City Plan Evaluation Scenarios:

Climate Vulnerability Cost Assessment

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This technical study was initiated to inform the development of The City Plan. The technical studies were considered alongside public engagement, modelling and professional judgment to determine overall outcomes for The City Plan.

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Background to City Plan

Edmonton's City Plan is being developed with a target of doubling the population to two million people over several decades. This forward looking Plan needs to be assessed from the perspective of several integral choices related to population growth; e.g., where will people live, where will people access services, and where will the new jobs be located.

The City Plan team is using a range of modelling tools to simulate the city-wide effects of how an increase of population could impact each of these choices. Modelling possible growth scenarios helps us to understand what those choices might look like, as well as generate evidence on the positive and negative (monetary and non-monetary) consequences associated with various land use and transportation permutations.

The overall approach to developing the Draft City Plan Concept involves four steps:

1. Develop three Evaluation Scenarios (see below);
2. Model the Evaluation Scenarios and assess outcomes against a set of predetermined performance indicators;
3. Extract learning from the assessment of the Evaluation Scenarios to inform the development of the Draft City Plan Concept Scenario; and
4. Model and reassess the Draft City Plan Concept Scenario against the performance indicators and update the Scenario as needed.

Three Evaluation Scenarios were developed by the City Plan team that illustrate the potential locations and intensity of growth for Edmonton to accommodate 2 million people. They are intended to have comparatively different growth patterns. They have been named the Central City (City I), Node City (City II) and the Corridor City (City III). Narratives have been developed to describe the three 'cities' and provide an overview of the built form, transportation, employment, green networks, and open space envisioned. The concept of nodes and corridors is represented at different scales and with differing purposes within each of the Evaluation Scenarios.

A Business-as-Usual (BAU) scenario and a Business-as-Planned (BAP) scenario have also been developed to (a) understand the financial implications of extrapolating current growth patterns into the future and (b) to provide a benchmark against which to assess the relative performance of the Evaluation Scenarios (at a high-level, or where technically sound, on a per capita basis). The Evaluation Scenarios will also be compared to a current base year.

A description of each Evaluation Scenario and the BAU and BAP scenario is provided below:

Business-as-usual Scenario (BAU)

The BAU Scenario is based on existing development patterns and development trends. This scenario distributes future growth in the same places Edmonton has seen growth over the past 10 years. It also attempts to encompass the required infrastructure upgrades that will be required to sustain the BAU development trends.

Business-as-Planned Scenario (BAP)

The BAP scenario assumes growth occurs according to the City's approved and strategic land use plans, including Area Structure Plans (and associated Neighbourhood Structure Plans) contained within in the Plans in Effect. The BAP scenario also contains plans for Area Restructure Plans, including infill redevelopments such as Blatchford, Bonnie Doon, and Mill Woods Town Centre. This scenario is more ambitious in terms of growth intensification than the BAU scenario in that more growth occurs through redevelopment in the mature and developed areas of the City relative to the BAU scenario.

Central City (City I)

This scenario looks to concentrate employment and population within a specific boundary centred mainly around current downtown and mature areas. Policies would focus on achieving a strong central core that is supported by a large concentration of population and employment within the central core boundaries. Nodes and corridors are mainly located within the central core with strategic nodes located outside the central core boundary.

Node City (City II)

This scenario will look to attract more people to reside in the central core and distribute new jobs to other areas of the City. Policies will work to ensure the city develops into a community of communities that are spatially bounded by 15 different City District boundaries. The Districts and a tiered network of activity centres (nodes) are the base structural elements of this scenario. Corridors are still present within this scenario; however, their location is more strategic in nature. Overall, they play a supportive/secondary role.

Corridor City (City III)

This scenario redistributes population and employment throughout the city along corridors, with less concentration in nodes. There is a heavy focus on rebuilding, repurposing or reclaiming underutilized land (commercial, institutional, industrial) to distribute medium intensity development and green spaces to all parts of the city. Policies would pursue achieving more equitable and spatially distributed access to services, jobs and housing by emphasizing high density corridors. Nodes still exist within this scenario; however, as with City II, their location is more strategic, and they play a supportive/secondary role.

Climate vulnerability and risk cost assessment

In 2018 the City of Edmonton released *Climate Resilient Edmonton: Adaptation Strategy and Action Plan*. This document outlines a pathway towards climate resilience for Edmonton—i.e., to better prepare for, respond to, and recover from the anticipated impacts of climate change. It is complementary to the *Community Energy Transition Strategy*, which aims to reduce greenhouse gas emissions in Edmonton. As part of the evidence gathering process to inform *Climate Resilient Edmonton: Adaptation Strategy and Action Plan*, an Edmonton-specific vulnerability and risk assessment was conducted, which measured potential risks and opportunities associated with current and future climate conditions in Edmonton. This included analyses of expected economic (damage) costs for Edmonton—estimated to amount to about $18.2 billion (2016 dollars) annually by the end of the century. The purpose of this short note is to extend the analysis, where possible, to the Evaluation Scenarios, to determine the relative climate-related costs arising under each scenario, as well as relative to the BAU scenario.

Climate change in Edmonton

Climatic conditions in Edmonton are changing. Mean annual temperature has increased at a rate of 0.17°C per decade since 1917. The rate of warming has accelerated over the last 50 years to 0.35°C per decade. The observed rate of warming in the winter months has been more pronounced than during the summer.

Looking to the future, Edmonton's climate is projected to change further:

- Warmer temperatures: Mean temperatures are projected to increase in all seasons, with the largest temperature increase projected for the winter months (December to February).
- Increased precipitation: Mean precipitation is projected to increase significantly in the spring season, and modestly in the winter and fall seasons; projected changes in summer precipitation are insignificant.
- Hotter drier summers: Substantial increases in temperature, coupled with essentially no change in summer precipitation, and significant evapotranspiration, will result in hotter, drier summers.
- Warmer wetter winters: Both mean winter temperature and mean winter precipitation are projected to increase significantly, leading to warmer wetter winters.
- More extreme precipitation: Warming temperatures increase the water holding capacity of the atmosphere, which supply storms, resulting in more intense rainfall events and ultimately to flooding.
- Extreme weather events: Increasing frequency, and in some cases severity, of extreme weather events such as windstorms, lightning, freezing rain and heavy snow.

These changes will have a range of consequences for Edmonton's buildings and infrastructure, municipal services, public health & safety, natural environment, economy and quality of life. The severity and

likelihood of a selection of future climate-related consequences for Edmonton were evaluated through a vulnerability and risk assessment, which also included analyses of associated economic costs (as mentioned above). Climate-related risks and associated costs were measured for three impact pathways[1], 17 climate hazards[2] and 20 asset and service areas of the City[3]. In addition, the impact of climate change for projected space heating and cooling demand in Edmonton was quantified as part of the assessment.

The tools used to perform the vulnerability and risk assessment have been used to evaluate climate-related impacts on elements of the Evaluation Scenarios, **for which data are compatible and available**. The results are summarized below. All costs reported are in 2010 constant dollars. Furthermore, all costs are expected (probability adjusted) annual averages for the year 2065.

Residential buildings

Climate impacts considered: All 17 climate hazards.

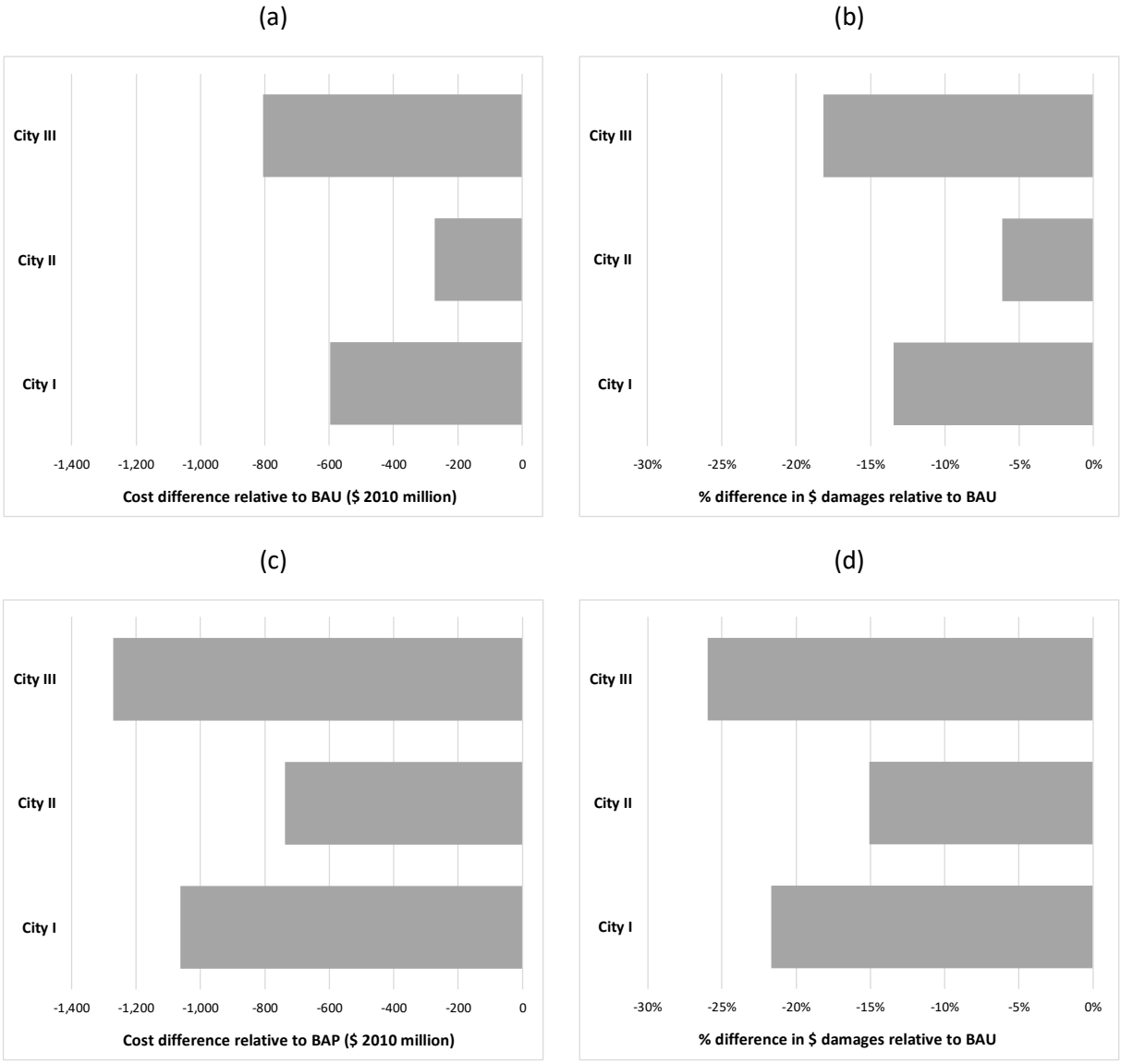
Climate scenario: Representative Concentration Pathway 8.5 (a high emission scenario).

Impact pathways considered: Direct physical damage and indirect service loss.

Costs included: Repair and replacement costs of buildings, replacement cost of building contents, relocation costs for temporary accommodation and disruption (for those properties requiring evacuation).

The figure below shows the difference (in dollar terms and as a % difference) between projected climate-related costs for residential buildings under each Evaluation Scenario (City I, City II and City III) and the BAU (panels a and b) and the BAP (panels c and d). The results of all Evaluation Scenarios are negative, suggesting costs are less under these scenarios than either the BAU or BAP. Relative to both the BAU and BAP the cost difference (saving) is greatest under **City III**. Fundamentally, there are less buildings under the Evaluation Scenarios, and thus less units exposed to climate hazards.

[1] Direct physical damage to the exposed asset (man-made, natural, people); indirect service losses resulting from damage to the exposed asset, where relevant; and direct service losses resulting from exposure of a vulnerable service flow to climate hazards.
[2] Extreme heat, urban flooding, timing of frost free season, wildland-urban interface fire, drought, low flow in river, extreme cold, freeze thaw cycles, heavy snow, rain on snow, freezing rain, blizzard, river flooding, high winds, hail, lightning strikes and tornado.
[3] For example, buildings, water infrastructure, electricity infrastructure, people, ecosystems, urban forests, roads, LRT, etc.



Space heating and cooling

Climate impacts considered: Projected Heating Degree Days and Cooling Degree Days (change relative to 1961-1990 norm for Edmonton).

Climate scenario: Representative Concentration Pathway 8.5 (a high emission scenario).

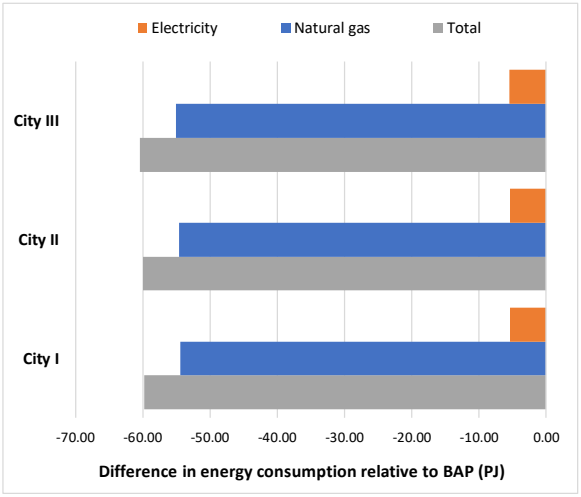
Impact pathways considered: Direct service loss (in this case, a net increase in home energy costs).

Costs included: Net cost of electricity and natural gas consumption for space heating and space cooling in residential and commercial sectors.

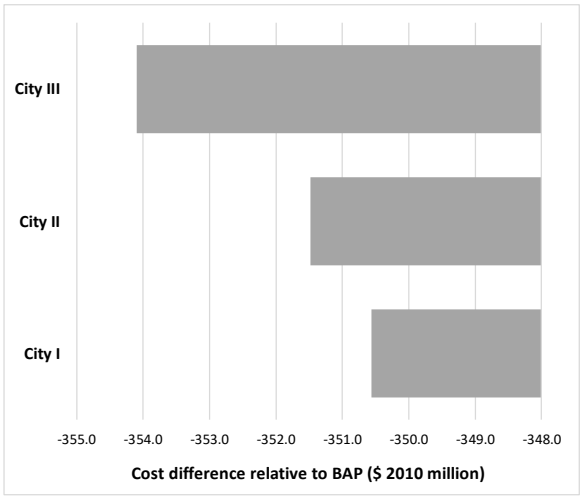
The figure below shows the difference (in dollar terms and as a % difference) between projected climate-related cost impacts on residential and commercial space heating and space cooling demand under each Evaluation Scenario (City I, City II and City III) and the BAP (panels b and c). The results of all Evaluation Scenarios are negative, suggesting space heating and space cooling costs are less under these scenarios than the BAP. Relative to the BAP the cost difference (saving) is marginally higher under **City III**.

Panel (a) shows the magnitude of the energy savings in physical terms, by main energy source. It is worth noting that in all scenarios, including the BAP, net energy costs are higher with climate change—i.e., increases in the cost of space cooling exceed decreases in the cost of space heating.

(a)



(b)



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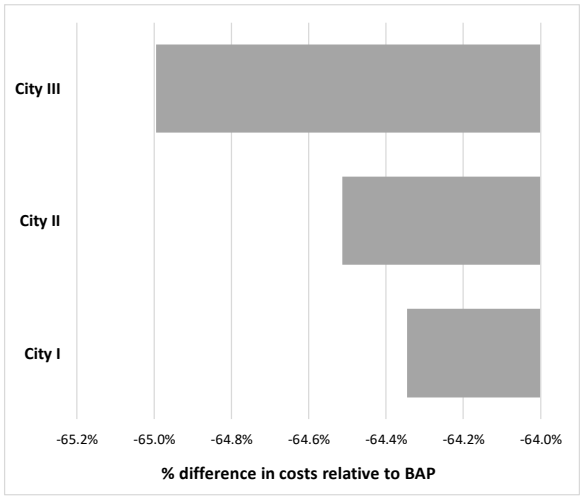


Natural environment

Climate impacts considered: All 17 climate hazards.

Climate scenario: Representative Concentration Pathway 8.5 (a high emission scenario).

Impact pathways considered: Direct physical damage, indirect service loss.

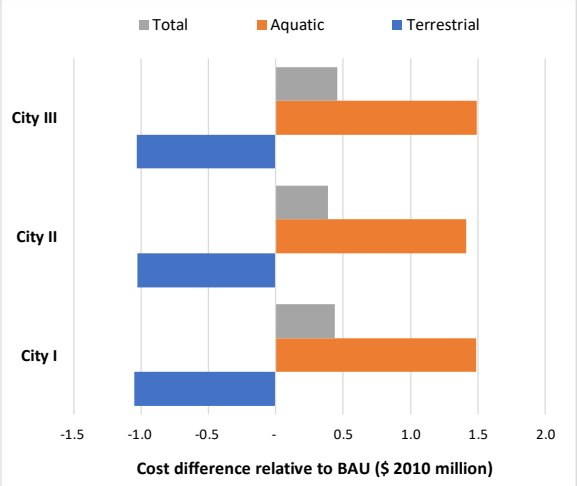
Costs included: Repair and replacement costs for damage to managed terrestrial and aquatic sites, social costs (forgone willingness-to-pay) associated with loss of ecosystem services for terrestrial and aquatic habitat.

The figure below shows the difference (in dollar terms and as a % difference) between projected climate-related costs for managed natural sites under each Evaluation Scenario (City I, City II and City III) and the BAU.

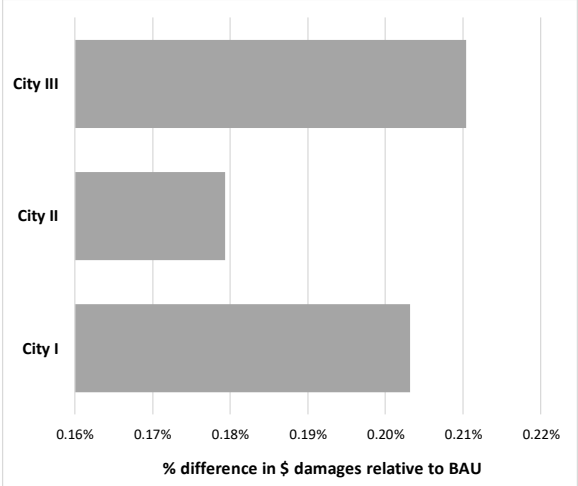
Management of natural sites

The results of all Evaluation Scenarios are positive, suggesting costs are higher under the Evaluation Scenarios than the BAU (data was not available for the BAP). Though, this is because there is more aquatic habitat under the Evaluation Scenarios. The additional climate-related costs of maintaining the additional aquatic habitat must be weighed against the wide ranging social benefits they provide. Relative to the BAU the cost difference (additional cost) is lowest under **City II** (bearing in mind the above caveat, the overall net social benefit of the other Evaluation Scenarios may be higher).

(a)



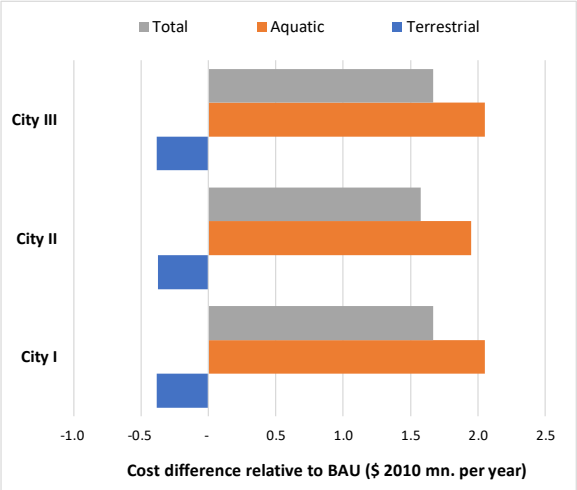
(b)

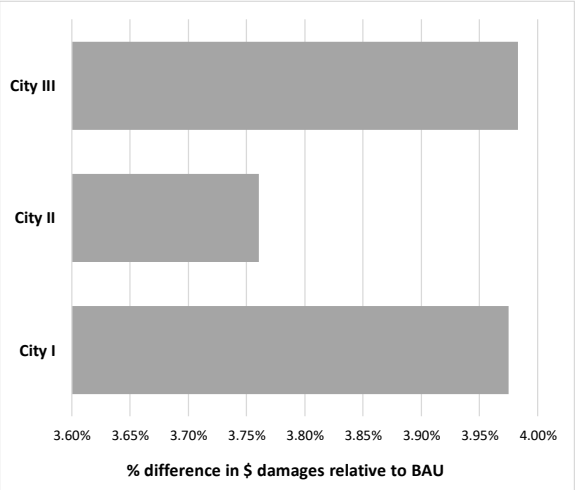


Ecological functionality of sites

The results of all Evaluation Scenarios are positive, suggesting costs are higher under these scenarios than the BAU (data was not available for the BAP). As above, this is because there is more aquatic habitat under the Evaluation Scenarios and the social value of wetlands is much greater than urban terrestrial habitat. Again, the additional climate-related costs of the additional aquatic habitat must be weighed against the wide ranging social benefits they provide that are not eroded by climate change. Relative to the BAU the cost difference (additional cost) is lowest under **City II** (bearing in mind the above caveat, the overall net social benefit of the other Evaluation Scenarios may be higher).

(a) (b)





Road transportation

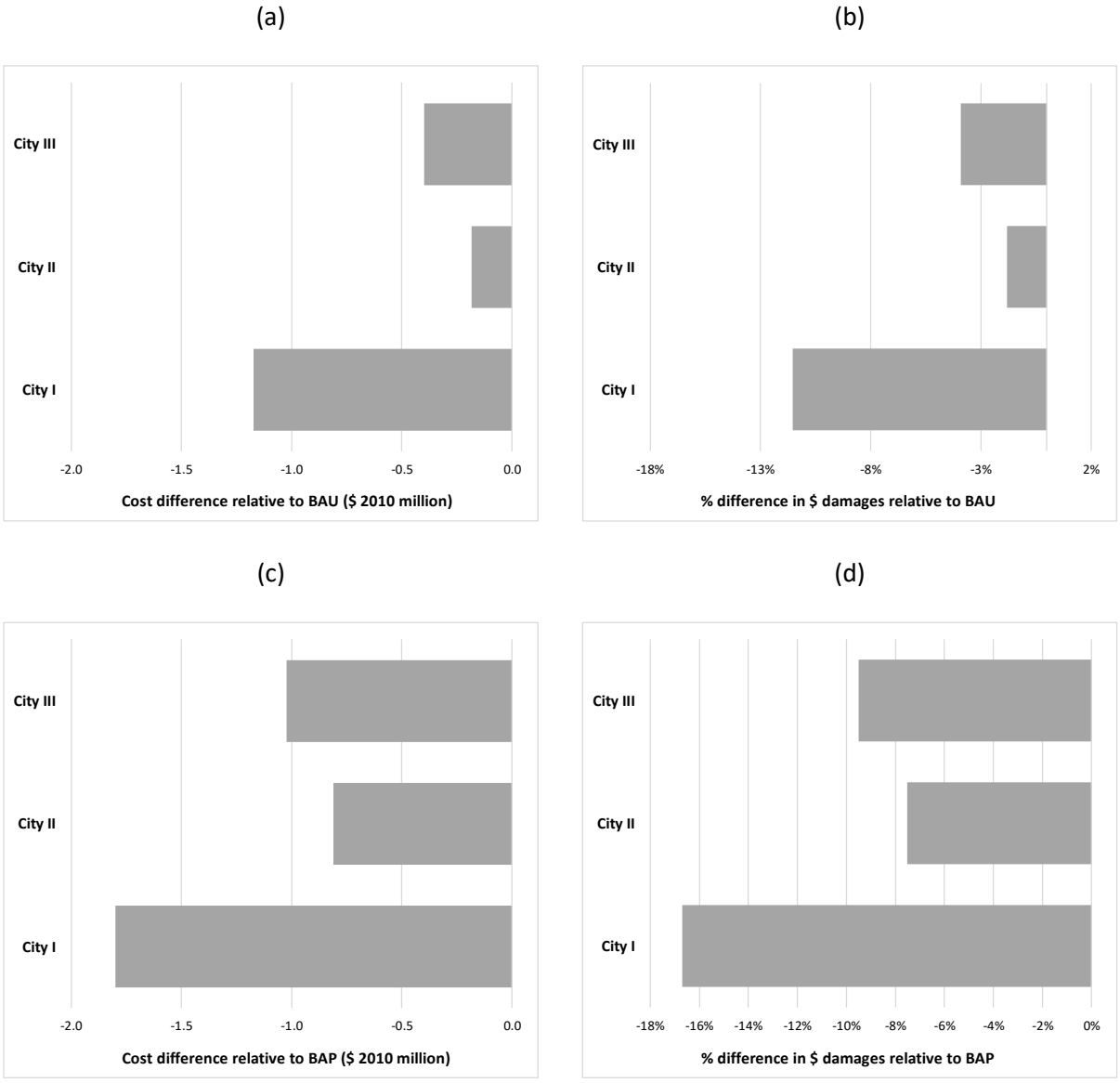
Climate impacts considered: All 17 climate hazards.

Climate scenario: Representative Concentration Pathway 8.5 (a high emission scenario).

Impact pathways considered: Direct physical damage, indirect service loss and direct service loss.

Costs included: Repair and replacement costs of damaged roads and the social cost (forgone willingness-to-pay) of disrupted passenger trips and commercial trips.

The figure below shows the difference (in dollar terms and as a % difference) between projected climate-related costs for roads under each Evaluation Scenario (City I, City II and City III) and the BAU (panels a and b) and BAP (panels c and d). The results of all Evaluation Scenarios are negative, suggesting costs are less under these scenarios than either the BAU or BAP. Relative to both the BAU and BAP the cost difference (saving) is greatest under **City I**. Basically, there are less roads and VKT under the Evaluation Scenarios, and thus less units exposed to climate hazards.



Air quality and climate change

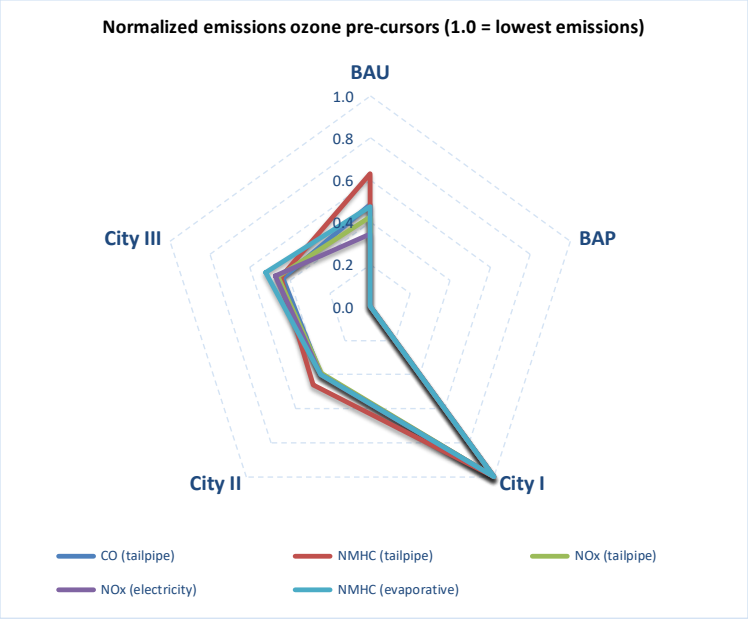
Emissions of non-methane volatile organic compounds (NMVOCs), nitrogen oxides, carbon monoxide and methane contribute to the formation of ground-level (tropospheric) ozone.

Tropospheric ozone can have adverse effects on human health and ecosystems. High concentrations adversely affect the human respiratory and cardiovascular system and there is evidence that long-term exposure accelerates the decline in lung function with age and may impair the development of lung function. Some people are more vulnerable to high concentrations than others, with the worst effects generally seen in children, asthmatics and the elderly. High concentrations of tropospheric ozone in the

environment are harmful to crops and trees, decreasing yields, causing leaf damage and reducing resistance to disease.

These adverse impacts are mainly a problem during the summer months. Climate change is expected to increase future ozone concentrations due to changes in meteorological conditions (mainly higher temperatures), as well as due to increased emissions of specific ozone precursors (increased biogenic emissions of VOC and NO) and emissions from wildfires (which are expected to increase in frequency).

All else being equal, the impact of climate change on ozone-related mortality and morbidity health effects in Edmonton will be more severe under City Plans that result in the emission of more ozone-precursors. The figure below shows the normalized emissions of three ozone pre-cursors (NOx, CO and NMHC) for each City Plan (I-III) and the BAU and BAP. A value of 1.0 indicates the best performing Plan (i.e., the one that emits the least ozone pre-cursors). All else being equal, **the impact of climate change on ozone-related mortality and morbidity health effects in Edmonton are expected to be lowest under City I** and highest under the BAP.



Summary of Findings

Results from the assessment of the relative climate change costs for the Evaluation Scenarios relative to the BAU scenario are summarized in Table 1.

Table 1: Summary of climate change costs relative to the BAU scenario for select assets and service and impacts in 2065 (% difference)

Asset / Service Area	City I (Central)	City II (Node)	City III (Corridor)
Residential buildings	-13.5% (**)	-6.1% (*)	-18.2% (***)
Space heating and cooling	-64.3% (*)	-64.5% (**)	-65.0% (***)
Road transport	-11.6% (***)	-1.8% (*)	-3.9% (**)
Managed natural sites ^	0.20% (**)	0.18% (***)	0.21% (*)
Habitat and ecological function ^	3.97% (**)	3.76% (***)	3.98% (*)
Air quality and health	***	*	**

Note: *** = best performing Evaluation Scenario for indicator; * = worst performing Evaluation Scenario for indicator. ^ see caveat in main text: more open / green space (as per City II) increases units exposed to climate hazards and thus costs, but these costs do not account for the multiple benefits provided by such sites. Care should therefore be exercised when interpreting City II as the best performing scenario regarding managed natural sites and habitat.

ALL ONE SKY FOUNDATION is a not-for-profit, charitable organization established in 2010 to help vulnerable populations at the crossroads of energy and climate change. We do this through education, research and community-led programs, focusing our efforts on adaptation to climate change and energy poverty. Our vision is a society in which ALL people can afford the energy they require to live in warm, comfortable homes, in communities that are able to respond and adapt to a changing climate.

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