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Uncovering the Synergies and Trade-Offs

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Climate Action Co-benefits and Integrated Community Planning: Uncovering the Synergies and Trade-Offs

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Abstract: Engaging in climate action through integrated sustainability strategies can yield benefits for communities in more effective ways than through compartmentalized approaches. Such strategies can result in co-benefits, that is, community benefits that occur from acting on climate change that extend beyond mitigation and adaptation. For example, creating more walkable cities can be a strategy for reducing greenhouse gases, but can also lead to healthier communities. Climate strategies with co-benefits can result in "win-win" situations and thus improve practices for integrated community planning. However, this planning approach also presents challenges because it requires understanding complex relationships between community development practices and identifying synergies. In addition, some co-benefit strategies may also have associated challenges and trade-offs. This research examines climate action co-benefits and trade-offs in order to develop a comprehensive picture of the relationships and potential effects of implementing certain plans and strategies. The research consisted of collecting data on climate action efforts occurring in eleven BC (Canada) communities and coding it to identify climate strategies, co-benefits, challenges, and trade-offs. Relationships between codes were then identified through a coding matrix, and these were used to build a series of models that illustrate co-benefits, challenges, and trade-offs associated with local climate action. Each model centered on a particular area of climate action, including energy innovation, urban densification, mixed-use and downtown revitalization, building stock, ecological capital, trails and transportation, and waste and water. The models provide a holistic impression of the advantages and disadvantages associated with different plans and strategies, which in turn can guide both quantitative analyses and qualitative explorations that contribute toward integrated community planning and decision-making.

Keywords: Community Climate Action, Local Adaptation and Mitigation, Co-Benefits, Trade-Offs, Integrated Planning, Community Planning, Systems Models

Introduction

Integrated planning is critical for realizing climate action plans and the implementation of sustainable community development. Solutions are beyond any one sector, any one discipline, and any one government to implement. Our current education and government systems are prone to what some describe as solitudes, silos, and stovepipes (Dale 2001), considerable barriers to integrated planning and the necessary collaboration for the resolution of modern-day challenges. Solitudes refer to the cleavages that result in divisions between actors and groups, such as language use, culture, and even geographical divisions. Silos refer to separation between researchers, private, and public sectors. Stovepipes refer to disciplinary structures and government departments. These barriers can result in disconnect between different actions and objectives, such as natural resource departments that contain both energy efficiency programs and incentives, while at the same time incentivizing traditional large extractive projects that contribute to increased greenhouse gas (GHG) emissions. Research shows that local communities most advanced in climate change innovation are those with policy congruence, policy coherence, and integrated planning processes (Dale et al. 2018).

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This article argues for integrated strategies for energy, transportation, land, water, and biodiversity conservation, as has been argued by others (e.g., Ahern 2013; Shaw et al. 2014). Without long-term integrated planning, there can be unintended consequences. For example, a lack of zoning density enhances transportation sprawl, with the associated costs of long commute times and greater propensity to obesity (Sturm and Cohen 2004). Climate change mitigation and adaptation strategies have many social benefits including health outcomes for human and non-human life, improved living conditions, and more sustainable communities (Berkhout 2005; Bosetti et al. 2009; Garnaut 2008; Government of British Columbia 2008; IPCC 2007; Stern 2007; UNEP 2011). For example, the direct benefits of urban green spaces are carbon sequestration (Strohbach et al. 2012), reduced urban heat effects (Harlan et al. 2006), and decreased building heating and cooling energy needs (Akbari and Taha 1992). Other benefits associated with green spaces include those related to community members having access to parks and trails, such as potentially combatting obesity (Dahmann et al. 2010) and its co-morbidities such as hypertension, osteoarthritis, sleep apnea, and strokes (NHLBI 1998).

The social benefits listed above demonstrate that climate action strategies can yield "co-benefits," that is, community benefits that occur from acting on climate change that extend beyond mitigation and adaptation. Strategies aimed at GHG emission reductions can lead to improved air quality and health outcomes by also reducing health-damaging air pollutants (Nemet et al. 2010). In this way, a "co-benefits approach" to climate action can result in "win-win" situations, and thus improve practices for integrated community planning. However, this planning approach also presents challenges because barriers exist to achieving certain co-benefits. For example, co-benefits of programs that promote and/or incentivize energy efficiency retrofits in residential buildings include reduced utility costs for those participating in these programs; however, in cases where heating costs are relatively inexpensive, it may be challenging to garner interest and participation (e.g., Newell and King 2012). In addition to challenges, some co-benefit strategies have associated trade-offs or "co-harms" (Spencer et al. 2016), which prevent these strategies from resulting entirely in "wins" or gains. Co-benefits are often unplanned and are in many ways happy accidents, but deliberately optimizing these benefits requires understanding interdependent relationships between community development practices, identifying synergies, and addressing potential barriers and trade-offs.

This research advances understanding on how to achieve more integrated climate planning and action through a detailed investigation of the relationships between strategies, co-benefits, trade-offs, and challenges. The research uses interview data collected on local climate action occurring throughout the province of British Columbia (BC), Canada. Analysis of the data resulted in a series of models, which provide pictures of the relationships and potential effects of implementing certain plans and strategies. The following sections report on this work and discuss the context of this research, data analysis and the modelling process, interpretations and main features of the models, and the implications of the models (and this research) for integrated local planning and decision-making.

Background and Context

This study is a part of a larger research project, Meeting the Climate Change Challenge (MC^3), which explores climate action and innovation within Canada. MC^3 researches climate action within BC in particular, where in the latter half of the 2000s, the provincial government engaged in a suite of policies and initiatives that encouraged and enabled local climate action and innovation (Burch et al. 2014; Dale et al. 2013). Research activities involve developing case studies on eleven BC communities[2] that were identified by the research team and research

[2] Case study communities consist of Vancouver, North Vancouver, Surrey, Eagle Island (located in West Vancouver), Victoria, T'Sou-ke First Nations, Campbell River, Dawson Creek, Revelstoke, Prince George, and Carbon Neutral Kootenays (an initiative involving a collection of communities in the Kootenay region).

partners as having implemented (or were in the process of implementing) innovative climate change strategies.

The project consists of two phases. Data for the first phase was collected in 2012 using semi-structured interviews, and interviewees comprised local government, practitioners, and community actors. The second research phase involved revisiting the case study communities to see if there had been any progress or changes with respect to local climate action. In 2016, a subsample of the original group (with representation from all eleven communities) was interviewed. Altogether, eighty-three people were interviewed in the first phase and twenty-seven were interviewed in the second phase.

The current study uses the MC^3 case study data. This data was not specifically collected for this work; however, the interview scripts contained questions pertaining to climate action co-benefits (as well as trade-offs and challenges). The data was, therefore, deemed appropriate and useful for this particular investigation.

Methods

The primary objective of this research is to elucidate relationships between strategies, benefits, and trade-offs/challenges for the purposes of developing a comprehensive impression of the advantages and disadvantages associated with different plans and strategies. To this end, interview data were coded using NVivo (v. 11) in areas where co-benefits and/or trade-offs associated with climate action strategies were observed. Data were aggregated for this analysis, and examining differences between communities was outside the scope of the study. In addition, the year of data collection was not considered relevant for this investigation because the inclusion of 2016 data solely served to gather more ideas and examples of co-benefits and trade-offs for a richer analysis, rather than for comparison between years. It is worth noting that certain events occurring between 2012 and 2016 created different opportunities and challenges for the communities in terms of implementing local climate action, for example, the 2014 municipal elections resulted in changes in leadership in some of the communities. However, the aggregation of data years was not considered a major study limitation because the co-benefits, challenges, and trade-offs identified in this study were considered to be relevant to both years.

In total, eighty-four codes were generated and applied to the data—thirty-six benefits, thirty-seven benefits, and eleven problems. Codes fell under one of three categories—strategy, benefit, or problem (i.e., trade-off or challenge). In many cases, a code could be framed as either a benefit or a problem, and decisions on framing were made based on the dominant narrative in the data that surrounded the code. For example, coding used for changes in vehicular traffic could be framed as “traffic reduction” (i.e., benefit) or “traffic” (i.e., problem); however, the framing selected was “traffic reduction” because this is how traffic changes were primarily discussed. Table 1 provides a complete list of the codes and their categorization.

Table 1: Codes Used for Analysis of Community Climate Action Interview Data

Type	Codes
Strategy	Biofuel, Brownfield redevelopment, Community engagement, Compost programs, Co-operative, Density, District energy, Downtown revitalization, Energy conservation, Flood management, Gardens and local agriculture, Green building, Green space and forests, Integrated design, Laneway cottages, Mixed-use, Pedestrian infrastructure, Public transportation, Recycling, Renewable energy, Retrofit rebates, Car sharing, Sensitive area permits, Sharing economy, Social planning, Social programming, Stormwater management, Trail network, Training and education, Trenchless technology, Urban trees and vegetation, Water meters, Water reclamation, Water stations, Wildfire management, Wood stove exchange
Benefit	Affordability, Air quality, Attract businesses, Beauty, Branding and exposure, Citizen accounts, Comfortability, Community support, Economic development, Employment, Energy security, Food bank services, Food security, Health, Land-use efficiency, Lighting quality, Local business, Microclimate, Municipal account, Noise reduction, Pride and motivation, Property value, Public awareness, Public safety, Recreation, Sense of place, Social capital, Social diversity, Social interaction, Tax base and labour, Tourism, Traffic reduction, Viewshed, Waste reduction, Water conservation, Water quality, Wildlife and habitat
Problem	Community opposition, Crime, Empty houses, Fossil fuel economy, Inconvenience, Inexpensive natural gas, Loss of developer interest, Loss of heritage, Overwhelmed with the issue, Upfront expense, Transport requirements

Source: Data Adapted from Newell, Dale, and Roseland

After applying codes, coded references were arranged into a coding matrix that showed where these references overlapped. These “areas of overlap” were examined to identify relationships between codes. The nature of a relationship differed depending on the types of codes within it. For example, a strategy-to-benefit relationship could be one where a certain benefit is received from enacting a strategy, whereas a strategy-to-strategy relationship would represent an association such as when one strategy is conducive to executing another. A strategy-to-problem relationship could be one where a trade-off from or barrier to enacting a strategy exists, while a problem-to-benefit relationship could represent challenges obstructing receipt of a particular benefit.

The directions of the relationships were identified, meaning they were characterized in terms of how a strategy, benefit, or problem exerts an effect on another (e.g., a strategy leading to a benefit or problem, a problem creating barriers to enacting a strategy, etc.). Relationships were also classified as either positive or negative depending on whether an effect was observed to be (respectively) enhancing/promoting or diminishing/counteracting in nature. For example, a strategy with a positive relationship with certain benefit represents a strategy resulting in co-benefits, whereas as a strategy with a positive relationship with a problem is one with associated challenges or trade-offs. A problem with a negative relationship with a benefit represents a challenge that could diminish or prevent a benefit, whereas a strategy with a negative relationship with a problem represents a strategy/benefit overcoming or mitigating a problem.

Altogether, 216 relationships were identified. These relationships were exported from NVivo and used to develop a series of systems models. Visual representations of the models were created using yEd Graph Editor (v. 3.17.2), and codes and relationships were respectively used to model nodes and connections. Due to the difficulties involved with clearly displaying all 84 nodes and 216 connections in one diagram, the analysis was separated and seven models were produced. Each model centers on a particular area of climate action, and these areas were selected by examining which strategy nodes had the most connections. The resulting models are defined as energy innovation, urban densification, mixed-use and downtown revitalization, building stock, ecological capital, trails and transportation, and waste and water.

Results

The following section reports on findings and relationships illuminated through the models, and where appropriate, the results refer to specific case study communities. When referring to a case study, the year that the data was collected is identified by placing DS12 (i.e., 2012 dataset) or DS16 (i.e., 2016 dataset) in parenthesis next to the name of the case study community. The results section also references other literature relevant to findings of the study; however, it is important to recognize that relationships modelled are only those found through the data analysis and additional literature was solely used to support these findings (i.e., rather than create new connections).

As the analysis resulted in 216 different types of connections, the discussion of the results is not exhaustive. In addition, due to space and size limitations, the model images are reduced in size. To view the models in their larger format, visit: www.changingtheconversation.ca/co-benefits.

Energy Innovation

The energy innovation model (Figure 1) captures mitigation strategies focused on transitioning from fossil fuels to green energy sources. A major strategy featured in the model is district energy,[3] and co-benefits observed with this strategy include energy security from localized generation and employment associated with system development and operations. Revelstoke (DS12) data suggests that using biomass as a fuel source for district energy holds further co-benefits associated with waste reduction (i.e., wood waste), and a Kootenay (DS12) interviewee explained that harvesting biomass fuel could also serve as a fire interface risk management strategy. A potential trade-off with district energy was noted by a Surrey (DS12) interviewee, who explained that implementing a district energy policy can “scare away” some developers as it adds certain requirements and specifications for the development.

Renewable energy was associated with a multitude of different co-benefits. Some co-benefits were applicable to a variety of communities and projects, such as education opportunities and employment surrounding the development of a local renewable energy industry. Other co-benefits differed depending on the nature of the renewable energy project. For example, the solar energy project in T’Sou-ke (DS16) has garnered great interest due to its scale, and this allowed the community to develop a successful tourism business around their solar energy operations. As another example, the wind farm near Dawson Creek (DS12) has a trail system around it, thusly producing co-benefits related to outdoor recreation and its associated health benefits (e.g., Dahmann et al. 2010).

Financial co-benefits associated with renewable energy were also observed in the data; however, there were also barriers to receiving these benefits. Local renewable energy projects can be used to reduce demand from utility companies resulting in financial savings, such as with T’Sou-ke’s (DS12) solar energy operations. However, costs of infrastructure and long payback periods on investment can create difficulties around generating buy-in for developing local renewable energy capacity. Extensive and effective community engagement could potentially aid in overcoming this barrier, as evidenced by Eagle Island (DS12) and T’Sou-ke (DS12).

[3] District energy refers to systems that “provide heating [and] cooling...from a central plant or a complex of distributed sources to many buildings—often in a neighbourhood, downtown district or campus” (C40 Cities Climate Leadership Group 2016, 5). Examples of district energy systems in BC communities include the biomass-based systems built in Prince George (Newell and King 2012) and Revelstoke (Burch 2012).

Health co-benefits were also brought into the energy innovations model, and these included benefits through woodstove exchange programs implemented in the Kootenay region (DS12), Campbell River (DS12), and Prince George (DS12). These programs involved exchanging older woodstoves for high efficiency models that produce lower levels of particulate matter, and thus result in increased air quality and lower rates of respiratory illness (Hong et al. 2017). In addition (although not so much a strategy), the model also included the air quality improvements experienced from closing a local industry that is both energy intensive and polluting, drawing from an interviewee's comments on pulp and paper in Campbell River (DS12). Although such a closure has both energy- and health-related benefits, it is also associated with a significant trade-off, this being the loss of local employment.

Renewable energy was associated with co-benefits related to the growth of the green economy, but it is important to note that energy transitioning has economic trade-offs as well. A Vancouver (DS12) interviewee pointed out the strong economic role the fossil fuel industry has in Canada, and from a provincial perspective, approximately 5,000 people are employed in oil and gas extraction in BC (BC Stats 2017). Therefore, similar to the pulp and paper example above, it is worth recognizing that phasing out certain industries is associated with both challenges and opportunities. This is a further argument for the need for integrated long-term planning that simultaneously considers ecological, social, and economic imperatives (Ling et al. 2007, 2009).

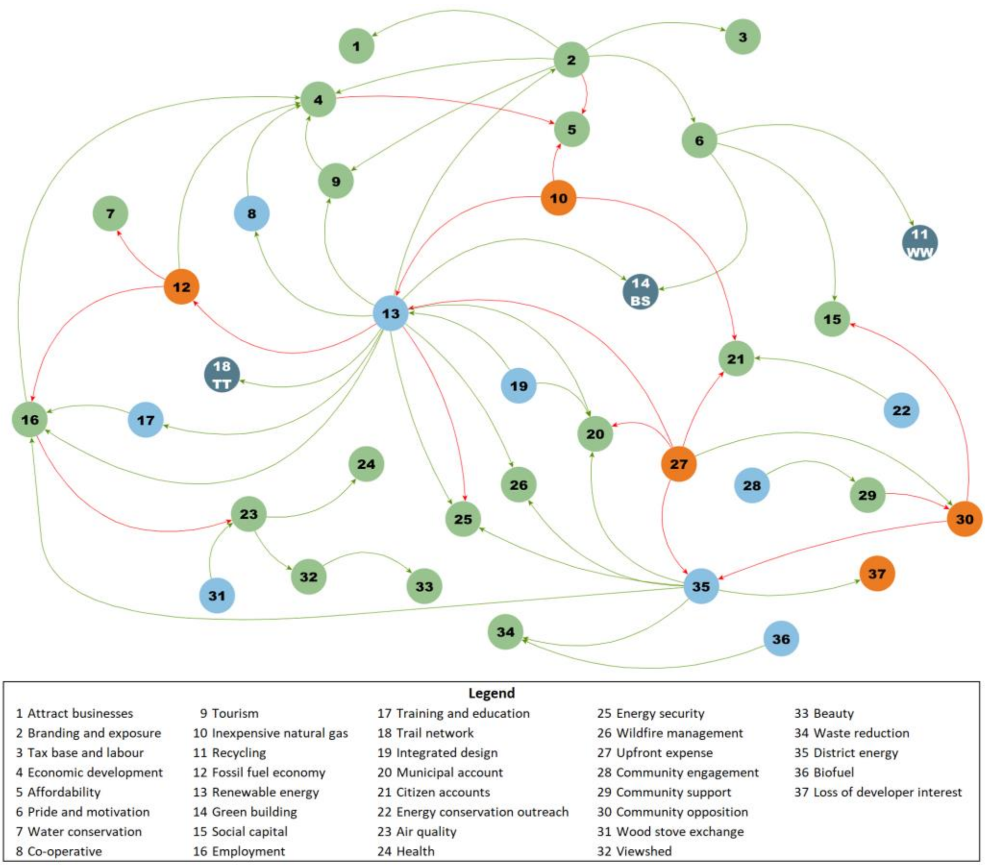

Figure 1: Model of Co-benefits and Trade-offs Associated with Energy Innovations
Light blue nodes represent strategies, and dark blue nodes represent strategies that link to other models (BS—building stock; TT—trails and transportation; WW—waste and water). Green nodes represent benefits, and orange nodes represent trade-offs or challenges. Green connections refer to positive relationships, and red connections illustrate negative relationships.
Source: Newell, Dale, and Roseland

Urban Densification

Densification achieves mitigation outcomes due to the efficiencies experienced with transportation and residential energy usage in areas of urban density (Dodman 2009). Results from this study support this finding, particularly in terms of transportation. As seen in Figure 2, densification provides opportunities for developing urban trail networks or pedestrian routes, and it also meets requirements for effective public transportation. As seen in a different model below, trails and transportation comprise a climate action strategy in their own right and thus these would not be considered co-benefits of climate action, per se; however, what these relationships demonstrate is that densification can enable other climate action that has its own associated co-benefits. In a similar vein, densification provides the necessary conditions for district energy systems, which is a featured element of the energy innovation model.

Infill and brownfield development were discussed as an avenue for densification, and this approach is beneficial in terms of reducing urban sprawl and making efficient use of municipal lands. Co-benefits experienced from land-use efficiency include maintaining ecological capital from reducing sprawl and urban encroachment on natural areas. In addition, co-benefits include cost avoidance in municipal budgets due to financial savings from delivering municipal services to more compact communities (as opposed to sprawling communities).

Some trade-offs and challenges were observed with densification approaches to community development. These primarily related to changes in the “character” of places, and the resulting effect on local sense of place. More specifically, densification can involve redevelopment that might affect older neighbourhoods with local history and heritage value. In addition, high-rise buildings can obstruct views, which impacts local viewshed experiences and ultimately sense of place. These effects could be mitigated through taking approaches to densification that involve low-rise infill developments, for example, Revelstoke (DS16) is exploring such an approach that involves laneway cottage development.

Potential trade-offs were also observed between densification and community cohesion, and such trade-offs also have implications for local place values and identities. These trade-offs related to concerns around new units being purchased by second home-owners and the potential “loss of community” that may result from empty houses (Gallent 2014), as was expressed in Revelstoke (DS16). Another issue regarding community cohesion relates to the community opposition that might emerge in response to new development. Such opposition could be mitigated by first targeting unattractive brownfield areas for development, as was described by an interviewee from Surrey (DS16) as “low hanging fruit.”

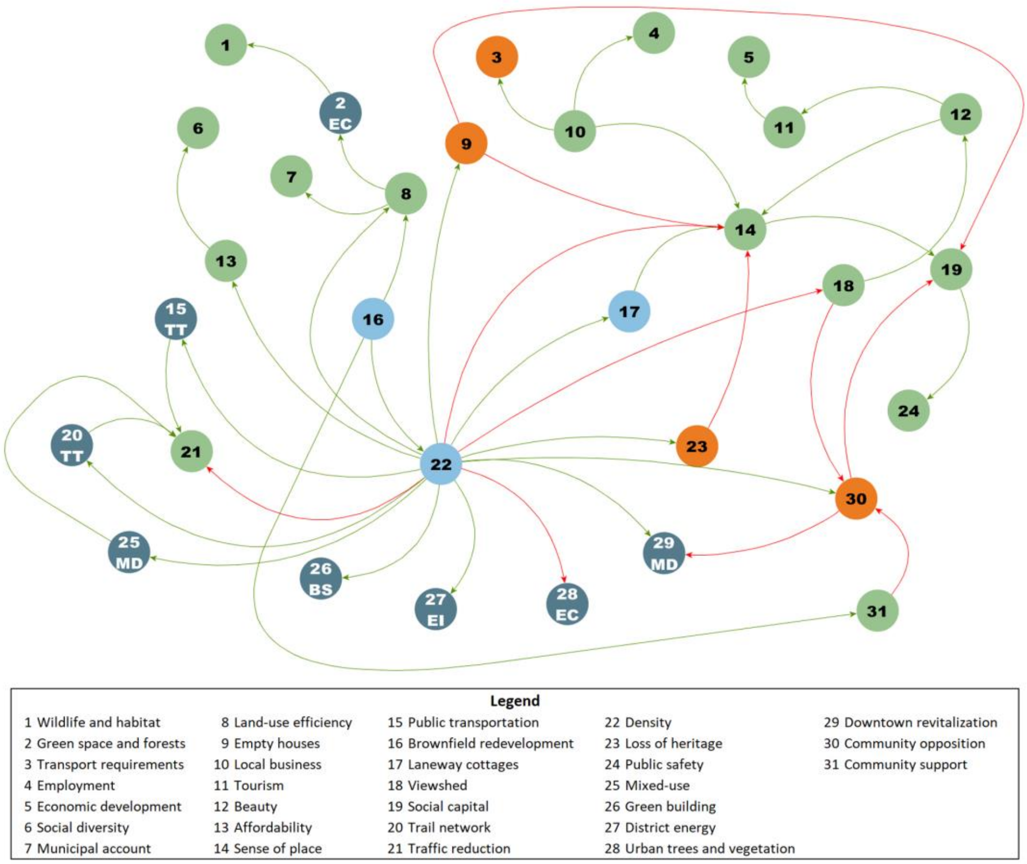

Figure 2: Model of Co-benefits and Trade-offs Associated with Urban Densification
Nodes and connections are formatted in the same manner as the models. Dark blue nodes represent strategies that link to other models, and these include: MD—Mixed-used and downtown revitalization; BS—building stock; EI—energy innovation; TT—trails and transportation; EC—ecological capital.
Source: Newell, Dale, and Roseland

Mixed-use Development and Downtown Revitalization

Mixed-used development as a climate action strategy is similar to urban densification in how it contributes to active transportation. However, this study separates these into two different models because the former refers to composition and urban form, whereas the latter refers to concentrations of buildings, workplaces, and dwelling units. Downtown revitalization was incorporated into the mixed-use development model (Figure 3) because references to such revitalization typically envisioned downtown areas as having commercial and residential functions (Kootenays, DS12; Campbell River, DS12; Campbell River, DS16; Prince George, DS12; Surrey, DS12).

A co-benefit of mixed-use development and revitalizing downtown areas is that they contribute to the economic viability of local businesses because such strategies place potential customers in proximity with businesses (i.e., local residents) and encourage other residents to visit these areas. Downtown revitalization can also contribute to tourism, which furthers the economic viability of local businesses. However, as noted by a North Vancouver interviewee (DS16), such revitalization can also present trade-offs in that these areas can also attract large retail companies that present significant commercial competition for smaller locally-owned businesses. In addition, a trade-off occurs with these areas becoming more desirable places to live, work, and play because property values increase with this desirability and (thus) affordability decreases.

The mixed-use development model is similar to urban densification in how it presents trade-offs related to sense of place. However, the models differ in that mixed-use approaches do not explicitly call for infill development and as a result could consist of new developments that encroach on natural spaces and impact ecosystems. These impacts potentially could be mitigated through strategies such as requiring sensitive area permits for developments, as suggested by a Kootenay (DS16) interviewee.

Although challenges exist with new development, such developments also present interesting opportunities for innovative methods around building and/or upgrading infrastructure. For example, trenchless pipe technology implemented in Victoria (DS12) can be repaired without excavating and replacing asphalt. Through these means, trenchless technology contributes to mitigation due reducing emissions associated with roadwork and materials, while having co-benefits such as costs savings and reducing traffic-related congestion.

A particularly interesting relationship observed in the data was between crime and vehicle traffic. Prince George (DS12) data revealed that people were less inclined to travel by active transport through a downtown area perceived as “unsafe.” The social programs strategy was then added to the model as a potential method for reducing local crime-related issues based on comments by a Revelstoke (DS12) interviewee, who discussed the city’s early childhood education program as potentially directing “at-risk” youth toward “the right path.” Although the link between this program, crime, and vehicle emissions was not explicitly made, integrating the findings from Revelstoke and Prince George data provides evidence for suggesting that communities should recognize the role social factors and conditions play in the production of GHG emissions when engaging in mitigation efforts.

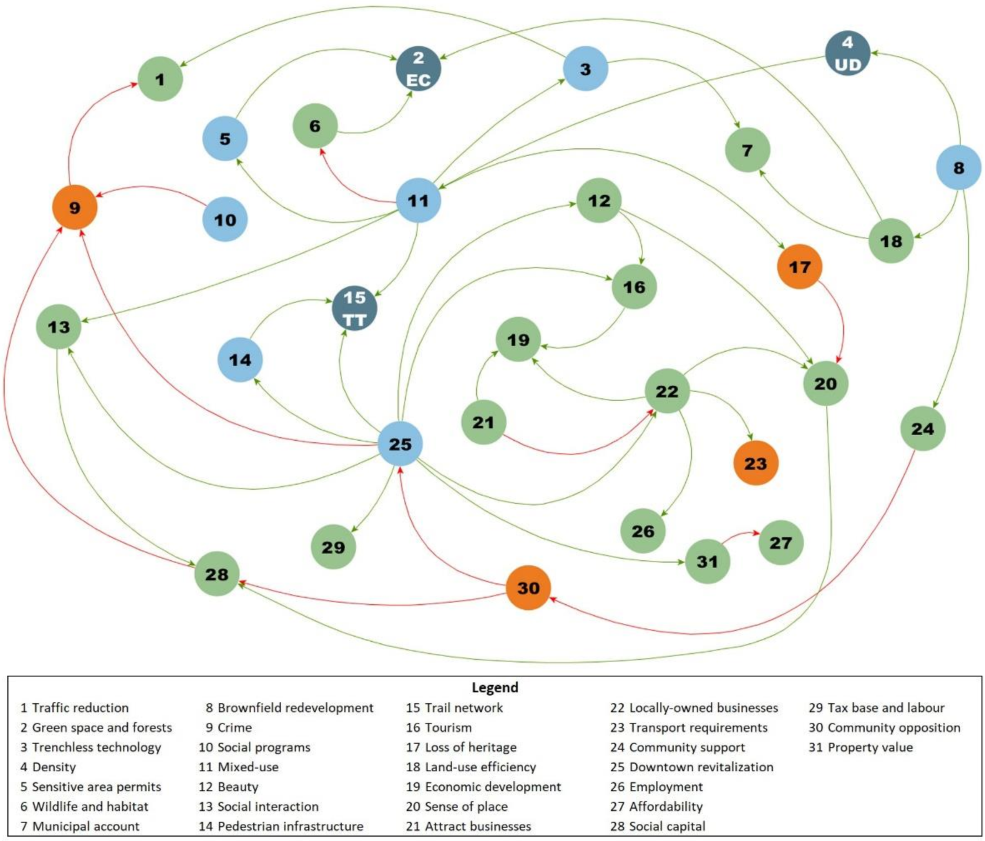

Figure 3: Model of Co-benefits and Trade-offs Associated with Mixed-use Development and Downtown Revitalization
Nodes and connections are formatted in the same manner as the models. Dark blue nodes represent strategies that link to other models, and these include: UD—Urban densification; TT—trails and transportation; EC—ecological capital.
Source: Newell, Dale, and Roseland

Building Stock

The building stock model (Figure 4) focuses on GHG emission reductions through green building and retrofitting strategies. Green buildings can contribute to mitigation efforts through increased energy efficiency, as well as having a role in adaptation planning through more efficient water usage. Due to energy and water efficiencies, a clear co-benefit of green building and retrofitting strategies is the financial savings for the operators or residents of these buildings, and indeed, this was a co-benefit that was featured in most of the case study communities. However, it was also noted that inexpensive natural gas prices present challenges for realizing such a benefit, as this can discourage local residents from retrofitting their homes (e.g., Prince George, DS12).

Several benefits and trade-offs in the building stock model relate to affordability. Upgrading the energy efficiency of a home increases the property value and is advantageous for the homeowner; however, it simultaneously decreases affordability for new home buyers. Affordability can also be affected more indirectly through how green innovations can increase the "appeal" of a city. Data from Victoria (DS16) suggests that proliferation of green buildings can increase exposure of a community in terms of being known and branded as a "green" place to live and work, and Vancouver (DS16) data indicates that such a brand can attract businesses. This in turn makes a community more attractive, thus driving up housing prices. However, this issue can (in part) be addressed by increasing affordability through a co-benefits approach that integrates social planning with energy planning. Such an approach was discussed in Surrey (DS16), where the city delivered workshops and partnered with landlords on ways of reducing utility expenses (i.e., energy planning) and in turn these savings could be (at least in part) passed on to tenants through lowered rental prices (i.e., social planning).

Community engagement is featured in the building stock model due to a particularly successful grassroots initiative in Eagle Island (DS12), where a local resident mobilized her community into conducting mass retrofits. The approach she took was to gather people for social events, where they discussed advantages and ways of going about retrofitting their homes. These events resulted in increased social interaction, and thus were co-beneficial in terms of building stronger social capital ties in that particular community.

The building stock model also features a relationship between green buildings and health. This benefit is experienced in two ways. The first is through the building design itself, for example, installation of solar tubes, such as done in a municipal building in Campbell River (DS12), delivers natural light to those within the building thus resulting in a health benefits associated with receiving natural (rather than artificial) light. The second relationship is indirect and involves integrating building design with green space and urban trees. Cultivating green space and trees within urban areas can help regulate local temperatures and reduce air conditioning related energy consumption, while also creating shaded microclimates that reduce vulnerability to heat stress (Harlan et al. 2006). Increased access to green space also results in increased mental health benefits (Sturm and Cohen 2014), as even the planting of ten trees on a street has health benefits equivalent to boosting income by $10,000 (Kardan et al. 2015).

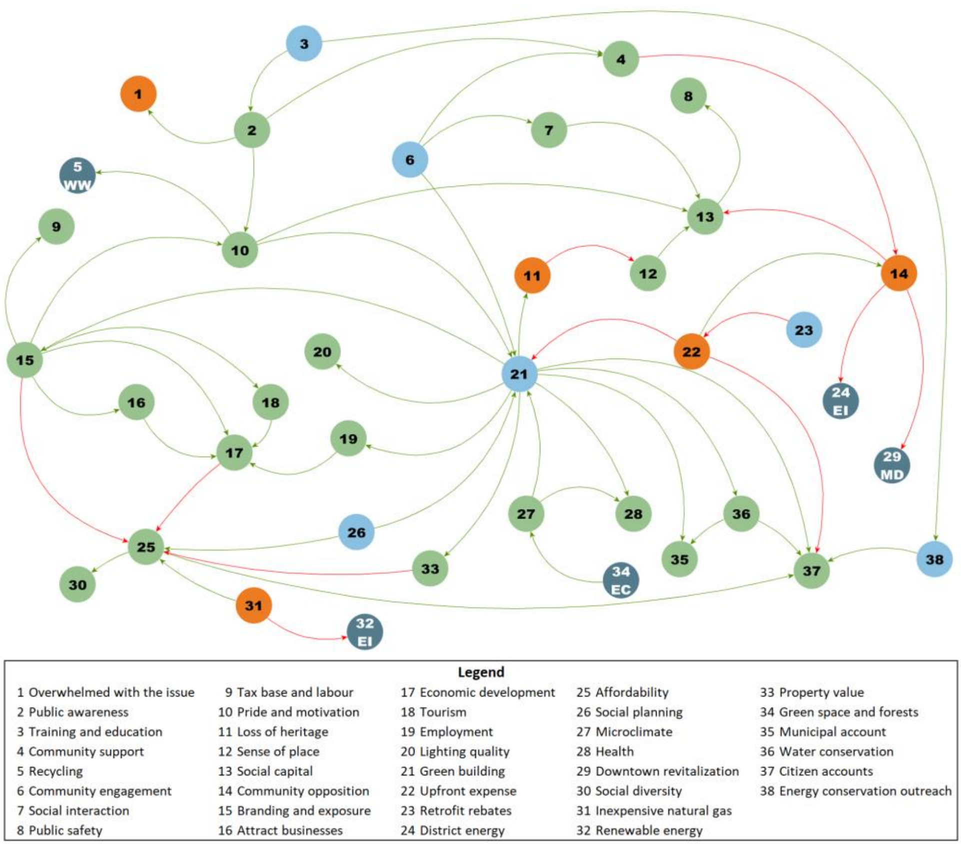

Figure 4: Model of Co-benefits and Trade-offs Associated with Building Stock Strategies
Nodes and connections are formatted in the same manner as the models. Dark blue nodes represent strategies that link to other models, and these include: MD—mixed-used and downtown revitalization; EI—energy innovation; EC—ecological capital; WW—waste and water.
Source: Newell, Dale, and Roseland

Ecological Capital

The ecological capital model (Figure 5) captures strategies relating to the cultivation, maintenance and protection of green space and urban vegetation. Such strategies constitute climate action through the mitigation benefits received from carbon sequestration (Spencer et al. 2016; Strohbach et al. 2012) and the adaptation benefits associated with flood control (Erwin 2009) and temperature regulation in warming climate (Brown et al. 2015). Health co-benefits were found to be associated with green spaces, including health benefits received from having access to green space (Mass et al. 2006) and the benefits drawn from having opportunities for recreation and exercise. Green spaces were also noted by interviewees to benefit wildlife and biodiversity, and this includes urban parks (Goddard et al. 2010; Jim 2004; Rudd 2002) as well as larger natural spaces located outside of developed areas. The latter is critically important given the alarming reports about current rates of biodiversity loss (Rockström et al. 2009; WWF 2016).

Another co-benefit associated with parks and urban vegetation is improved local aesthetics and added beauty to communities. This in combination with afforded recreational opportunities can contribute to tourism and local economic development. However, it was found through Revelstoke (DS12) data that such a benefit also comes with a trade-off related to the stress increased tourism can place on ecosystems. Trade-offs were also identified for urban tree and vegetation strategies, particularly through West Vancouver (DS16) data where it was noted that some community members would prefer to have certain trees removed as they obstruct their views. These viewshed trade-offs are specific to individual property owners; however, they are worthwhile considerations when thinking about reasons why certain residents may or may not support certain climate action strategies in their neighbourhood.

Gardens and local agriculture were incorporated into the ecological capital model, and they can be regarded as climate action strategies because of the reductions in transportation requirements experienced with local food production. However, as displayed in Figure 5, locally produced food can also become an export item to increase economic viability of an agricultural operation. Therefore, the export activity of local food sources should be considered when engaging in climate action planning and GHG accounting, and cooperative food strategies involving local government, community stakeholders, and regional authorities (e.g., Oldejans 2017) could be explored when considering how to improve local distribution networks.

Agricultural operations can be integrated into local park systems, such as the farm located in Loutet Park in North Vancouver (DS16), and like green spaces, they produce co-benefits associated with local aesthetics and wildlife (e.g., pollinators). Urban farms also provide food security co-benefits due to increased local food capacity and access to healthy foods. In addition, local agriculture provides economic benefits through employment, as well as educational opportunities for residents to learn about agriculture and farming practices. Furthermore, it creates opportunities for building social capital between customers and food producers, as well as sharing knowledge on growing and food practices (Seyfang 2006).

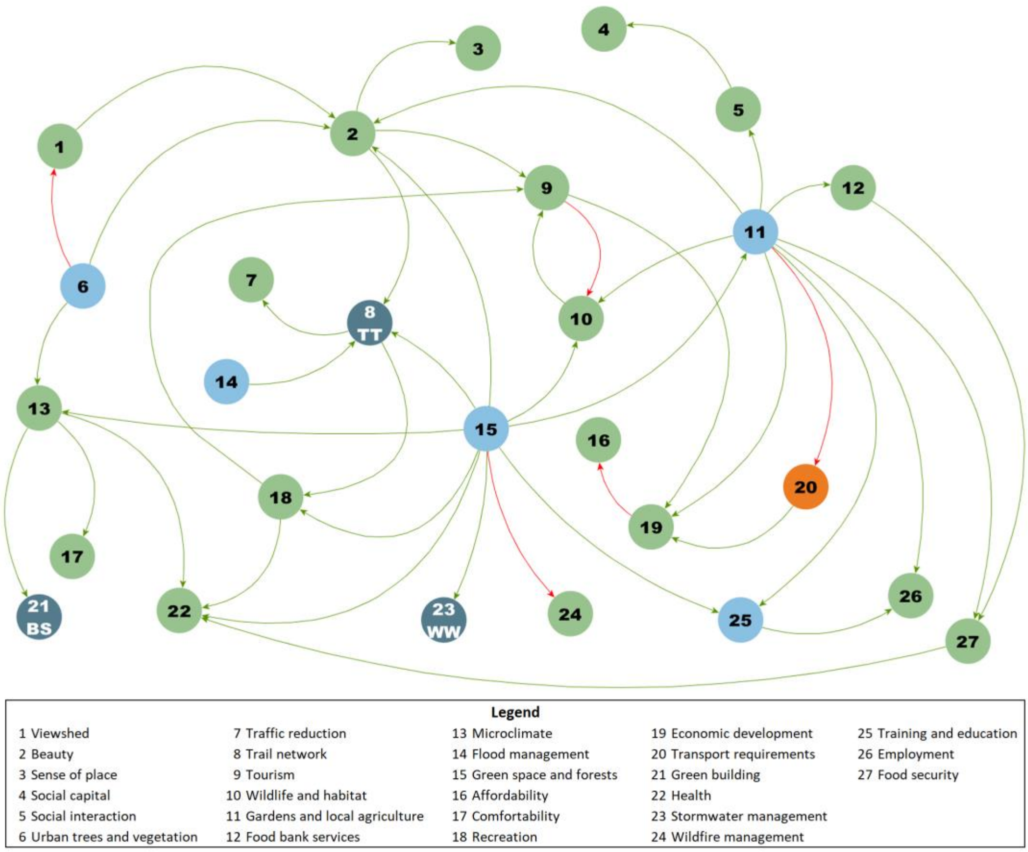

Figure 5: Model of Co-benefits and Trade-offs Associated with Ecological Capital Strategies
Nodes and connections are formatted in the same manner as the models. Dark blue nodes represent strategies that link to other models, and these include: BS—building stock; TT—trails and transportation; WW—waste and water.
Source: Newell, Dale, and Roseland

Trails and Transportation

The trails and transportation model (Figure 6) centered on mitigation strategies aimed at reducing vehicle traffic. One of the major strategies featured in this model is the development of trail networks and pedestrian routes. Such routes can be used for both recreation and active transportation, and the co-benefit that emerges from this include improved health outcomes, such as reduced hypertension and obesity (Sturm and Cohen 2004). Other co-benefits from developing trail networks include economic benefits from attracting tourists, community aesthetics associated with building greenways, and financial savings for residents who engage in active transportation rather than drive.

Trail network strategies exhibited synergies with adaptation planning, in particular flood management. An example of this was observed in the Kootenay (DS12) data, where a strategy was discussed that involved restoring a creek to natural conditions and lowering its flow rate. The strategy aimed to improve stormwater management and reduce flood risk; however, it also opened up opportunities to create a creekside trail that follows a beautiful natural feature. This example demonstrates that opportunities exist for integrating mitigation and adaption, while also promoting community health and quality of life.

Co-benefits associated with public transportation and car sharing were identified as well. These primarily stemmed from reductions in vehicular traffic, such as health benefits from improvements in local air quality resulting from reductions in car emissions (Frank and Raine 2007) and a more pleasant living experience due to decreases in local congestion and traffic noise. Car sharing and public transportation also had the added co-benefit of financial savings for users of these services, particularly in times of rising fuel costs. In terms of problems, the inconvenience that results from having to plan trips based on bus schedules or shared vehicles was identified as potential barrier to transportation strategies, as it can discourage transit ridership and participation in shared vehicle programs. However, such inconvenience can be reduced through improving trail systems and more integrated pedestrian/bike routes in order to provide options for multiple modes of transportation.

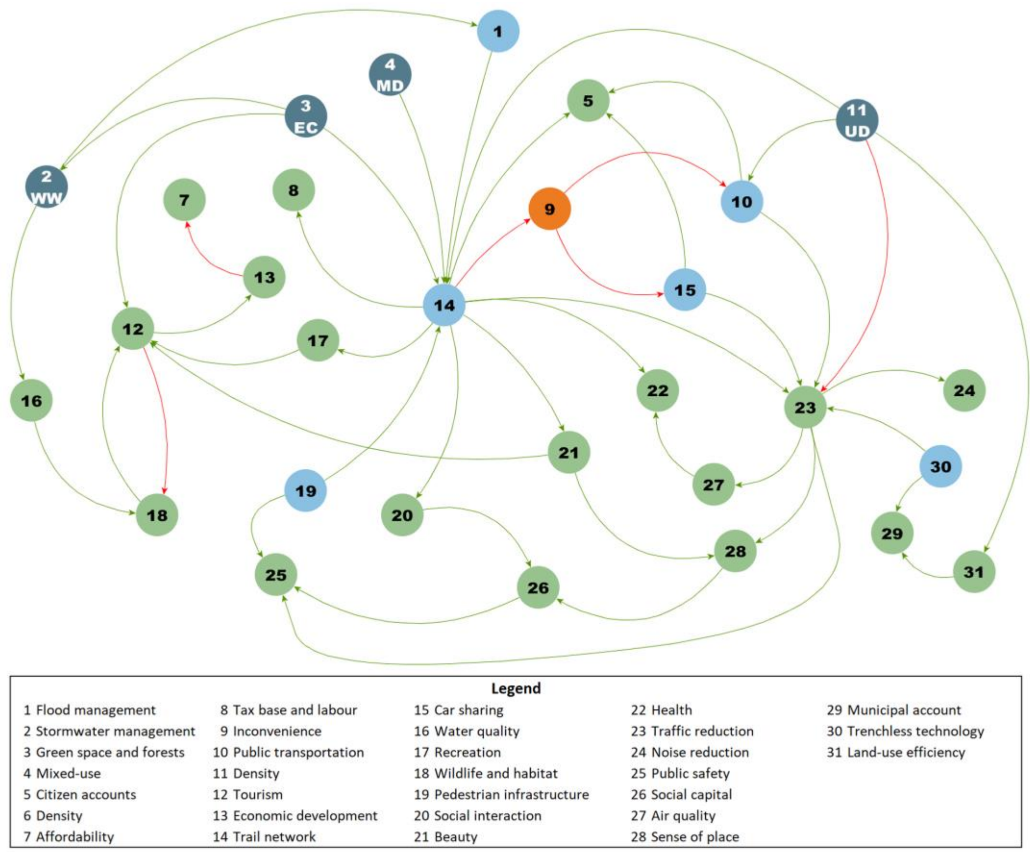

Figure 6: Model of Co-benefits and Trade-offs Associated with Transportation Strategies
Nodes and connections are formatted in the same manner as the models. Dark blue nodes represent strategies that link to other models, and these include: UD—urban densification; MD—mixed-used and downtown revitalization; EC—ecological capital; WW—waste and water.
Source: Newell, Dale, and Roseland

Waste and Water

Waste management is relevant to climate action because waste stream diversion leads to climate-mitigation benefits related to reductions in energy consumption and deposition of methane-producing wastes in landfills (Weitz et al. 2011). Water was incorporated into the waste model (Figure 7) due to waste- and stormwater considerations; however, unlike solid waste, water strategies are more adaptation focused. These include managing stormwater and flood risks and conserving water to maintain adequate supply in the face of increasingly severe drought seasons (Easterling et al. 2000).

Several strategies contribute to waste reduction and diversion from landfill, and these include recycling, using waste wood for biomass energy, converting organic waste into biofuel, providing water stations for refillable bottles, and composting. Co-benefits received from waste reduction relate to land-use efficiency, as diversions from the waste stream decrease the rate in which landfill capacity is reached and new land is required for waste deposition. In addition, initiatives such as biomass energy and composting programs have benefits associated with treating waste items as useable products. Composting is particularly beneficial for gardening and local agriculture, and it was noted in a Campbell River (DS16) interview that organic waste can even have economic value if processed and sold as fertilizer.

Although waste reduction strategies can serve climate action purposes, it is important to recognize that there are transportation-related GHG emissions associated with recycling and composting programs. Therefore, when examining the benefits and trade-offs of certain strategies, it is worthwhile to consider how these strategies are being executed. For example, composting can be done within a private or local community garden, or it can be picked up and brought to a composting facility. The latter case will have emissions associated with the transportation of the compost.

The sharing economy is incorporated into the waste and water model, based on comments made by a Victoria (DS12) interviewee, who explained that sharing systems can contribute to mitigation. The model represents this relationship as a connection between sharing economy and waste reduction; however, in reality, it is a broader relationship that encompasses emissions from manufacture, transport, and discarding of goods. Sharing systems (theoretically) can reduce demand for new items and also provide a place for older items that might otherwise get discarded during "spring cleaning" or downsizing activities. Sharing economy has co-benefits associated with social capital, as these economies often involve community spaces where shared goods are stored.

Water conservation strategies include water metering and reuse of greywater. As seen in the building stock model above (Figure 4), water conservation is associated with financial savings co-benefits due to reduced utility costs; however, it is important to recognize that this is not necessarily the case with all water conservation strategies. In particular, although water reclamation is a conservation strategy, reclamation systems can be quite expensive and this creates difficulties in making a direct relationship between water conservation strategies and financial savings. This was exemplified in Dawson Creek (DS12), where an interviewee explained that a local industrial water reclamation project could not be feasibly operated by the municipality without the support of their industry partner.

Stormwater management is associated with the ecological capital model because green space and urban vegetation provide permeable surfaces for increasing water infiltration and reducing runoff (Young 2010). Due to this association, stormwater management is indirectly tied to the co-benefits associated with the ecological capital model. In addition, stormwater management is directly linked with wildlife and habitat benefits, as this management involves reducing the amount pollutants introduced into freshwater systems through surface runoff (Arnold and Gibbons 1996).

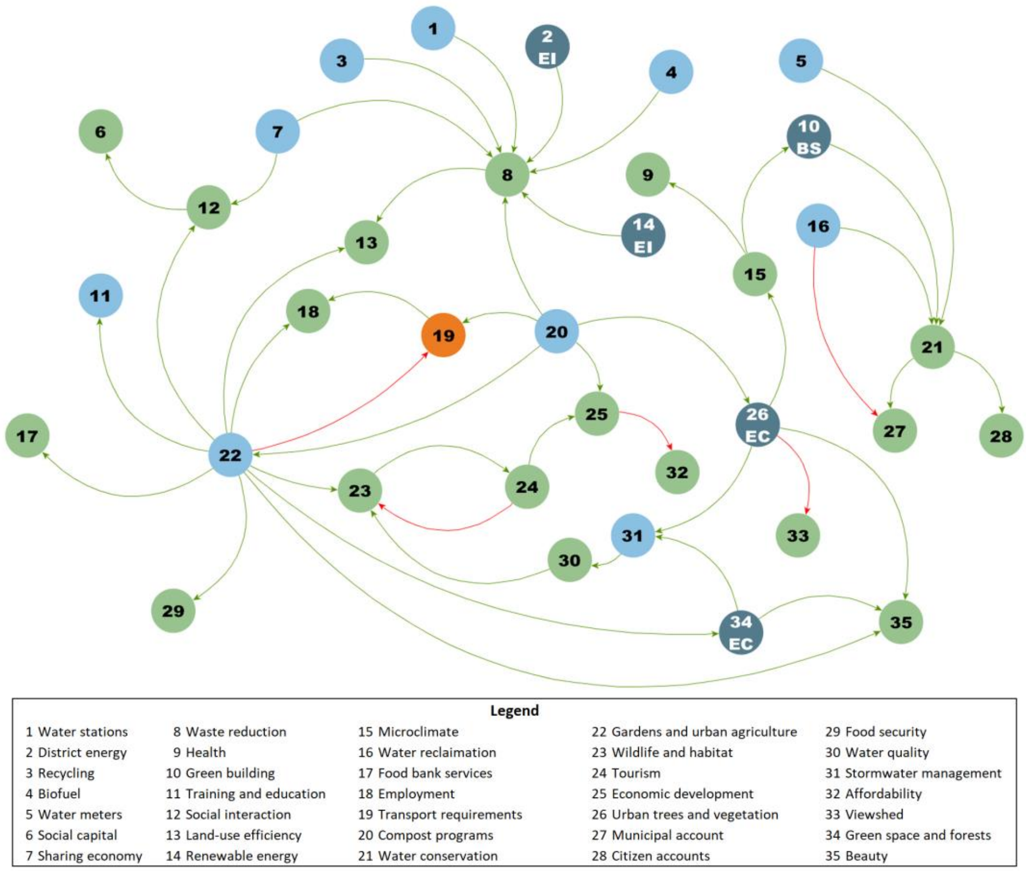

Figure 7: Model of Co-benefits and Trade-offs Associated with Waste and Water Strategies
Nodes and connections are formatted in the same manner as the models. Dark blue nodes represent strategies that link to other models, and these include: BS—building stock; EI—energy innovation; EC—ecological capital.
Source: Newell, Dale, and Roseland

Discussion

The intent of modelling the relationships between climate action strategies, co-benefits, challenges, and trade-offs was to demonstrate the value that these models can contribute to integrated planning efforts. The models produced from this work can be used for integrated planning purposes in multiple ways. One such way involves using them as tools for informing the design and objectives of quantitative urban systems modelling exercises. For example, the trails and transportation model suggests walkability, health, and air quality are important variables to consider when thinking about the co-benefits associated with reducing vehicle-based emissions. Therefore, a quantitative modelling exercise could include relationships between walkability and health outcomes (e.g., Berke et al. 2007), as well as relationships between walkability and air quality (e.g., Marshall et al. 2009). In addition, the trails and transportation model links to the ecological capital model and biodiversity conservation through a relationship between trail networks, green space and habitat preservation; thus, the quantitative analysis could also include variables/relationships associated with green space, such as wildlife habitat (e.g., Grêt-Regamey et al. 2013), as well as the effects residential proximity to parks has on mental (e.g., Sturm and Cohen, 2014) and physical health (e.g., Maas et al. 2006). Ultimately, through exploring the conceptual co-benefits models and the paths of connections within these models, more variables can be identified for including within urban systems modelling exercises. In turn, the urban systems model can be used for examining possible outcomes of different development scenarios, for example, the community health and emissions outcomes that might occur from developing extensive trail networks or locating high-density residential areas near green space. Alternatively, they can also be used for redesigning urban space and infill developments.

Although the conceptual co-benefits models have value as a basis for quantitative modelling, many of the factors within these models do not have quantitative measures. In addition, certain items that have been quantified in previous research, such as social capital (e.g., Grootaert et al. 2004) and sense of place (Cross et al. 2011; Jorgensen and Stedman 2001), do not have a standard method for measurement and there is currently no clear approach for linking these variables to others within quantitative modelling process. However, Sustainability Assessment tools such as the Community Sustainability Balance Sheet and the Telos Triangle can incorporate proxy values in quantitative models as needed. The Balance Sheet for example is based upon a community capital framework, which consists of a set of six capital stocks—natural, physical, human, social, economic, and cultural. Each stock includes targets, thresholds, and indicators. Where indicators do not exist for a particular value, appropriate alternatives can be determined. The Balance Sheet enables municipal or neighbourhood assessment of progress toward goals over time using measurable indicators; it can also be used to highlight progress toward goals for a specific policy or project (Roseland 2012).

In some cases where quantitative measures and methodology are unclear, the co-benefits models can provide guidance on selecting other tools and methods that could be useful for planning processes. For example, in the urban densification model, a trade-off was observed between density and sense of place through a potential loss of local "character." In addition, a trade-off was also seen between density and viewshed, and as seen in other research (e.g., Devine-Wright and Howes 2010), impacts to viewsheds can affect local sense of place. Therefore, when exploring strategies that have urban density implications, planners can consider employing tools that can provide insights on such factors, in particular realistic visualizations that can convey impacts to local views and place-based values (Newell and Canessa 2015; Newell and Canessa 2017; Newell et al. 2017). There are a variety of other innovative planning tools can assist such integrative planning processes and analysis. The Community Capital Scan, for example, is a web-based tool for early stage evaluation of expected impacts of projects and policies. The Scan is a dialogue- and decision-support tool that can be used to gauge decision-maker and stakeholder perceptions of proposed projects and policies across six forms of community capital. The Scan has the potential to combine the scientific rigor of an expert-led, top-down approach with the collaborative engagement process of bottom-up participation by community members. Scan participants can be selected to provide a representation of the whole community and/or be chosen based on their knowledge of the community, local expertise, stake in a particular form of capital, and/or their ability to represent a distinct population within the community (Roseland 2012). Other planning tools such as MetroQuest and Community Viz also incorporate visualization.

The co-benefits models can also be used for purely qualitative explorations, which can guide planning discussions and stakeholder workshops. Such a process could involve bringing local government and community stakeholders together to discuss different options for climate action, and the co-benefit models can be brought into the sessions to stimulate thinking around advantages and disadvantages of these options. For example, Barron et al. (2012) describe how the development of the 2007 King County Climate Plan (King County, WA) consisted of a community engagement process involving stakeholders and government (regional and local) who gathered to discuss priority areas for policy formation. They explain that the Climate Plan outlined climate adaptation and mitigation objectives in areas such as land use, growth management, transportation, water, and clean energy, and through a co-benefits approach, government and stakeholders could explore how policies would address these objectives while also aligning with other social, ecological, and economic imperatives.

While our research has demonstrated the co-benefits relationships within each of the seven models and suggested uses for these models, it raises the question of how we link all seven models together in a way that is useful for researchers and practitioners. We separated our analysis into seven models due to the difficulties of clearly displaying all 84 nodes and 216 connections in a single diagram. Even if we were able to display them all in one diagram, trying to make sense of it would be daunting although not impossible. Geneticists and astrophysicists, for example, routinely deal with complex data; while these are still early days for big data in the social sciences, it would appear that big data may have significant potential when applied to this kind of challenge. In the meantime, how can these seven models be taken together to advance theory and practice with respect to co-benefits? We need a framework.

A framework, as an analytical category, is a set of principles and guidelines. Sustainability frameworks often attempt to interconnect multiple sustainability dimensions and they are intended to be replicable (i.e. applicable across various settings). In the realm of urban sustainability, Joss et al. (2015) identified forty-three frameworks, most of which were established since 2008. Some of the more widely known of these include BREEAM Communities, Eco-Districts, Global City Indicators Facility, LEED-ND, One Planet Communities, and Star Community Rating System.

The multitude of definitions and sustainable development plans, the various agendas reflecting specific actors' interests, and the lack of a shared understanding in sustainability assessment have contributed to limited and inconsistent application of sustainability principles. A common sustainability language and well-grounded theoretical foundations, coupled with an integrated framework and real-world model applications, are required in order to achieve effective implementation of local sustainability. Lack of public uptake is due in part to monitoring, assessment, and decision-support frameworks and tools that do not engage citizens and their governments in a shared, strong sustainability analysis, and/or vision (Roseland and Spiliotopoulou 2016).

Although the contextual character of sustainability may pose scoping and implementation difficulties due to questions of boundaries, comparability, and data accessibility (Joss et al. 2015), standardized, out-of-the-box frameworks may be too data-driven and not always place-relevant, as community values and culture may disconnect data from reality. Researchers generally agree that effective indicators need to be relevant and meaningful, measurable and feasible, sufficient, timely and consistent, scale appropriate, participatory, systemic, and flexible (Bond et al. 2013; SDSN 2014).

Current research on sustainability performance assessment demonstrates that the field is not yet fully developed. While there are many frameworks in existence, their development appears to be taking place amidst the solitudes, silos, and stovepipes (Dale 2001) we noted at the outset. Most of these frameworks and the decision-making processes that result from them fail to acknowledge the importance of several aspects of sustainability, for example, the systemic nature of urban areas, the strong need for integration of human and environmental health interests, the "globalizing world" in which resources are produced and consumed in different regions, the need for emphasis on social inclusion, equity, constructive societal mobilization, and security (Newman and Jennings 2008). These concerns are now manifested in demand for strong sustainability approaches and a common language for sustainability researchers and practitioners. Sustainability frameworks need to be enhanced and possibly aggregated (Joss et al. 2015; Roseland and Spiliotopoulou 2017), so as to promote a shared understanding of integrated planning and development.

A promising step in this direction is the United Nations' adoption of the 2030 Sustainable Development Goals (SDGs), where 169 targets and 230 indicators are grouped under seventeen individual goals into a single framework (SDSN 2014). While the inclination and temptation of many observers will be to examine each of the seventeen goals separately in order to achieve greater depth, arguably the greatest significance of the SDGs is that they are indeed a set.

Institutions such as universities and governments are now engaging in SDG mapping to determine what programs, policies, and initiatives within their organizations correspond to which SDGs, where their organizational strengths and weaknesses are with respect to the SDGs, and to inform their program planning and development (SDSN Australia/Pacific 2017).

Conclusion

The purpose of this research is to examine climate action co-benefits and trade-offs in order to develop a comprehensive picture of the relationships and potential effects of implementing different plans and strategies. Another objective was to develop models that would assist decision-makers in assessing which actions yield optimal benefits. While the research achieved this objective, it is important to recognize that the models were built using data aggregated from multiple communities that varied in size, urbanness, and culture. In one sense, this could be considered a strength of the research because the models were informed by a diversity of different conditions and ideas, rather than being limited to a particular community context. However, this also means that the models are not place-specific, and users would need to consider how the various model relationships and elements relate to their local context. Such considerations can be handled collaboratively through local government and stakeholder workshops that involve discussions on different climate action strategies and their broader implications. Using the models in such collaboration can result in a holistic impression of the advantages and disadvantages associated with implementing certain plans and strategies in the local community, which in turn can inform and enhance integrated community planning and decision-making.

As previously discussed, in many cases, co-benefits have not been planned nor have they been measured or accounted for in the bottom line, particularly the increased job opportunities. However, this research shows that co-benefits can be deliberatively planned and can serve as a basis for integrated planning. Understanding and modelling these co-benefits can result in powerful tools that can enhance community engagement processes and sustainability, where government and stakeholders can bring in place-specific considerations and explore how to achieve multiple goals through certain strategies and bring in place specific considerations. Although trade-offs or "co-harms" (Spencer et al. 2016) may be inevitable, many could possibly be avoided through this kind of integrated deliberative planning and modelling. At the very least, a conversation could be started on recognizing both the advantages and disadvantages of taking a particular development path.

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