Building	Height (m)	Residential	Retail	Office	School	GFA (m2)
1	24	100%	0%	0%	0%	5070
2	24	100%	0%	0%	0%	4540
3	18	83%	17%	0%	0%	3000
4	72	92%	1%	7%	0%	15600
5	96	100%	0%	0%	0%	20800
6	18	67%	17%	17%	0%	11820
7	18	59%	7%	34%	0%	3900
8	60	95%	5%	0%	0%	13000
9	66	100%	0%	0%	0%	12851
10	18	83%	17%	0%	0%	7065
11	24	88%	12%	0%	0%	7024
12	24	91%	0%	0%	9%	9190
13	24	100%	0%	0%	0%	12150
14	78	100%	0%	0%	0%	15187
15	18	100%	0%	0%	0%	3783
16	18	82%	0%	18%	0%	8496
17	18	100%	0%	0%	0%	5819
18*	30	0%	0%	0%	0%	NA
19*	6	0%	0%	0%	0%	NA

Figure 3: The 2D input for the CEA model includes footprints, heights, program. The node and pipe network can be manually added or created using a network analysis tool in the CEA.
** = building used only for shading*

a morphing procedure that was undertaken by researchers at the Pacific Climate Impacts Consortium (PCIC) (Cannon, 2015; Cannon et al., 2015, PCIC, 2018).

Dynamic Forecasting (CEA)

The City Energy Analyst (CEA) dynamic demand forecasting package, version 2.90, was employed as the building energy demand engine (The CEA Team, 2019). The demand module is a hybrid statistical-dynamic model for energy demand forecasting from Fonseca and Schlueter (2015). The model interprets the impact of site-climate information through a Daysim radiation module on the power and temperature requirements for individual building's space heating and cooling, domestic hot water, and electricity. The CEA's underlying building component database, developed initially to reflect Switzerland's building standards, was edited with the values shown in Table 1 to reflect UBC's codes and standards (UBC Planning, 2018).

Thermal Network (CEA)

For scenarios with district heating or district cooling systems, the CEA's thermal-network package, version 2.90, was employed laying out the distribution network and accounting for distributions losses within the thermal district pipe network (The CEA Team, 2019). The results of the demand calculation are used by the CEA to determine the layout and supply of a thermal district. A submodule in the CEA determines the most efficient layout for the district, uses the demand results to determine the supply, and finally calculates the losses throughout the network.

Accounting for Peaking and Waste Heat

The use of natural gas peaking plants to assist the heat pumps when district demand exceeds their capacity is currently planned for the district heating system. This was not simulated in the CEA and had to be accounted for after the simulations were performed, depicted in Figure 2.

The output from the demand forecasting module and thermal network losses module for Scenarios 1 through 3 and 5 through 7 (those with district heat supply) were used to recalculate supply-side energy for the district plant. In the time series output data, any demand that exceeded the potential supply of the waste heat driven heat pump was assigned a lower COP (2.7). This monthly number was provided by documents from the district utility (Infrastructure Agreement, 2014). Any demand beyond the less efficient heat pump that exceeded the heat pump capacity of 1,100kW was assigned to the natural gas peaking plants, which have an efficiency of 84%.

This realignment of demand to supply technologies within the scenarios that were connected to the district heating system provided a more accurate account of the total supply energy required for the development, as well as the consequent cost and carbon emissions data for scenarios on the district heating system.

Accounting for Portable Cooling

Based on the BC Hydro survey on cooling, an additional load on buildings from electric portable cooling devices was assumed. Cooling solutions in scenarios for which building-wide cooling was not provided (S1,S4,S6,S9), were added post simulation using a reduced space cooling demand from an analogous performance scenario.

For Standard Performance scenarios S1 and S4, the space cooling demand of S3 was applied. For High Performance scenarios S6 and S9, the demand of S8 was applied. The applied demand was reduced to 40% of its source scenario. This demand was then divided by the efficiency of the portable cooling device (COP 2.63). This provided an additional demand point for scenarios that were not initially provided with cooling services in simulation. This additional demand reflects further in the methodology when accounting for carbon and cost.

Economic Analysis

The final factor considered in the study was total annualized operational expenditure (OPEX) and capital expenditure (CAPEX). The period of cost under consideration was the first 25 years of the development's lifetime, including both capital costs and operational costs. Fine grain capital costs were not available for each scenario, but some cost data was provided by the developer for the baseline. Table 2 describes the various cost assumptions that followed the baseline input. S1, being the baseline, was a known cost to which marginal cost factors were applied assuming the inclusion of extra equipment for different heating and cooling arrangements. The marginal mechanical cost factors were assumed by the authors in consultation with the project developers as further cost data was not available. The "11% Premium" was provided by the project developer as an estimate of achieving a "High Performance" construction, compared to a similar standard construction. For example, the cost for S7 is derived by applying the "11% Premium" to the shell and mechanical cost of S2, which is seen as the "Standard Performance" equivalent to S7. The cost of S2 is the shell cost added to the mechanical cost multiplied by that scenarios marginal mechanical cost factor. Operational costs were calculated from the simulated performance of each scenario and the current utility rates for the region. The total cost of each scenario was compared using Total Annualized Cost ($C_{ann,tot}$).

$$(Eq. 1)\ C_{ann,tot} = CRF(i, R) C_{NPC,tot}$$

Total Annualized Cost is the annualized value of the total net present cost where CRF is the Cost Recovery Factor, requiring i, the annual real discount rate, and R, the lifetime considered. $C_{NPC,tot}$ is the total net present cost for the lifetime considered. An annual maintenance cost was also factored in at 5% of the respective scenario's total capital cost.

Table 2: The cost assumptions made for each scenario.

S	Shell ($/m²)	Mech. ($/m²)	Total ($/m²)	Marginal Mech. Cost Factor from Baseline	Marginal Total. Cost Factor from Standard Equivalent
1	$ 75.00	$ 53.00	$ 128.00	1.00	-
2	$ 75.00	$ 79.50	$ 154.50	1.50	-
3	$ 75.00	$ 106.00	$ 181.00	2.00	-
4	$ 75.00	$ 39.75	$ 114.75	0.75	-
5	$ 75.00	$ 79.50	$ 154.50	1.50	-
6	$ 83.25	$ 58.83	$ 142.08	-	1.11
7	$ 83.25	$ 88.25	$ 171.50	-	1.11
8	$ 83.25	$ 117.66	$ 200.91	-	1.11
9	$ 83.25	$ 44.12	$ 127.37	-	1.11
10	$ 83.25	$ 88.25	$ 171.50	-	1.11

Results

Simulations for ten scenarios were performed using three weather files representing the change in climate across the century under unmitigated carbon emissions pathway, first utilizing the CEA's demand forecasting and thermal network modules. For scenarios with district heating the supply-side energy was recalculated to reflect the peaking natural gas plants and limited supply of waste heat. For scenarios without cooling a minor electrical load was calculated based on similar scenario with cooling to reflect portable cooling devices that are assumed to be used based on local surveys. Cost and emissions were then calculated for all scenarios.

Figure 4 displays a comparison of each scenario's total energy flow as simulated using the climate weather file for the *2020s*. Each Sankey diagram in Figure 4 displays a pair of scenarios, one being a Standard Performance scenario (greyed out) and the other being the High-Performance equivalent. The High-Performance scenarios benefitted from improved heat retention in terms of delivering heating services. However, no change or even more demand for cooling services was seen in High-Performance scenarios over their standard equivalents.

Four criteria were set out as performance indicators in evaluating the scenarios: interior temperature as a proxy for comfort, total energy use, operational greenhouse gas emissions, and total annualized cost.

Interior Temperature

For each scenario each building's time series record of interior temperature was compiled to gather the mean hours over 28°C. Figure 5 shows the results of this across each climate change period. Scenarios S1, S4, S6, and S9 were all simulated without cooling systems present – portable cooling demand was calculated after the simulation process. The other scenarios all had cooling systems applied for simulation. An increase in overheating hours between Standard Performance and High-Performance is seen, as well as a general rise in overheating hours as climate change becomes more severe. The demand side of cooling services did not change or slightly increased. The conclusion is that the High-Performance buildings are overheating in hours outside of the cooling season (15th Mar. to 30th Sept.), a

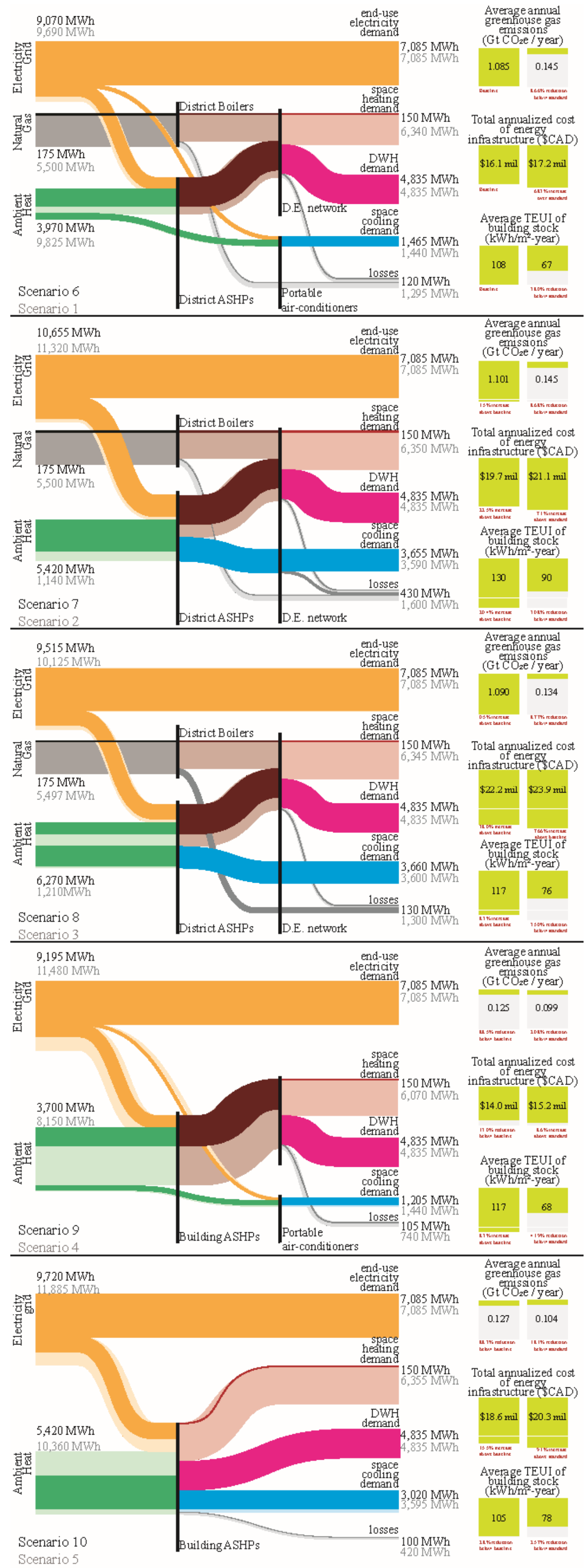


Figure 4: The energy flow in each scenario is diagrammed here as a comparison between standard performance scenarios (lighter shades) and high-performance scenarios (darker shades) under 2020s climate.

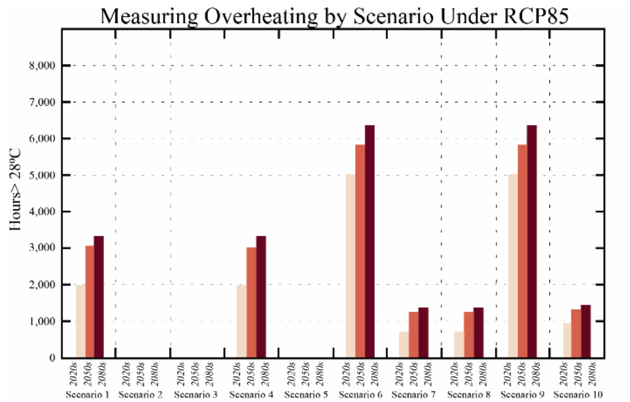


Figure 5: Every building was sampled within each scenario to derive the mean number hours above 28C for each scenario.

constraint within the CEA that dictates which calendar day marks the start and end of heating and cooling seasons. There is increased risk from climate change, which shifts the traditional boundaries of heating and cooling seasons.

Energy Use

Marginal Total Energy Use Intensity (TEUI) was measured across the scenarios. S1 in the *2020s* was considered the baseline, indicated Figure 6. The range in Figure 6 illustrates the diversity in results measured at the building level. Marginal TEUI was calculated at the building level (Eq. 2).

$$(Eq. 2)\ TEUI^{Sx}_{marginal} = TEUI^{Sx}_{Bldg1} - TEUI^{S1}_{Bldg1}$$

It is important to note that the baseline scenario only had portable cooling loads associated with it, which leads to some scenarios having much large TEUIs than the baseline.

Scenarios S4, S6, and S9 show similar or reduced TEUI below the baseline. Scenarios S6 and S9 clearly benefit from increased heat retention strategies, a finding that is noticeable in the significantly reduced space heating demand seen in Figure 4.

The addition of space cooling services results in a similar-to-baseline TEUI for High Performance Scenarios S7, S8 and S10, as well as slightly increased, which calls into question plans to reduce energy consumption in building through heat retention strategies such as thicker insulation and improved air tightness. The findings suggest that climate change will complicate the execution of this plan further into the future if the planet warms severely as cooling loads offset savings in reduced heating loads. However, the Standard Performance scenarios with cooling services (S2, S3, and S5) all see reduced TEUI with climate change, while still meeting comfort goals.

Carbon Emissions Comparison

Several of the scenarios present significantly more carbon emissions than others, due only to the fact that they are connected to heating and hot water systems that are fuelled by the natural gas peaking plants. All other scenarios are only connected to the electrical grid, which has a carbon emissions factor of 10.8kg CO_2e/MWh compared to the natural gas factor of 180kg CO_2e/MWh (BC Environment,

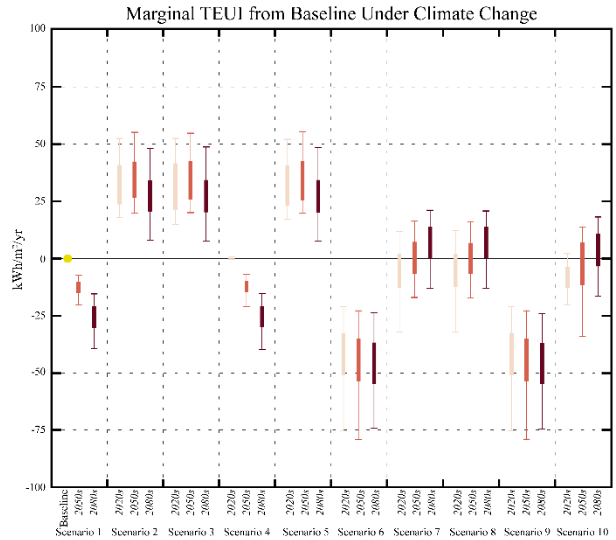


Figure 6: The marginal Total Energy Use Intensity (TEUI) across each scenario for each climate period.

2019 Table 3 and Table 1 respectively). Figure 7 displays the operational emissions associated with each scenario across all three periods of time. The figure is separated into two ranges along the Y-axis to better display the scenarios that did not rely on natural gas. It is key to note that scenarios S6, S7, and S8 were all connected to the thermal district and therefore the natural gas peaking plants, but do not have the indicative carbon emissions of a natural gas fuelled system. This is because the building envelopes were able to retain enough heat that the demand on the system was at or below the capacity of the heat pumps.

Cost

Figure 8 displays the cost breakdown for capital expenditure and the operation and maintenance costs (discounted) for each year within the climate periods; *2020s* (2011-2040), the *2050s* (2041-2070), and the *2080s* (2071-2100). The primary difference in cost is the “11% premium” assumed for the High-Performance scenarios. While present when comparing the CAPEX costs alone, it is diminished when considering the Total Annualized Cost metric. In comparing TAC, a range of 6.6% to 9.3%, is seen between comparable Standard and High-Performance scenarios. This is due to the reduced operational costs over the lifetime of the project.

Discussion and conclusion

This study compared the simulated performance of a primarily residential new development in a Marine climate under the assumption that global carbon emissions remain unmitigated. The results show that cooling systems should be installed into any building despite its level of performance if overheating is to be managed. However, High-Performance scenarios are at a larger risk of overheating under present and future climate assumptions. From a carbon perspective the best performing scenarios are those that do not need to utilize the natural gas peaking

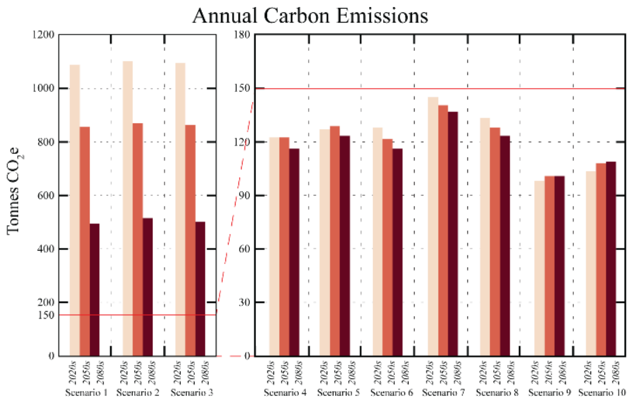


Figure 7: Annual operational carbon for each scenario for each climate period.

plants. Operational carbon emissions decline with a warmer climate in all but Scenarios S9 and S10. Despite this they both remain the lowest emitting scenarios. In Scenario S9, this is due to the lack of a cooling services load. In Scenario S10 this is because the heat pump providing services are in the buildings and therefore do not have any losses associated with a distribution network. This also reduces cost below other scenarios that provide cooling services.

Assuming that cooling is an absolute necessity to the design of a building going forward the question of whether a district heating system is viable is brought up. Cooling systems are more efficient when placed in the building and if a heat pump is installed in a building, the economic argument for using a centralized system is diminished under the cost assumptions made in this study. Scenarios S2 and S7 represent a situation in which district heating would be present, but cooling systems would instead be in each building. Comparing these with Scenarios S5 and S10, which have heating and cooling located in buildings, shows reduced cost and reduced carbon emissions.

Scenarios S5 and S10 then become of interest as potential solutions to the development's need for cooling. Scenario S5 has a clear economic benefit to Scenario S10 but does have a higher operational carbon. Scenario S5 does not have the same risk of overheating as Scenario S10 due to a less insulated envelope and less airtight construction. From here a more detailed analysis of design choices between the two is recommended, as certain shading designs and window operation may succeed in defining a better performing development than both Scenarios S5 and S10.

Limitations

A variety of limitations reduce this study's scope and introduce areas for improvement in future research. First, the assumption that the design of the buildings (form, orientation, massing, etc.) in the high-performance scenarios would follow the standard performance does not follow the practice of high-performance design. It was a decision that was made to simplify the study development as well as conform to existing design proposals. The mechanical system and energy mix would likely also be

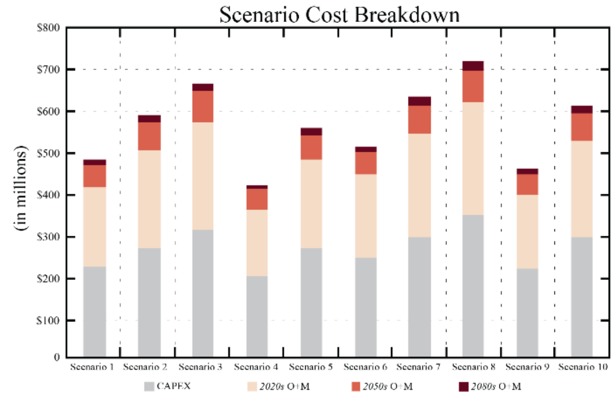


Figure 8: Scenario cost breakdown with CAPEX separated from climate period OPEX and Maintenance.

more complex, particularly in decentralized buildings with the inclusion of a secondary energy source for peak heating. Lastly, the demand forecasting module was not calibrated to existing datasets of building performance for this area. Future research should utilize more realistic schedules to show more authentic building demand.

Future Climate Weather Files

This study aims to make use of newer and better climate models and their consequent boundary conditions for building performance simulation. However, the current methodology is still flawed as TMY morphing fails to account for extreme conditions, as well is based on the mean of climate projections, whereas a range of boundary conditions would better represent climate models at the scale of the urban district. Improving our methodologies surrounding future climate weather file creation is essential to proper design and operation of buildings.

Grid Capacity and Increased Load

The region of study benefits from a low-carbon electric utility. However, as cooling demand increases, along with a larger electrification of many economic sectors the capacity of this grid will likely be reached. It is therefore paramount to consider energy efficiency as a resource in abating the need for expanding generation capacity.

Impact of Climate Change

Climate change is forcing architects and building scientists to reconsider their traditional modes of performance simulation towards multi-scalar and longer-term evaluation. The impact of this on studies such as this will be increased complexity in managing data and results. By simply applying three future climate boundary conditions the simulation results of this study and the factors to consider were multiplied three times. This could become cumbersome as we begin to consider the range of uncertainty found in climate projections and ask professionals not familiar with managing large datasets to interpret those results.

Carbon Targets

Lastly, this study benefits from a fictionalized environment in which existing infrastructure can be cast off. The reality is that there are current energy production systems that rely on fossil fuels and there are significant economic entrenchments to those systems. While the development in this study still has the opportunity to disconnect from a potential carbon emissions source in the natural gas peaking plants, it is important to consider that as a body we must begin to assess how to transfer existing developments from these legacy sources of power and quickly as we are soon approaching a key limit in the Paris Target.

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