Addendum to the Durham Region Roundtable on Climate Change Committee Agenda

Council Chambers
Regional Headquarters Building 605 Rossland Road East, Whitby

Friday, March 18, 2022   10:00 AM

Note: Additional agenda items are shown in bold

1. Roll Call

2. Declarations of Interest

3. Adoption of Minutes

A) DRRCC meeting of February 18, 2022 (Attachment #1)

4. Delegations

New **A)** **Alyssa Scanga, Climate Justice Durham, re: Land Need Assessment Scenarios**

   Requires motion to be heard

5. Presentations

A) Overview of Alternative Land Need Assessment Scenarios – Colleen Goodchild, Manager Policy & Special Studies, and Brad Anderson, Principal Planner, Durham Region Planning Division (Summary report [available here](#))

B) Climate considerations associated with land needs assessment scenarios – Yuill Herbert, Sustainability Solutions Group **(Attachment #2)**

C) Climate and Sustainability Program Update – Ian McVey, Manager of Sustainability, Durham Region

6. Items for Information and discussion

A) Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report Working Group II report – Impacts, Adaptation and Vulnerability ([Available here](#))

B) Whitby memo to Council – Proposed Changes for the Next Edition of Ontario's Building Code ([Available here](#))

C) Report #2022-P-7 – Envision Durham Identifying a Regional Natural Heritage System ([Available here](#))

If this information is required in an accessible format, please contact 1-800-372-1102 ext. 2097.

D)   Report #2022-INFO-9 – Envision Durham – Growth Management Study – Alternative Land Need Scenarios ([Available here](#))

E)   Report #2022-INFO-15 – Durham Greener Homes Program Update ([Available here](#))

F)   Report #2022-INFO-16 - Proposed Wastewater Energy Transfer Project - Dockside Development in the Town of Whitby ([Available here](#))

7.   Other Business

8.   Date of Next Meeting

        April 22, 2022

9.   Adjournment

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Region of Durham

Impact of Land-use Scenarios on GHG Emissions

Briefing V.1

March 3, 2022

SSG   *whatIf?*

Disclaimer
The information in this analysis has been compiled to offer an assessment of the GHG emissions for the Region of Durham. Reasonable skill, care and diligence have been exercised to assess the information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains, and the information and basis on which it relies, are subject to changes that are beyond the control of the author. The information provided by others is believed to be accurate but has not been verified.

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Findings

The correlation between lower density and higher GHG emissions is well-established. Lower density results in high emissions because people drive more, dwellings are larger, and land which would otherwise be sequestering carbon is used for development. The analysis of GHG emissions indicates that the higher density scenario (Scenario 5) could reduce emissions by more than 1 million tonnes per year relative to the low-density scenario (Scenario 1). For reference, Durham's total community GHG emissions in 2016 were 5.6 million tonnes.

Saving GHG emissions generally results in saving energy, which results in financial savings. For example, at $20/GJ[1], the improved efficiency of Scenario 5 saves approximately $160 million per year in energy costs relative to Scenario 1.

Lower density development is more expensive to decarbonize than high density development. Key climate solutions, such as higher-order transit and district energy, are cost prohibitive or are impractical in low-density built environments.

From the perspective of the climate emergency and Durham's Community Energy Plan, maximizing density in future land-use scenarios reduces GHG emissions, reduces the cost of and challenge of decarbonizing the Region, and keeps future low carbon options on the table, such as district energy and transit.

Context

Durham Region is undertaking a Growth Management Study (GMS) as part of Envision Durham, the Municipal Comprehensive Review (MCR) of the Regional Official Plan (ROP). The GMS includes a Lands Needs Assessment to evaluate how to accommodate the Growth Plan for the Greater Golden Horseshoe region. The plan forecasts that Durham's population will grow by 1.3 million by 2051 and there will be an additional 460,000 jobs in the region.

In 2019, Regional Council passed the Durham Community Energy Plan, a strategy to achieve GHG emissions reduction of 80% below 2007 levels by 2050. In 2020, Durham Regional Council voted to declare a climate emergency. In 2022, the Intergovernmental Panel on Climate Change issued a five-year assessment of the impacts of climate change that is a clarion call for more urgent action.[2]

This briefing assesses the impact of land-use patterns on climate change, and the implications for the Region's targets and objectives.

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[1]Gasoline a $2/litre is equivalent to nearly $60/GJ.

[2] IPCC (2022.). Climate Change 2022; Impacts, Adaptation and Vulnerability. Summary for Policy Makers. https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

The relationship between density, energy use and GHG emissions is well-understood in the literature. As one influential study states[3]:

> *For decades, the relationship between travel and the built environment has been one of the most studied in urban planning. Built environments that are high on the D-variables—development density, land-use diversity, street connectivity, destination accessibility, and distance to transit (which is low in compact developments)—are often described as compact. Those that are low are described as sprawling. A major tenet of the literature both on regional development and neighborhood design is that compact development reduces driving.*

This pattern is evident in analysis completed by SSG for the Durham Community Energy Plan, where vehicle kilometres travelled (VKT) are higher in lower density areas in the region (Figure 1). Per capita VKT ranges from 2,200 km per year in denser zones in the south to 13,000 km per year in rural zones in the north. The much higher densities contemplated in the Lands Needs Assessment would increase this differential as densities increase.
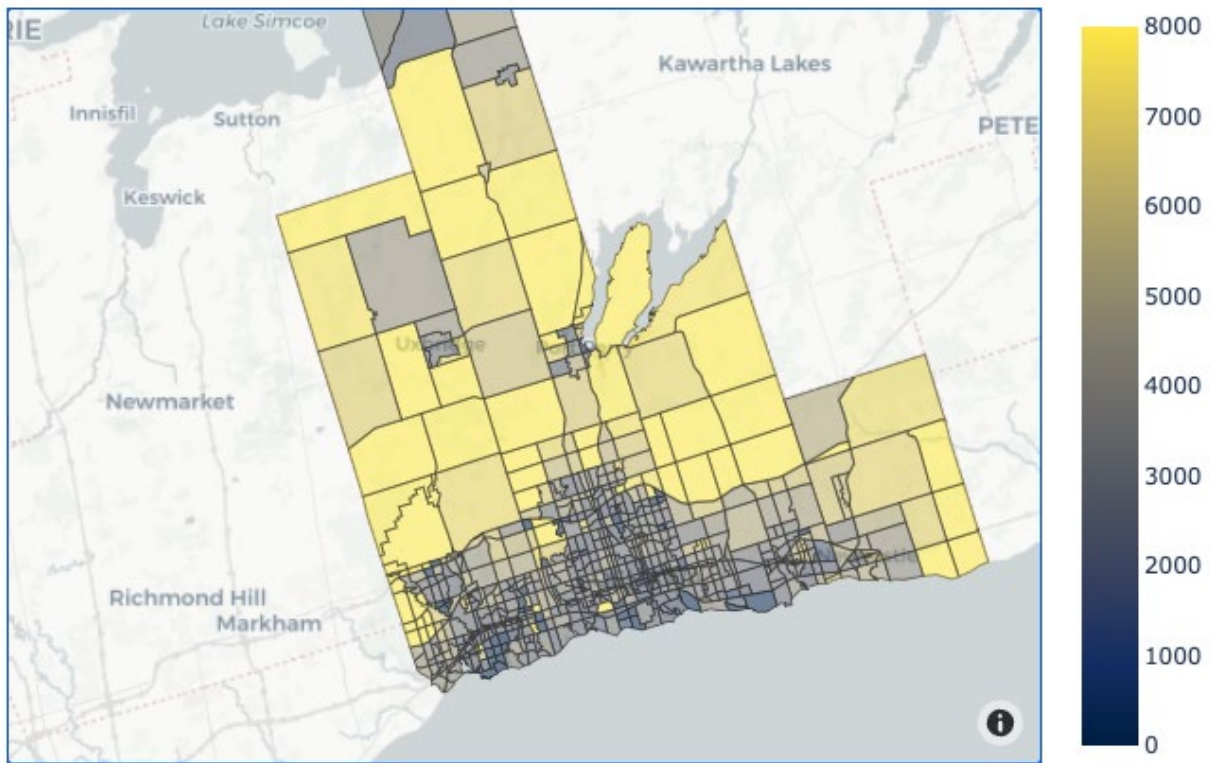
Figure 1. Home-based VKT per capita by zone, 2016.[4]

In addition to transportation energy and emissions, the character of the built environment also impacts energy use and emissions from buildings. A similar pattern of increasing energy

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[3] Ewing, R., & Cervero, R. (2017). "Does compact development make people drive less?" the answer is yes. Journal of the American Planning Association, 83(1), 19-25.

[4] Analysis completed by SSG for the Durham Community Energy Plan. Unpublished, 2018.

consumption per capita from south to north is also evident in Durham, but is less pronounced. As the level of density increases, it is expected that this pattern will become more evident.
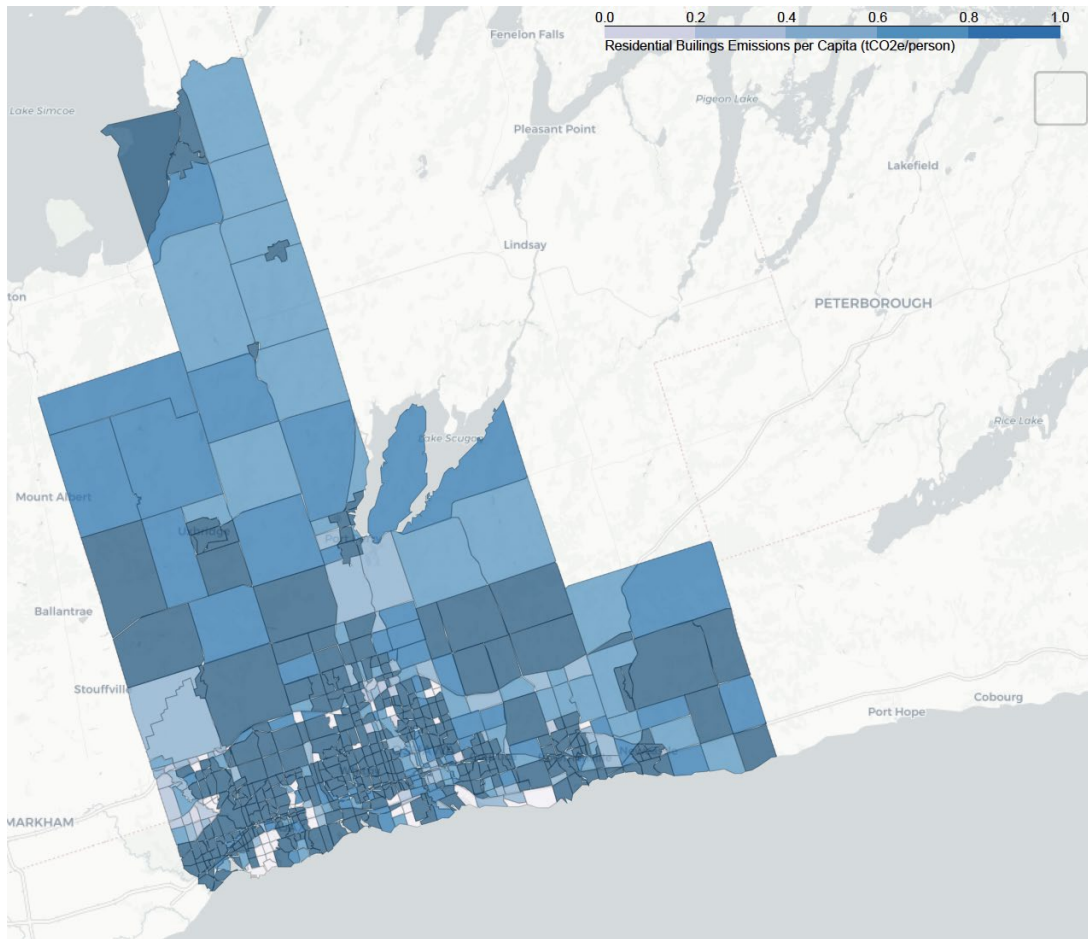

Figure 2. Residential energy consumption per capita by zone, 2016.[5]

Another study in the GTA analyzed both transportation and building energy and emissions from high density and low density developments. It found that GHG emissions were 2.6 times greater in the low density development.[6]

Lock-in and Path Dependence: Atlanta vs. Barcelona

Atlanta's population is comparable to Barcelona's, but Atlanta is ~25 times larger than Barcelona and its GHG emissions from transportation are ~10 times higher. Barcelona's compact form locks in low-carbon lifestyles, whereas Atlanta's investments in roads and buildings result in an energy and emissions trajectory that is costly and difficult to change. Whereas Barcelona can consider solutions such as district energy and enhanced transit to

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[5] Analysis completed by SSG for the Durham Community Energy Plan (2018). Unpublished.

[6] Norman, J., MacLean, H. L., & Kennedy, C. A. (2006). Comparing high and low residential density: life-cycle analysis of energy use and greenhouse gas emissions. Journal of urban planning and development, 132(1), 10-21.

generate positive economic returns, these solutions may not be possible in Atlanta. Land-use planning determines population density and connectivity to goods and services and is therefore critical in enabling future low-carbon opportunities.

	ATLANTA	BARCELONA
POPULATION	2.5 million	2.8 million
URBAN AREA	4,280 km2	162 km2
EMISSIONS	7.5 tCO2e/person (public & private transportation)	0.7 tCO2e/person (public & private transportation)
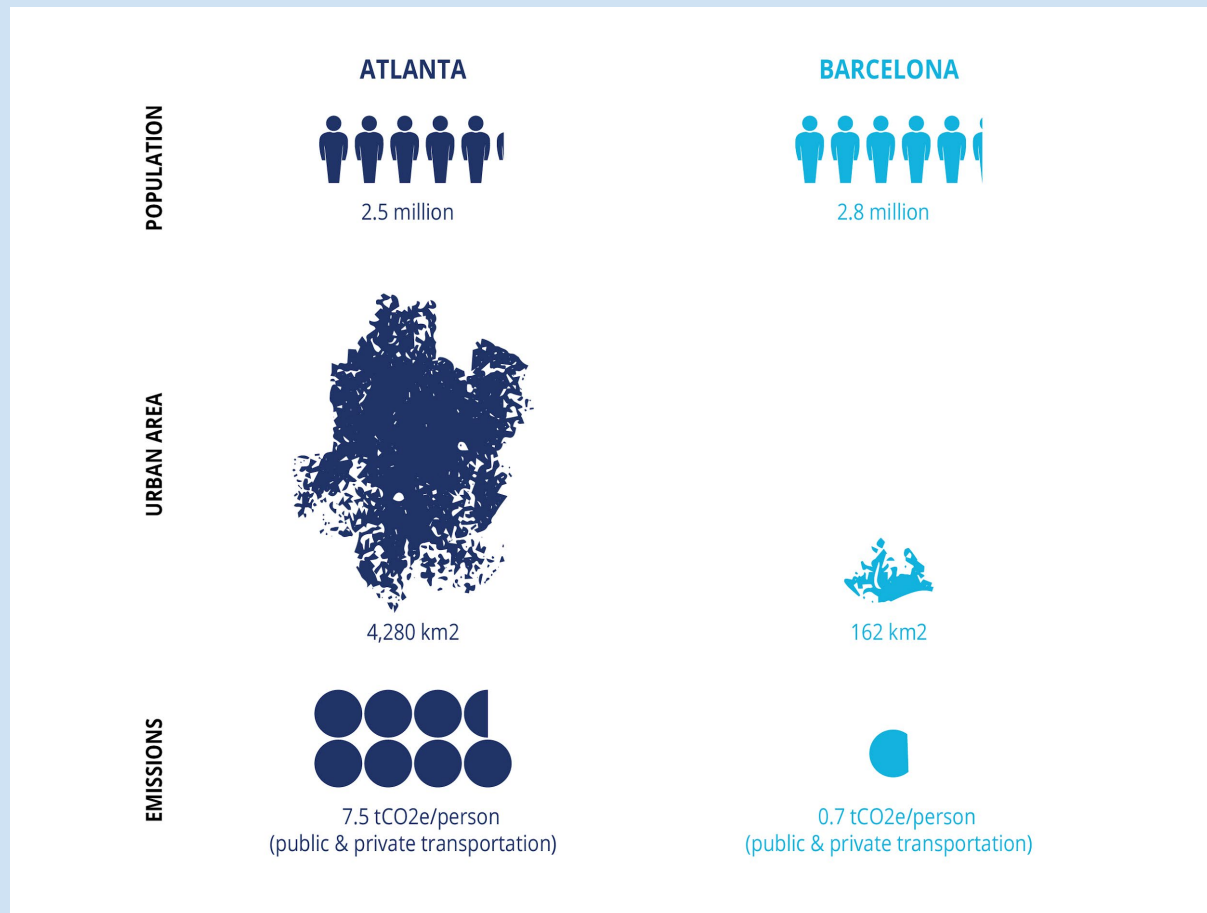
Methodology

Analysis

The total GHG emissions of each scenario in Durham's Alternative Land Need Scenarios Assessment Summary Report (2022) were calculated for transportation, stationary energy (household energy consumption), and land-use change using projections for population and land-use consumption.

The Kaya factor method[7] was used to calculate GHG emissions. In this approach. GHG emissions are the product of an activity driver (e.g., floor area of building space), energy use per unit of

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[7] Grafton, R. Q. (2012). Kaya Identity. In A Dictionary of Climate Change and the Environment. Edward Elgar Publishing Limited.

activity (e.g., energy per unit floor area for space heating), and an emissions factor (carbon emissions per unit of energy).

The analysis asks what would happen if an additional 581,000 people are added to the Region of Durham under current conditions. As a result, all other variables reflect current conditions, including the emissions factor of electricity, fuel efficiency of vehicles, and vehicles kilometres travelled.

This analysis provides a framework for relative comparisons among various land-use scenarios in terms of their potential impacts on energy consumption and GHG emissions. This is necessarily a high-level exercise given that many important contributions to the overall goal of energy and GHG reductions depend on important initiatives outside the realm of land-use planning. The goal is to quantify the marginal impact on energy usage and GHG emissions resulting from the intensification-verses-greenfields tradeoffs inherent in any scenarios to be evaluated, and also to provide a basis for assessing the relative magnitude of these differences in relation to other actions that could be taken to achieve reductions.

Although the approach is geared to addressing the various scenarios that are currently being developed as part of Durham's Land Needs Assessment, the analysis should be sufficiently general to allow it to be applied to other similar scenarios, should they be needed.

Weighting parameters were used to capture the impact of density and dwelling type on travel behaviour, including vehicle ownership and average VKT, based on our analysis of current transportation patterns for different characteristics of the built environment. Available data with sufficient granularity is limited, necessitating some assumptions even regarding current conditions. As these parameters can be expected to change over time, the object here is to provide reasonable values that facilitate relative comparisons among the scenarios.

Limitations

1. **Embodied emissions:** A preliminary analysis of embodied emissions was undertaken for five scenarios. However, embodied emissions are highly sensitive to construction techniques. In one case a single family dwelling can have a lower GHG footprint than an apartment unit, whereas under different assumptions this outcome is reversed. As a result, these calculations are not included.

2. **Technological change:** The analysis assumes current technologies. If and when the electricity grid becomes cleaner and when electric vehicles begin to dominate the vehicle stock, the GHG impact of travel will decrease.

3. **Employment:** The analysis did not quantitatively assess the impact of employment activity on GHG emissions, beyond the inclusion of journey to work. Non-residential buildings were not included.

4. Land-use change: While the loss of the carbon sink represented by agricultural land, wetlands and forests is included as a result of conversion of this land. The annual carbon sequestration rate has not been calculated, which would be an additional benefit for avoided use of greenfield sites.

Results

Increased density decreases emissions

GHG emissions are reduced in land-use, transportation and buildings as the density of the scenarios increase (Figure 4). The major impacts are in land-use, as land which sequesters carbon is consumed and vehicular traffic is reduced. In total, the GHG emissions are reduced by 40% in scenario 5 over Scenario 1. Scenario 5 achieves a reduction of 1 million tCO2e relative to Scenario 5, relative to Region of Durham's total emissions of 5.5 million tCO2e in 2016.

Note that the GHG reduction in land-use occurs once when the agricultural lands, forests and wetlands are converted from a carbon sink, whereas reductions in transportation and buildings occur annually, scaled to however many households have been constructed at any point in time.
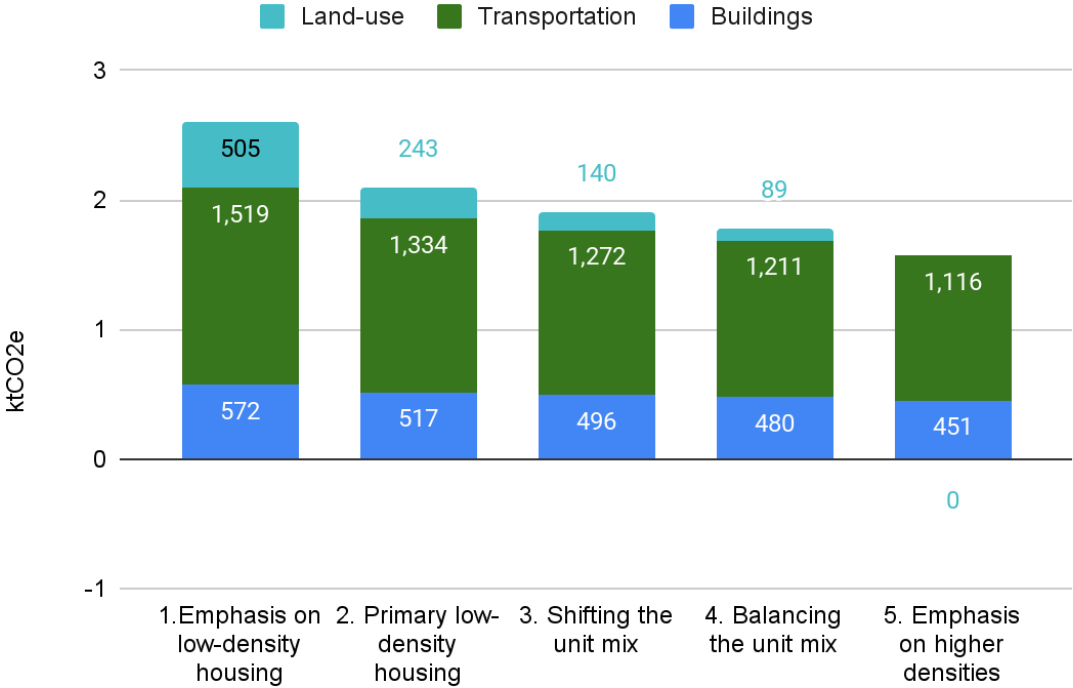
Figure 4. Total GHG emissions for each scenario.
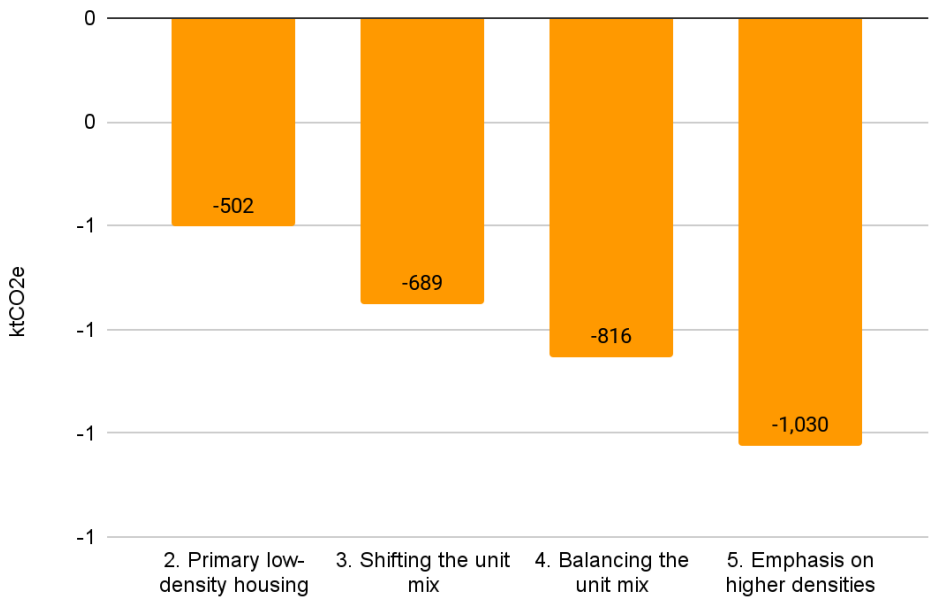
Figure 5. Incremental GHG reductions relative to Scenario 1.

The GHG emissions results calculated in this analysis need to be caveated by assumptions used. For example the ratio between the energy use intensity of low density and high density projects influences the energy consumed and therefore the GHG emissions reductions.

A more efficient built environment decreases the cost of the energy transition

A more efficient built environment has cascading impacts on land-use, energy costs and biodiversity based on how much energy it requires.

A more efficient urban system requires less land for energy production, while a less efficient system requires more land. An energy system requires land for mining, processing, generation and distribution.

One way to evaluate urban efficiency is to calculate the area of land that would be required if the future growth in Durham was powered by solar. No energy system is likely to be powered 100% by solar PV, so this calculation is only an illustration of the efficiency of the five scenarios, and not a representation of the actual area of land that will be required.

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Figure 6. Incremental reduction in land required for each scenario relative to scenario 1, if homes and transportation were powered by solar PV.

Using a land use intensity that also includes infrastructure such as powerlines[8], Scenario 1 requires 390,000 ha of solar PV and associated infrastructure to power the 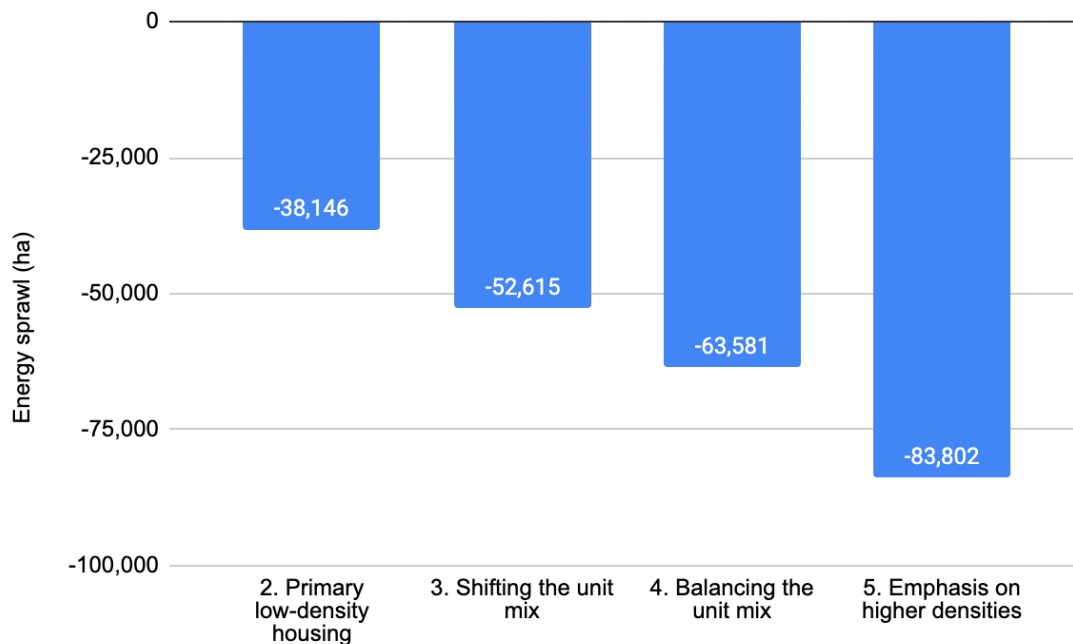system, while Scenario 5 requires 300,000 ha, a reduction of 22%. Every trip that is walked or cycled, or home that is more efficient is energy that need not be generated. This avoided energy generation reduces capital and operating costs, land requirements, conflicting land-use and other impacts, which is likely the most affordable decarbonisation strategy available.

The financial benefits of a more efficient built environment

A financial benefit results from reducing energy consumption and GHG emissions, increasing the affordability of housing. A person who is able to walk to work avoids the cost of gasoline required for a vehicular commute. An apartment with shared walls will pay less for heating than a single family dwelling with more external walls. For example, at $20/GJ[9], the improved efficiency of Scenario 5 saves approximately $160 million per year in energy costs relative to Scenario 1.

Additionally, as climate change becomes more urgent, the value of GHG emissions stored in the soil and trees will become more valuable.

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[8] Solar PV was selected as appropriate for a low carbon future, but a similar analysis could have been undertaken with oil, gas, wind or other energy technologies. The solar intensity was source from: 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.
[9] Gasoline a $2/litre is equivalent to nearly $60/GJ.

Conclusions

Land-use policy is an important GHG emissions reduction strategy as it can avoid locking in infrastructure systems and activities that are costly to retrofit or to provide without generating GHG emissions. More directly, land-use policy can enable cost effective emissions reductions. For example, it is more affordable to provide zero emissions transportation and zero emissions energy to a compact, complete community than to a dispersed population. When destinations are in close proximity, people can walk or cycle, which requires no energy generation. Houses tend to be smaller and share walls, which can also reduce energy consumption. District energy is more viable when heat loads are concentrated.

Land-use policy is also the most cost-effective action a municipality can take, as it can enable GHG emissions reductions without requiring a direct investment by the municipality or society.

Appendices

Appendix 1: Residential Building Calculations

Table 1. GHG emissions from buildings, built-up areas.

Built Up Area						
Scenario						
	1.Emphasis on low-density housing	2. Primary low-density housing	3. Shifting the unit mix	4. Balancing the unit mix	5. Emphasis on higher densities	Key
Low-density units	4,800	4,900	9,300	5,100	5,200	a
Average floor area (m2)	230	230	230	230	230	*
EUI (GJ/m2)	0.344	0.344	0.344	0.344	0.344	b
Emissions factor (kgCO2/GJ)	40.0	40.0	40.0	40.0	40.0	b
Sub-total (tCO2e)	15,184	15,500	29,419	16,133	16,449	
Medium-density units	29,400	30,200	36,500	31,000	32,000	a
Average floor area (m2)	140	140	140	140	140	*
EUI (GJ/m2)	0.32	0.32	0.32	0.32	0.32	b
Emissions factor (kgCO2/GJ)	36.4	36.4	36.4	36.4	36.4	b
Sub-total (tCO2e)	48,001	49,307	59,593	50,613	52,246	
High-density units	35,500	55,000	55,100	64,800	74,300	a
Average floor area (m2)	100	100	100	100	100	*
EUI (GJ/m2)	0.615	0.615	0.615	0.615	0.615	b
Emissions factor (kgCO2/GJ)	29.8	29.8	29.8	29.8	29.8	b
Sub-total (tCO2e)	65,101	100,861	101,044	118,832	136,254	
Secondary units	4,100	5,870	5,870	5,870	5,870	a
Average floor area (m2)	70	70	70	70	70	*
EUI (GJ/m2)	0.249	0.249	0.249	0.249	0.249	b
Emissions factor (kgCO2/GJ)	32.9	32.9	32.9	32.9	32.9	b

Sub-total (tCO2e)	2,355	3,371	3,371	3,371	3,371	
Total (tCO2e)	**130,640**	**169,039**	**193,427**	**188,949**	**208,320**	
Total Units	73,800	95,970	106,770	106,770	117,370	

Table 2. GHG emissions from buildings, greenfield areas.

Designated Greenfield Area						
	Scenario					
	1.Emphasis on low-density housing	2. Primary low-density housing	3. Shifting the unit mix	4. Balancing the unit mix	5. Emphasis on higher densities	Key
Low-density units	110,700	76,600	60,800	53,500	36,000	a
Average floor area (m2)	260	260	260	260	260	*
EUI (GJ/m2)	0.344	0.344	0.344	0.344	0.344	b
Emissions factor (kgCO2/GJ)	40.0	40.0	40.0	40.0	40.0	b
Sub-total (tCO2e)	395,857	273,917	217,417	191,313	128,734	
Medium-density units	18,220	25,300	27,500	28,800	33,100	a
Average floor area (m2)	160	160	160	160	160	*
EUI (GJ/m2)	0.32	0.32	0.32	0.32	0.32	b
Emissions factor (kgCO2/GJ)	36.4	36.4	36.4	36.4	36.4	b
Sub-total (tCO2e)	33,997	47,208	51,313	53,738	61,762	
High-density units	5,480	13,200	16,300	22,600	25,500	a
Average floor area (m2)	110	110	110	110	110	*
EUI (GJ/m2)	0.615	0.615	0.615	0.615	0.615	b
Emissions factor (kgCO2/GJ)	29.8	29.8	29.8	29.8	29.8	b
Sub-total (tCO2e)	11,054	26,627	32,881	45,589	51,439	
Secondary units	460	660	660	660	660	a
Average floor area (m2)	80	80	80	80	80	*
EUI (GJ/m2)	0.249	0.249	0.249	0.249	0.249	b

Emissions factor (kgCO2/GJ)	32.9	32.9	32.9	32.9	32.9	b
Sub-total (tCO2e)	302	433	433	433	433	
Total (tCO2e)	**441,210**	**348,185**	**302,044**	**291,074**	**242,368**	
Total Units	134,860	115,760	105,260	105,560	95,260	

Table 3. Energy use intensity (EUI).

	Energy use intensity (GJ/m2)				Key
Dwelling types	**Heating EUI**	**Domestic hot water EUI**	**Electricity EUI**	**Total**	
Single detached	0.201	0.065	0.078	0.344	b
Row house	0.154	0.064	0.102	0.32	b
Mid-rise apartment	0.206	0.107	0.302	0.615	b
Semi-detached	0.083	0.064	0.102	0.249	b

Table 4. Weighted EUI.

	Natural gas	**Electricity**	**Weighted average EUI (GJ/m2)**
Single detached	77.33%	22.67%	40.0
Row house	68.13%	31.88%	36.4
Mid-rise apartment	50.89%	49.11%	29.8
Semi-detached	59.04%	40.96%	32.9

Table 5. Emissions factors.

Emissions Factor (kgCO2e/GJ)	
Natural gas	48.7
Electricity	10.2

Appendix 2: Transportation

Table 6. Transportation, built-up areas.

	Built Up Area					
	Scenario					
	1.Emphasis on low-density housing	2. Primary low-density housing	3. Shifting the unit mix	4. Balancing the unit mix	5. Emphasis on higher densities	Key
Low-density units	4,800	4,900	9,300	5,100	5,200	a
Commuting factor	0.80	0.80	0.80	0.80	0.80	*
VKT (km/vehicle/year)	17,356	17,356	17,356	17,356	17,356	c
Vehicles per household	2	2	2	2	2	d
Efficiency (l/100 km)	9	9	9	9	9	e
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283	f
Sub-total (tCO2e)	34,235	34,949	66,331	36,375	37,088	
Medium-density units	29,400	30,200	36,500	31,000	32,000	a
Commuting factor	0.70	0.70	0.70	0.70	0.70	*
VKT (km/vehicle/year)	15,187	15,187	15,187	15,187	15,187	c
Vehicles per household	1.5	1.5	1.5	1.5	1.5	d
Efficiency (l/100 km)	9	9	9	9	9	e
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283	f
Sub-total	137,610	141,354	170,842	145,099	149,779	
High-density units	35,500	55,000	55,100	64,800	74,300	a
Commuting factor	0.60	0.60	0.60	0.60	0.60	*
VKT (km/vehicle/year)	13,017	13,017	13,017	13,017	13,017	c
Vehicles per household	1.00	1.00	1.00	1.00	1.00	d
Efficiency (l/100 km)	9	9	9	9	9	e
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283	f
Sub-total	94,949	147,105	147,372	173,316	198,725	

Secondary units	4,100	5,870	5,870	5,870	5,870	a
Commuting factor	0.50	0.50	0.50	0.50	0.50	*
VKT (km/vehicle/year)	10,848	10,848	10,848	10,848	10,848	c
Vehicles per household	0.7	0.7	0.7	0.7	0.7	d
Efficiency (l/100 km)	9	9	9	9	9	e
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283	f
Sub-total	6,397	9,158	9,158	9,158	9,158	
Total (kgCO2e)	**273,191**	**332,566**	**393,703**	**363,948**	**394,751**	
Total (litres)	119,663,262	145,670,520	172,450,019	159,416,614	172,908,873	
Total (GJ)	4,188,214	5,098,468	6,035,751	5,579,581	6,051,811	

Table 7. Transportation, greenfield.

Designated Greenfield Area						
	Scenario					
	1.Emphasis on low-density housing	2. Primary low-density housing	3. Shifting the unit mix	4. Balancing the unit mix	5. Emphasis on higher densities	Key
Low-density units	110,700	76,600	60,800	53,500	36,000	a
Commuting factor	1.00	1.00	1.00	1.00	1.00	*
VKT (km/vehicle/year)	21,695	21,695	21,695	21,695	21,695	c
Vehicles per household	2.2	2.2	2.2	2.2	2.2	d
Efficiency (l/100 km)	9	9	9	9	9	e
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283	f
Sub-total (tCO2e)	1,085,633	751,215	596,264	524,673	353,051	
Medium-density units	18,220	25,300	27,500	28,800	33,100	a
Commuting factor	0.90	0.90	0.90	0.90	0.90	*
VKT (km/vehicle/year)	19,526	19,526	19,526	19,526	19,526	c
Vehicles per household	1.8	1.8	1.8	1.8	1.8	d
Efficiency (l/100 km)	9	9	9	9	9	e

Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283 f
Sub-total	131,576	182,704	198,591	207,979	239,032
High-density units	5,480	13,200	16,300	22,600	25,500 a
Commuting factor	0.80	0.80	0.80	0.80	0.80 *
VKT (km/vehicle/year)	17,356	17,356	17,356	17,356	17,356 c
Vehicles per household	1.4	1.4	1.4	1.4	1.4 d
Efficiency (l/100 km)	9	9	9	9	9 g
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283 f
Sub-total	27,360	65,903	81,380	112,834	127,312
Secondary units	460	660	660	660	660 a
Commuting factor	0.70	0.70	0.70	0.70	0.70 *
VKT (km/vehicle/year)	15,187	15,187	15,187	15,187	15,187 c
Vehicles per household	0.8	0.8	0.8	0.8	0.8 g
Efficiency (l/100 km)	9	9	9	9	9 e
Emissions factor (kgCO2/l)	2.283	2.283	2.283	2.283	2.283 f
Sub-total	1,148	1,648	1,648	1,648	1,648
Total (kgCO2e)	**1,245,716**	**1,001,469**	**877,883**	**847,134**	**721,043**
Total (litres)	545,648,853	438,663,629	384,530,574	371,061,745	315,831,346
Total (GJ)	19,097,710	15,353,227	13,458,570	12,987,161	11,054,097

Appendix 3: Sequestration

Table 8. Sequestration calculation.

	Scenario					Key
	1.Emphasis on low-density housing	2. Primary low-density housing	3. Shifting the unit mix	4. Balancing the unit mix	5. Emphasis on higher densities	
Additional DGA Community Area (ha)	5,400	2,600	1,500	950	-1	
Total DGA Community Area (Ha)	11,753	8,953	7,853	7,303	6,352	
Sequestration (tCO2e/ha)	94	94	94	94	94	
Total (tCO2e)	**505,170**	**243,230**	**140,325**	**88,873**	**-94**	

Table 9. Sequestration absorption rates.

	Sequestration (t/ha/yr)	Key
Agricultural sequestration	0.5	i
Forest	0.75	j
Wetlands	0.25	k

Table 10. Sequestration storage.

	Storage (t/ha)	**Share**	**Storage (t/ha)**	**Key**
Agricultural soils	80	85%	68	i
Forest	220	10%	22	j
Wetlands	71	5%	4	k
			94	

Appendix 4: Energy Footprint

Table 11. Impact of energy generation on land use, built-up area.

	Scenario					
	2.283	2.283	2.283	2.283	2.283	Key
Total GJ required	8,139,823	10,323,930	11,897,731	11,459,408	12,568,599	
Energy (GJ/ha)	0.01	0.01	0.01	0.01	0.01	h
Ha required	**83,433**	**105,820**	**121,951**	**117,459**	**128,828**	

Table 12. Impact of energy generation on land use, greenfield area.

	Scenario					
	2.283	2.283	2.283	2.283	2.283	Key
Total GJ required	30,311,467	24,405,818	21,420,364	20,788,798	17,706,879	
Energy (GJ/ha)	0.01	0.01	0.01	0.01	0.01	h
Ha required	**310,692**	**250,159**	**219,558**	**213,085**	**181,495**	

Table 13. Modelling sources.

a	Alternative Land Need Scenarios Assessment Summary Report March 2022
b	Calculated in NRCan's HTAP to align with OBC 2020
c	Transportation Tomorrow Survey
d	Extrapolated from: Transportation Tomorrow Survey
e	Statistics Canada, Market Snapshot: How does Canada rank in terms of vehicle fuel economy?
f	Government of BC, 2020 BC Best Practice Methodology
g	Blame the exurbs, not the suburbs: Exploring the distribution of greenhouse gas emissions within a city region. J Wilson, et al. Energy Policy, 2013.
h	McDonald et al., (2009). Energy Sprawl or Energy Efficiency: Climate Policy Impacts on Natural Habitat for the United States of America
i	C. Tarnocai and B. Lacelle. 1996. Soil Organic Carbon Database of Canada. Eastern Cereal and Oilseed Research Centre.

j	W.A. Kurz and M.J. Apps. 1999. "A 70-Year Retrospective of Carbon Fluxes in the Canadian Forest Sector."
k	Ducks Unlimited, "Carbon sequestration and greenhouse gas emissions in wetlands." www.ducks.ca/conserve/research/ projects/climate/carbon.html.
*	Assumptions (weights), provided as 'best guess' starting points.

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