Modelling Toronto's Low Carbon Future

Technical Paper #4:

Considerations of Co-benefits and Co-harms Associated with Low Carbon Actions for TransformTO

A literature review

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SSG SUSTAINABILITY SOLUTIONS GROUP

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City of Toronto
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Executive Summary

This report provides a synopsis of the literature describing co-benefits and co-harms of actions and policies designed to reduce greenhouse gas (GHG) emissions, focusing on health, social equity and economic prosperity.

Relevant policies and strategies from the City of Toronto were reviewed to provide context for the literature review. These documents demonstrate that the City has a comprehensive policy context that address different aspects of health, social equity and economic prosperity.

In many cases, actions that reduce GHG emissions in cities correspond or directly overlap with actions that create a vibrant cityscape, improve public health outcomes, reduce municipal operating and capital costs, and support innovation; these are no-regrets policies.[1] Actions that reduce GHGs are synergistic with a wide range of other public goods, and in fact, these actions can be justified from the perspective of any of a number of public goods. One review of more than a dozen studies on GHG mitigation policies found that the co-benefits of reduced air pollution—a single co-benefit—often equaled or exceeded the benefit of the GHG reduction itself.[2]

While generally true, a positive synergistic outcome is not universal—there is potential for co-harms and negative feedback cycles. For example:

- Compact urban development reduces emissions but without careful design there is a risk that people, including children and the elderly, will be exposed to elevated levels of air pollutants as they walk or cycle in close proximity to traffic.
- Infrastructure to reduce emissions will require major investments and the distributional effects of those investments may favour households with higher incomes at the expense of those with lower incomes.
- Increased costs in urban centres may result in increased lower cost housing at the edge of the City or outside of its boundary, leading to an increase in transportation emissions and congestion.

In almost every such case, however, negative impacts be can be mitigated or reversed by policy design that considers not only GHG emissions but also health and equity impacts.

The transition to a low carbon economy represents a massive economic opportunity. One analysis pegged the global economic opportunity of investments in low-carbon urban actions at $16.6 trillion[3]—the financial savings resulting from energy savings and lower cost generation in transportation, buildings and waste sectors. The value of energy savings is such that energy efficiency has been reconceptualised as the “first fuel”, in recognition that the energy use avoided by IEA countries was larger than any other supply-side resource including oil, gas, coal and electricity. In addition to seizing the economic opportunity, actions to reduce GHG emissions also support competitiveness and innovation, reduce municipal operating costs and capital costs and reduce household and business energy costs.

There are clear equity benefits also, from increasing accessibility through compact urban form and increased transit to lower household energy costs. However, equity benefits are contingent on the way in which the actions and policies are implemented.

Following the literature review on social equity, health and economic prosperity, options for evaluating co-benefits and co-harms were reviewed, including possible indicators and criteria to support the multi-criteria analysis.

Beyond the MCA analysis, a method is suggested (Appendix A) on how one could spatially evaluate the social equity and health implications of the low carbon scenario, drawing on the indicators which have been developed for Wellbeing Toronto. Using the energy and emissions model CityInSight’s spatial capabilities,

1 Kamal-Chaoui, L., & Robert, A. (2009). Competitive cities and climate change. Retrieved from http://www.oecd-ilibrary.org/governance/competitive-cities-and-climate-change_218830433146

2 OECD. (2000). Ancillary Benefits and Costs of Greenhouse Gas Mitigation. OECD Publishing.

3 Gouldson, A. P., Colenbrander, S., Sudmant, A., Godfrey, N., Millward-Hopkins, J., Fang, W., & Zhao, X. (2015). Accelerating low carbon development in the world’s cities. Retrieved from http://eprints.whiterose.ac.uk/90740/

different outcomes of the low carbon scenario could be overlaid on top of different social and economic indicators for neighbourhoods in Toronto, providing a more nuanced analysis of the impacts of the low carbon scenario.

In conclusion, the co-benefits of an evidence-based climate action plan suggest that it could equally, and as successfully, be an economic development strategy, a healthy city plan, a competitiveness and innovation plan, a City fiscal management plan, an active transportation strategy, and an energy plan, all rolled up into one. With careful consideration, the climate action plan can also be a poverty alleviation strategy, and an inclusion strategy.

Introduction

Planning for a low carbon future is an ambitious and broad undertaking. This task is being executed at a time when urban planning is grappling with a high degree of complexity in societal, economic and environmental domains, as illustrated by Figure 1: an analysis of co-benefits of climate change mitigation interventions completed for the Lancet's Commission on Health and Climate Change. At the city scale, an initial and interactive illustration of some of the co-benefits of efforts to address climate change may be found at www.changingtheconversation.ca/capp.

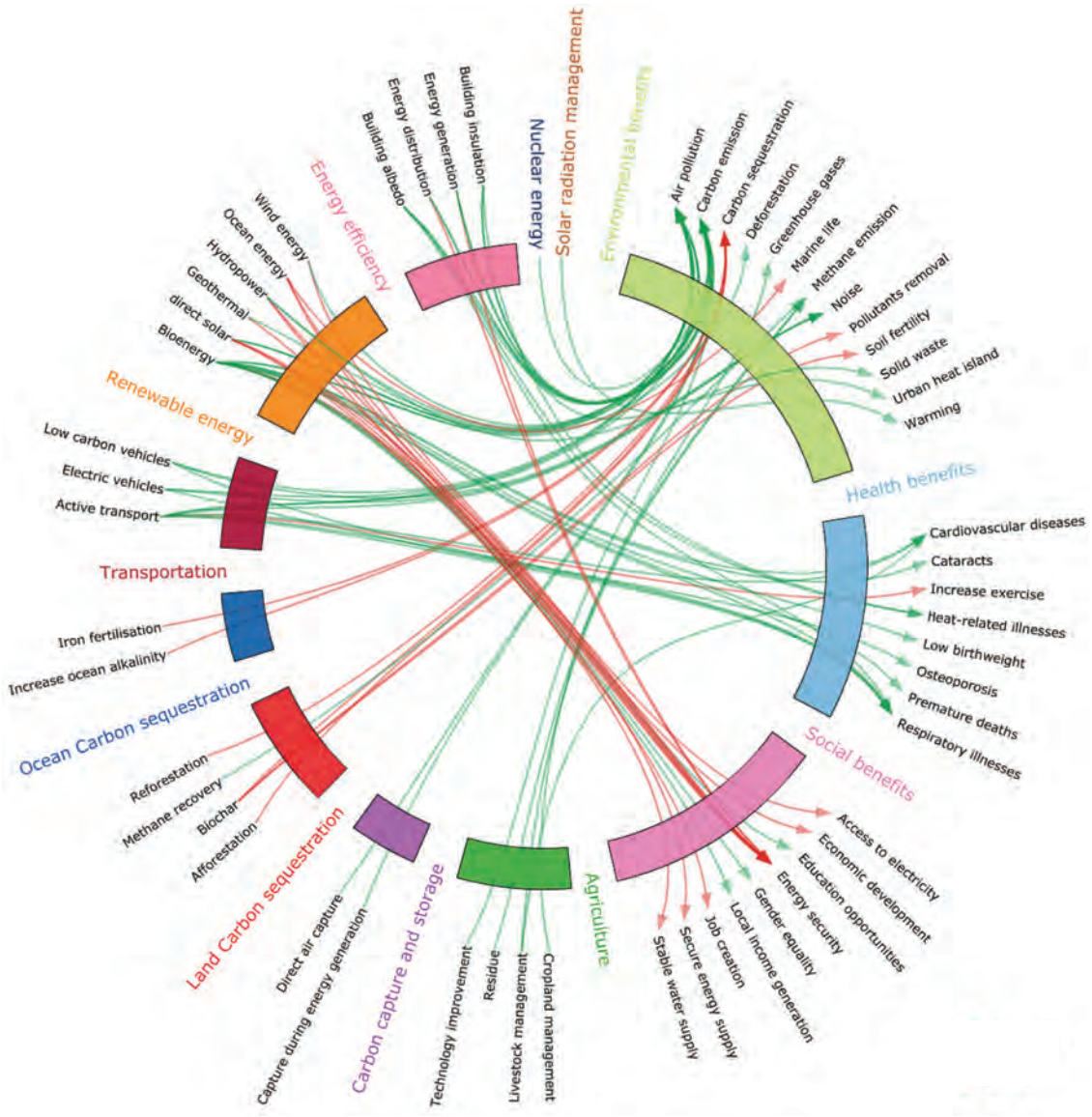

Figure 1. Illustration of co-benefits of climate change mitigation techniques.[4]

4 The Lancet Commissions. (2015). Health and climate change: policy responses to protect public health. Retrieved from http://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(09)60935-1.pdf

This report provides additional insights on the potential co-benefits and co-harms of actions that reduce GHG emissions. The review of literature on the subject and of practitioner approaches helps to better understand the effect of such actions on broader societal and citywide goals. The assessment of the information will help prioritize which actions are aligned with Toronto's goals and objectives—actions that synergistically reduce greenhouse gas emissions while advancing ecological, social and economic objectives. Co-benefits increase the likelihood of success of actions by engaging more diverse communities of interest and by demonstrating compelling short term value from non-greenhouse gas effects.[5] An assessment of co-benefits can also provide insight on new or innovative pathways to reduce GHG emissions.[6]

This report comprises four parts: a review of Toronto's context in terms of policies and initiatives; a review of frameworks for the evaluation of co-benefits and co-harms; a summary and assessment of academic and gray literature on the co-benefits and co-harms of climate action; and a description of different strategies to evaluate co-benefits and co-harms.

5 OECD. (2000). Ancillary Benefits and Costs of Greenhouse Gas Mitigation. OECD Publishing.

6 Floater, G., Heeckt, C., Ulterino, M., Mackie, L., Rode, P., Bhardwaj, A., Huxley, R. (2016). Co-benefits of urban climate action: A framework for cities. LSE Cities.

Part 1: Toronto's Context

The City of Toronto has extensive existing policies on health and economic development. The TransformTO objectives of economic prosperity and social equity are not well defined within these policies, however.

As climate change and low carbon actions are often interrelated in nature, many actions will involve, impact, or be impacted by, Toronto's efforts in a variety of other areas. Some City efforts complementary to TransformTO have been completed or are underway.

The City has been assembling neighbourhood statistics, population, geographic data and health data and making it publicly available via Wellbeing Toronto, a web-based measurement and visualization tool launched in 2011. This tool helps evaluate community wellbeing and quality of life across the city's 140 neighbourhoods using interactive geographic information software. The free tool supports decision making and seeks to engage citizens and businesses in understanding the challenges and opportunities of creating and maintaining healthy, prosperous neighbourhoods. A further analysis of how Wellbeing Toronto may help inform an evaluation of a low carbon scenario can be found in Appendix A.

1.1 Health Context

Toronto Public Health and other departments have completed many projects and studies assessing and addressing public health in the city. Most recently and relevantly, the *Health Benefits of a Low Carbon Future* report[7] summarizes health and climate change scientific literature. Potential health benefits and harms of GHG-reduction actions for the transportation, buildings (including energy), urban form, food systems, and waste management sectors are discussed.

The review of published research indicates that many GHG-reduction actions that are good for health share common features. The types of GHG-reduction actions that benefit health are generally those actions that:

- Increase physical activity;
- Reduce fossil fuel consumption and air pollutant emissions;
- Reduce the risk of injury (especially traffic-related pedestrian and cyclist injuries); or
- Encourage a healthier diet.

The report identifies priority actions that have multiple beneficial health and climate change outcomes, including:

- Creating complete streets to promote safe and active transportation modes;
- Increased access to convenient, affordable, appealing transit service;
- Accelerated retirement of older model, heavy-duty diesel trucks;
- Improvements to existing and new apartment buildings to enhance energy efficiency, social cohesion and healthy living conditions, and
- Compact, mixed-use neighbourhoods that include desirable services, such as healthy food sources, within walking distance.

The City has explored building heat levels in its *Extreme Heat and Maximum Indoor Temperature Standard for Multi-unit Residential Buildings*[8] update report to the Board of Health. Initiated by the concern that many multi-unit buildings experience excessive heating during cold weather, this report provides an update on whether

7 IndEco Strategic Consulting Inc. Health Benefits of a Low Carbon Future Report. City or Toronto, 2016.

8 City of Toronto Medical Officer of Health (2015). Update on Extreme Heat and Maximum Indoor Temperature Standard for Multi-unit Residential Buildings (Staff Report).

a maximum indoor temperature standard is needed for apartment buildings, and it describes the planned approach to consult and engage stakeholders.

Green City: Why Nature Matters to Health is a Technical Report and staff summary report to the Board of Health that focuses on the impact green space has on physical health, mental health and wellbeing, along with green space features which can benefit health. The available evidence shows that both small and large green spaces contribute to better health. There is also evidence that vulnerable groups, such as people with low income and children, gain the most benefit from increased access to green spaces.

1.2 Economic Prosperity Context

Toronto City staff have prepared annual reports evaluating progress in following Toronto's 2008 *Agenda for Prosperity*.[9] The Agenda presents a roadmap for economic prosperity in the city, drawing on Toronto's strengths of high quality of life, social and cultural diversity, economic diversity, environmental sustainability, and creativity, among others. It sets a vision for Toronto to be an inspiring global business city, a hub of environmental innovation, a beacon of diversity and cohesion, a centre for education, and a base for open institutions.

The Agenda has four pillars guiding economic direction in the city:

1. **Proactive Toronto: Business Climate**

   Improve the business climate within the city to enable, accelerate and attract economic growth.

2. **Global Toronto: Internationalization**

   Diversify Toronto's international portfolio by substantially increasing economic activity with cities beyond North America with a focus on emerging markets.

3. **Creative Toronto: Productivity and Growth**

   Anchor and expand strategic industry sectors through increased competition and collaboration.

4. **One Toronto: Economic Opportunity and Inclusion**

   Enhance and expand Toronto's labour force and ensure that all residents have equitable access to the benefits of Toronto's enhanced economic competitiveness and growth.

The Agenda stresses working collaboratively to strengthen and expand key industry and geographic clusters such as aerospace, automotive, food processing and other manufacturing, financial services, business and professional services, biotechnology, screen-based industries, cultural industries, tourism, design, education and strategic nodes including business improvement areas, downtown and waterfront. The report also encourages developing, supporting and showcasing Toronto's emerging green industries including building enhancements, products, services, technologies and related initiatives for both economic and environmental benefit.

In 2012, the *Sustainable Competitive Advantage and Prosperity*[10] report was prepared for the City. It advocated continued preservation of the industrial employment land base for its wealth generating capacity, a focus on targeting new office space construction to realize future growth potential, and increasing employment diversity. The report provided dozens of policy and action recommendations, grouped under four themes:

1. Integrating long range plans for transit, land use and economic policy to enable the city to develop intensified office employment clusters in mixed use environments.

2. Continuing to protect industrial lands and existing industrial uses from uses that conflict with their functionality.

3. Continuing to provide a variety of places for growth in the retail, service and institutional sectors.

9 City of Toronto. (2008). Agenda for Prosperity.
10 City of Toronto. (2012). Sustainable Competitive Advantage and Prosperity Report.

4. Following through on the Growth Plan direction targeting major transit station areas for intensification.

Toronto's Economic Development and Culture (EDC) Division provides programs and initiatives in economic competitiveness, culture, and business. The Division is responsible for the delivery of three City Strategic Action priorities: increasing economic opportunities, accelerating economic growth and investing in culture. The *Creative Capital Gains*[11] and *Collaborating for Competitiveness*[12] strategies guide the Division's workplan.

The *Creative Capital Gains* report is a cultural economic action plan for the city. It details some of the challenges faced by the city's population, including: access to affordable and sustainable space for cultural organizations in many neighbourhoods; space and infrastructure for start-up cultural entrepreneurs; the equitable distribution of cultural services throughout the city and to all segments of the population; ongoing sufficient and stable core operating funding to the not-for-profit arts sector; the recognition and support of cultural clusters to amplify the work of our cultural industries; and the need for much greater collaboration to promote cultural tourism and Toronto's identity as a Creative Capital. EDC works to address these challenges, using the recommendations of the report, recognizing that City investment in cultural resources generates immense cultural returns for the city and financial returns for cultural organizations and communities.

Collaborating for Competitiveness is a strategic plan for accelerating economic growth and job creation in Toronto. The plan is focussed on business development and economic competitiveness, growing Toronto to be have strong global economic presence through job creation, commercial and industrial developments, employment growth, real estate and infrastructure availability and quality, workforce development, company and investment attraction, small and medium enterprise support, and strengthening industry and manufacturing. The guiding vision for this strategic plan is to foster the creation of a virtuous cycle of sustainable economic growth and job creation in order to improve the quality of life for all residents. Its goal is to advance the city's prosperity, opportunity and liveability.

1.3 Social Equity Context

The City's Equity, Diversity and Human Rights (EDHR) vision statement and efforts[13] focus on "diverse communities", defined as including women, Aboriginal peoples, racial minorities, people with disabilities, seniors, youth, and LGBTTT. Often termed "vulnerable populations", these demographic focuses of EDHR are estimated to be those most impacted by climate change.

The *Toronto Strong Neighbourhood Strategy 2020*[14] identifies inequitable outcomes at a geographic scale through "Neighbourhood Improvement Areas," that are at unfair and unnecessary disadvantage. The Strategy is the City's neighbourhood equity action plan for ensuring that each of Toronto's 14O neighbourhoods can succeed and thrive. It adopts five domains of focus from the World Health Organization: physical surroundings, economic opportunities, healthy lives, social development, and participation in civic decision-making. The Strategy includes an action catalogue with several themes, including: quality jobs, local economy, clean, healthy environment, mental health, active living, access to food, neighbourhood beauty and safety, accessible transit, and parks and green space. 248 specific actions populate the themes.

The City defines equity as 'not only equal access to opportunities but equal benefits as well. It requires the removal of systemic barriers and the accommodation of differences so that individuals can benefit equally." The City defines access alongside equity as: 'people from diverse groups gaining equal opportunity to the use of goods, services, programs, facilities, public spaces and participation in social, economic, cultural and political life.'

The City's goals for social equity go beyond equal benefits, access, and opportunity, and actions and indicators with respect to social equity are described in the *Poverty Reduction Strategy*. Priority areas outlined in the strategy include: housing stability, service access, transit equity, food access, quality jobs & livable incomes, and

11 City of Toronto. (2013). Creative Capital Gains Report.
12 City of Toronto. (2011). Collaborating for Competitiveness Report.
13 City of Toronto. (2016). Equity lens - definitions.
14 City of Toronto. (2015). Toronto Strong Neighbourhoods Strategy.

systemic change. The Strategy has over 70 recommended actions to be taken during 2015-2018 with aims to address immediate needs, create pathways to prosperity, and drive systemic change. It also has a long-term, 20-year strategy of four three-year cycles of action, evaluation and work plan updating.

The *Poverty Reduction Strategy* includes action themes that coincide with climate change mitigation efforts, such as:

- Expanding incentive programs and increasing support for home and building air quality and energy efficiency improvements;
- Supporting housing choice, availability of a variety of housing types, and affordable housing;
- Increasing quality, availability, and financial and physical accessibility of the public transit system;
- Increasing access to locally grown food and supporting urban agriculture;
- Supporting the creation of quality jobs and an equitable local economy, and
- Improving systemic and government conditions to better address root causes of poverty and social inequity.

As part of the TransformTO project, the City of Toronto has completed two papers on equity. The *Equity Indicators Background Report*[15] completed a review of scholarly work on equity and sustainability metrics. The *Equity + Engagement*[16] report developed a three-stage engagement framework that will help inform, engage and empower Toronto's diverse communities in the TransformTO project.

15 City of Toronto. (2016). TransformTO Equity indicators Background Report.
16 City of Toronto. (2016). Engagement + Equity.

Part 2: Frameworks for the Evaluation of Co-benefits and Co-harms

There is increasing discussion on co-benefits of city-scale climate change mitigation efforts, in recognition that actions that reduce greenhouse gas emissions can also provide other benefits, and that illustrating these benefits can increase climate action plan effectiveness. Consideration also needs to be given to potential co-harms, and understanding and exploring these impacts is critical to advancing sustainable development.[17]

The academic literature analysing the co-benefits of city-scale climate action plans as a whole is limited, however there is a wealth of literature, discussed below, on specific activities or aspects of the built environment or the energy and transportation system that contribute to low carbon outcomes.

In a review of climate action plans from across North America, no comprehensive assessment of co-benefits and co-harms was identified that was integrated within the plan, although there are a number of climate action plans that address economic and equity impacts. A recent review of co-benefits in community energy plans was completed in Canada, with similar findings.[18]

2.1 Definitions and Characteristics

Co-benefits and co-harms are effects that result from and are incidental to actions reducing GHG emissions.

The term co-benefits, and its corollary, co-harms, have a variety of synonyms including ancillary effects and ancillary benefits and costs and an equal variety of definitions.

In the context of completing a monetary analysis, these definitions become particularly important. One distinction, made by the OECD, is that co-benefits are effects that are valued in the mitigation costs of a policy or action, whereas ancillary benefits are effects that are incidental and are not accounted for in that analysis.[19] For the purposes of this paper co-benefits or co-harms are assumed to be any benefits or harms additional to the impact on GHG emissions.

Co-benefits and co-harms are not equal: they have different categories of effects.

Not all co-benefits are equal, and one set of characteristics in considering the co-benefits of low carbon actions is as follows:[20]

- **Synergies:** Many low carbon actions have multiple socio-economic benefits, including transit, energy efficiency, and compact urban design.
- **Urgency:** Some actions are associated with a higher degree of urgency in order to avoid loss of inertia, lock-in effects, irreversible outcomes, or deferred, elevated costs. Examples include road infrastructure decisions, major ecosystems displacement and urban form. Some low carbon actions require time to realize their effects, making immediate implementation paramount.
- **Costs:** Costs of early action is generally lower than later action, in particular because delayed action involves ongoing investments in infrastructure, activities and utilities that are higher emitting than would be low carbon solutions. Examples include district energy, transit, and energy efficiency.

17 Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., Dewar, D., ... others. (2014). Human settlements, infrastructure and spatial planning. Retrieved from http://pure.iiasa.ac.at/11114/

18 Cairns, S, & Baylin-Stern, A. (2016). Community energy planning: The value proposition- environmental, health and economic benefits. Quality Urban Energy Systems of Tomorrow. Retrieved from http://gettingtoimplementation.ca/wp-content/uploads/2016/02/Full-Report_ValueProposition_OnlineVersionFeb92016.pdf

19 OECD. (2000). Ancillary Benefits and Costs of Greenhouse Gas Mitigation. OECD Publishing.

20 Adapted from (Fay et al., 2015).

- **Longevity:** Related to urgency, the longevity of planning and development decisions locks cities into their effects for decades, if not centuries as illustrated in Figure 2.
- **Distribution effects:** Low carbon actions have different impacts on different subsets of the population, including income levels, generations (including future generations) and ethnicities.

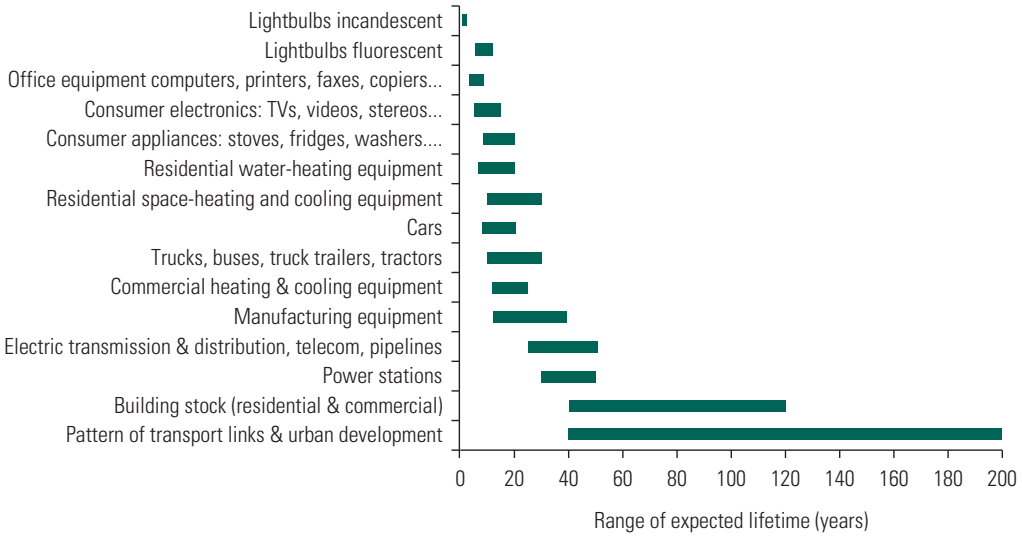

Figure 2. Expected life spans of different products.[20]

2.2 Classification of Co-benefits and Co-harms

A co-benefits and co-harms assessment framework needs to be comprehensive while reflecting Toronto's priorities.

In order to systematise the approach to co-benefits, various frameworks have been developed recently, particularly in the grey literature. In a paper for C40, LSE Cities proposes a framework that includes five strategic sectors: health, mobility, resources, buildings and economy (Figure 3). The sectors are designed to align with policy areas where many city governments already have strategic goals and were drawn from a survey of 100 cities.[22]

The strategic sectors in this framework do not explicitly address equity or prosperity, which are focus areas for the City of Toronto. The Environmental Change Institute at the University of Oxford developed a broader framework with the aim of achieving "both a fair and a fast transition to a low-carbon economy in a way that benefits local residents, reduces social divides and builds public support for action" (Figure 4).[23] This analysis considered in particular how efforts to tackle climate change can increase or exacerbate income inequality.

The most sophisticated or integrated framework was the result of a project led by California-based Public Health Institute (Figure 5),[24] which focused on the relationship between health, equity and climate change. The framework emerged from a process that included a review of the literature and prior reports on climate change and public health, qualitative research, a day-long workshop and an iterative peer-review process. The target audience is public health agencies as opposed to municipalities.

21 Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. M. (2015). Decarbonizing development: three steps to a zero-carbon future. Washington, DC: World Bank Group.

22 Floater, G., Heeckt, C., Ulterino, M., Mackie, L., Rode, P., Bhardwaj, A., Huxley, R. (2016). Co-benefits of urban climate action: A framework for cities. LSE Cities.

23 Mayne, R. (2016), p.V. Building stronger and fairer communities: sharing the co-benefits of local action on climate change. Environmental Change Institute. Retrieved from http://www.agileox.org/wp-content/uploads/2016/07/LC-Oxford-whole-report.pdf

24 Rudolph, L., Gould, S., & Berko, J. (2015). Climate change, health and equity: Opportunities for action. Oakland, CA: Public Health Institute. Retrieved from https://www.phi.org/uploads/application/files/h7fjouo1i38v3tu427p9s9kcmhs3oxsi7tsg1fovh3yesd5hxu.pdf

Strategic sectors	City goals (examples)	Policy actions (examples)	Co-benefits	Coordinated governance
HEALTH	Improve outdoor air quality	Reduce conventional vehicle use	Reduced premature deaths and health problems	Health, Transport, Land Use, Energy, Digital, Economy, Air Quality, Buildings, Tourism
MOBILITY	Reduce congestion	Reduce vehicle use	Increased economic efficiency, quality of life, air quality	Transport, Economy, Land Use, Digital, Energy, Education, Tourism, Air Quality
RESOURCES	Improve food security	Promote agricultural production	Increased economic efficiency, quality of life, reduced health impacts	Food Security, Waste, Water, Health, Land Use, Transport, Buildings, Energy, Education, Disaster & Emergency
BUILDINGS	Reduce fuel poverty	Increase building energy efficiency	Cost savings	Buildings, Energy, Health, Education
ECONOMY	Support economic growth	Establish cleantech business clusters and incentives	Innovation, productivity, SME growth in technology sector	Economy, Education, Transport, Buildings, Digital, Water, Waste

Figure 3. LSE Cities co-benefits framework.

Figure 4. Oxfordshire co-benefits framework.

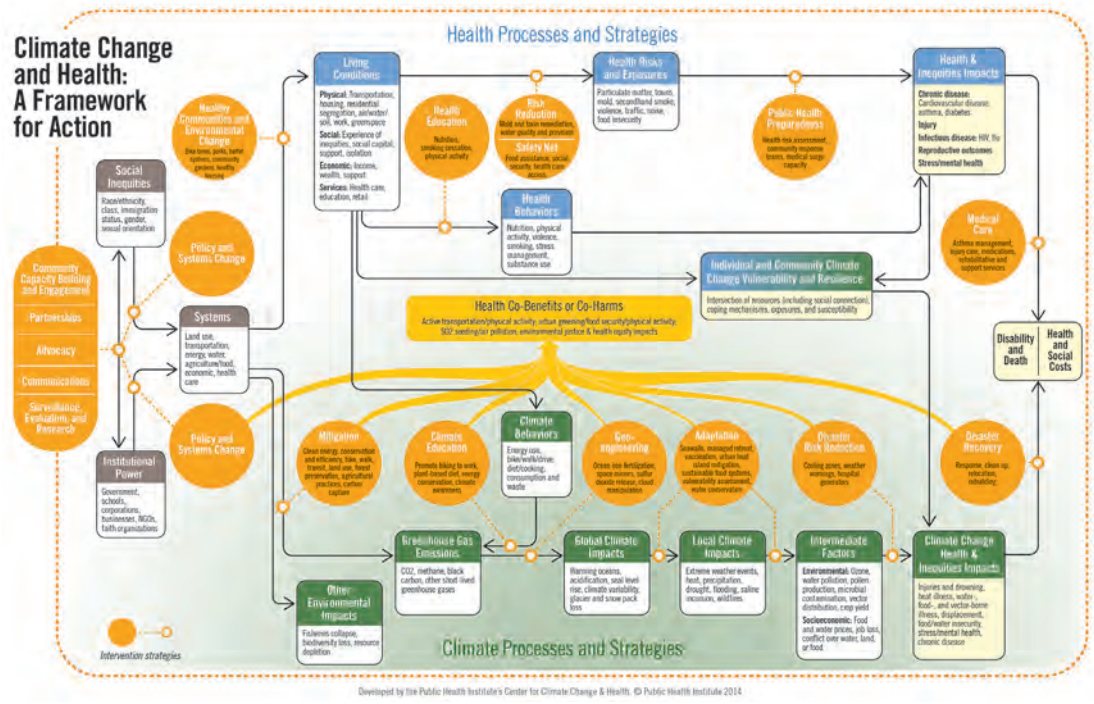

Figure 5. Complex pathways: health and equity.

The United Nations Framework Convention on Climate Change has developed a framework for assessing co-benefits using a sustainable development lens with environmental, social and economic pillars (Figure 6).[25]

While none of these frameworks directly address the priorities of the City of Toronto, the authors derived the following principles to guide TransformTO's consideration of co-benefits and co-harms, both in terms of the criteria used in the multi-criteria analysis, and in the final assessment of co-benefits and co-harms:

- Ensure relevance to city powers and influence.
- Seek comprehensive coverage of potential co-benefits and co-harms.
- Describe interactions of co-benefits where possible.
- Illuminate the costs and benefits whenever possible.

25 Cohen, B., Rennkamp, B., Mendes, A. M. R., Gonzales-Zuniga, S., Boulle, M., Gunfaus, M., & Logan, A. (2015). Incorporating co-impacts into climate mitigation planning: Experiences from Latin America. Retrieved from http://www.mapsprogramme.org/wp-content/uploads/Paper_Incorporating-Co-Impacts-into-Climate-Mitigation-Planning3.pdf

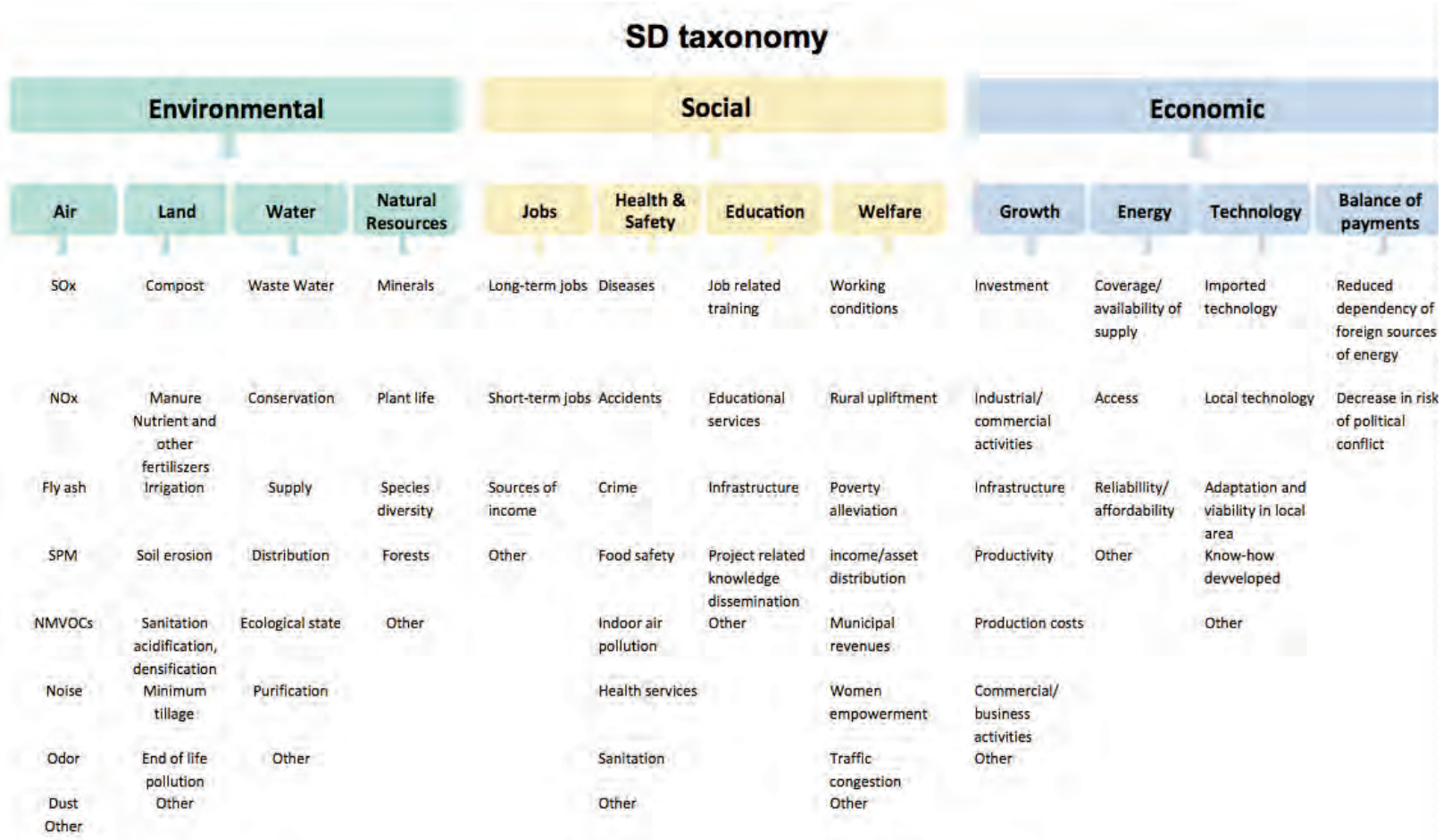

Figure 6. Framework for assessing co-benefits using a sustainable development lens.

Part 3: Co-benefits and Co-harms in the Literature

3.1 Health

A built environment that reduces GHG emissions also results in improved health outcomes.

Toronto's *Health Benefits of a Low Carbon Future* report[26] provides a comprehensive review of health impact of efforts to reduce GHG emissions. Much of it is included here, along with additional and complementary evidence.

The World Health Organization (WHO)'s current definition calls health "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[27]

Research indicates that climate change is leading to adverse physical and mental health effects.[28] The under-privileged, in particular, are at elevated climate change-induced health risks. Poor living conditions increase vulnerability to climate change and cause poor health status; poor health status even further increases climate vulnerability. Climate change mitigation actions that also have positive health outcomes will thus be especially beneficial to vulnerable populations.

Researchers have described the relationship between the built environment and health in a diagram called the health map,[29] which captures the breadth of factors to be considered. People are at the heart of the map, which is set within the bioregion and the global ecosystem, on which people ultimately depend. Cities have impacts across all dimensions of the map.

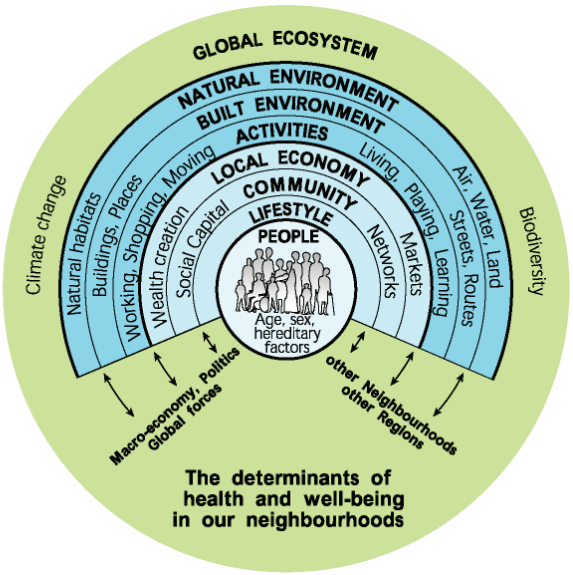

Figure 7. The health map.

26 IndEco Strategic Consulting Inc. Health Benefits of a Low Carbon Future Report. City or Toronto, 2016.

27 World Health Organsation. (2003). WHO definition of health. Retrieved November 14, 2016, from http://www.who.int/about/definition/en/print.html

28 Barrett, B.; Charles, J.W.; Temte, J.L. Climate change, human health, and epidemiological transition. Prev. Med. 2014, 70, 69–75.

29 Barton, H., & Grant, M. (2006). A health map for the local human habitat. The Journal of the Royal Society for the Promotion of Health, 126(6), 252–253.

The British Columbia Healthy Built Environment Linkages Toolkit[30] provides direction for BC municipalities' neighbourhood development and redevelopment in ameliorating health outcomes. Drawing on recommendations from a summary of academic and urban planning practitioner research, the toolkit focuses on five built environment themes to identify 21 recommendations for considerations in the built environment that improve health outcomes. It is a useful summary of healthy built environment research, providing a simple summary of effective health improvement actions that are applicable in any city; nearly all of the recommendations overlap with actions to reduce GHG emissions .

Figure 8. BC Healthy Built Environment Linkages Toolkit summary.

Figure 9 summarizes the relationships between various sectors for low carbon actions, the elements they effect, and the health factors they affect, focusing on three health domains, chronic disease, mental wellbeing and physical injury.[31]

30 BC Provincial Health Services Authority. (2014) Healthy Built Environment Linkages Toolkit.

31 Milner, J., Davies, M., & Wilkinson, P. (2012). Urban energy, carbon management (low carbon cities) and co-benefits for human health. Current Opinion in Environmental Sustainability, 4(4), 398–404. https://doi.org/10.1016/j.cosust.2012.09.011

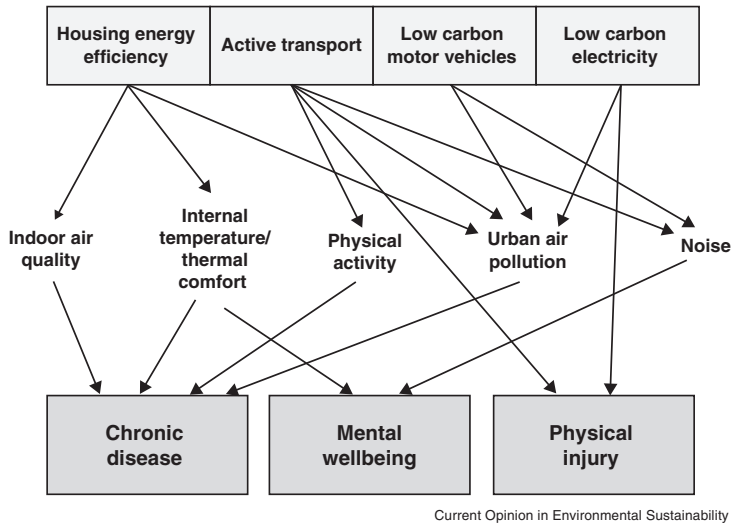

Figure 9. Summary of low carbon actions and health benefits.[31]

The City of Toronto has also performed research in this area and has produced several reports stressing the importance of fostering an active city with healthy built environments, including:

- *Active City, Designing for Health*:[32] explores how an active city creates a built environment that integrates physical activity into day to day living. This includes accessible recreation facilities, parks, and social spaces for people of all ages and abilities. It explores how making physical activity fundamental to commuting, errands or appointments, can make healthier choices easier.
- *Improving Health by Design in the Greater Toronto-Hamilton Area*:[33] assesses approaches to reintegrating physical activity into daily life, recognizing that there are great challenges to public health in the coming years as the population of the area rapidly increases. The report recognizes that current infrastructure decisions lock in access to physical activity for many decades.
- *Healthy Toronto by Design*:[34] stresses the roles across City departments to integrate health concerns and approaches into their visioning and strategic policy, urban and social planning, and program delivery. Healthy Toronto by Design is also a series of reports that includes:
- *Toward Healthier Apartment Neighbourhoods*:[35] synthesizes zoning barriers and opportunities to promote healthy neighbourhoods, particularly in clusters of residential apartment towers in low income areas and inner suburbs of Toronto.
- *The Walkable City*:[36] summarizes the findings of a Residential Preferences Survey that gauges public demand for walkable versus more auto-oriented neighbourhoods, and links this information with travel choices, physical activity levels and body weight.
- *Inventory of Best Practices*:[37] showcases examples of innovative practices and policies across city government in Toronto that promote healthy built environments.

32 Toronto Public Health, City of Toronto Planning, City of Toronto Transportation Services and Gladki Planning Associates. Active City: Designing for Health. May 2014 City of Toronto. http://www.toronto.ca/legdocs/mmis/2014/hl/bgrd/backgroundfile-69334.pdf

33 Medical Officers of Health in the GTHA (2014). Improving Health by Design in the Greater Toronto-Hamilton Area. http://www.toronto.ca/legdocs/mmis/2014/hl/bgrd/backgroundfile-69323.pdf

34 Toronto Public Health. Healthy Toronto by Design. Toronto, Ontario. October 2011. http://www1.toronto.ca/city_of_toronto/toronto_public_health/healthy_public_policy/hphe/files/pdf/healthytoronto_oct04_11.pdf

35 Toronto Public Health and the Centre for Urban Growth and Renewal. Toward Healthier Apartment Neighbourhoods: A Healthy Toronto by Design Report. September 2012. City of Toronto. http://www.toronto.ca/legdocs/mmis/2012/hl/bgrd/backgroundfile-49926.pdf

36 Toronto Public Health. The Walkable City: Neighbourhood Design and Preferences, Travel Choices and Health. April 2012. https://www1.toronto.ca/city_of_toronto/toronto_public_health/healthy_public_policy/hphe/files/pdf/walkable_city.pdf

37 Toronto Public Health. Creating Healthy Built Environments – Highlights of Best Practices in Toronto. May 2012. http://www1.toronto.ca/city_of_toronto/toronto_public_health/healthy_public_policy/hphe/files/pdf/healthy_environment.pdf

- *Road to Health*:[38] synthesizes evidence on health benefits and risks associated with walking, cycling and physical activity related to the use of public transit, as well as economic assessments and specific strategies to increase the use and safety of active transportation in Toronto.
- The Health Impact Assessment Software Tool has been developed to assist policy and decision-makers understand how different approaches to neighbourhood design might impact health-related outcomes such as physical activity levels, body weight and greenhouse gas emissions.

3.1.1 Air Quality

One of the most beneficial and immediate health co-benefits of GHG reductions is improved air quality.

Air quality can be improved by making changes to the technologies used to produce and consume energy, as well. Many of the changes that would reduce greenhouse gas emissions would reduce other emissions as well, such as nitrogen oxides (NOx), sulfur dioxide (SO2), particulate matter, and mercury, and the resulting pollution-related disease.[39] Several studies have concluded that substantive morbidity and mortality benefits would result from improved air quality, especially from the reduction of micro-particulates that would result from burning lower amounts of fossil fuels and firewood.[40]

Improvements in fuel-efficiency, increased use of public transport, and fewer diesel engines could all contribute to improved air quality and better health outcomes. It has been found that traffic-related air pollution at relatively low concentrations in Ontario was associated with increased mortality from cardiovascular disease.[41] Studies confirm that traffic-related air pollution increases prevalence of asthma and allergic diseases.[42] An assessment for Toronto found that nitrous oxide (NO) was significantly associated with increased ischemic heart disease risk, and that living near major roadways and highways increased the risk of heart disease.[43]

Studies have also found that children living near major highways are at higher risk of developing asthma and reduced lung function.[44] Compact urban design can reduce GHG emissions, but as this literature indicates, while aggregate rates of air pollution may decline, the increased proximity of people to traffic in a dense urban form can increase exposure.[45]

3.1.2 Physical Activity

Increasing physical activity results in immense individual and population health benefits. Arrangements that increase physical activity coincide closely with GHG reduction actions.

Studies in Copenhagen[46] and Shanghai[47] have shown that all cause mortality was 30-40% less among those who cycled compared to those who did not use active transport or get equivalent amounts of leisure time exercise.

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38 Toronto Public Health. Road to Health: Improving Walking and Cycling in Toronto. April 2012. http://www1.toronto.ca/city_of_toronto/toronto_public_health/healthy_public_policy/hphe/files/pdf/roadtohealth.pdf

39 Nemet, G.F.; Holloway, T.; Meier, P. Implications of incorporating air-quality co-benefits into climate change policymaking. Environ. Res. Lett. 2010, 5, 1–9.

40 Barrett, Bruce, Maggie Grabow, Cathy Middlecamp, Margaret Mooney, Mary Checovich, Alexander Converse, Bob Gillespie, and Julia Yates. "Mindful Climate Action: Health and Environmental Co-Benefits from Mindfulness-Based Behavioral Training." Sustainability 8, no. 10 (October 17, 2016): 1040. doi:10.3390/su8101040.

41 Chen, H., Goldberg, M. S., Burnett, R. T., Jerrett, M., Wheeler, A. J., & Villeneuve, P. J. (2013). Long-term exposure to traffic-related air pollution and cardiovascular mortality. Epidemiology, 24(1), 35–43.

42 Bowatte, G., Lodge, C., Lowe, A., Erbas, B., Perret, J., Abramson, M., ... Dharmage, S. (2015). The influence of childhood traffic-related air pollution exposure on asthma, allergy and sensitization: a systematic review and a metalanalysis of birth cohort studies. Allergy, 70(3), 245–256.

43 Beckerman, B. S., Jerrett, M., Finkelstein, M., Kanaroglou, P., Brook, J. R., Arain, M. A., ... Chapman, K. (2012). The association between chronic exposure to traffic-related air pollution and ischemic heart disease. Journal of Toxicology and Environmental Health. Part A, 75(7), 402–411.

44 Brugge, D., Durant, J. L., & Rioux, C. (2007). Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks. Environmental Health, 6, 23.

45 Mansfield, T. J., Rodriguez, D. A., Huegy, J., & MacDonald Gibson, J. (2015). The effects of urban form on ambient air pollution and public health risk: A case study in Raleigh, North Carolina. Risk Analysis, 35(5), 901–918.

46 Andersen LB, Schnohr P, Schroll M, Hein HO. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. Arch Intern Med2000;160:1621-8.

47 Matthews CE, Jurj AL, Shu XO, Li HL, Yang G, Li Q, et al. Influence of exercise, walking, cycling, and overall nonexercise physical activity on mortality in Chinese women. Am J Epidemiol2007;165:1343-50.

A 19% reduction in all-cause mortality risk has been shown to occur with 30 minutes of daily moderate-intensity activity, 5 days per week. When populations engaged in 7 hours of moderate activity weekly, the all-cause mortality risk dropped by 24% compared to those with no activity.[48] All-cause mortality rates in moderately and highly active people have been found to be 50% lower than those with no activity. The same studies have found that cycling to work would also reduce all-cause mortality rates by 40%.[49]

Active travel, through cycling and walking, is beneficial for the health due to increased physical activity, but active travel may increase the intake of air pollution, leading to negative health consequences. A recent study, however, has shown that the benefits of physical activity by far outweigh risks from air pollution, even under the most extreme levels of active travel.[50]

Studies have shown that children who walk or bike to school are fitter than those who travel by car or bus, with 30% higher vigour in boys, and seven times higher in girls.[51] It is estimated that the doubling of people walking would reduce the risk to each individual walker by approximately one-third.[52] A review reported that public transport usage could increase physical activity by 8–33 minutes per day.[53]

Research has identified a statistical correlation between community form and health. A study of more than ten thousand residents of Atlanta, Georgia, found the following: a positive correlation between urban form's influence on physical activity and emissions; every additional thirty minutes spent in a car was associated with a 3% increase in the odds of being obese; and living in mixed-use neighbourhoods, nearby shops and services, is the best urban form predictor of reduced obesity rates.[54] Ewing et al. also found that compact development is directly correlated with lower rates of obesity and hypertension.[55]

One study in Scotland found that residents in neighbourhoods with ample green space were three times more likely to be physically active and 40% less likely to be overweight than those in neighbourhoods with limited green space.[56] Another study found that seniors living in neighbourhoods with walkable green spaces nearby lived longer on average.[57]

3.1.3 Noise

Traffic-related noise has been associated with a number of health impacts including cardiovascular disease,[58] annoyance,[59] sleep disturbance and heart attacks,[60] a potential co-harm associated with a more compact urban form.

48 Woodcock, J., Franco, O. H., Orsini, N., & Roberts, I. (2011). Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. International Journal of Epidemiology, 40(1), 121–138.

49 Andersen LB, Schnohr P, Schroll M, Hein HO. All-Cause Mortality Associated With Physical Activity During Leisure Time, Work, Sports, and Cycling to Work. Arch Intern Med. 2000;160(11):1621-1628.

50 Tainio, Marko, Audrey J. de Nazelle, Thomas Götschi, Sonja Kahlmeier, David Rojas-Rueda, Mark J. Nieuwenhuijsen, Thiago Hérick de Sá, Paul Kelly, and James Woodcock. "Can Air Pollution Negate the Health Benefits of Cycling and Walking?" Preventive Medicine 87 (June 2016): 233–36. doi:10.1016/j.ypmed.2016.02.002.

51 Voss C, Sandercock G. (2010). Aerobic fitness and mode of travel to school in English schoolchildren. Med Sci Sports Exerc. 2010 Feb;42(2):281-7.

52 Jacobsen, P. L. (2003). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Injury Prevention, 9(3), 205–209.

53 Rissel, C., Curac, N., Greenaway, M., & Bauman, A. (2012). Physical Activity Associated with Public Transport Use—A Review and Modelling of Potential Benefits. International Journal of Environmental Research and Public Health, 9(7), 2454–2478.

54 Litman, T. (2010). Evaluating Public Transportation Health Benefits. Victoria, B.C.: American Public Transportation Association, Victoria Transport Policy Institute.

55 Ewing, R., L. Frank, and R. Freutzer. (2006). Understanding the Relationship Between Public Health and the Built Environment. A Report Prepared for the LEED-ND Core Committee.

56 [CABE] Commission for Architecture and the Built Environment (n.d.). Future Health: Sustainable places for health and well-being. London, U.K.: CABE.

57 Bray, R., C. Vakil, and D. Elliot. (2005). Report on Public Health and Urban Sprawl in Ontario: A review of the pertinent literature. Ontario College of Family Physicians.

58 Curran, J. H., Ward, H. D., Shum, M., & Davies, H. W. (2013). Reducing cardiovascular health impacts from traffic-related noise and air pollution: intervention strategies.

59 Miedema, H. M. E., & Oudshoorn, C. G. M. (2001). Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals. Environmental Health Perspectives, 109(4), 409–416.

60 De Nazelle, A., Nieuwenhuijsen, M. J., Antó, J. M., Brauer, M., Briggs, D., Braun-Fahrlander, C., ... Lebret, E. (2011). Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. Environment International, 37(4), 766–777.

3.1.4 Mobility and Accessibility

Increased mobility and accessibility connects communities, improves air quality, increases physical activity, and provides opportunity to marginalized communities while reducing GHGs.

Dense, well-managed urban development and the provision of accessible, affordable public transport can have a positive direct effect on the poor and other disadvantaged groups by increasing their ability to access goods, services, and economic opportunities, and by providing opportunities for participation in the supply of transport-related infrastructure and services.[61]

Community severance and barriers to sociability created by infrastructure for cars provide additional examples of the negative impacts of urban accessibility pathways which incentivise private vehicle use.[62] In relation to transport, three common types of 'community severance' have been identified:[63] first, physical barriers such as spatial structures limiting interaction or road traffic causing disruption; second, psychological barriers triggered by perceptions related to traffic noise or road safety; and third, long-term social impacts where communities are disrupted, creating a more sustained form of disconnectedness from certain people and areas close by. A decline in social relationships may not only have negative impacts on physical and mental health, but also on economic resilience and productivity, particularly for the most disadvantaged.[64]

3.1.5 Benefits of Improved Buildings

Mental and physical health are improved by a variety of building-level actions that reduce emissions.

As we typically spend 90% of our time indoors,[65] indoor health conditions are an important consideration. The phenomenon of 'sick building syndrome', prevalent in the 1980s and 1990s, and continuing today, identified building indoor air quality as a major health-influencing factor. Improvements in ventilation systems and less toxic building materials (eg: insulation, wall panelling) improves air quality, often while reducing energy use. Improving energy efficiency can also affect health directly by influencing indoor temperatures, the use and cost of energy (with indirect effects on choices for low income families), and the emission of toxic pollutants to the local environment.[66]

Increasing building green space (eg: green roofs) helps to reduce the urban heat island effect (UHI) and better regulate building temperature by reducing cooling demand in summer months and reducing heating demand in winter months. As shown through Toronto's current work on building overheating, reducing overheating in winter months provides positive health outcomes.[67]

A 2009 analysis of the effect of energy efficiency improvements to the UK housing stock of the type and scale required to meet 2030 climate change mitigation targets suggested overall benefits to health benefits which could be further maximized through judicious selection of intervention measures such as mechanical ventilation and heat recovery (MVHR) systems with particle filtering. If however, such systems are not installed, operated and maintained correctly then there is the potential for health disbenefits.[68] Figure 10 summarizes some health benefits of energy action.

61 Floater, G., Heeckt, C., Ulterino, M., Mackie, L., Rode, P., Bhardwaj, A., ... Huxley, R. (2016). Co-benefits of urban climate action: A framework for cities. LSE Cities.

62 Rode, Philipp, Graham Floater, Nikolas Thomopoulos, James Docherty, Peter Schwinger, Anjali Mahendra, and Wanli Fang. "Accessibility in Cities: Transport and Urban Form," 2014.

63 Bradbury, A., Tomlinson, P.,Millington, A. (2007). Understanding the evolution of community severance and its consequences on mobility and social cohesion over the past century. European Transport Conference 2007, Creating a Livable Environment Seminar, Association for European Transport and Contributors.

64 Rode, Philipp, Graham Floater, Nikolas Thomopoulos, James Docherty, Peter Schwinger, Anjali Mahendra, and Wanli Fang. "Accessibility in Cities: Transport and Urban Form," 2014.

65 U.S. Environmental Protection Agency (EPA). 1989. Report to Congress on Indoor Air Quality — Vol. II: Assessment and Control of Indoor Air Pollution. EPA/400/1-89/001C. Washington, D.C.: US EPA. Available at tinyurl. com/CCN-2013-R017E

66 Milner, J., Davies, M., & Wilkinson, P. (2012). Urban energy, carbon management (low carbon cities) and co-benefits for human health. Current Opinion in Environmental Sustainability, 4(4), 398–404.

67 Wilkinson P, Smith KR, Davies M, Adair H, Armstrong B, Barrett M, Bruce N, Haines A, Hamilton I, Oreszczyn T et al.: Public health benefits of strategies to reduce greenhouse-gas emissions: household energy. Lancet 2009, 374:1917-1929.

68 Wilkinson P, Smith KR, Davies M, Adair H, Armstrong B, Barrett M, Bruce N, Haines A, Hamilton I, Oreszczyn T et al.: Public health benefits of strategies to reduce greenhouse-gas emissions: household energy. Lancet 2009, 374:1917-1929.

Figure 10. Summary of co-benefits of energy efficiency related measures.[69]

Table 4.1 Overview of direct and indirect impacts of improved energy efficiency on health and well-being

Energy efficiency measures	Impacts associated with energy efficiency measures		Potential health outcomes - direct		Potential health outcomes - indirect	
Insulation	Warmer, drier, indoor environment	Comfortable temperature	Reduced deaths from cold and hot spells^{+++}	Reduced excess (winter and summer) mortality^{+++}	Reduced absenteeism from school^{++}	Reduced public and private spending on health
Draught-proofing, pipe lagging, lighting			Reduced symptoms of respiratory disease: asthma, lung cancer, Chronic Obstructive Pulmonary Disease^{+++}		Improved academic performance^{+}	
Extractor fans	Well ventilated/ good air quality	Reduced damp*	Reduced symptoms of cardiovascular disease (e.g. angina, atrial fibralation, risk of stroke)$^{+++}$	Reduced hospitalisation^{++}	Reduced absenteeism from work^{++}	
		Reduced mould*	Reduced depression^{++}		Increased productivity^{+}	
			Reduced arthritis and rheumatism^{++}		Increased earning power^{++}	
			Reduced injuries and death^{+}			
Efficient, effective heating systems		Comfortable temperature	Reduced allergies^{++}	Reduced pharmaceuticals $^{+}$		
		Reduction of gas and particulates* $^{+++}$	Reduced respiratory disease: asthma, lung cancer, Chronic Obstructive Pulmonary Disease^{+++}	Reduced hospitalisation^{+++}		
			Reduced injuries and death^{++}			
		Increased usable living space	Reduced stress^{++}		Increased sociability^{+}	
			Reduced close contact infectious diseases^{++}		Increased space for homework^{+}	
Efficient and effective cooking/ refrigeration systems		Reduced gas and particulates*	Reduced injuries and death^{+}			
		Improved fitness for purpose (i.e. better refrigeration and cooking facilities)	Improved nutritional status^{++}			
	Reduced energy bills/ reduced exposure to energy price fluctuations	Increased sense of control^{+}	Reduced stress and despression^{++}			
		Less fear of falling into debt^{+}				
		More disposable income	Increased purchase of food and other essentials^{+}		Improved nutrition^{++}	
					Increased access to preventative health care^{+}	

Notes: This graphic illustrates the impact pathways from energy efficiency measures to three major impacts. Colour coding established in the impacts column corresponds with the various outcomes a measure could generate for health. This simplified flow diagram does not depict all of the complex interrelationships related to energy efficiency and health and well-being outcomes.
$^{+}$, $^{++}$, or $^{+++}$ symbol indicates the strength of the evidential basis, with $^{+}$ being lowest and $^{+++}$ being highest.
* Caution: Sealing homes without adequate ventilation can cause unintended negative consequences for health.
Source: Unless otherwise noted, all material in figures and tables in this chapter derives from IEA data and analysis.

69 International Energy Agency. (2014). Capturing the multiple benefits of energy efficiency. Paris, France. Retrieved from http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf (page 103).

3.2 Economic Prosperity

The low carbon transition represents a major economic opportunity, but as with any transition, it will be challenging for some.

Economic prosperity is defined as the capability to flourish, a definition developed by the UK Sustainable Development Commission.[70] In articulating this definition, the authors cite broad questions posed by the economist Amartya Sen about how people are able to function: Are they well nourished? Are they free from avoidable morbidity? Do they live long? Can they take part in the life of the community? Can they appear in public without shame and without feeling disgraced? Can they find worthwhile jobs? Can they keep themselves warm? Can they use their school education? Can they visit friends and relations if they choose?[71]

The notion of the capability to flourish as a definition of economic prosperity is consistent with the intention of key City documents such as *One Toronto* and *TO Prosperity: Toronto Poverty Reduction Strategy*. It is complementary to the categories on health and social equity discussed elsewhere in this report, and, as the UK Sustainable Development Commission argued, is also consistent with the intention of preventing dangerous levels of climate change.

In considering potential co-benefits and co-harms of efforts to reduce GHG emissions, the aspects of economic prosperity which will be considered include employment, household incomes, enterprises, public finance, environmental capital, and social capital.

3.2.1 Employment

Studies and projections show immense potential in the green jobs market, effective immediately.

In general, the transition to a low carbon economy is expected to have four categories of impacts on labour markets. First, additional jobs will be created in emerging sectors (eg: electric vehicles and energy efficiency controls). Second, some employment will be shifted (eg: from fossil fuels to renewables). Third, certain jobs will be eliminated (eg: vehicle mechanics who specialize in gasoline motors). Fourth, many existing jobs will be transformed and redefined.[72]

At a city scale, the transition from a fossil fuel based energy system to a system based on renewable energy will require massive investments in infrastructure—from vehicles to district energy, from transit to energy efficiency. This mobilisation of public and private finance—of up to $3.2 billion per city in one estimate[73]—requires many new jobs. For example, the IEA estimates that 8 to 27 jobs are created for each EUR 1 million invested in energy efficiency.[74]

Energy NorthEast (now Acadia Centre) found that efficiency programs in Canada return $3 to $5 in savings for every $1 of program spending, and generate 30 to 52 job-years per million dollars of program spending.[75]

Low carbon technologies tend to be more labour intensive than high carbon activities, at least in the short term (Table 1). In the long term, as the cost of renewable energy decreases the ratios may decline.

70 Jackson, T. (2009). p.21 Prosperity without growth: economics for a finite planet. London ; Sterling, VA: Earthscan.

71 Nussbaum, M., Sen, A., & Research, W. I. for D. E. (1993). The Quality of Life. Oxford University Press.

72 Martinez-Fernandez, C., Hinojosa, C., & Miranda, G. (2010). Green jobs and skills: the local labour market implications of addressing climate change. Working Document, OECD. Retrieved from http://www.oecd.org/regional/leed/44683169.pdf

73 Gouldson, A., Colenbrander, S., McAnulla, F., Sudmant, A., Kerr, N., Sakai, P., ... Kuylenstierna, J. (2014). The economic case for low carbon cities. A New Climate Economy. Retrieved from http://eprints.whiterose.ac.uk/82868/

74 International Energy Agency. (2014). Capturing the multiple benefits of energy efficiency. Paris, France. Retrieved from http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

75 ENE. (2014). Energy efficiency: Engine of economic growth in Canada. Retrieved from http://acadiacenter.org/wp-content/uploads/2014/11/ENEAcadiaCenter_EnergyEfficiencyEngineofEconomicGrowthinCanada_EN_FINAL_2014_1114.pdf

Table 1. Average employment over the life of a facility (jobs/MW).[76]

	Construction, manufacturing, installation	O&M and fuel processing	Total employment
Solar PV	5.76-6.21	1.2-4.8	7.41-10.56
Wind	0.43-2.51	0.27	0.71-2.79
Biomass	0.40	0.38-2.44	0.78-2.84
Coal	0.27	0.74	1.01
Gas	0.25	0.70	0.95

Note: Ranges refer to the results of different studies. Employment is shown relative to the average installed capacity, correcting for differences in capacity factor. (Because renewable installations operate only 20% of the time, compared with 80% for fossil fuel plants, 4 MW of renewable capacity is needed to produce the same output as 1 MW of fossil fuel capacity).

An analysis of policies to reduce vehicular GHGs, air pollutants and noise in Germany found that increasing the modal share of walking and cycling and increased public transit increased the GDP, total employment and employment in transport.[77] Similarly, an assessment in the United States estimated that US$1 billion dollars of spending on public transportation generated over 36,000 jobs, $3.6 billion dollars of output and $1.8 billion dollars of Gross Domestic Product (GDP) annually,[78] and employment generation from transit was 70% higher than the 2.4 million man hours generated per US$1 billion investment in highway projects.[79]

Reducing GHG emissions from the electricity grid through regulation can also result in job creation. In the US, the Natural Resources Defense Council projected that stricter emissions standards for electricity generation could net 210,000 national jobs by 2020.[80]

3.2.2 Household Incomes

Many emissions reduction actions benefit household incomes. However, care must be taken to ensure this does not result in increased spending on emissions-generating activities.

Measures to reduce greenhouse gas emissions can reduce household energy costs, as energy requirements for transportation, electricity and heating and cooling dwellings decline. The result is increased disposable incomes. Transit-oriented urban development (TOD) can reduce per capita use of automobiles by 50 per cent, resulting in household transport expenditure by 20 per cent.[81] An analysis in New York estimated density-related cost savings on cars and petrol translates at approximately US$19 billion annually.[82]

Increased density can result in co-harms as well. For example, if increased density drives up housing prices, lower cost development may occur on the outskirts of the city or in neighbouring municipalities, which can then have the effect of increasing emissions from transportation, as well as congestion, vehicle use and other impacts associated with greenfield development.[83]

The rebound effect—when households use the financial savings resulting from energy efficiency gains to access

76 Fankhaeser, S., Sehlleier, F., & Stern, N. (2008). Climate change, innovation and jobs. Climate Policy, 8(4), 421–429. https://doi.org/10.3763/cpol.2008.0513

77 Doll, C.,Hartwig, J. (2012). Clean, safe and healthy mobility through non-technical measures - Linking individual and public decision levels. Transportation Demand Management - mobil.TUM2012 International Scientific Conference on Mobility and Transport, Munich, Institute of Transportation, Technische Universitaet Muenchen

78 Reno, A.,Weisbrod, G. (2009). Economic Impact of Public Transportation Investment. Transit Cooperative Research Program. Rérat, P. (2012). "The new demographic growth of cities: The case of reurbanisation in Switzerland." Urban Studies 49(5): 1107- 1125.

79 SGA (2011). Recent lessons from the stimulus: Transportation Funding and Job Creation, Smart Growth America.

80 Stanton, E., Comings, T., Takahaski, K., Knight, P., Vitolo, T., & Hausman, E. (2013). Economic impacts of the NRDC carbon standard. Retrieved from https://www.nrdc.org/sites/default/files/ene_13070101a.pdf

81 Arrington, G.,Cervero, R. (2008). TCRP Report 128: Effects of TOD on Housing, Parking, and Travel. Transportation Research Board of the National Academies. Washington, DC.

82 Cortright, J. (2010). New York City's Green Dividend. CEOs for Cities.

83 Gaigné, C., Riou, S., & Thisse, J.-F. (2012). Are compact cities environmentally friendly? Journal of Urban Economics, 72(2), 123–136.

services that use more energy—is an important negative feedback cycle that can reduce the GHG emissions reductions resulting from a project, but may also generate additional wellbeing co-benefits, particularly for low-income households.

3.2.3 Economic Development

Emissions reduction policies and actions have multiple major co-benefits to cities, with many easy wins.

Cities have policy levers that can unlock major economic opportunities, which can lead to new opportunities for for-profit and social enterprises both in the city and as exports to cities around the world. One analysis indicates that low-carbon urban actions available today could generate a stream of savings in the period to 2050 with a current value of US$16.6 trillion.[84]

Economic development can accompany a focus on compact urban form. London's population growth since 2000 has been concentrated within a 10 km radius of the city centre, and half of new floor area between 2004 and 2011 was within 500 metres of transit. London's economy grew around 40% between 1995 and 2011.[85]

Actions that reduce vehicular use and vehicular GHG emissions, such as mode shifting to walking, cycling or transit also reduce congestion, which imposes a variety of costs on enterprises including lost work hours, reduced labour mobility, increased expenditure on fuel, and health costs from air and noise pollution. Such actions, however, need to limit the potential rebound effect from reduced congestion. In terms of regional GDP impacts, the costs of congestion are estimated to be 1.1% for New York, 1.5% for London, 4.0% for Cairo, 4.8% for Jakarta, 7.8% for São Paulo, and up to 15% for Beijing.[86]

The New York City metropolitan region alone is estimated to lose US$13 billion annually as a direct result of traffic congestion, resulting in a notional loss of about 52,000 jobs annually.[87] Effective public transit increases productivity and purchasing power and attracts companies and investment.[88]

Action to reduce GHG emissions can help businesses address key risks. For example, using global fossil reserves is incompatible with emissions reductions targets.[89] Enterprises or investors with ownership of these reserves face a risk that these assets may be stranded. Actions to reduce GHG emissions help to refocus the economy on low carbon solutions; delaying policies on climate action increases the risk of stranded assets.[90] On the opportunity side, new markets and investment opportunities are emerging. For example, the rapid growth of green and climate bonds[91] gives rise to new financial sectors, an opportunity for the City of Toronto.

At the level of the individual enterprise, direct impacts include new business opportunities, including for export,[92] reduced costs and increased productivity, increased value, improved working conditions and risk mitigation. An example of the breadth of different co-benefits that firms can accrue as a result energy efficiency projects are described in Table 2.

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84 Gouldson, A. P., Colenbrander, S., Sudmant, A., Godfrey, N., Millward-Hopkins, J., Fang, W., & Zhao, X. (2015). Accelerating Low Carbon Development in the World's Cities. Retrieved from http://eprints.whiterose.ac.uk/90740/

85 Global Commission on the economy and climate, & Global Commission on the economy and climate. (2014). Better growth, better climate: the new climate economy report : the global report. Retrieved from http://archives.enap.ca/bibliotheques/2014/09/030678240.pdf

86 Gouldson, A. P., Colenbrander, S., Sudmant, A., Godfrey, N., Millward-Hopkins, J., Fang, W., & Zhao, X. (2015). Accelerating Low Carbon Development in the World's Cities.

87 PFNYC. (2013). "Growth or Gridlock." Retrieved 28 April 2014, 2014, from http://www.pfnyc.org/reports/ GrowthGridlock_4pg.pdf

88 PWC. (2013). Cities of opportunity: Building the future. Retrieved from http://www.pwc.com/gx/en/capital-projects-infrastructure/publications/assets/pwc-cities-of-opportunity-building-the-future.pdf

89 Carbon Tracker Initiative. (2011). Unburnable carbon: Are the world's financial markets carrying a carbon bubble? Retrieved from http://www.carbontracker.org/wp-content/uploads/2014/09/Unburnable-Carbon-Full-rev2-1.pdf

90 Nelson, D., Herve-Mignucci, M., Goggins, A, Szambelan, S., Vladeck, T., & Zuckerman, J. (2014). Moving to a low-carbon economy: The impact of policy pathways on fossil fuel asset values.

91 Climate Bonds Initiative. (2016). Bonds and climate change: The state of the market in 2016. Retrieved from https://www.climatebonds.net/files/files/reports/cbi-hsbc-state-of-the-market-2016.pdf

92 Fankhaeser, S., Sehlleier, F., & Stern, N. (2008). Climate change, innovation and jobs. Climate Policy, 8(4), 421–429.

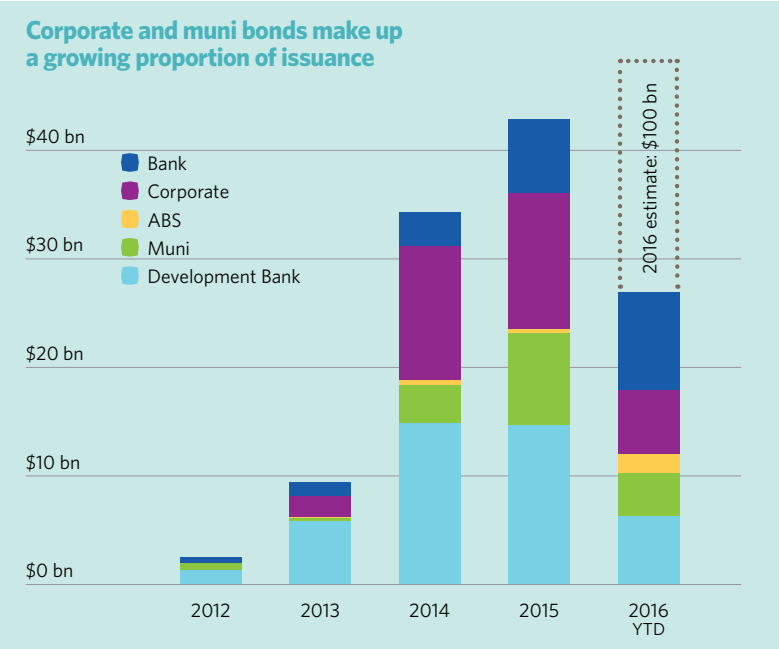

Figure 11. The growth of the labelled green bonds market.[93]

Table 2. Company level benefits from energy efficiency projects.[94]

Benefit	Description
Ability to enter new markets/ increased market share	Overcoming technical barriers to trade or overcoming market perceptions or resistance; Expanded capacity or new product features that enable entrance in new markets.
Reduced production costs	Reduced costs per unit or enabling the company to access and capitalise on a new complementary or substitute factor of production and in doing so opening up new opportunities for growth.
Deferred plant capital investments	Optimising processes or upgrading equipment or extended equipment lifetime can defer the need for capital costs in replacing equipment. Optimising processes for energy efficiency can also lead to situations where certain equipment is redundant.
Corporate risk reduction	Mitigation of corporate risk through reducing liabilities and helping to achieve or go beyond current regulatory requirements.
Improved reputation, corporate image	Improved corporate image through publicising energy efficient (sustainable) business.
Capacity utilisation	More efficient equipment or processes can lead to shorter process times and use of lower cost factors of production (labour and materials), which can lower production costs and enable higher product output.
Improved product quality	Downstream improvements in reductions in product defects and warranty claims as well as contributing to enhanced brand reputation.
Increased product value	Improved quality and consistency contributes to added value which in turn can contribute to enhanced brand reputation.

93 Climate Bonds Initiative. (2016). Bonds and climate change: The state of the market in 2016. Retrieved from https://www.climatebonds.net/files/files/reports/cbi-hsbc-state-of-the-market-2016.pdf

94 International Energy Agency. (2014). Capturing the multiple benefits of energy efficiency. Paris, France. Retrieved from http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf (pg 134).

Benefit	Description
Improved operation	Improved operation and process reliability leads to reduced equipment downtime, reduced number of shutdowns or system failures and can entail reduced process time (which can contribute to increased productivity), process optimisation can also reduce staff time required to monitor and operate a processing plant is therefore reduced, which reduces overhead costs.
Reduced need for maintenance	Energy efficiency projects can lead to investments in new equipment, system optimisation, optimisation or change of processes which in turn can lead to lower maintenance requirements (or avoidance of extraordinary maintenance), reduced costs for maintenance, reduced cost for maintenance materials.
Improved site environmental quality	Improved work environment from improved thermal comfort, lighting, acoustics and ventilation. Improved conditions can help retain and attract skilled staff. Improved work conditions and work environment can increase labour output.
Increased worker health and safety	Process improvements and equipment upgrades implemented as part of energy efficiency projects can reduce the risk and incidence of work-related accidents or negative impacts on worker health. Such improvements can lead to reduced health insurance costs and medical expenses (as well as reduce corporate risk – liability in case of accidents).
Reduction of air pollution and emissions	Reducing energy use can reduce sulphur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), and CO2 emissions and associated credit or reduced compliance costs. Process changes reduce combustion and process emissions can be important to industry when there are regulatory or compliance issues. Associated cost savings include avoiding fines or taxes.
Solid waste reduction	Reducing waste streams through e.g. production improvements, product redesign, improved operation result in less waste, which reduces waste disposal/abatement costs and input materials purchase cost
Wastewater reduction	Process optimisation, improved operation, improved maintenance can reduce water needed to run processes or water needed for cleaning purposes. Reducing wastewater has environmental benefits but can also entail reduced costs for wastewater treatment.
Reduction of input materials, e.g. water	Reduction of input materials reduces upstream environmental impacts from extraction, processing and transport.

3.2.4 Impact on Municipal Finances

A low carbon city reduces municipal capital and operating costs.

Actions to reduce greenhouse gas emissions can impact both municipal revenues and expenditures in a variety of ways, an analysis of these impacts is not typically included in climate action plans.

In terms of dollar value, the most significant impact is the result of land-use planning. Choices on managing urban growth and infrastructure investment lock-in economic and climate benefits for decades and even centuries.[95] Private sector investment follows public sector policies and investments, resulting a long-term configuration of the built environment that is costly to retrofit or undo, a form of path dependency.

95 Floater, G., Rode, P., Robert, A., Kennedy, C., Hoornweg, D., Slavcheva, R., & Godfrey, N. (2014). Cities and the New Climate Economy: the transformative role of global urban growth. Retrieved from http://eprints.lse.ac.uk/60775/

Sprawling patterns of urban growth result in higher municipal capital and operation costs than compact forms of development, a result that correlates with GHG emissions. An analysis in the US estimated direct cost savings for building road and utility infrastructure in smart growth developments relative to dispersed, car-dependent developments at between US$ 5,000 and US$75,000 per household unit.[96]

A comparison of two development trajectories for the City of Calgary calculated total cost savings of 33 per cent for denser development compared to a dispersed development scenario, resulting in capital cost savings of $11.2 billion and operating costs savings of $130 million per year over the next 60 years.[97] The savings result from reduced capital costs in road construction, transit costs, water and wastewater infrastructure and the provision of fire stations, recreation centres, and schools, as well as shorter distances for services.

The operational costs of urban transport are also directly related to urban form characteristics, with sprawling urban development leading to higher costs relative to higher density development.[98] In the case of the City of Toronto where greenfield development potential is limited, benefits can be derived from a focus on transit-oriented development.

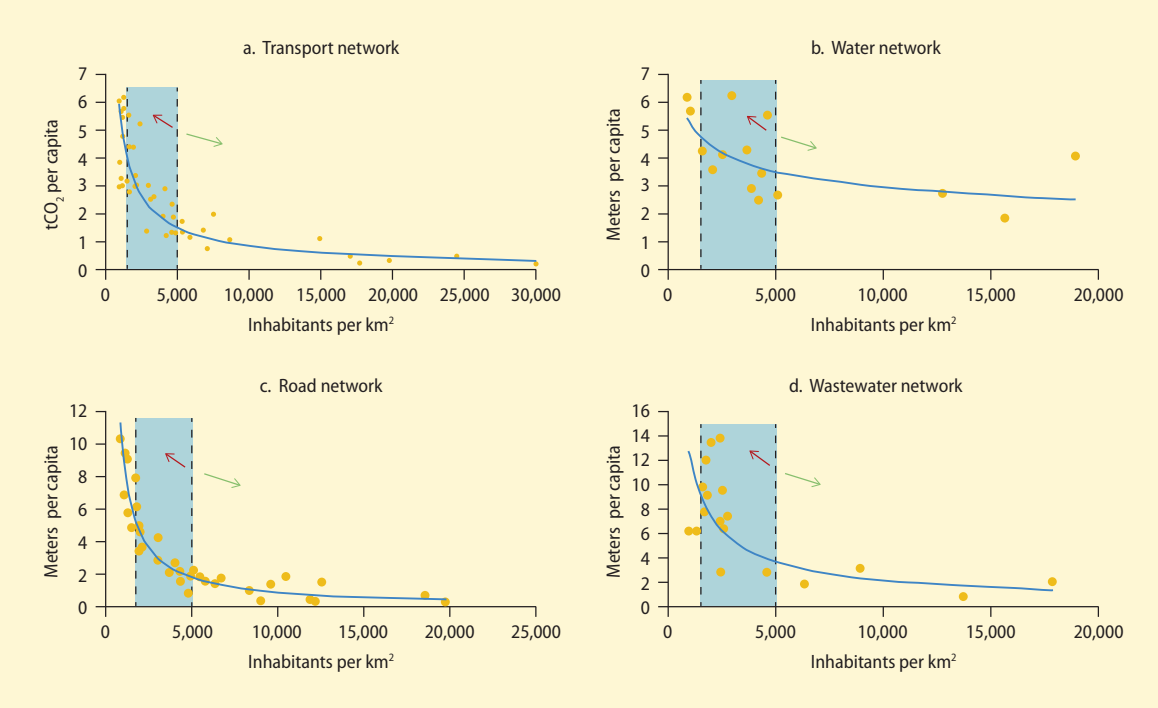

Figure 12. Relationship between density and selected municipal services for different samples of cities.[99]

While compact land-use patterns can reduce the geographical scope for municipal infrastructure and services, energy efficiency measures can also reduce the per unit cost of delivering the services through reduced energy requirements in buildings and transportation.[100]

Investment in low carbon projects can result in new revenue sources of municipalities, In the case of Toronto, the development of Enwave resulted in a significant asset that provided a financial return to the City.

96 Litman, Todd (2016). Understanding Smart Growth Savings. Victoria Transport Policy Institute.

97 IBI Group. (2009). The implications of alternative growth patterns on infrastructure costs. City of Ca

98 Burchell, R. W., Lowenstein, G., Dolphin, W. R., Galley, C. C., Downs, A., Seskin, S., Still, K. G.,Moore, T. (2002). Costs of sprawl--2000, Federal Transit Administration.

99 World Bank, & World Bank. (2014). Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization. The World Bank. Retrieved from http://elibrary.worldbank.org/doi/book/10.1596/978-1-4648-0206-5

100 International Energy Agency. (2014). Capturing the multiple benefits of energy efficiency. Paris, France. Retrieved from http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

3.2.5 Innovation

Cities showing leadership in the 'green economy' show accelerated innovation in all sectors.

Actions that reduce GHG emissions will stimulate innovation as enterprises reposition themselves and invest in research and development to provide new services, business models and markets. This process is and will trigger a process of technology diffusion, adaptation and novel experimentation.

Innovation has a powerful effect on productivity and economic growth as well as creating opportunities to advance well-being. There are the obvious technological innovations, hydrogen fuel cells, electric vehicles, batteries, solar photovoltaics, and others, but there are also social innovations such as energy cooperatives or car sharing, which attract less attention. Other examples will disrupt major established energy delivery systems, such as microgrids, decentralised generation and storage and advanced district energy. District energy, passive houses and microgrids are examples of innovating systems, rather than specific technologies. These examples are but a few of how low carbon innovation is rapidly transforming society and actions to reduce GHG emissions can support and encourage these innovations and innovators.[101]

On the negative side of the equation, innovation can contribute to or enhance inequality as some low-productivity jobs remain.[102] Previous episodes of innovation-led structural change, however, indicate that this process can result in job creation, productivity increases and growth by creating new consumers rather than competing with existing consumers, and providing a simpler offering and applying new business models. In the case of the climate economy, an example is providing electric vehicles as a service.

3.2.6 Reputation

Sustainability branding can garner recognition, investment, and success.

Branding and image are potential co-benefits of climate action. The Brand Finance company valued the City of Vancouver's brand at $31 billion, and found that it was associated with the environment, 'green' living and environmental leadership, ahead of other cities including San Francisco, Singapore, Sydney, Shanghai and Hong Kong.[103] Various rankings including the Sustainable Cities Index,[104] the Green City Index[105] and RepTrak[106] contribute to brand positioning with respect to climate action and sustainability.

3.2.7 Social Capital

Simple urban sustainability interventions grow community and social capital.

Economic prosperity also includes other forms of capital, such as social capital, defined by the OECD as the links, shared values and understandings in society that enable individuals and groups to trust each other and work together.[107]

Actions that encourage people to walk and cycle, increase the opportunity for people to make new and different connections and simply to engage with one another. As Kevin Leyden writes, "Spontaneous 'bumping into' neighbours, brief (seemingly trivial) conversations, or just waving hello can help to encourage a sense of

101 Willis, R., Webb, M., & Wilsdon, J. (2007). The Disrupters: Lessons for low-carbon innovation from the new wave of environmental pioneers. Retrieved from http://sro.sussex.ac.uk/47867

102 Fankhaeser, S., Sehlleier, F., & Stern, N. (2008). Climate change, innovation and jobs. Climate Policy, 8(4), 421–429.

103 City of Vancouver. (n.d.). Written evidence of tthe City of Vancouver- Appendix 82. Retrieved from http://vancouver.ca/files/cov/Evidence-Edgar-Baum-Vancouver-brand-valuation.pdf

104 Arcadis. (n.d.). Sustainable Cities Index 2016. Retrieved November 11, 2016, from https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2016/

105 Economist Intelligence Unit. (2011). US and Canada green city index: Assessing the environmental performance of 27 major US and Canadian cities. Retrieved from http://www.siemens.com/entry/cc/features/greencityindex_international/all/en/pdf/report_northamerica_en.pdf

106 City RepTrak 2015- Most Reputable Cities. (n.d.). Retrieved November 11, 2016, from https://www.reputationinstitute.com/Resources/Registered/PDF-Resources/City-RepTrak-Report-2015.aspx

107 OECD. (n.d.). OECD Insights: What is social capital? Retrieved from http://www.ingentaconnect.com/content/oecd/16815378/2007/00002007/00000001/0107101ec007

trust and a sense of connection between people and the places they live. These casual contacts can occur at neighborhood corner shops, at local parks, or on the sidewalk. To many residents, such contacts breed a sense of familiarity and predictability that most people find comforting".[108]

Putnam, who helped conceptualise social capital, has asked rhetorically if it is more desirable to have more police on the streets or for more people to know their neighbours, illustrating the economic benefits of neighbourhoods and cities that are connected socially.[109]

3.2.8 Environmental Capital

Environmental footprints and trade-offs must be carefully considered when implementing emissions reductions actions and policies.

Environmental or natural capital typically includes three different aspects:[110]

- Land – provides space for human and natural activities.
- Subsoil resources – underground stocks of minerals, fossil fuels and water that provide flows of raw materials and energy.
- Ecosystems – self-maintaining natural systems that provide on-going flows of a wide variety of ecosystem goods and services (e.g., timber and carbon sequestration).

The co-benefits and co-harms of actions to reduce GHG emissions on environmental capital are complex and seldom considered, as illustrated in a paper on energy sprawl.[111] While GHG emissions are a threat to biodiversity and ecosystems, as well as human well-beings, all forms of energy generation, including renewables have a spatial footprint, which has been defined as energy sprawl.

Energy sprawl is defined as the potential habitat effect of different energy fuels and technologies. The land-use intensity of different energy sources varies significantly, from nuclear (1.9-2.8 km2 /TWh/yr) to biofuels (320-375 km2/TWh/yr); in other words, significantly more energy per unit of area can be extracted for nuclear as opposed to biofuels. The only energy source which does not result in increased requirement for land-area is energy efficiency. While energy sprawl considers the impact on habitat, a more compact way of producing energy may still have a greater impact on biodiversity. For example, impacts not related to land-use intensity or energy sprawl include impacts on water quality, air quality, water consumption and water flows. Further, the longevity also varies, for example nuclear contamination may last millennia.

GHG emissions reduction actions that reduce energy consumption or generate renewable energy locally will reduce energy sprawl and the impact on habitat. GHG emissions reduction actions that increase energy requirements such as fuel substitution for renewable energy may increase energy sprawl.

As well as energy sprawl, there are also considerations of patterns of urban development. In contrast to greenfield development, compact, brownfield or compact development, in addition to reducing emissions, can also preserve ecosystem services within the City boundaries and on the periphery of the City, by enabling contiguous greenspace rather than a fragmented landscape. Urban greenspace in turn enhances mental and physical well-being.[112]

A co-impact of efforts to reduce GHG emissions within a city boundary are impacts on embodied emissions—GHG emissions which are released in the process of manufacturing goods that are consumed within a city boundary.[113] Actions to reduce GHG emissions can result in induced reductions or increases of emissions in

108 Leyden, K. (2003). Social capital and the built environment: The importance of walkable neighbourhoods. American Journal of Public Health, 93(9), pp. 1546-1551, p. 1546.

109 Putnam, R. D. (2001). Bowling Alone: The Collapse and Revival of American Community. Simon and Schuster.

110 Smith, Robert. (2016). Comprehensive wealth in Canada- Measuring what matters in the long run. International Institute for Sustainable Development. Retrieved from http://www.iisd.org/sites/default/files/publications/comprehensive-wealth-full-report-web.pdf

111 McDonald, R. I., Fargione, J., Kiesecker, J., Miller, W. M., & Powell, J. (2009). Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America. PLoS ONE, 4(8), e6802.

112 Stott, I., Soga, M., Inger, R., & Gaston, K. J. (2015). Land sparing is crucial for urban ecosystem services. Frontiers in Ecology and the Environment, 13(7), 387–393.

113 Hammond, G. P., & Jones, C. I. (2008). Embodied energy and carbon in construction materials. Proceedings of the Institution of Civil

other locations. While a number of cities are assessing GHG emissions associated with consumption, the impact on embodied energy and emissions is another lens from which to consider potential low carbon actions.

3.3 Social Equity

Actions and policies that reduce GHG emissions will have positive social equity impacts as long as they are holistically and considerately implemented.

Equity is the absence of avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically.[114] Social equity implies fair access to livelihood, education, and resources; full participation in the political and cultural life of the community; and self-determination in meeting fundamental needs.[115]

Not all individuals or all communities are equally affected by climate change.[116] People living in different geographies, with different capacities, and with different jobs will experience climate change effects differently. Climate change vulnerability is the degree to which people and places are at risk from the impacts of climate change, and also takes into account how well they can cope with those impacts.[117]

Climate change resilience is essentially the flip side of vulnerability. It is "the ability to survive, recover from, and even thrive in changing climatic conditions."[118] Some aspects of resilience include physical and psychological health, social and economic equity and well-being, availability of information and effective risk communication, integration of governmental and non-governmental organizations, and social capital and connectedness.[119]

Climate change amplifies vulnerability and hampers adaptive capacity, especially for the poor, women, the elderly, children, and ethnic minorities. These demographics often lack power and access to resources, adequate urban services, and functioning infrastructure. Poverty reduces the capacity to absorb rising food, water, or energy prices. Following a disaster, it is much harder for low-income communities to rebuild especially since fewer low-income people have insurance.

Toronto has explored some of the health inequities between its neighbourhoods using the Urban HEART (Health Equity Assessment and Response Tool), adopted from the World Health Organization. The tool demonstrates that Toronto's geographic core demographics are generally affluent, in good health, well-educated, live in walkable neighbourhoods, and are gainfully employed.

Conversely, Toronto's inner suburbs have higher rates of unemployment, elevated poverty, lower education rates, high levels of marginalization, and poorer health. Rates of diabetes are noticeably higher in the inner suburbs. The inner and outer suburban neighbourhoods have low walkability. The majority of neighbourhoods faring very poorly across population health indicators are also faring poorly across social and human development domains. The tool's outputs indicate a need for a coordinated approach across social, economic, educational, and health sectors to meaningfully address the various issues in any one sector.

Another concept that integrates the idea of place with social equity is Soja's idea of spatial justice,[120] that is,

Engineers - Energy, 161(2), 87–98. https://doi.org/10.1680/ener.2008.161.2.

114 World Health Organization. http://www.who.int/healthsystems/topics/equity/en/

115 Summers, J. K., & Smith, L. M. (2014). The role of social and intergenerational equity in making changes in human well-being sustainable. Ambio, 43(6), 718–728. https://doi.org/10.1007/s13280-013-0483-6

116 Rudolph, L., Gould, S., and Berko, J. "Climate Change, Health and Equity: Opportunities for Action." Oakland, CA: Public Health Institute, 2015. https://www.phi.org/uploads/application/files/h7fjouo1i38v3tu427p9s9kcmhs3oxsi7tsg1fovh3yesd5hx

117 IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (Field CB, Barros VR, Dokken DJ, et al., eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014.

118 Asian Development Bank. Urban Climate Change Resilience: A Synopsis. 2014. Manila, Philippines. Available at http://www.adb.org/sites/default/files/ publication/149164/urban-climate-change-resiliencesynopsis.pdf

119 U.S. Environmental Protection Agency. Reducing urban heat islands: compendium of strategies: trees and vegetation. US EPA, Climate Protection Partnership Division, Office of Atmospheric Programs. 2008. Available at: http://www.epa. gov/heatisland/resources/pdf/TreesandVegCompendium. pdf

120 Soja, E. (2009). The city and spatial justice. Justice Spatiale/Spatial Justice, 1. Retrieved from http://www.jssj.org/wp-content/uploads/2012/12/JSSJ1-1en4.pdf

"location will always have attached to it some degree of advantage or disadvantage." Increasing inequities between 'have' and 'have-not' communities will result in increased polarization between those who feel included and those who feel excluded. To the degree that actions or policies that reduce GHG emissions reinforce existing patterns of neighbourhood advantage or disadvantage, they are co-harms and in reverse, co-benefits; an approach to analysing these effects is explored in Appendix A.

3.3.1 Benefits for Improved Equity

Actions that achieve a low carbon city can vastly improve the lives of many residents and strengthen communities.

Dense, well-managed urban development and the provision of accessible, affordable public transport can have a positive direct effect on the poor and other disadvantaged groups by increasing their ability to access goods, services, and economic opportunities, and by providing opportunities for participation in the supply of transport-related infrastructure and services.

Addressing community severance and barriers to sociability created by infrastructure for cars helps mitigate the negative social impacts of urban accessibility pathways which incentivise private vehicle use. Community severance elements include: physical barriers such as spatial structures limiting interaction or road traffic causing disruption; psychological barriers triggered by perceptions related to traffic noise or road safety; and long-term social impacts where communities are disrupted, creating a more sustained form of disconnectedness from certain people and areas close by. A decline in social relationships may not only have negative impacts on physical and mental health but also on economic resilience and productivity, particularly for the most disadvantaged.[121]

Increasing mixes of land-use in neighbourhoods and providing high quality, frequent, and accessible transit have the effects of bringing jobs close to home and empowering people to get around the city. Concentrating a higher rate of growth in areas with frequent transit service can help expand access and housing choices for marginalized populations. Because access to transit can help to offset higher housing costs, substantial investment in affordable housing close to light rail and frequent bus service can increase access to education and employment opportunities and help to stem displacement.[122]

Densification efforts need to be coordinated with affordable housing strategies and policies ensuring minimal displacement of existing communities, so that vulnerable populations are not adversely affected. Empowering marginalized populations to be active decision-makers in how their communities grow is an important factor of delivering climate change actions in effective, non-discriminatory manners. Additionally, public investments, programs and policies that meet the needs of marginalized populations while reducing racial disparities should be prioritized.[123]

As part of their Equitable Development Implementation Plan, The City of Seattle has developed a spatial Displacement Risk Index and an Access to Opportunity Index that are used in policy, program, and development decision-making (Figure 13). Each have 14 indicators that form an equity analysis of potential decisions. Equity criteria are used to select community development and planning projects.

Energy efficiency and renewable energy installations can have a positive effect on marginalized populations, saving households money spent on energy use. Energy actions also create jobs in trades and construction, as discussed in the section above.

121 Bradbury, Tomlinson and Millington (2007).

122 City of Seattle. "Equitable Development Implementation Plan," April 2016. http://2035.seattle.gov/wp-content/uploads/2016/05/EDI-Imp-Plan-042916-final.pdf.

123 City of Seattle. "Equitable Development Implementation Plan," April 2016. http://2035.seattle.gov/wp-content/uploads/2016/05/EDI-Imp-Plan-042916-final.pdf.

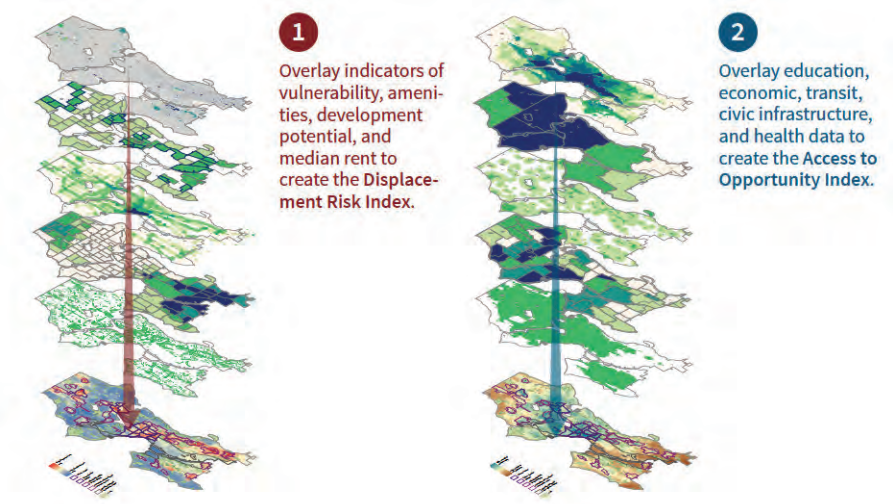

Figure 13. City of Seattle's Displacement Risk Index and Access to Opportunity Index.

3.3.2 The Elderly

The elderly can benefit from improved mobility, health and savings related to low carbon actions.

Increased access to public transportation can overcome barriers for all those who cannot drive or who cannot afford an automobile – low-income people, the elderly, as well as the physically impaired.[124] For the elderly, the physical health implications of sprawl include less active lifestyles, respiratory issues and increased use of medication due to higher ozone levels and increased air pollution, and fatalities due to automobile accidents.[125]

There can also be mental and social capital implications that come with increased isolation and weakened community networks. Further, this isolation and lack of connectivity can negatively impact the mental acuity of the elderly, all together creating a vicious cycle of increasing loss of capacity – physical, psychological, mental and spiritual.

A built environment designed for walking encourages physical fitness and exercise, increasing overall health among elderly people. Oxygen uptake and flexibility both increase with physical activity,[126] and it has also been proven to increase psychological and spiritual health. According to one author, "physical activity in the natural environment not only aids an increased life-span, greater well-being, fewer symptoms of depression, lower rates of smoking and substance misuse but also increases ability to function better at work and home".[127]

As already mentioned, retrofitting buildings for energy efficiency can reduce the impact of heat on the elderly, a high-risk population in terms of developing severe heat stroke, heat exhaustion, fainting, swelling or heat cramps during a heat wave. Heat stroke can be a severe problem for the elderly due to an increase in the urban heat island effect.[128]

124 Jackson, R. and C. Kochtitzky. (2010). Creating a Healthy Environment: The Impact of the Environment on Public Health. Centers for Disease Control and Prevention. Sprawl Watch Clearinghouse Monograph Series.
125 Frumkin, H. (2002). Urban Sprawl and Public Health. Public Health Reports, 117, 201-217.
126 Morris, N. (2003). Health, Well-being and Open Space. OPENspace: the Research Centre for Inclusive Access to Outdoor Environments. Edinburgh College of Art and Heriot-Watt University.
127 Morris, 2003, p.17.
128 Frumkin, 2002.

3.3.3 Children

Current and future children are the most at risk from climate change impacts.

Although they will bear the burden of climate change impacts, children and the rights of future generations currently have little say in climate change-related policy. Empowerment of children in climate action decision-making processes encourages a sense of contribution, ownership and pride that in turn encourages sustained civic and community engagement. Taking action on climate change now will lessen the climate impacts burden on children throughout their lives. Leaving climate change unaddressed would likely lead to shorter lifespans, increased risk of disease, increased risk of poverty, and increased risk of orphanhood for children.

3.3.4 Intergenerational Equity

In discussions on equity, future generations are seldom discussed.

Climate action can lend itself to intergenerational equity through approaches that safeguard the rights of the most vulnerable and share the burdens and benefits of climate change actions.[129] In particular, the burden of action increases the longer action is delayed. In 2015, twenty-one youth from across the United States filed a landmark constitutional climate change lawsuit against the federal government in the U.S. District Court for the District of Oregon. The youth successfully asserted that, in causing climate change, the federal government violated the youngest generation's constitutional rights to life, liberty, property, as well as failed to protect essential public trust resources.[130]

3.3.5 Dependencies

Co-benefits and co-harms within complex systems such as cities are sometimes unpredictable.

Co-benefits and co-harms cannot be evaluated in the context of only one policy or action, as they are integrated within a system. For example, the co-benefit fromreduced air pollution from resulting from decreased vehicle use associated with transit-oriented development will be limited if transit service is inadequate.

A project in the UK investigated the relationship between the policy to reduce GHG emissions in the housing system with outcomes for health, equity and environmental sustainability, using a complex system approach, illustrated in Figure 14.

The analysis illustrates the complexity of interactions with respect to policies to and actions that reduce GHG emissions and therefore emphasises the need to consider co-benefits and co-harms in order to better understand the system and increase the effectiveness of the interventions. One specific outcome of this study was a list of criteria for future policy assessment with an emphasis on co-impacts. The list of criteria included carbon emissions from housing, community connection, fuel poverty, housing adaptation to climate change, affordability, mental and emotional well-being, physical well-being/health, policy coherence and social and income equity.

129 Mary Robinson Foundation. "Climate Justice: An Intergenerational Approach," November 2013. http://www.mrfcj.org/media/pdf/Intergenerational-Equity-Position-Paper-2013-11-16.pdf.

130 Our Children's Trust. (2016). Landmark US federal climate lawsuit. Retrieved November 14, 2016, from https://www.ourchildrenstrust.org/us/federal-lawsuit/

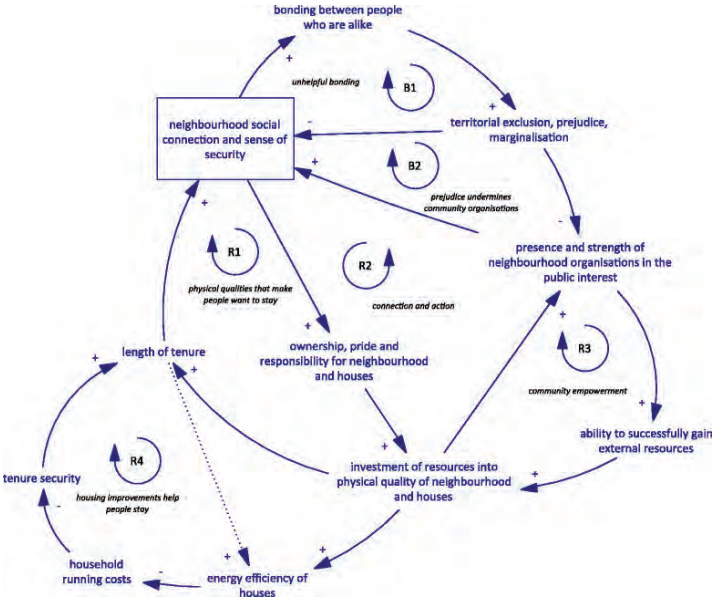

Figure 14. A causal loop diagram illustrating the relationship between energy efficiency and other aspects of housing.[131]

Diagram explanation: *Community connection and the physical quality of neighbourhoods. Arrows with a positive sign (+) indicate a change in the variable at the arrow-tail leads to a change in the variable at the arrow-head in the same direction. Arrows with a negative (−) sign indicate a change in the arrow-tail variable leads to an inverse change in the arrow-head variable (opposite direction). R – Reinforcing loop, the result of which is an amplification of the initial pattern of behaviour. B – Balancing loop, the result of which may be to dampen the initial pattern of behaviour or create oscillation). The dashed connection was one where there remained disagreement about the relationship.*

3.3.6 Delivery and Implementation

Consideration of governance mechanisms and business models may be as critical to the success of the low carbon actions as consideration of technical and economic factors.

While the nature of the action or policy determines whether it is accompanied by co-benefits or co-harms, the delivery mechanism and implementation process also have a significant influence on social equity. For example, co-benefits associated with renewable energy include reduced air pollution with its associated health benefits and stabilised energy prices. Co-benefits or co-harms associated with social equity are, however, dependent on the policy context that enables the delivery of renewable energy. Questions that can help articulate the social impacts of renewable energy deployment are as follows:[132]

- Function and service: what is the generated energy being used for in terms of the services (comfort, warmth, visibility, mobility etc.) that it is providing? Who utilises these potential services and what physical and institutional distance is there between the point of energy production and the point of service 'consumption'?
- Ownership and return: who owns the technology and how is this ownership organised – privately, publicly, collectively – and at what scale – locally, nationally, internationally? What benefits, monetary or otherwise, are returned as a consequence of ownership?

131 Macmillan, A., Davies, M., Shrubsole, C., Luxford, N., May, N., Chiu, L. F., ... Chalabi, Z. (2016). Integrated decision-making about housing, energy and wellbeing: a qualitative system dynamics model. Environmental Health, 15(Suppl 1). https://doi.org/10.1186/s12940-016-0098-z

132 Walker, G., & Cass, N. (2007). Carbon reduction,"the public"and renewable energy: engaging with socio-technical configurations. Area, 39(4), 458–469.

- Management and operation: who manages, controls and maintains the hardware and how is this organised – privately, publicly, collectively; locally, remotely? To what extent is management regulated and through what principles and mechanisms?
- Infrastructure and networking: is the energy that is generated fed into an electricity or heat network (is it on or off grid?) and if so, what scale of network – local, regional or national? What/who does this network supply and how is it managed (locally, distantly; publicly or by regulated market?)

Table 3 illustrates how different delivery mechanisms will benefit different segments of the population and many development pathways may result in or enhance patterns of social unevenness and inequality.[133] Ensuring that marginalised or low income people are engaged, can participate and benefit from renewable energy and other low carbon actions will require careful analysis of policies; an analysis found decentralising electricity generation in the UK without consideration of governance and business models could perpetuate or even exacerbate socio-economic and spatial inequalities.[134] Consideration of the social relations and social pathways may be as critical to the success of the low carbon actions as consideration of the technical and economic factors.

Table 3. Mechanisms of delivering renewable energy; adapted.[135]

Mode of delivery	Underlying discourses	Ownership and return
Public utility	Universal provision	Public, return to state
Private supplier	Consumer choice, market logic	Private, differentiated, return to shareholders
Community	Participation	Cooperatives, return to members
Household	Personal environmental responsibility, self reliance, autonomy	Household as owner or host; direct or indirect return to household
Business	Business efficiency	Business as owner or host; direct or indirect return to business

Cities will require major investments to finance low carbon pathways, and in many cases private capital will be involved in those financing arrangements. One typical pathway for securing financing is bonds, an investment opportunity that is only accessible to high net worth investors and major investors such as pension funds and insurance companies.

New pathways, however, are emerging; one idea, for example, is to issue low value bonds ($100 or more) using a platform such as Neighborly.[136] At this investment level, bond offerings could be used as a mechanism to for low income community members to accumulate investments while simultaneously financing low carbon actions in the same community. An additional benefit is that the community would have a vested interest in the success of the actions.

133 Walker, G., & Cass, N. (2007). Carbon reduction,"the public"and renewable energy: engaging with socio-technical configurations. Area, 39(4), 458–469.

134 Johnson, V., & Hall, S. (2014). Community energy and equity: The distributional implications of a transition to a decentralised electricity system. People, Place and Policy Online, 8(3), 149–167. https://doi.org/10.3351/ppp.0008.0003.0002

135 Walker, G., & Cass, N. (2007). Carbon reduction,"the public"and renewable energy: engaging with socio-technical configurations. Area, 39(4), 458–469.

136 Cortese, A. (2015, July 10). Putting the Public Back in Public Finance. The New York Times. Retrieved from http://www.nytimes.com/2015/07/12/business/mutfund/putting-the-public-back-in-public-finance.html

Part 4: Evaluating Co-benefits and Co-harms

4.1 Approach to Evaluating Co-benefits and co-harms

The evaluation of co-benefits or co-harms is challenging because the techniques for measuring each impact vary and in some cases, the technique of measuring itself may be inappropriate. As well, cause and effect relationships are imprecise. The Impact Assessment Guidelines, produced by the European Commission, recommend analysis methods that can integrate a mixture of qualitative, quantitative and monetary data, with varying degrees of certainty.[137]

The IEA distinguishes between two types of evaluations: a comparative appraisal (ex ante) in which one assesses and chooses between various policies and an impact assessment (ex post) when the impacts of a chosen action or policy are evaluated.[138]

A key step in the evaluation of policies and actions is establishing the reference scenario or baseline as this 'sets the bar' against which impacts are assessed. The assumptions underlying the reference scenario need to be transparent and the effect of variation in those assumptions should be explored in order to better understand the impact of the reference case on the magnitude of the co-benefits and co-harms.

This section describes several key approaches to evaluation, drawing on the results of this paper. Marginal abatement curves are a useful tool- with limitations- for assessing the economic impacts of actions. Multi-criteria analysis is a decision-making approach that enables the prioritisation of actions or policies with different types of inputs. Finally, indicators are used to track progress and measures impact over time. Each of these approaches has strengths and weaknesses and different considerations, described below.

4.1.1 Evaluating Economic Impacts: Marginal Abatement Curves

MACs are quick, compelling visual assessments of 'bang-for-your-buck' actions, making for excellent communication tools.

Marginal abatement cost (MAC) curves are a visual (graphic) illustration of the results of model-based scenarios that convey both the economic co-benefits (costs or savings) of an action or policy and the potential GHG reduction that can be achieved with the action or policy.

Marginal abatement curves are calculated by dividing the net present value (NPV) of an action or policy by the GHG emissions reductions that are generated over the lifetime of that project. NPV estimates the overall current value of a series of cash flows including all future cash flows. It requires an assessment of the dollar value of the initial costs, as well as the costs and benefits over the duration of the project life, discounted in terms of a present value. If a dollar value can be assigned other co-benefits or co-harms, they can be incorporated into this equation.

As an example, the Global Commission on the Climate and Economy took the global MAC curve developed by McKinsey & Company and applied benefits which could be quantified in financial terms such as health benefits from air quality. Note that this MAC curve is reversed vertically in comparison with other MAC curves, so that the measures which have a benefit are positive and those with a cost are negative. The results indicated that many abatement options have a positive benefit even in narrow financial terms become substantially larger and more numerous once multiple benefits are included. Some options with net costs swing to net gains and net benefits of some energy efficiency options are tripled.

MAC curves have three important limitations to note. First, the MAC curve implies that a given amount of

137 European Commission. (2009). Impact Assessment Guidelines. Retrieved from http://ec.europa.eu/smart-regulation/impact/commission_guidelines/docs/iag_2009_en.pdf

138 International Energy Agency. (2014). Capturing the multiple benefits of energy efficiency. Paris, France. Retrieved from http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf

GHG reductions is associated with a certain carbon price; in all likelihood there are a number of government and market failures that will inhibit that action even if that level of carbon price is implemented. Second, MAC curves do not provide information on the time dimension of the measures, for example how long it takes to implement a measure, thus which are more urgent and if there is there is an order to implementation in that one action or policy is required in order to incur reductions from another.[139] Third, MAC curves do not account for distributional impacts, for example who bears the costs and who derives the benefits of policies and actions.[140]

Making decisions solely on the abatement cost can limit future emissions reductions because of slow capital turnover, slow technological diffusion, availability of skilled workers, financial constraints and institutional constraints and social norms. For this reason, the World Bank indicates that short-term targets need to be optimised for long-term objectives and not short-term objectives. For example, the in the case of decarbonising the European electricity sector, the optimal approach is not, as a purely financial analysis would indicate, to switch from coal to natural gas to electricity, but rather to invest early in renewable generation to avoid stranded investments in gas power plants.[141]

The temporal aspect can be added to MAC curves by connecting it with a wedge curve, which then displays when early efforts are needed to reduce emissions, even if they are more expensive.

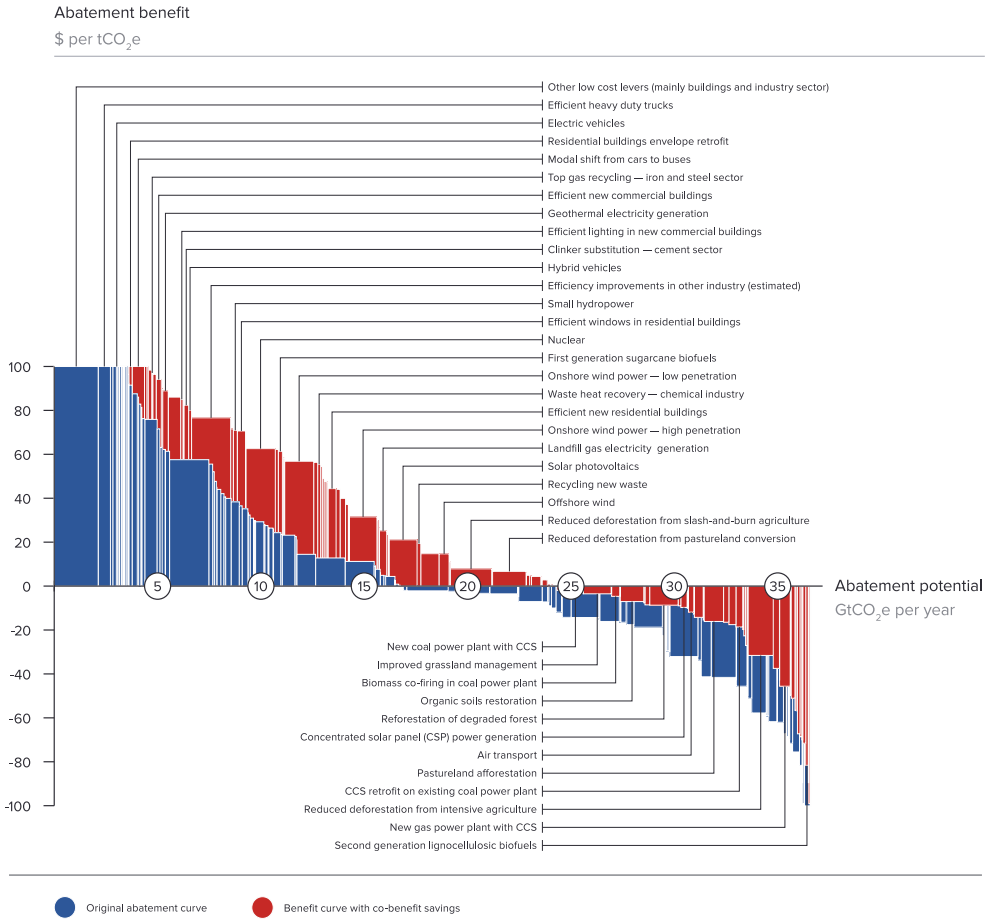

Figure 15. Impact of including co-benefits on the abatement costs of measures to reduce GHG emissions.[142]

139 Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. M. (2015). Decarbonizing development: three steps to a zero-carbon future. Washington, DC: World Bank Group.

140 Saujot, M., & Lefèvre, B. (2016). The next generation of urban MACCs. Reassessing the cost-effectiveness of urban mitigation options by integrating a systemic approach and social costs. Energy Policy, 92, 124–138.

141 Lecuyer, O., & Vogt-Schilb, A. (2014). Optimal transition from coal to gas and renewable power under capacity constraints and adjustment costs. World Bank Policy Research Working Paper, (6985). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2475072

142 142 Global Commission on the economy and climate. (2014). Better growth, better climate: the new climate economy report : the global report. Retrieved from http://archives.enap.ca/bibliotheques/2014/09/030678240.pdf

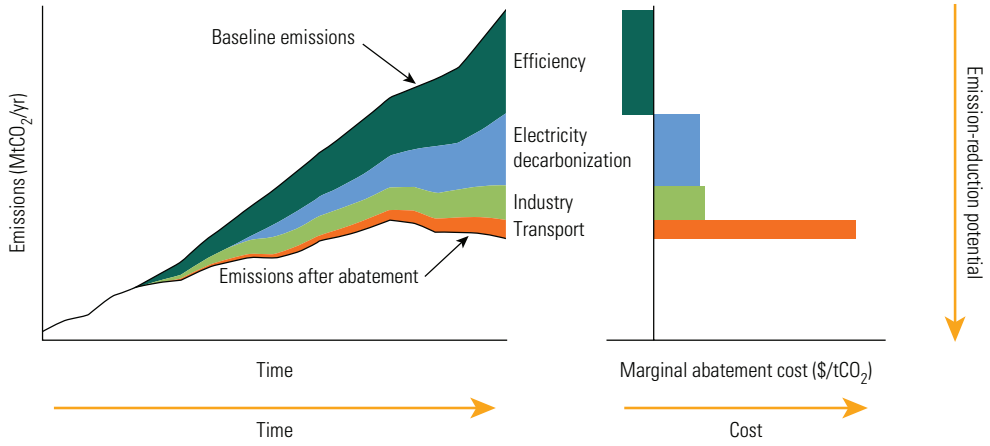

Figure 16. Combining a wedge curve and an MAC curve.[143]

4.1.2 Prioritising Actions: Multi-Criteria Analysis

MCA offers a decision-making aid to meaningfully discuss and assess quantitative and qualitative elements of actions.

There are many different strategies to translate co-benefits and co-harms into a dollar value, including market valuation, willingness to pay, willingness to accept, revealed preference, con-joint analysis, direct query, an orders of magnitude approach others. If all the relevant co-benefits and co-harms can be assigned a dollar value, traditional economic decision-making techniques such as cost-effectiveness analysis and benefit-cost analysis can be applied.

In cases when the impacts cannot be quantified for any of a number of reasons, MCA (also known as multi-criteria decision analysis) is appropriate. MCA can manage quantitative, monetary and qualitative data in a single framework, as well as varying degrees of certainty. MCA provides a transparent analysis of the impacts and distributional effects. The consulting team prepared a separate summary of MCA as a decision-making tool, titled *Modelling Toronto's Low Carbon Future: Multi-Criteria Analysis Backgrounder*.

As MCA is used to prioritise actions, it can also incorporate criteria beyond co-benefits and co-harms, for example criteria related to implementation, such as capital costs, political considerations or even a general assessment of implementation feasibility.

Table 4 includes a sample list of criteria for a MCA for TransformTO that incorporates findings from this paper, the overall objective of GHG reductions, and implementation considerations. Note that the criteria are listed in a random order. The actual criteria used in the MCA will be co-developed with the TransformTO team and the Modelling Advisory Group.

143 Global Commission on the economy and climate. (2014). Better growth, better climate: the new climate economy report : the global report. Retrieved from http://archives.enap.ca/bibliotheques/2014/09/030678240.pdf

Table 4. Sample overview of criteria for MCA.

#	Criteria	Question	Quantitative/ qualitative	Measurement	Primary themes
1	Public health outcomes	How does the action impact chronic diseases?	Quantitative	Health outcomes	Health, social equity
2	Air pollution	How does the action impact air pollution in the City?	Quantitative	Criteria air pollutants	Health, social equity
3	Poverty levels	What is the impact on poverty in the City?	Qualitative	Number of people of below the low income cutoff	Social equity
4	Employment impacts	What the impact of the low carbon scenario on employment?	Quantitative	Person years of employment created	Social equity, economic prosperity
5	Household energy costs	What is the impact on household energy costs?	Quantitative	$/household	Social equity, economic prosperity
6	Well-being	What is the impact of the action on perceived well-being?	Qualitative	Well-being survey	Social equity, economic prosperity
7	Accessibility to destinations	Does the action increase the ability of people to access destinations by active modes or transit?	Quantitative	% of modes by walking, cycling or transit	Health, social equity
8	Walking and cycling	Does the action increase the ability of people to access destinations by active modes or transit?	Quantitative	% of modes by walking or cycling	Health, social equity
9	Social capital	What is the impact of the action in the level of trust people have in others?	Qualitative	Level of trust	Health, social equity
10	Feasibility of implementation	How difficult is the policy to implement?	Qualitative	N/a	N/a
11	GHG reduction	What is the associated GHG emissions reduction?	Quantitative	tCO2e	Climate impact
12	Cost of implementation	What is the capital cost of the action?	Quantitative	$	Economic prosperity
13	Prevents lock in	Does the action avoid irreversible decisions or getting locked into patterns or technologies that would be difficult and costly to reverse?	Qualitative	N/a	Climate impact
14	Investment opportunities	What is the investment opportunity?	Quantitative	IRR	Economic prosperity
15	Abatement cost	What is the marginal abatement cost per tCO2e reduced?	Quantitative	$/tCO2e	Economic prosperity
16	Political considerations	Does the action resonate with the current political discourse?	Qualitative	N/a	N/a

4.1.3 Tracking Progress: Indicators

Thoughtful, rigorously tracked indicators will provide an indication of progress. Care must be taken in choosing them so that they are not too onerous to manage. Indicators that can be represented spatially lend themselves to easily assessed visual displays.

Indicators provide easily understood information on the impact of complex projects by separating out discrete aspects as a mechanism to measure an otherwise unmeasurable outcome. These characteristics are also their weakness as they can oversimplify and hide the interrelations of the system as a whole. The set of indicators is by definition biased according to the worldview of those who select them.[144] The OECD has developed an indicators framework appropriate to this analysis and consistent with the focus on health, economic prosperity and social equity, addressing:[145]

- the well-being of people, rather than on the macro-economic conditions of economies;
- the well-being of different groups of the population, in addition to average conditions.
- well-being achievements, measured by outcome indicators, as opposed to well-being drivers measured by input or output indicators.
- objective and subjective aspects of people's well-being as both living conditions and their appreciation by individuals are important to understand people's well-being.

In terms of scope, the OECD's indicators address material living conditions, quality of life and the sustainability of the socio-economic and natural systems where people live and work. Table 5 illustrates how the impact of a general set of actions or policies to reduce GHG emissions on the OECD's well-being indicators and provides insight on how they can be evaluated.

Table 5. Relationship between co-benefits and co-harms and OECD's well-being indicators.

Well-being indicator themes	Co-benefits of actions to reduce GHG emissions	Co-harms of actions to reduce GHG emissions	Evaluation technique
Housing	Household energy costs decline. Quality of housing increases.	Cost of housing can increase in urban centre.	Impact on household energy costs can be quantified.
Income	Increased disposable income as energy costs decline.		Qualitative
Jobs	Jobs created in new sectors.	Jobs lost due to transitioning economy.	Quantitative
Social connections	Increased social connections in walkable neighbourhoods.		Qualitative
Education and skills	New fields of expertise require stimulating education and skills development.	Some traditional fields of training become less relevant.	Qualitative
Environmental quality	Air pollution is reduced, energy sprawl is reduced, more green space is protected.		Air pollution impacts can be quantified (not currently included in CityInSight).

144 Jones, A., Mair, S., Ward, J., Druckman, A., Lyon, F., Christie, I., & Hafner, S. (2016). Indicators for sustainable prosperity? Challenges and potentials for indicator use in political processes. Economic & Social Research Council. Retrieved from http://www.cusp.ac.uk/wp-content/uploads/WP03-AJ-et-al-2016-Indicators.pdf

145 OECD. (2011). Compendium of OECD well-being indicators. Retrieved from https://www.oecd.org/std/47917288.pdf

Well-being indicator themes	Co-benefits of actions to reduce GHG emissions	Co-harms of actions to reduce GHG emissions	Evaluation technique
Civic engagement	Civic engagement increases in development of climate action plans.		Qualitative
Health status	Health is improved from increased active transportation.	Potential impact of increased exposure to air pollution.	Active transportation impacts can be quantified.
Subjective well-being/life satisfaction	Well-being benefits from reducing a public harm.[146]		Qualitative
Safety	Unknown impact		Qualitative
Work-life balance	Unknown impact		Qualitative

In a report for the TransformTO project, a Delphi model was proposed as a mechanism to identify or validate indicators related to equity, a three step process.[147] The report also cites the UrbanHeart @Toronto indicators, which were analysed spatially for each neighbourhood in the City of Toronto, as a measure of well-being:[148]

- Unemployment rates
- Percent of residents who are in low-income
- Percent of residents accessing social assistance
- High school graduation rates
- Percent of persons 25-64 with post-secondary training and education
- Marginalisation index
- Municipal voting rates
- Access to healthy food options
- Neighbourhood walkability score
- Local parks and green space
- Community space where residents can meet
- Diabetes rates
- Premature mortality rates
- Percent of residents who report very good or excellent mental health
- Preventable hospitalisation rates

As these indicators are spatial, it is possible to evaluate the impacts of actions to reduce GHG emissions on a number of these indicators (see Appendix A); however most would rely on a qualitative assessment.

Table 6 lists each of the co-benefits or co-harms considered in this paper along with relevant indicators. The use case for these indicators would be to systematically track the impacts of low carbon actions on co-benefits and co-harms.

146 Lubell, M., Zahran, S., & Vedlitz, A. (2007). Collective Action and Citizen Responses to Global Warming. Political Behavior, 29(3), 391–413. https://doi.org/10.1007/s11109-006-9025-2

147 City of Toronto. (2016). TransformTO- Equity indicators: Final document.

148 Centre for Research on Inner City Health, City of Toronto, Toronto Central local Health Integration Network, United Way Toronto, & WoodGreen Community Services. (2014). Urbanheart@Toronto: An evidence-based standard for measuring the well-being of Toronto's neighbourhoods. Retrieved from http://www.torontohealthprofiles.ca/urbanheartattoronto/UrbanHeart_ExecutiveReport.pdf

Table 6. Sample indicators to assess the impact of the low carbon scenario on co-benefits and co-harms associated with health, social equity and economic prosperity.

Co-benefit/ co-harm	Possible indicator	Spatial
Health		
Air quality	Change in city-wide air pollution levels.	No
Physical activity	Change in active transportation mode shift.	Yes
Decreasing noise	Total vehicular trips by neighbourhood.	Yes
Increasing accessibility	Portion of dwellings within 400m of frequent transit.	Yes
Improved buildings	Portion of dwellings and commercial buildings retrofit.	Yes
Economic prosperity		
Employment	Number of new jobs created.	No
Household incomes	Impact on household energy costs by neighbourhood.	Yes
Economic development	Total investment required to support the low carbon scenario.	No
Municipal finances	No indicator identified	
Innovation	No indicator identified	
Reputation	No indicator identified	
Social capital	No indicator identified	
Environmental capital	Difference in greenspace between the BAU scenario and low carbon scenario.	Yes
Social equity		
Poverty	Impact on household energy costs by neighbourhood.	Yes
Elderly	Active transportation mode share in the neighbourhoods with a high portion of the population over 65.	Yes
Children	Portion of the population within 400m of a school.	Yes
Intergenerational equity	Ratio of per capita GHG emissions over level of per capita emissions required to prevent dangerous climate change.	Yes

4.1.4 Uncertainty

When faced with considerable uncertainty, it is important to keep options open.

Uncertainty reigns in many aspects of these types of analysis, from developing the baseline and reference case to assessing the impacts on GHG emissions and co-benefit and co-harms, and it is challenging for the participants to agree on the relevant parameters. The World Bank has characterised this condition as deep uncertainty and recommends the following guidelines for policy development:[149]

1. Avoid making irreversible decisions and getting locked into patterns or technologies that would be difficult and costly to reverse if new information or changing preferences arise.

2. Climate policies should be robust, in that they should perform well under a broad range of possible futures, rather than just being optimal for the most likely future.

3. Climate policies need to combine multiple policy goals and create consensus.

The guiding metrics recommended are synergies, when a policy or action provides net local and immediate co-benefits and urgency, when a policy or action is associated with economic inertia. Table 7 illustrates how different actions can be categorized in terms of synergy and urgency. The prioritized actions are those with

149 Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. M. (2015). Decarbonizing development: three steps to a zero-carbon future. Washington, DC: World Bank Group.

greater inertia and risk of irreversibility as well as more positive synergies. In this case, actions which satisfy those two considerations are land-use planning and public transit. The provision of renewable energy is easier to implement at any point and does not provide as many synergies and therefore is a lower priority.

Table 7. Example of analysis of measures using synergies and urgency.[150]

		Synergies	
		Low or negative (trade-offs) (to be considered at higher level of income or paid for by external funds)	Positive (attractive regardless of income, provided that financial mechanism can be found)
Urgency	Low: less inertia and irreversibility risk	• Higher-cost renewable power threatening electricity costs • Reforestation/afforestation of degraded landscapes	• Lower-carbon, lower-cost energy supply (e.g., hydro) • Loss reduction in electricity distribution • Loss reduction in food supply chain • Energy demand management (e.g., in building)
	High: greater inertia and irreversibility risk	• Reduced deforestation • Increase investment in energy and transport R&D • Pilot project with expensive technologies • (carbon capture and storage, concentrated solar)	• Land-use planning • Public urban transport and transit-oriented development

150 Adopted from: Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. M. (2015). Decarbonizing development: three steps to a zero-carbon future. Washington, DC: World Bank Group.

Recommendations and Conclusions

This report has reviewed the academic and grey literature on the co-benefits and co-harms of actions and policies designed to reduce GHG emissions, focusing on health, social equity and economic prosperity. Avoiding dangerous climate change, which has profound implications for all of these areas, was not reviewed as addressing this issue through reducing emissions was the primary objective.

The literature review indicates that there are many co-benefits associated with policies or actions to reduce GHG emissions and very few co-harms; those co-harms that there are can be managed through careful policy design. For example, increased exposure to air pollution associated with compact city planning can be managed through careful urban design. Gentrification associated with transit-oriented development can be addressed with an affordable housing strategy.

There are prerequisites and/or dependencies for many co-benefits. Compact development enables district energy which in turn provides energy security. These dependencies are an illustration that most low carbon policies or actions represent an intervention into a complex system, which has unpredictable outcomes, resulting from feedback cycles and high levels of uncertainty.

This observation gives rise to another: most climate action plans are focused on the technological pathways to a low carbon future but the social pathways are likely as important, if not more so, to ensuring broad support, and improved social and economic outcomes for everyone.[151]

In total, the evidence in this paper indicates that a low carbon action plan can provide a host of co-benefits for health, social equity and economic prosperity.

Building on the work of the TranformTO project, the City could consider undertaking the following steps to further integrate considerations of co-benefits and co-harms into its low carbon action work. The list below provides some considerations and/or opportunities:

1. **Prioritise actions using co-benefits:** Develop a set of criteria to use as a co-benefits/co-harms lens to facilitate the prioritisation of actions using MCA with multiple stakeholders.

2. **Consider co-benefit/co-harms at the neighbourhood level:** Spatially evaluate the low carbon scenarios against Wellbeing Toronto [CF1] indicators, as illustrated in Table 6. There is a unique opportunity to assess the impact of the low carbon scenario on particular neighbourhoods in Toronto. This assessment will likely yield unanticipated insights.

3. **Consider co-benefits/co-harms in program design:** Integrate considerations of social equity, health and economic prosperity into the design of policies and actions to maximize the co-benefits.

4. **Monitor impacts using indicators:** Using the analysis in recommendations #1 and #2, develop a standardized set of indicators such as those described in Table 6 to enable tracking of the co-benefit/co-harm impacts of the low carbon actions at an aggregate level on an ongoing basis.

151 Gillard, R., Gouldson, A., Paavola, J., & Van Alstine, J. (2016). Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation: Transformational responses to climate change. Wiley Interdisciplinary Reviews: Climate Change, 7(2), 251–265. https://doi.org/10.1002/wcc.384

Glossary

This glossary clarifies how key terms have been used in this report.

Ancillary benefits/co-benefits have been traditionally used to describe the impacts of energy efficiency beyond reductions in energy demand – i.e. the benefits that occur in addition to a single prioritised policy goal. While these terms have been used interchangeably with multiple benefits in other literature, this publication opts to use multiple benefits in order to avoid a pre-emptive prioritisation of various benefits; different benefits will be of interest to different stakeholders.

Benefit-cost ratio is the ratio of monetised outcome benefits to project investment costs (it can be understood interchangeably with cost-benefit ratio, used in some publications). This calculation is the result of a benefit-cost analysis, a commonly used method for assessing whether a policy delivers good value or return on investment for its actual cost.

Discount factor is the ratio applied to current values in order to derive a value for future annual revenues and costs; it reflects factors such as perceived future risk and the premium that is placed on immediate revenues and deferred costs.

Economic prosperity is defined as the capability to flourish.

Effect describes an additional factor (or factors) that can influence how benefits and impacts manifest.

Energy efficiency improvement is an improvement in the ratio of energy consumed to the output produced or service performed. This improvement results in the delivery of more services for the same energy inputs or the same level of services from less energy input.

Equity is the absence of avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically.

Fuel poverty refers to a situation in which a household technically has access to energy but cannot afford adequate energy services to meet their basic needs (see Box 4.1).

Impact is any kind of result from an action or measure. In this publication, impact is used to describe any result, positive or negative, arising from an energy efficiency measure. In this context, the impact could be reduced energy consumption, for example, or increased economic activity (which may drive up energy consumption overall).

Health is defined as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity

Indicator is an observable or measurable result that shows evidence of whether an impact has occurred and the nature of that impact. It provides a metric by which one can quantify and define the scale of a resulting change.

Induced impacts refer to impacts that arise further down the causal chain, as a result of indirect impacts (see definition above); examples might include additional spending by the people employed as a result of direct or indirect benefits.

Marginal abatement cost (MAC) curves are a visual (graphic) illustration of the results of model-based scenarios that convey both the economic co-benefits (costs or savings) of an action or policy and the potential GHG reduction that can be achieved with the action or policy.

Monetisation is the attribution of financial value to phenomena, usually by relating a change in status of a good or service to the relevant market value of the good or service.

Multi-criteria analysis describes any structured approach used to determine overall preferences among

alternative options. The actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Explicit recognition is given to the fact that a variety of both monetary and nonmonetary objectives may influence policy decisions.

Multiplier effect is a further extension of an induced impact, referring to ripple effects arising across the wider economy from the original energy efficiency policy. For example, a multiplier effect would be that stores, restaurants or other service providers benefit from the spending of people who are newly employed (directly or indirectly) because of an energy efficiency policy and have greater capacity to spend or invest their earnings.

Net benefit is the measure of the value of an outcome after the cost of delivering the outcome has been accounted for and deducted.

Social capital is the links, shared values and understandings in society that enable individuals and groups to trust each other and so work together.

Social equity implies fair access to livelihood, education, and resources; full participation in the political and cultural life of the community; and self-determination in meeting fundamental needs.

Well-being refers to the integrated physiological, psychological and mental state of an individual, a household or group of people. It is broader than health, which typically refers to the physical state of an individual, family or group of people (public health).

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Appendix A

Spatial aspects of CityInSight

Detailed spatial analysis of the low carbon scenario could provide co-benefits and co-harms insights, particularly for social equity indicators.

CityInSight incorporates a wide range of data at a spatial resolution of transportation zones for scenarios, as illustrated in A-1. If this data can be mapped to the neighbourhoods for the City, it is possible to assess the impact of specific policies and actions, or combinations of policies and actions on neighbourhoods.

Figure A-1. Transport zones in Toronto.

As an example, it is possible to take an analysis of household income by neighbourhood and overlay change in household energy costs to assess the impacts of low carbon actions on lower income neighbourhoods.

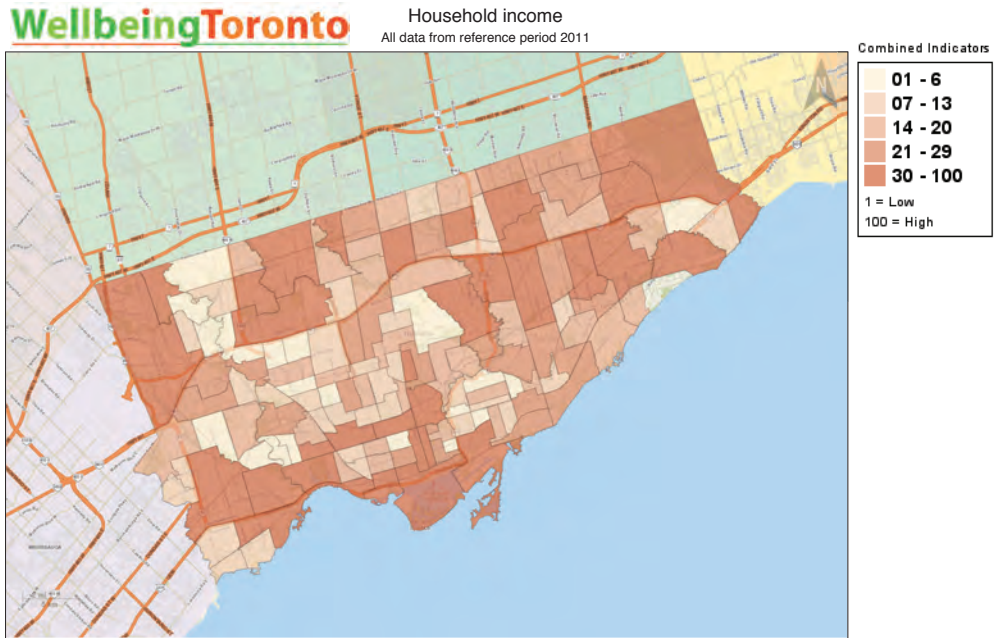

Figure A-2. Household income by neighbourhood in the City of Toronto.

Wellbeing Toronto represents a number of other indicators spatially, enabling an impact analysis on variables such as, children and elderly, visible minorities, unemployment, high shelter costs, rented dwellings, walk score, social assistance recipients, debt risk score, tree cover, pollutants released to the air and TTC stops. As indicated above, a number of these variables are captured in Wellbeing Toronto's neighbourhood equity score, Figure A-3.

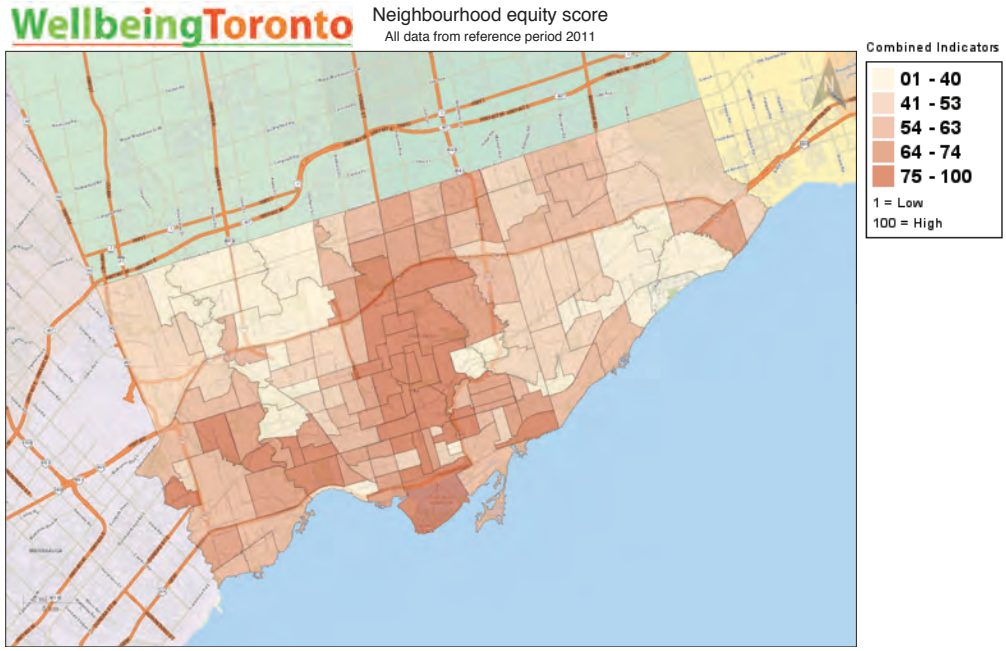

Figure A-3. Neighbourhood equity score for the City of Toronto.

Data for specific indicators from the Wellbeing Toronto can be overlaid with the impact of low carbon actions for the City of Toronto. The comparison has a temporal discrepancy because the low carbon scenario extends to 2050, whereas the Wellbeing Toronto indicators represent data from 2014. The assessment would occur at neighbourhood level and would not demonstrate causality. For example, one could identify the top twenty percent of neighbourhoods with the highest concentration of elderly and evaluate whether those neighbourhoods will experience an increase in active mode shares. As the elderly do not represent 100% of the population in that neighbourhood, but if the active transportation mode share is increasing in that neighbourhood, it is likely that the elderly will benefit. A-1 demonstrates, for illustrative purposes, what this kind of analysis could look like.

Table A-1. Sample spatial assessment of the impact of the low carbon scenario on equity and health indicators (red is positive, orange is negative).

		Impact on top 20% of neighbourhoods with:												
		Most children	Most elderly	Most visible minority	Most unemployment	Highest shelter costs	Most rented dwellings	Highest walk score	Most social assistance recipients	Highest debt score risk	Least tree cover	Most pollutants released to the air	Least TTC stops	Lowest neighbourhood equity score
As a result of the low carbon scenario	Change in active ransportation mode shift													
	Vehicular trips													
	Accessibility to transit													
	Buildings retrofit													
	Household energy costs													
	Accessibility to a school													
	Change in greenspace													

While this analysis is beyond the current scope of the project it illustrates the strength of a spatial analysis in exploring co-benefits and co-harms. This spatial analysis can help refine the list of indicators described in Table 8.

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