A SYSTEMS APPROACH TO HOUSING POLICIES

PAPER 3

HOUSING SYSTEM OUTCOMES AND NET ZERO CARBON.

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1. HOUSING AND THE ENVIRONMENT: INTRODUCING CONNECTED SYSTEMS.

***Longstanding, but Limited Concerns**.*

Since the onset of human settlement there has been a recognition that there are recursive relationships between the outcomes of structures (however rudimentary and impermanent) used for comfort, privacy and shelter and the environment of stocks of natural capital and its associated biodiversity and ambient flows of water, air, and fire (Hall, 1998). In contemporary, predominantly urban, settlement systems the stock of housing is the most extensive component of the built environment in which lives are led (Jacobs, 1961). Humans always have a housing-related environmental footprint.

Water supply, sewage disposal, and heating systems within homes impacted ambient environmental flows of water and air quality in early urban settlements. Evidence from early urbanisations in Asia, Latin America, and Africa suggest that many, like the Greeks and Romans, also introduced intra-settlement zoning to separate land uses associated with noise, fire hazards, smoke, and noxious odour spillovers from the homes of citizens. In growing 19th century cities, with industrialisation and growth fuelled by coal, households with resources paid a premium to locate away from contaminated water flows, noxious odours (emanating from glue factories and city animal markets), and smoke and smog pollution. 'West end' neighbourhoods, where prevailing winds were westerlies, quickly attracted 'quality' housing price premia and higher social status residents. Downstream water supply points were identified as sources of ill health and early death.

Poor environmental outcomes very quickly had feedback effects on housing outcomes. Localised sharp differences in environmental quality juxtaposed high- and low-quality homes and accelerated neighbourhood segregations of higher- and lower-income households within cities. Adverse environmental outcomes for poorer households have been an intrinsic feature of urbanisation processes always shaping close interactions between environmental, built, and socio-economic environments.

In addition to these ambient flow effects on urban environments, there is also a longstanding recognition that creating the built environment intrudes physical capital into natural ecosystems and inevitably destroys natural capital. Replacing nature with built structures has major implications for the stock of natural capital, the ability of citizens to access natural capital and ecosystem services, and biodiversity effects, and has local and global climate impacts through absorption, radiation and 'heat island' effects (Spirn, 1985). And the ways in which the design, layout, and density of homes, streets, precincts, squares, plazas of city cores, and suburbs too constitute a visual representation of the built environment, as a 'public goods' that can create citizen value.

Long-lasting Interventions.

Building regulation and city planning have been key policy tools in shaping better housing-environment outcomes (Hall, 1998), and they have a natural local, or municipal, emphasis. The wider spread of environmental damage from local actions was not generally regarded as a major issue until after the 1970s when local smoke pollution was recognised as leading to acid rain in different jurisdictions (and nations) and that local waste and water pollution were already impacting the deep oceans. Environment Ministries at federal and provincial levels emerged, almost half a century ago, to address problems related to waste, water pollution, air pollution (including acid rain effects) and noise pollution. Many of these difficulties had been significantly addressed before the start of this millennium with much-reduced pollution levels in most OECD countries and later concerns about fluorocarbon-induced erosion of the ozone layer also largely resolved. Undoubtedly there is more to be done, but it is important to note that strong policy actions and technical innovation have managed what was regarded as potentially environmental policy challenges.

As that progress has been made there has been a recognition of more complex environmental challenges, most obviously the accumulating damage of rising greenhouse gas (GHG) emissions, which are multi-locational in origin and impact, and that require to be addressed by a multiplicity of policy instruments (charges, prices, standards as well as land-use planning) and a range of orders of government. It remains true, nevertheless, that it is building and land-use regulation and planning, and not economic or environmental policy divisions or silos, that has remained the major policy domain in which housing-environment interactions are governed within all orders of government. That said, provincial and municipal governments are at the forefront of land and planning strategies. Fiscal instruments, such as property and land taxation, different charges and levies have also played roles, within largely local settings and on this markedly varied policy landscape, across Canada, new sub-national rules and subsidies, and strategy time scales and targets are being unfolded to address transitions towards net zero GHG emissions.

How has 'housing policy', conventionally defined (see Paper 1) linked to 'environmental' policy? Social justice and health improvement cases for better, affordable homes for the poor have been at the core of conventional 'merit good' cases, for lobbyists and policymakers, both a century ago and now. Underlying these 'social needs' cases there has always been an extensive and changing pattern of adverse environmental outcomes that have been both regressive in their impacts and damaging to individual capabilities (most obviously through poor health effects). Yet housing lobbies and policymakers focussed within the 'housing as social policy silo' have not concentrated on the environmental outcomes of housing systems for, arguably, the last 50 years. At national levels, environment ministries with little understanding of housing systems made minimal efforts to link housing and environmental outcomes[1]. In many respects, the housing sector left the issue of the environmental outcomes of buildings and the built environment to 'planning' silos. Across all orders of government planning policy and implementation silos saw their status, employee numbers and power erode from the 1980s onwards. There is evidence that in some times and places planning processes can reduce housing supply flexibility (see Paper 1), but it is also equally clear that much of the research on housing and planning issues emphasises the remarkably ideological content not just of policy but research and says nothing of the sustainability benefits of quality planning that minimises the environmental damage of building and

[1] In 2003, as Chief Economist at the Department of Sustainability and Environment in the State Government of Victoria and working for a remarkably competent and prescient Minister and Department Secretary (arguing for acclimate change strategy 20 years ago) I signed-off a transfer of $80m dollars unspent in the Environment budget to the Housing Minister to support better insulation within relatively poor quality public housing. There was a near furore of criticism from my peers and an immediate threat to reduce the Environment budget for the following year. Much has changed since.

using homes. As the emphasis is now changing, and rapidly, so that housing policy and governance seek to better address key environmental issues associated with the global 'climate emergency' and Canada's connected system of local 'housing crises' then the synergies across housing, infrastructure, planning, energy and environmental departments and ministries may need rethinking. This essay suggests some important concerns for policy and governance change to address in shaping a new understanding and governance of the housing system that supports measures to meet the challenge of reducing GHG.

The Existential Challenge!

In this Anthropocene the use of fossil fuels has produced carbon dioxide (CO2) at rates that have raised the average temperature of the earth's atmosphere (Stern, 2007). Aside from the rising global wide increases in CO2 production, the unlinking and mismatch of the original location of production of the CO2 'externality' and the location of the climate change damage 'impact' creates a major difficulty in inducing and coordinating local actions to shape a global solution. Not only is the 'origins-incidence' mismatch geography more complex but there is now an established science consensus that the 'carbon-global warming-damage' system is close to an edge of chaos moment that will see currently un-forecasted dynamics to the geography and extent of probably irreversible climate changes (IPCC, 2023). Now global warming poses an existential threat to how 21st-century economies and societies function. Arguably the infrastructure and governance systems devised to cope with locally generated and regionally impacting environmental damage no longer match the requirements for good environments and effective governance for the decades ahead.

There is now wide agreement (COP 26 and 27) that it is essential to move towards, and reach, net zero carbon economic and social systems by mid-century to avoid local, regional, national, and global weather systems crises. The recent Climate Assessment Synthesis Report of the IPCC (2023) has restressed the importance and urgency of reducing human impacts on adverse climate change. They report that policy responses to the goal of limiting temperature increase to 1.5 C by 2100 have been inadequate (globally) and imply a future some 3 degrees warmer. That rise, they argue, will lead to greater levels of human discomfort, damage and death induced by the increases in storms, floods, droughts, record temperature highs and lows arising from climate change. For many growth will be immiserising if we continue to use the current energy and infrastructure systems that evolved in the era of fossil fuels to pursue future lives.

Canada, the IPC report, will be adversely affected, with northern Canada already warming at twice the global average. This essay, whilst recognising the continuing importance of major ambient flows and biodiversity loss focusses, takes the links between 'housing' and global warming induced by GHG as the key illustration of how housing systems outcomes on the environment require reintegration into housing policy thinking.

So how does reshaping housing markets, systems and policies play into this existential concern for Canadian ways of living?

Housing Markets and Systems Always Matter in the Environment: and Vice-Versa.

Aside from the ambient environmental flows that characterise particular neighbourhoods, aspects of 'view' and topography are environmental attributes that impact housing choices and prices. The quality, layout, design, mix of green space and built structures within neighbourhoods all become part of the 'housing product' that households chose and paid for. In an economic sense, housing and neighbourhoods are always joint goods. In consequence, housing markets have long been the mechanism by which households have, where they have sufficient resources, and the ability to choose from the local environment offered. The housing market capitalises local environmental spillover benefits and costs into house prices (Albouy, 2016). For instance, a great living-room view raises prices and living immediately below the flight path to a major airport dampens them. The broad sweep of evidence from a wide swathe of hedonic house price studies, that identify the weight of the effect of different housing and neighbourhood attributes in overall house prices (Malpezzi, 2002) is that the environmental attributes of a home and neighbourhood commonly shape 10 to 20 pc of dwelling values, with higher shares for higher income/wealthier households.

And with housing as a built structure with embedded energy and water systems then clearly the CO2 embedded in construction, maintenance, and renovation as well as the energy efficiency of these structures and systems will play key roles in shaping CO2 emissions. Likewise, because housing location provides more or less access to the locations that households use in their daily lives, then the home location will be crucial in determining the travel distance, and modes that also drive the use of fossil fuels.

Housing activities and housing stock attributes critically affect GHG production by households.

Just Transitions Matter Too!

In turn, the influence of incomes on the ability to pay for housing means that those with the least resources will tend to be in the localities with the lowest environmental quality. It is a salutary lesson for modern policymakers that the nineteenth-century housing 'reformers' from Joseph Rowntree and Robert Owen to Le Corbusier, argued not just for decent homes for the poor but for 'garden city infrastructures, amenities, and quality environments. For then decent dwellings were a necessary but not sufficient condition for adequate homes, as the associated neighbourhood mattered too. In that respect, the current debate (discussed further below) around 10-15-30 (take your pick!) neighbourhoods is neither a 'socialist conspiracy', nor a recent idea, nor indeed completely sufficient to address the mix of accessibilities, services, and infrastructures this will best serve just transitions.

As governments and markets begin to transform core systems of living over the next few decades there will be localities, within any city or region, that gain and others that lose. Housing policy will be important in ensuring that it is not the poorest people and places that are most negatively impacted by transition nor indeed that in the new geographies of daily life that the poor will segregate into the most difficult localities for living with zero carbon. Arguably, facing a widespread imminent crisis of housing affordability now, few governments have yet thought through how the transition ahead will be just or reinforce rather than reduce inequalities between Canadians.

Systems Understanding and Systems Governance: An Imperative

There has to be a transition to net zero carbon. Thinking and action require systems thinking, identifying, and changing human activity, to explore housing to climate change links. Rethinking how the activities and outcomes of the housing system play into system transitions is urgent but it is also important. In all nations the housing system is a key transmission system between household activities and environmental systems. There are already apparent examples of the adverse recursive effects back from the warming global environment on costs and choices in the housing system.

Housing policy, particularly at Federal and Provincial orders, in Canada has emphasised social aims and outcomes and in Paper 1 the omission of important housing system outcomes in shaping economy policy was often simply ignored. The same might be said for the environmental effects of housing outcomes. They have, primarily, been left in 'planning' silos and restricted to a subset of housing system effects on the environment. The global warming policy problem requires a systematic response. Scientists understanding the warming processes, ecologists assessing impacts and environmental policymakers now naturally lean towards a complex system of systems view of the processes involved.

This paper illustrates how housing policymakers, given the nature of housing and housing systems, if they are to make an effective contribution to achieving transitions, especially just transitions, now have no choice but to implement a systems framing of what housing is and does to the environment. At present the effects of housing outcomes on global warming are incompletely understood, they are (often) not part of the core case for housing policy investments. There are few instances, on a wider scan, of how governments actually link housing outcomes to missions to achieve any or all of the United Nation's Sustainable Development Goals (Pareja-Eastaway & Winston, 2007). Governance arrangements to interface housing actions with environmental programmes remain weak and indeed, there is policy 'innovation inversion' with cities and municipalities often at the forefront of Canadian progress. Policy fractures across sectoral silos within orders of government and across these orders seem to prevail and new housing system governance needs to be explored.

***Presenting the Systems Case*.**

This paper begins that exploration. In the next Section (2) the broad definition of housing outlined in Paper 1 is used along with the 'housing as activities and attributes' approach to set out a heuristic framework to link housing to environmental effects and highlight a schematic housing-energy-carbon system, and the recursive effects back from natural capital to the housing system. Section 3 outlines the severity and urgency of the GHG-induced climate change issues facing Canada and how the nation ranks in the severity of issues and intensity of actions amongst the advanced economies.

Housing systems have particularly important implications for reaching net-zero carbon targets that are explored in successive sections:

- Housing development displaces natural capital by using energy, labour, and materials, that produce or may contain previously embedded CO2, to undertake the construction of dwellings that in their direct operations produce further CO2 emissions -the carbon impacts of new construction are explored in Section 4.
- The ways in which households use housing attributes to produce 'housing services' drive residential energy use are explored in Section 5.
- Section 6 then considers how changing the physical attributes of housing produced, including items such as insulations, design, energy systems and building materials can be altered, either by changing the nature of new construction or by investment in retrofitting existing homes, and how consumers regard such changes.
- The locational and neighbourhood characteristics of a dwelling are critical shapers in terms of the extent to which a household can adequately localise their pattern of household activities and demands and their ability to connect to wider urban activity points by zero carbon transport modes. Neighbourhood dimension to energy provision systems and energy transition delivery vehicles are also important. Section 7 explores the GHG implications of the attributes of homes that lie beyond the curtilage of buildings as they have important effects that mean residential energy use, whilst being important, is not the only housing outcome that needs to be decarbonised.

The increasing scale and emerging geographic incidence of the recursive effects of carbon-induced climate change and their implications for housing systems are briefly explored in Section 8. Section 9 emphasises broad changes in instruments, strategies and governance required to shape transitions, indeed just transitions, to net zero carbon and emphasises the imperative of a fresh approach to linking housing outcomes to environmental outcomes.

2. FRAMING HOUSING SYSTEM AND ENVIRONMENT LINKS.

Embracing the Heuristic Approach.

Paper 1 utilised 'heuristic' models to highlight potentially important housing-economy-housing system linkages that typically disappear in theoretical thinking and that play little role in housing and economic policymaking. The heuristic model illustrates ways in which abstracted complexity may be reintroduced into thinking and action to solve complex problems and this process is, itself, illustrated by the simple heuristic in Figure 1.

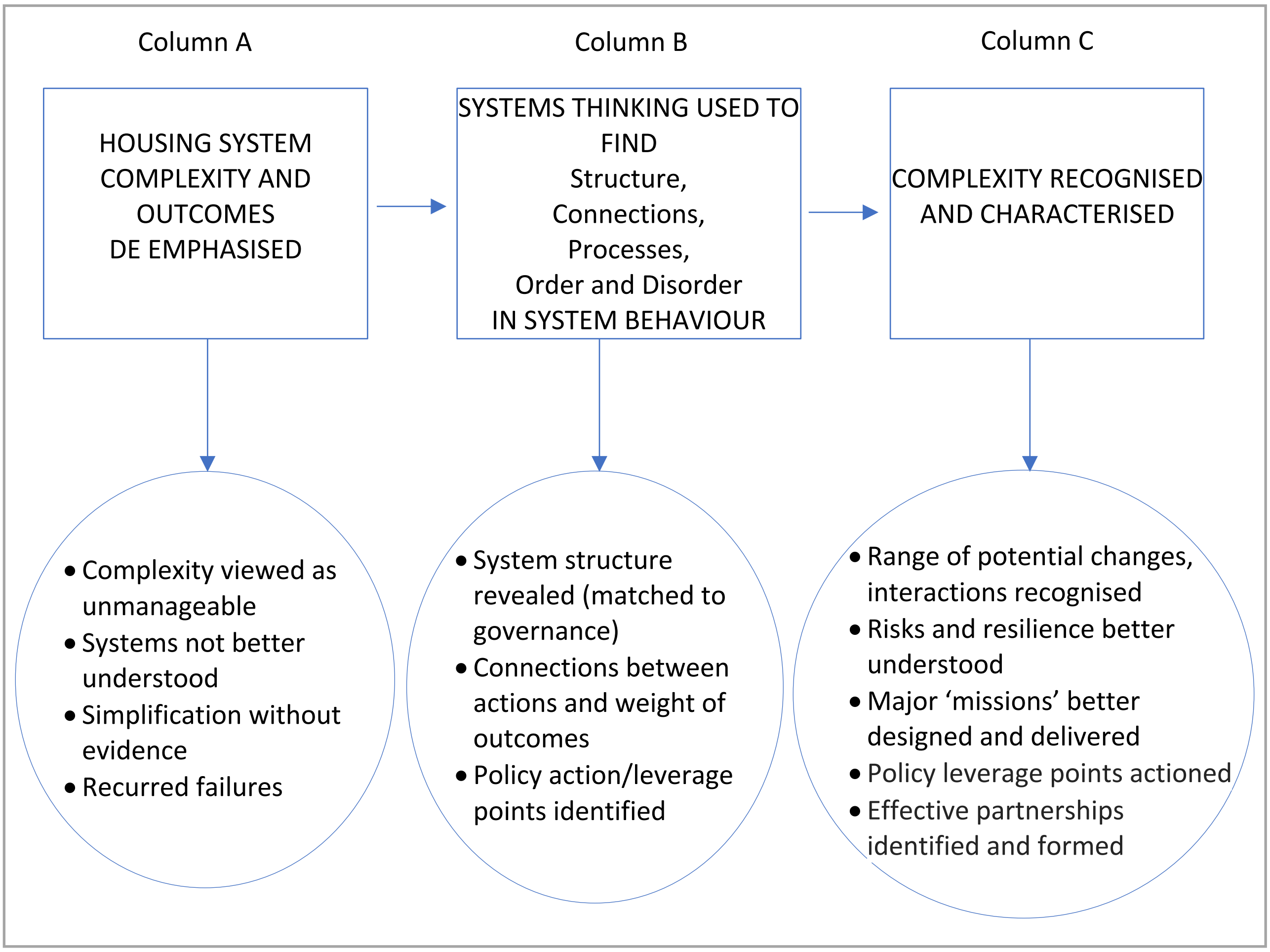

Figure 1. Complexity Embraced Heuristic Models

Source: Adapted from

In this section, the aim is to move from de-emphasised housing to environment and GHG effects (column A) to introduce a framework for accounting for housing-environment-housing system structures, connections and outcomes (column B). As for the economics systems effects in Paper 2, the transition from better system recognition to better governance (column C) is deferred until Paper 4.

Developing a Housing-Environment Systems Heuristic.

There (at least) dimensions of housing system outcomes to environment effects, and recursive consequences. In what follows the heuristic is applied primarily to GHG effects. The key 'building blocks' are to recognise that:

- The 'environment' is broadly defined to comprise the 'natural environment', comprising of stocks of natural capital and ambient flows of air, smoke, fire, GHG, noise and water, waste, sewage and other effluents: and the 'built environment' that changes the flows of the natural environment and its absorption and biodiversity characteristics as well as create, as the dominant land-use in urban settlements, a visual amenity for households.
- As discussed in detail in Paper 1, housing is both a set of activities (and the focus here is on new construction and renovation) and a set of geographically fixed housing attributes that households use to live, work, learn and play and that lie at the heart of their daily patterns of activities and travel behaviours and that also involve other household capital, services, time and, importantly, energy use.
- Pursuing these housing and household activities involves the creation of an array of environmental effects and spillovers that impact flows and natural capital and, in relation to the concerns of this paper, underpin the major release of GHG from fossil fuels in home energy use and most modes of travel. GHG emissions attributable to housing include both those used in household 'operations' and those 'embedded' in the processes and materials used in constructing housing capital. Both 'embedded' and 'operational' capital have to be considered.
- GHG emissions, here and now, have impacts on weather systems, far afield and far into the future, that in turn impose recursive effects on housing systems, especially on property damage and potentially adverse social sorting in housing systems.

These building blocks of system complexity are arranged and connected in the heuristic in Figure 2, in ways that suggest the links that analysis and policies need to understand and that are known, from evidence, to be important if (sometimes) not fully explored. It is also important in developing heuristic potentially important related systems/sub-systems that are beyond the focus of the discussion. This heuristic (teaching or learning) model can be developed in several stages, with a broad schematic outline indicating the key structures followed by a more mapping of nodes and connections of interest.

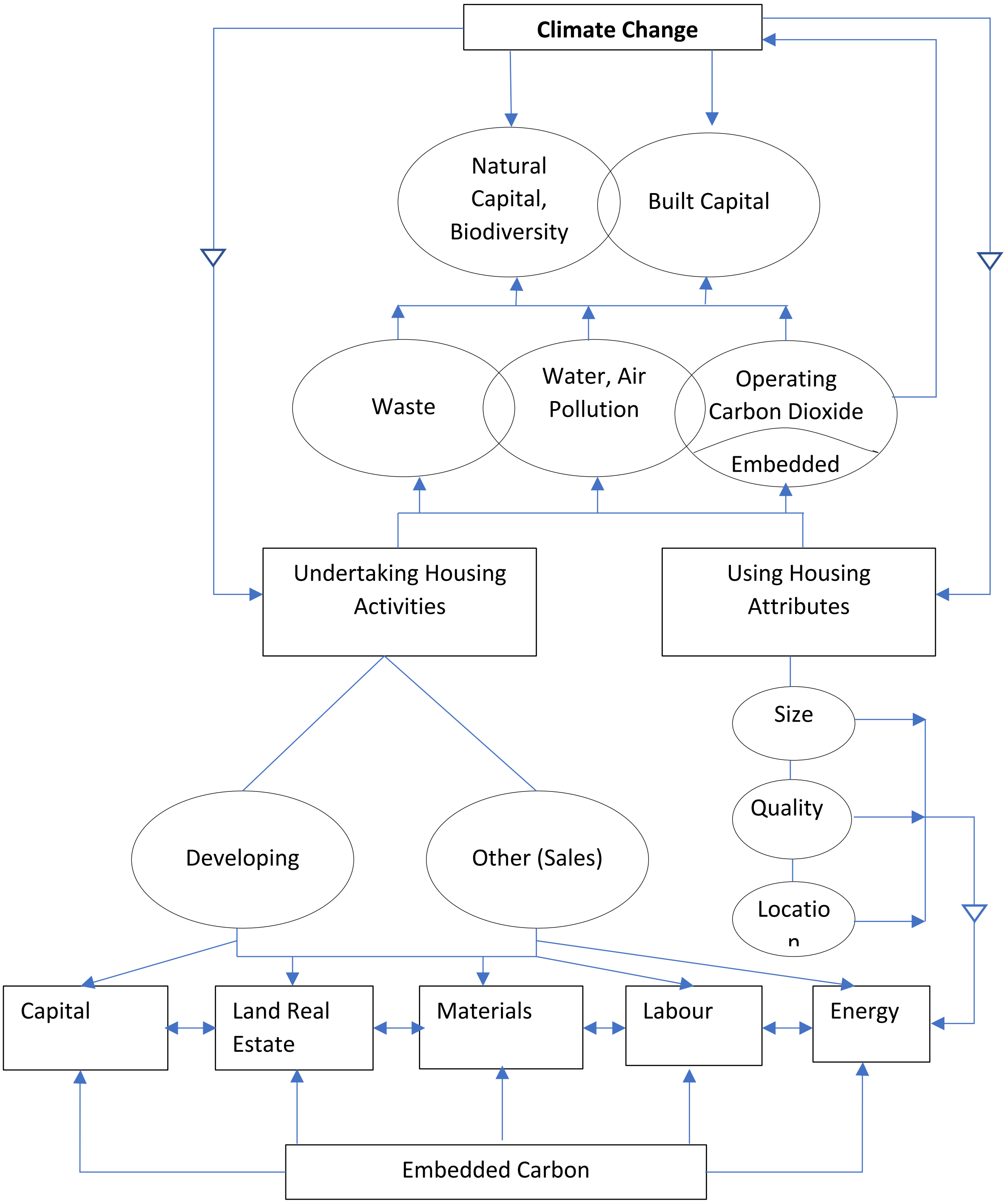

Figure 2. Housing Activities and Using Housing Attributes: Embedded and Operational Carbon Links

Using this broad framework of connections can usefully capture the effects of housing activities (notably construction and development) and of using housing attributes (Undertaking Housing and Using Housing boxes) on the use of embedded carbon (already used) in existing buildings, machines, and materials as well as additional carbon produced in activities and the use of housing attributes. These housing activity and attribute then produce polluted air and water, as well as solid waste, that negatively affect natural capital but that, by producing GHG, exacerbate change that in turn impacts natural capital.

The different, and overlapping, spatial scales at which housing-GHG interactions take place are similar to those used in Paper 2 to describe major ranges of functioning and effects. The global dimensions of GHG are well established as are transnational impacts of water and air pollution, national scales matter for policymaking, whilst regional-metropolitan environmental systems and impacts are central to questions of resource use, water supply and of sprawl and fossil fuel use in transportation. Neighbourhoods also have significant neighbourhood dimensions. All four spatial scales of drivers and geographies of impact are considered.

What is the evidence that circuits of connection exist and are important in the Canadian housing system? As illustrations, rather than complete system mappings, the environmental effects of construction activity (Section 3), the carbon effects of the use of housing attributes within the dwelling (Section 4), and the consequences of residential location and density (sections 5 and 6) are explored below.

***Markets at the Core of Systems of Effects and Solutions*.**

The Heuristic models set out above highlight the flows and connections that need to be recognised and understood. Explaining how these systems operate requires an understanding of the decisions of households, firms and governments that create, mitigate or adapt to GHG production. Much of the production of GHG occurs as an externality, that is in pursuing an activity of consuming goods for one purpose or another there are effects on other parties that are not considered by the 'producer'. This may arise from ignorance of the effects on others or because there is no incentive to consider their well-being, in the absence of laws or regulations that require such considerations.

Externalities and market failures are inherent features of real market systems. The recent OECD report on decarbonising construction usefully reminds us that CO_2 is produced in 'real' market systems and this paper, with an applied economics approach in mind, uses that perspective in exploring system functioning problems (market failures, and unjust transitions) and shaping the means to correct them. Our discussion assumes that climate change issues are produced and will have to be resolved in a market-led economy.

Paper 2 highlighted the real housing markets are always beset by a lack of consumer information, uncertainty, market structure imperfections and localised monopolies and long periods out of 'balance'. Hoeller et al. (2023), for OECD, note that:

> *'Specific market failures and imperfections complicate greenhouse gas emission reductions in the housing sector. For instance, people do not know how poorly insulated their homes are, and buyers have difficulties observing the energy efficiency of homes they consider purchasing. Many demand-side behavioural biases have been identified, such as myopia, bounded rationality, hyperbolic discounting, or dynamic inconsistencies (Gerarden et al., 2017, p1007). Market imperfections imply that owners and tenants do not undertake privately profitable investments, for instance, to raise energy efficiency (Fowlie et al., 2015). Even with programme assistance and information campaigns, the take-up of zero out-of-pocket energy efficiency investments remains low, as non-monetary costs and rational inattention are major obstacles to home improvements (Sallee, 2014). This requires standards and incentives (carrots and sticks)'…*

The complexity of the housing 'continuum' is almost a guarantee of market failures and in the long-sighted requirements to work to efficient transitions for life three decades ahead. Informing consumers and citizens, knowing, and acting on policy sector synergies in addressing market failures and unfair transitions within bureaucracies and the corridors of political power will all be critical to make housing systems contribute best to net-zero is critical. Governance transition of the housing sector to achieve net zero is not just about regulation, government spending, and taxation, but also involves shifting political attitudes and also consumer and community behaviours.

3. GHG EMISSIONS AND TARGETS: CANADA AND THE GLOBE.

A number of international agencies have highlighted the significance of both the construction sector and the 'residential energy' sector in producing GHG emissions, such as the International Energy Agency (IEA) and the OECD. Both significantly underestimate the CO2 production consequences of housing processes and outcomes as they attribute accessibility-related carbon emissions to the 'transport sector' (and the transport policy silo) rather than identifying the strong synergy between housing and transport decisions (that may need housing investment location solutions rather than more roads and rails). Despite that important omission, reshaping the construction and residential energy sectors are major routes towards net zero.

To give a flavour to the extent of the problem and solution routes the IEA identified (International Energy Agency (IEA), 2021) that to meet net zero by 2050 (and subsequent IPC warming estimates imply a faster and deeper set of improvements is required) require:

- Retrofit rates for buildings to be "zero-carbon ready" reach about 2.5% a year by 2030 in advanced economies and 2% a year by 2030 in emerging-market economies with 85 per cent of existing stock retrofitted by 2050.
- The share of zero-carbon-ready new homes to rise from 5pc in 2021 to 100pc by 2030.
- The number of domestic heat pumps to rise to 600m in 2030 to 1.2 billion by 2050.

They also expect significant increases in the rate of adoption of energy-saving equipment within homes and, critically, the proportion of the total population with access to clean electricity to rise from 7 to 10 billion by 2050 with massive expansions in clean cooking and solar power. These figures make clear both the scale of the problem, and the scale of the global opportunity in remaking residential energy systems.

Hoeller et al. (2023) also emphasise the scale of the 'housing sector decarbonisation challenge' and note that the environmental and GHG consequences of the activities and attributes of the housing system involved in constructing, maintaining, improving, and using housing capital are major drivers of greenhouse gas emissions. They report that in 2020, the residential construction sector accounted for around 6 pc of GHG emitted in the OECD countries (the global estimates for the construction sector are 8pc), with concrete and steel, which are both energy intensive in production, being critical components of most construction. They further noted that the 2020 energy used in providing 'housing services' within the home accounted for 23% of total CO2 emissions in the OECD. Housing stock, including energy systems, has to be used along with energy flows, household time, other forms of capital, and domestic appliances to heat, cool and ventilate space, heat water, refrigerate food, clean, connect digitally, play music (and much more) to provide flows of 'housing services' that contribute, for example, to household comfort, shelter, and connectivity.

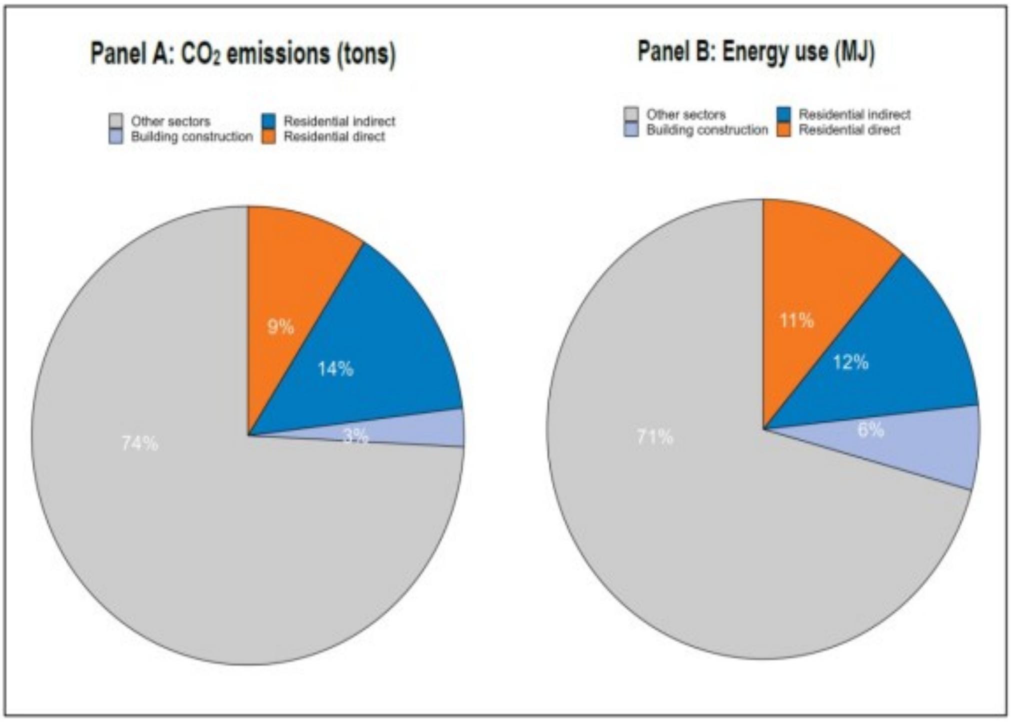

Figure 3. Housing Sector Emissions and Energy Use in OECD Countries.

Source: Hoeller et al. (2023).

Residence-based per capita CO2 emissions, as OECD report (Hoeller et al., 2023), vary markedly from country to country, and indeed from region to region within countries. At the national scale, 2020 estimates suggest that these range from three tonnes of carbon per capita in the USA to around zero in Norway. Harsh climate conditions may impose more severe challenges but clearly policy actions to reduce emissions, when the problem is recognised, may lead to significant moves towards net zero that are successful. OECD report, there is a low correlation between per capita residential energy use and per capita CO2 emission, and this undoubtedly reflects policy variations.

They suggest that variation in carbon emission intensity of residential energy use illustrates *'the effect of different choices regarding the split between direct and indirect emissions, the carbon content of fuels combusted directly by households and the carbon content of primary energy sources used to produce electricity or district heating (indirect emissions)'*.

Progress in emissions reductions in the OECD has been made and total CO2 emissions of the residential sector have declined by 17% from 2000 to 2020, notwithstanding an increase in population and the number of dwellings (and it can be argued despite greatly increased shares with workers, scholars and students working more at home through 2020 and 2021 as a consequence of Covid-19). The energy efficiency of homes and appliances has improved, and many countries have successfully started to reduce the carbon content of the energy supplied. However, Hoeller et al. (2023) also note that *'in non-OECD countries, total CO2 emissions from the buildings sector have risen considerably (International Energy Agency (IEA), 2021), reflecting strong economic growth, fast urbanisation and limited progress in reducing CO2 intensity, as coal and other fossil fuels remain central to the energy mix of many emerging economies including the largest non-OECD member countries (Huo et al., 2021).'*

There are, however, despite the overall reduction in the OECD and a growing number and intensity of national and sub-national policy actions, two significant problems. First, the limited OECD-wide average decline in GHG emissions over the last 20 years hides a wide variation in cross-country performance. In Denmark, Estonia, Lithuania and Sweden, emissions have declined by more than 50%, while they have risen by more than 50% in Chile, Colombia, and Türkiye. Denmark exhibits the steepest decarbonisation of the residential sector as CO2 emissions have declined by more than 60% in the last 20 years (Figure 3). This drop is explained by a drastic reduction in carbon intensity, mainly due to a shift from coal and natural gas to carbon-free heat generation systems relying on electricity production via renewable resources such as wind power. Since the late 1990s, Denmark has also pioneered gas-powered district heating networks, and recently upgraded at a relatively low cost to biomass and waste-powered primary energy sources (Menu, 2021).

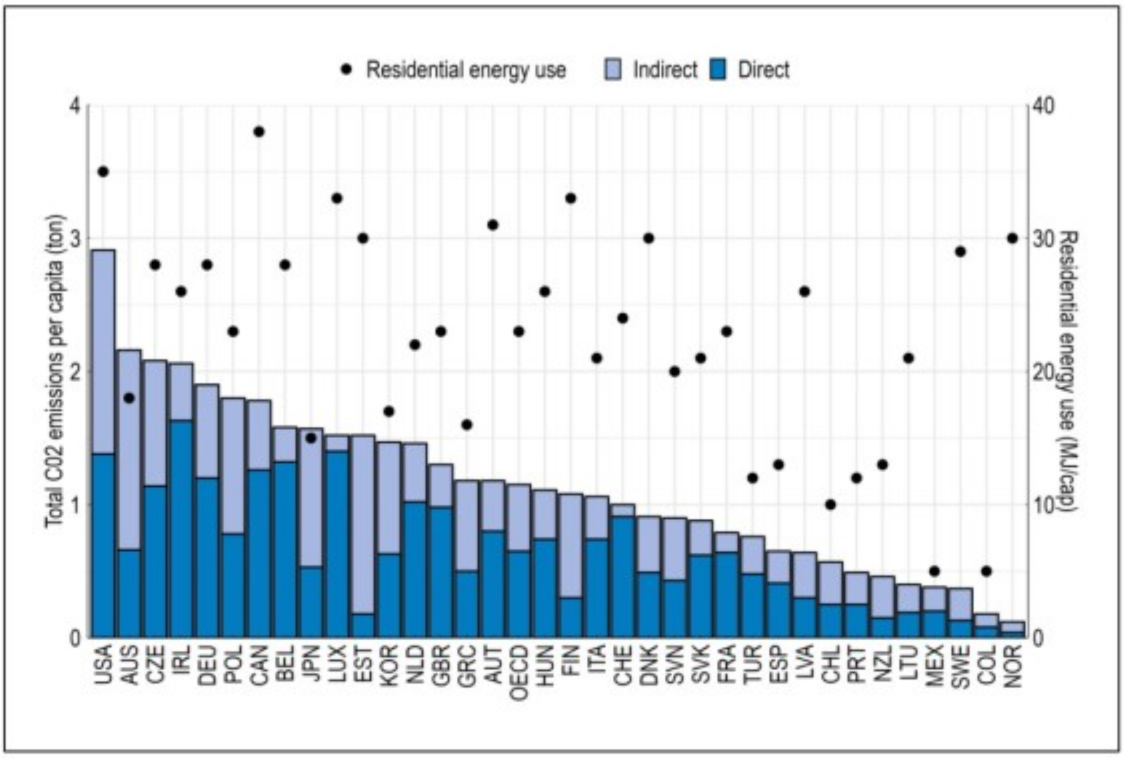

Figure 4. Cross-National Differences in CO2 Emissions and Residential Energy Use.

Source: Energy Efficiency Indicators (IEA, 2021), Emission Factors database (IEA, 2021, and OECD.

The second difficulty is that they have not, on average, been rapid enough. Contrasting the IPCC warning of the need to move faster to limit global warming to 1.5 by 2050 with the observed slow decline in the OECD makes it immediately clear that net zero carbon targets are unlikely to be attained unless there are sharp reductions in housing related GHG emissions primarily driven by domestic energy use. However, by 2020, most governments had made very different, and generally insufficient, choices about whether and how to pursue such reductions.

How is Canada progressing concerning its OECD peer group of countries? What choices need to be revisited, renewed, and resourced? The patterns for 2020 indicate that Canada has, by far, the highest per capita residential energy use in the OECD but residential CO2 (per capita) emissions are just above the estimated average (however the carbon footprint of Canada's spatial pattern and density of housing development is one of the global worst). This is a mixed performance for a nation that regards itself, and has been regarded by others, as a global leader in combatting GHG.

There have, however, been important elements of Canadian progress in 'decarbonising the housing stock' in recent decades. The Bank of Canada (BMO) (2021) reported that '*improvements to the building envelope, along with more efficient appliances, have yielded a 24% decline in residential energy intensity and an absolute decline in emissions for the sector since 2004'*. However, this progress remains too slow to reach net-zero targets, and, they argue, that there will have to be a step change in scaling up energy efficiency retrofits for existing homes. They comment that achieving the annual scale required, which some commentators estimate may peak at around 500,000 homes per to reach the 2050 target year *'will be difficult, as deep energy efficiency retrofits are disruptive'* (BMO, 2021). It should also be noted that in Paper 2 some misgivings were expressed as to whether the Canadian residential construction sector, already working at peak capacity, and requiring to expand supply substantially (a doubling and more) by 2030 to stabilise housing prices and rents and meet immigration requirements. Energy retrofitting of housing and infrastructure will be competing for many of the same construction sector resources and a more coherent, integrated supply system strategy for the new construction, infrastructure and energy retrofit sectors is very urgently required if targets are to be met effectively.

Individual research studies, some now a little out of date, highlight variations in emissions and emission intensities across Canadian cities in 2010. Fercovic and Gulati (2016) examined GHG emissions from gas, natural gas and electricity used by households in 17 CMA's. Then, they found, Canadian households in these CMAs create around half of the nation's GHG emissions, and around a third of that (or a sixth of all GHG emissions) at home. They found that Vancouver and cities in Quebec had the lowest per capita GHG emissions for average income household and, at that time, Edmonton and Calgary are the highest. This highlighted not only the positive effect of low temperatures on GHG emissions (a downside of regional geography) but the nature of regional fuel sources (an upside of regional geography) with hydroelectric domestic energy sources leading to lower per capita GHG emissions for all income groups and this has been a strong feature of GHG limitation in Quebec. This echoes the OECD findings that clean, alternative sources (to fossil fuels) for electricity production led to significantly lowered residential GHG emissions. This pattern also emphasises how achieving Federal CO2 and climate change targets is heavily dependent on local systems and resources.

Marginally different estimates of the share of Canadian GHG directly produced from homes (or the wider category buildings) range from 13pc to 18pc of annual GHG emissions (arising from in home combustion of fossil fuels for space and water heating; electricity use for cooling, lighting, and appliances). BMO estimated that in 2021, 57% of building emissions (66 Mt CO2e annually) are from residential structures. In summary, the emission intensity of energy consumption in Canada's residential real estate sector must decrease by 64% by 2030, and by more than 100% by 2050 to align with net-zero targets. The Federal government of Canada established (in 2020) targets to reduce greenhouse gas (GHG) emissions by 40-45% below 2005 levels by 2030, reach net-zero electricity generation by 2035, and achieve net-zero emissions across the economy by 2050.

It is clear from the growing gap between progress and required outcomes to meet net zero targets that the conclusion for the OECD as a whole applies equally to Canada. The nation is performing relatively poorly in progress towards net zero targets, in relation to wealthier, and colder, EU countries, in progress towards net zero carbon housing. Apart from developing decarbonisation strategies, policy must go well beyond environmental matters and encompass economic, social, innovation, tax and spending policies, as well as governance arrangements, to drive transformational change. That speaks to rethinking the governance of the Canadian housing system, its GHG outcomes and an expanded notion of the core goals of housing policies.

What are the routes to progress? The Canada Green Building Commission launched by the Federal Government in 2022 illustrates the scope and ambition of the task of just transition in housing. Its role is 'Helping to reduce energy costs for our homes and buildings,' while driving down emissions to net zero by 2050 and boosting climate resiliency through the development of the $150-million Canada Green Buildings Strategy in the Federal 2022 Budget. Working with provinces, territories, and other partners, the strategy will build off existing initiatives and set out new policies, programs, incentives, and standards needed to drive a massive retrofit of the existing building stock, and construction to the highest zero-carbon standards. Under the 2030 Emissions Reduction Plan, the Canada Greener Homes Loan program will receive an additional investment of $458.5 million. Together, these measures and others outlined in the 2030 Emissions Reduction Plan, will help Canadians reduce emissions, save money on renovations and heating and cooling costs, and stimulate well-paying jobs in the economy'. The sections below consider some of these important developments, but they also highlight housing outcomes that the GCBC ignores (beyond the remit) and reflects, towards the end of the paper on whether adequate governance evolution is envisaged.

4. CREATING PHYSICAL HOUSING CAPITAL TO SUPPORT NET ZERO: BUILDING HOMES.

Housing as an Activity: Creating A System of Attributes.

Paper 1, in defining 'housing', made an important distinction between the **attributes** of the physical stock of housing and the **activities** that built, installed, maintained, and modified them, or financed and exchanged them. That distinction between attributes and activities is carried forward into this discussion. This section considers the ways in which the processes involved in the construction of new homes augment GHG emissions. Maintenance and retrofitting activities will have similar process effects but definitive separate effects for these activities were not available in this review. The GHG outcomes of changes to the housing stock through construction and retrofitting, that shape the detailed characteristics of dwellings including their energy structures and systems, are discussed in the subsequent sections on domestic energy efficiency, neighbourhood/community consequences and the locational/accessibility features of the home.

Constructing New Housing: Greenhouse Gas Implications.

The construction sector delivers infrastructure, homes and buildings to society by consuming large amounts of, land, labour, energy (Huang et al., 2018) and materials[2]. Paper 1 emphasised the complex supply systems, or chains, involved in producing housing stock. Until recent years the focus of research, and much of policy, has been on the energy efficiency of dwellings produced rather than the greenhouse gases used, or embedded, in construction processes (Ahn et al., 2013). This section focusses on the GHG emissions produced in construction processes.

Energy used in construction is made up of two different components: direct, or operational energy, which is the energy needed for on-site construction operations, and indirect, or embedded, energy, which is the energy required to provide products and services for construction operations (Huang et al., 2018). For instance, materials, and

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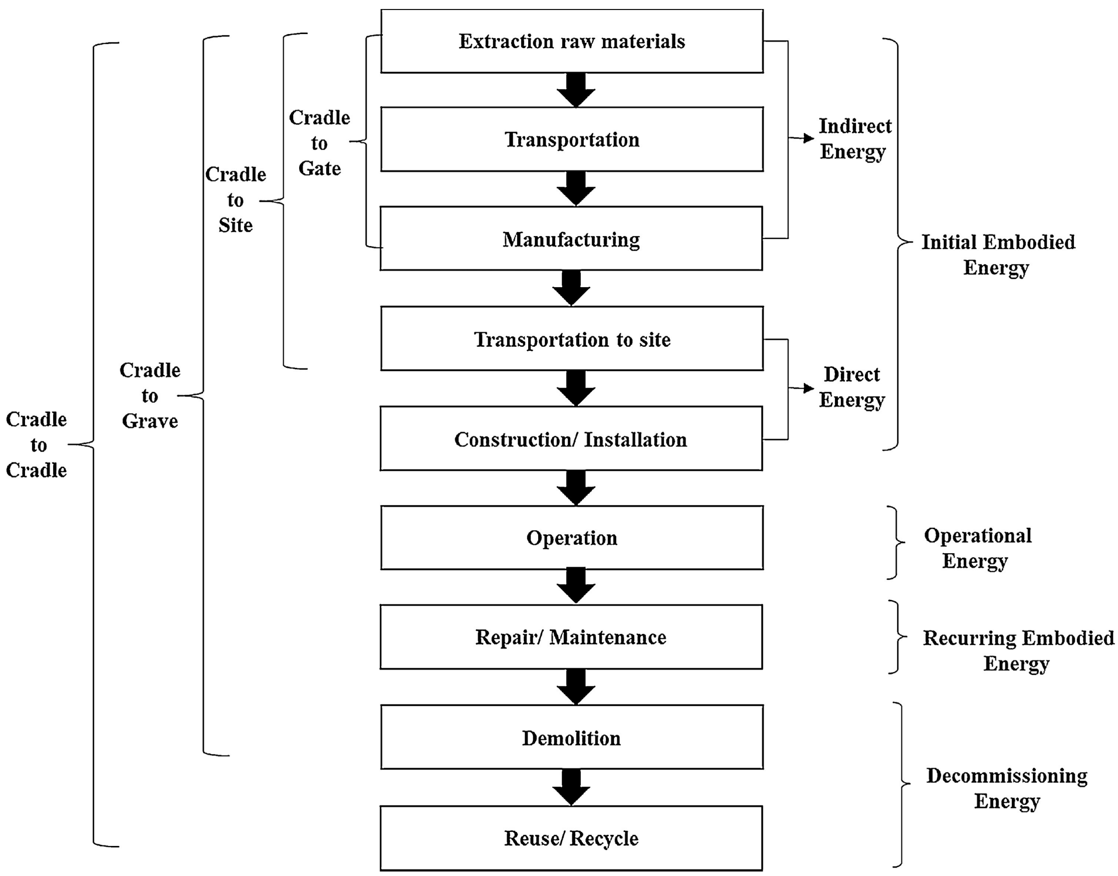
[2] Aside from the greenhouse gas effects of energy consumption housing construction processes have numerous environmental effects, as discussed in section 5, that include air emissions, waste generation, and water pollution and biodiversity reductions.

labour, are transported to construction sites. Materials, in the prior processes of resource extraction, manufacturing and assembly of their component parts, are readied for use in construction with substantial use of energy. Steel and concrete are key components of construction that require intensive energy use in production and hence already ‘embody’ much GHG production before they arrive onsite. A systems approach to the housing supply chain is essential in identifying ‘embedded’ as well as ‘operational’ GHG in constructing and retrofitting homes. Indeed, in moving forward, many technical experts now follow the approach of Zeng and Chini (2017), who suggest a building life-cycle system view of the GHG implications of construction projects, and this is illustrated in Figure 5. This paper adheres to the simpler direct/embedded dichotomy due to the absence of data relating to the multi-stage life cycle model.

Figure 5. *Energy in Construction Supply Chains.* (Copied from Zeng and Chi (2017)



Additionally, it has been argued that both the direct and indirect energy used in the construction sector mostly comes from non-renewable energy resources, usually carbon rich fossil fuels (Huang et al., 2018). Globally, the buildings construction industry (including residential buildings and non-residential buildings) accounts for about 6% of final energy consumption and about 10% of energy-related CO_2 emissions in 2020 (United Nations Environment Programme, 2021). Construction, in that sense, is a dirty business. Among all sectors, the buildings construction industry is the only sector in which the relative share of emissions is higher than the relative share of energy use (United Nations Environment Programme, 2021), indicating a relatively low energy efficiency status in this sector. In an early study, Ahn et al. (2013), suggested that when embedded carbon in construction, and onsite energy and transport activities were included, the GHG effects of housing construction were equivalent to twice the CO_2 effects produced by the total residential electricity use of all households in British Columbia.

An ex-ante auditing of housing system supply chains is still largely absent in Canadian housing investment strategies (at all scales of government). Although GHG and sustainability assessments are made of particular building innovations there are still few signs of government housing investment planning undertaking detailed carbon and embedded carbon audits of housing investment processes and overall outcomes. At present, though this could change rapidly, there are few detailed assessments of GHG consequences of the construction activities implied by particular housing investment strategies.

An immediate concern arises. With widespread housing shortages, rising immigration rates, and new demands for retrofitting existing homes to contribute to emissions reductions there has to be a recognition that expansive housing supply policy could, in the absence of rapid decarbonisation of supply chains, substantially raise induced GHG emissions. Indeed, in housing policy debates cases for supply expansion are often made independently of reference to GHG implications (or on the naïve assumption that the best net zero supply chains will be used in construction). This section, and those that follow, makes it very clear that in a modern, systems approach to housing the implications of housing outcomes for GHG need to be a core part of housing policy design and investment decisions.

Construction Processes and GHG

In existing studies, generally, four methods are identified for reducing energy use in and emissions from the construction sector. Firstly, reducing the emissions from construction machinery (by ensuring that it is well maintained, designed to use fuel efficiently and to have reduced dependency on carbon-intensive fuels) is identified in research and pilot studies to significantly reduce direct carbon emissions (Azzi et al., 2015; Immonen et al., 2016; Lee et al., 2014). However, numerous studies, including Huang et al. (2018), have findings that indicate indirect carbon dominates carbon emissions from the construction sector.

There is considerable potential for reducing embodied carbon in construction through the use of materials that require less energy during manufacturing. The experience in New Zealand suggests that in contrast to concrete, and steel structures, the construction of wooden homes entails less embodied energy (Buchanan & Honey, 1994). Some of these potential savings have been identified for a decade and more. Venkatarama Reddy and Jagadish (2003) estimated that using different construction techniques and low-energy materials could obtain a 30–45% reduction in embodied energy. Another opportunity for reducing embodied energy is through the use of recycled materials in the construction sector. Thormark (2000) compared buildings which were built with a large proportion of reused materials and components as opposed to all new materials and components. The results showed that about 55% of energy could be saved with a 'circular economy' of reused materials and components. Building materials are recognised as the predominant part of indirect carbon emissions in the construction sector (Cabeza et al., 2013).

The third route to reducing CO2 emissions from construction involves shifting away from fossil fuels as an energy source. Non-renewable energy resource use (85% of sources) in embedded energy drive high indirect carbon dioxide emissions, with only 6% of the indirect energy use in the construction sector being renewable (Huang et al., 2018).

The fourth route may also include all of the above three directions for change. The idea of modular (or 'offsite') construction of homes has been long established. Over the last decade engineering and building researchers have published widely on the impact of modular construction on costs, carbon, and technical quality. Kouhirostami and Chini

(2022) have presented a recent and balanced review of research on this topic. They found that variations in study designs and methods and products assessed require some caution in drawing unqualified conclusions. However, they report that inefficiencies in construction processes using traditional methods are an important source of high construction costs, low labour productivity, slow production, and variable quality, as well higher levels of waste and energy use. With caveats, they note several studies that suggest that modular housing construction processes can, broadly, almost halve GHG emissions from construction processes (and in life-cycle estimates). Given the housing shortages, already high costs and targets for reducing residential GHG in Canada by 2030 an urgent review and programme development for significantly increasing the share of modular construction are required. Scandinavian countries have 30-40pc of homes produced by modular construction and Canada just over 5pc.

Construction Sector Economic Behaviours

The important technical possibilities to reduce GHG in construction processes and in maintaining homes pose economic and behavioural questions. Technical trade-offs have to be known, behaviours and aims and households may have to change, and non-conformity with standards and regulations addressed. The design of efficient policy instruments to deliver GHG reductions in construction processes, see Section 9 below, is often not interwoven with technological possibilities and there needs to a stronger housing environmental economics (contrast, for example, the widespread empirical work on transport and environmental economics). Ahn et al. (2013) argued a decade ago that indirect GHG effects were not well understood in the construction sector and that appears to be still the case. Further, the inherent nature of the industry, with multiple, shifting coalitions of differently skilled sub-contractors, has hindered research on quantifying accurately the environmental effects of the sector.

Further, the generally fragmented nature of the sector and the often unique, customised nature of each construction project frustrates both productivity growth and GHG emission measurement. The development of artificial intelligence is likely to replace human employment in significant sectors by 2050, indeed overall estimates suggest a 25pc ‘jobs threat’. The measure is 48pc for architects and dwelling designers, but at 6pc for construction workers, it is clear that the challenges of improving resource use and reducing emissions within construction processes remain significant.

In addition to new construction activities, the maintenance processes for existing buildings, which have been largely neglected in existing literature, also contribute to energy consumption and carbon dioxide emissions in the construction sector. Retrofitting homes with new energy-related structures and systems have significant GHG emissions arising from direct onsite activities and embedded in indirect carbon inputs. They are not explored further here, and consideration now switches to the energy use and GHG consequences of the sets of housing characteristics produced.

5. RESIDENTIAL ENERGY AND GHG IMPACTS.

Focus is switched, here, from activities producing new physical housing capital to how housing attributes are used to meet household demands and needs by providing ‘housing’ services. Individuals use one or more specific attributes of a house, along with their own time (relaxing in front of a warm heat pump takes time!), consumer durables, and household equipment to produce ‘services’. Energy use is central to most domestic service provisions. This section considers the nature and scale of these energy demands and supplies, and the next, 6, considers how houses are designed, and adapted (retrofitted) to change activities and energy efficiency and the role of equipment in influencing energy use.

Residential Energy Use

The residential sector accounts for a significant portion of both energy use and emissions, which constitutes 16.6% of the secondary energy use and 12.7% of GHG emissions, respectively (Natural Resources Canada, 2018; Zhang et al., 2021). In 2018, the main energy end uses of the residential sector were space heating (64%), water heating (18%), appliances (13%), lighting (3%) and space cooling (2%), with around 81% of the total domestic energy being consumed by space and water heating (Natural Resources Canada, 2019). Actually, the current situation in residential energy use and GHG emissions is relatively promising. Although energy use grew by 6% from 1990 to 2017, GHG emissions decreased by 15% during the same period (Natural Resources Canada, 2018). The residential sector thus contributed 27% to the total GHG savings (Natural Resources Canada, 2018). Nevertheless, a faster reduction is now required.

The existing literature in Canada identifies three types of measures to save energy consumption and reduce greenhouse gas emissions: demand side (including strategies to reduce building heating and cooling load and other end-uses with energy retrofits and upgrades), supply side (consisting of renewable energy solutions) and transformation of energy consumption patterns (United Nations Environment Programme, 2021; Zhang et al., 2021). Technology advances, policies, programs, and consumer and business choices have lowered aggregate GHG emissions by nearly 55 megatons and saved Canadians more than $26 billion in energy costs by 2020 (Natural Resources Canada, 2021).

Improvements in the energy efficiency of homes and buildings play a critical role. The experience of the past 20 years in Canada has demonstrated the significant impact of energy efficiency measures (Natural Resources Canada, 2021), relying on more advanced energy use technologies (Mohazabieh et al., 2015). Over the 2000 to 2018 period energy efficiency in the residential sector improved by 28% (Natural Resources Canada, 2019). Recent data shows that although secondary energy use in Canada increased by 8.4% between 2000 and 2018, it would have increased by 36.1% without residential energy efficiency gains (Natural Resources Canada, 2019). Energy use per household and per unit of floor space has decreased significantly.

***Housing Service Demands*.**

Space heating and cooling

Space heating and cooling account for 64% of the total residential energy consumption in Canada (Natural Resources Canada, 2019), with space heating always being the largest end use for residential energy (Vakalis et al., 2021). Galvez and MacDonald (2018) distinguish three main ways to reduce emissions from space heating: increasing the insulation and airtightness of buildings, improving the energy efficiency of heating equipment, and switching from heating with fossil fuels to heating with non-emitting electricity. Renewing space heating and ventilation equipment of multi-unit residential buildings (MURBs) can be conducive to lessening the environmental burdens (Liu et al., 2015; Vakalis et al., 2021). Energy used to cool Canadian homes increased between 2000 and 2018, driven by the increase in the number of households and significant increases in the number of summer days exceeding 30C (especially in the major cities) and that feedback energy demand from global warming would have been higher had not households installed more efficient room and central air conditioners (Natural Resources Canada, 2019).

Water heating

Water heating is the second-largest end use of residential energy (Natural Resources Canada, 2019). The energy used for water heating has significantly decreased thanks to the switch from oil-fired to more efficient natural gas water heaters, the application of stricter energy standards for all water heaters, the utilization of tankless water heaters, the installation of low-flow showerheads and faucets, the running of full loads in dishwashers and washing machines, and the use of cold water for laundry (Natural

Resources Canada, 2019). These transformations have led to more than 10% reduction in energy use per household for water heating since 1990 (Building, 2018).

Appliances and Lighting

Appliances and lighting are energy consumers and contributors to emissions (Natural Resources Canada, 2019). The main electrical appliances used in Canadian households are refrigerators, freezers, dishwashers, clothes washers and dryers, in addition to cooking equipment, air-conditioning equipment and consumer electronics (Natural Resources Canada, 2019). The increased efficiency of various energy-consuming items in homes such as air conditioners, appliances, furnaces and light bulbs reduces greenhouse gas emissions (Natural Resources Canada, 2019). The increased use of energy-saving light bulbs, such as LEDs, led to a decrease in lighting energy use per household. It has been identified that in 2011, ENERGY STAR qualification was held by 67% of refrigerators, 79 per cent of dishwashers, and 75 per cent of clothes washers in Canada (Natural Resources Canada, 2019). Empirically, The results from 9773 Canadian households show that replacing an old refrigerator with a new one, replacing an incandescent lamp with a LED lamp, and upgrading old central heating was estimated to save energy (Newsham & Donnelly, 2013). However, energy savings from major appliances was exceeded by the increase in energy use for minor appliances, such as electronic devices (Building, 2018).

***Supply Transformation*.**

At the same time as Canadian households have reshaped energy-related equipment and consumables, Canadian governments and energy provider sectors have embarked on ambitious energy transformations, expanding energy sector investments in clean and sustainable energy sources (Natural Resources Canada, 2022). In Canada, natural gas, electricity and home wood fulfil 95% of the above-mentioned residential energy demands (Natural Resources Canada, 2019), see 6. Since 2003, there has been a downward trend in the relative share of electricity in residential sector emissions and a stabilisation of the relative share of gas (Building, 2018).

Further, 7 displays the total electricity generation by source in Canada. This figure shows that Canada is one of the leading countries in using renewable energy, with approximately 65% of the total electricity in 2019 generated from hydro, wind, solar and other sources (International Trade Administration, 2021). When taking geographical differences into consideration, the proportion of electricity from hydro power is relatively higher in Quebec, British Columbia, Manitoba, Newfoundland and Labrador, Prince Edward Island and Yukon (International Trade Administration, 2021). In contrast, some provinces, including Alberta, Saskatchewan, Nova Scotia, and New Brunswick, still produce a significant amount of their electricity from fossil fuels (Canada Energy Regulator, 2022).

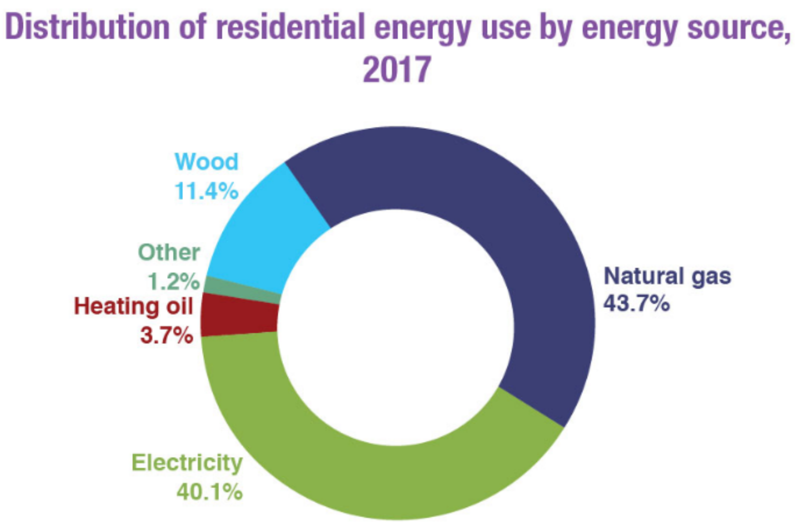


Figure 6. Distribution of Residential Energy Use by Energy Source

Source: Natural Resources Canada (2019).

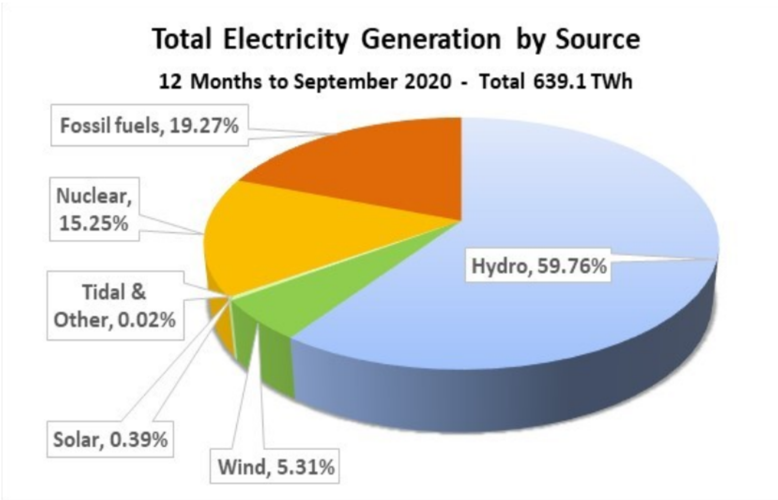


Figure 7. Total Electricity Generation by Source

Source: International Trade Administration (2021).

BMO (2021) has stressed the imperative of the shift to clean electricity in the decarbonising of the Canadian residential energy sector and concluded that ‘decarbonization of the real estate sector will primarily be achieved through electrification, with a concurrent increase in the supply of clean power. Both strategies must be facilitated by government policy direction and investment’. Despite one of the cleanest electricity grids in the world, and with prospects of further green energy gains, they stress that electricity ‘accounts for only 38% of residential end-use energy consumption, resulting in 30% of emissions in Canada’s housing sector. The remaining 70% (46 Mt CO_2e annually) of emissions are generated from fossil fuel combustion at the point of use, primarily from natural gas (37 Mt CO_2e annually) used for space and water heating’. The high residual GHG gas emissions, they argue, stem from provinces with unclean electricity sources and failures to switch housing attributes to electric and efficient energy systems.

In consequence, despite gains in energy efficiency and the switch to cleaner sources of energy since 2000, the GHG reduction targets set for 2030 and the aim of net zero by 2050 mean that even faster progress is now required to decarbonise the housing Canadian housing system. How the attributes of housing are designed and used have to change, faster. Changing what is built, altering the attributes of existing housing, changing neighbourhood attributes, and altering wider metropolitan accessibilities of homes are all required.

6. CHANGING HOUSING ATTRIBUTES: NEW AND OLDER HOMES.

***What Works, Technically? New Homes*.**

BMO, in the housing decarbonisation review pertinently noted that it is easiest to configure housing attributes, structures and systems, when homes are being built. There has, in the last decade, been sustained innovation in building materials, domestic energy and other systems that constitute physical housing capital. Philla-Rivera et al (2018) found that growing concerns about GHG had prompted exploration and measurement of the Carbon Footprint (CFP) of buildings and a proliferation of means to mitigate their emission. Use of low carbon materials, minimisation of material use, reuse and recycle of materials, adoption of local material sources and use of biofuels were evaluated and in the context of Quebec, different scenarios suggest modular homes could reduce CO2emissions by just under 40pc from the conventional baseline scenario. In Ontario, Vero Solutions, build modular high rise with small CFP footprint. PLITEQ has developed ways of recycling used car tires into building materials. There have been thousands of similar commercially viable and, often globally available, housing construction components that lower GHG. More efficient home energy systems and more effective, remote electronic management systems reduce domestic energy demands. Integrating photovoltaic cells into panels of buildings and placing wind turbines in communities, see some homes and neighbourhoods as sources of alternative, zero carbon energy. Residential energy induced GHG, and costs, seems set to fall. Meeting the challenge of reducing GHG from housing energy use is not a technological challenge, it is arguably not a societal economic problem (as GHG will fall and alternative energy costs fall), though it is an initial income distribution issue as adjustment costs to install new required housing attributes have a disproportionately high effect for poorer households. It may primarily be a question of the efficacy of politics and governance systems.

New technologies and their outcomes, which are GHG reducing and economically feasible are already being introduced into new building codes and regulations. For instance, Li et al. (2021) reviewed major emerging residential codes emerging or proposed in Canada energy Code effectiveness in Canada. They found that Passive House criteria are more effective in reducing the space heating GHG emissions (89pc) than the BC Step Code (77pc) in contrast to the space heating GHG emissions for a new single home. Meeting these standards clearly has less effect in regions where fuel carbon intensity is low, and they found that in BC the Step Code and Passive House criteria had similar GHG emission reduction effects per unit area of housing.

Implementing the Passive House requires seeing the house as a partly closed energy demand-supply system. When buildings are being designed architect plans are computer assessed to identify potential areas of heat loss and gain and thus lead to design revision. The energy demand to heat a house meeting the Passive standard is so low that 'most of the required heat is supplied by home appliances such as the refrigerator and stove, plus heat from the residents' bodies. Passive housing codes would reduce GHG in an Ontario house built to current codes by 90pc with an estimated additional cost of 2 to 10pc of the dwelling (Toronto Star, 2022), implying payback in 5 to 6 years.

There is an extensive Canadian literature in building and engineering that has underpinned the new Canadian Green Buildings Code (CGBC) outlined by the GOC in 2022, see Section 9 below. The CGBC has established a building code for "net-zero-ready" (NZR) new house construction. The "2020 Model Codes," requires that new houses be sufficiently energy efficient that its day-to-day energy use can be met either by the addition of solar panels or the purchase of other 'renewables' energy. Further work to strengthen a revised code to reduce embodied carbon (generally associated with steel and concrete used in construction) is currently being undertaken (Toronto Star, 2022). The GOC plan is to introduce the new Code by 2030 in a series of five steps.

In a critique of pre-CGBC, Singh et al. (2019) suggested that construction and design quality was the most pivotal contributor to the adoption of a net zero energy home. They also noted that buildings being built before 2019 had not adequately adopted low-carbon solutions across the full life cycle of dwellings. Both the Passive House and NZR codes meet that criticism. There is however a continuing concern that the phased introduction of the NZR in five steps to 2030 will allow up to half a million new homes per year to escape the new code, and with the national housing stock growing at close to 1pc per annum this will leave four-fifths of Canada's stock unaltered. Canadian houses have typically lasted around 70 years so the 2050 residential zero net emissions target without greatly improving the emissions standards of almost all the 14 million existing homes in Canada away from fossil fuels through significant retrofitting of existing housing attributes.

Passive and NZR standards driving new construction to net zero homes aim for many of the features indicated in 8, below. The key challenge in decarbonising housing in Canada is for the existing housing stock be retrofitted to have similar features and performance.

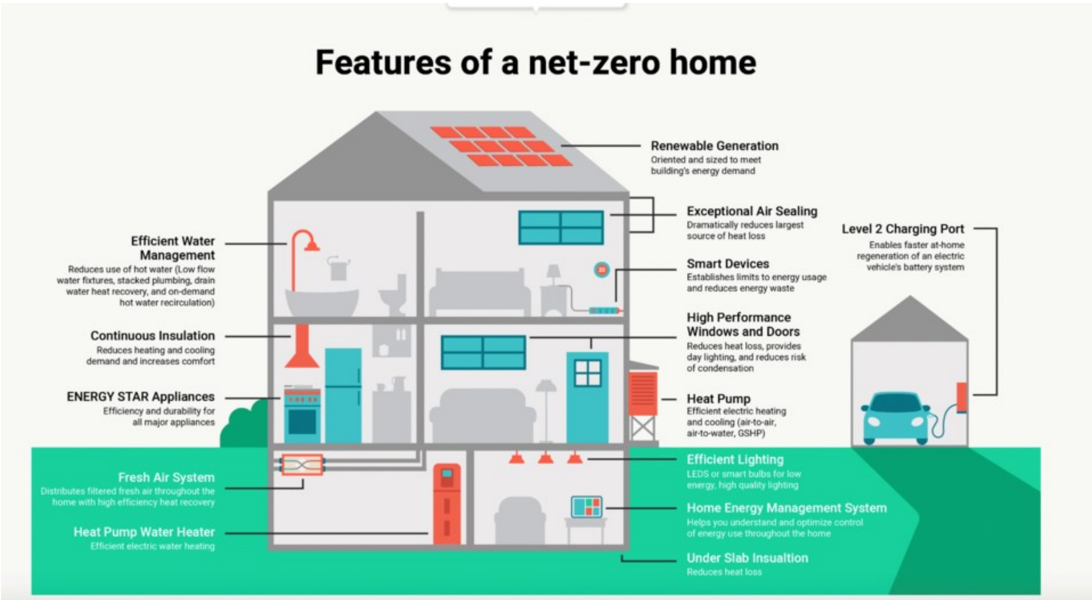


Figure 8. Fossil Fuels by 2030

Source: Efficiency Canada

Retrofitting Homes? More Difficult Works

Retrofitting for domestic energy reduction is especially relevant where significant stocks of older high-rise residential buildings exist (Stopps et al., 2021). Over half of residential buildings in Canada are more than 30 years old, and over a fifth are older than 50 years or more (Natural Resources Canada, 2020). By OECD standards, Canada has a relatively young housing stock. Older buildings mostly use non-renewable energy sources, often with aged internal energy systems. In order to attain similar levels of 'housing services' to, say, Passive Housing Standards, they require more resources leading to higher environmental impacts and larger emission footprints (Natural Resources Canada, 2020). There is a great potential for renovating existing building stock to achieve climate action targets and savings in operational cost. Many of the innovations in materials and domestic energy systems used in new construction also apply in renovation. However, there are significant strategic policy questions to be addressed.

Heidari et al. (2022) grasped these scale and strategy questions and established a comprehensive roadmap for decarbonisation and electrification of typical existing single-family houses in Canada. The results indicated, for example, that when a phased approach for the retrofits is considered, using the most appropriate energy technologies in the home, an approximate average investment of 40,000 CAD would be required and would result in a 78% energy saving and 96% emissions reduction in an existing residential building in Ontario. For Vancouver, the energy and emission savings are reported to be 85% and 100%, respectively.

These are important findings and need to be repeated for different dwelling types (as suggested by Vakalis et al., 2021) and they highlight a roadmap to significant progress. The next policy is to establish effective 'delivery vehicles' to drive towards the goal. The BMO (2021) in exploring the decarbonisation of Canadian housing notes (see next section) that the most economical time to decarbonise a dwelling is when it is under construction (at least if building regulations require appropriate standards and households paying for new homes have the incentives to install GHG reduction housing systems), however, some three-quarters of Canadian housing stock that will exist in 2030 had already been built by 2020.

So, decarbonisation requires significant retrofitting. By 2050, BMO (2021) estimates '*that approximately nine million buildings housing a total of 16 million single unit dwellings must undergo at least one deep retrofit to reduce their property-level energy consumption to the levels required to achieve net-zero goals'*. And they conclude that '*Canada's rate of deep retrofit renovations therefore will have to increase from less than 1% of homes currently to 5–12% annually by 2030, comprising up to 1 million dwellings each year at an estimated cost of $321–517 billion present value by 2050*'.

These different reports by Heidari et al. (2022), Vakalis et al. (2021), and BMO (2021) are the basis of a housing supply policy approach to addressing energy descent, in all orders of governments, to net zero by 2050. Vagueness won't cut it. Other commentators confirm that in Canada, there is a lack of structured approaches aimed towards reducing energy consumption and associated greenhouse gas emissions from existing buildings (Ruparathna et al., 2017).

There are however major issues of costs, and other barriers to take-up. DeLand and Vanderhoof (2022) pertinently ask for the Federal government target for reducing global warming whether '*IS THIS ALL HOT AIR?'*. In essence, they argue that meeting the 2030 target (reducing 2030 GHG emissions from buildings by 45pc from their 2019 level) for retrofitting will 'cost up to $6.3 billion annually and require the retrofitting of more than 500,000 homes every year'. Assuming that households convert from using oil and gas to heat homes to electrical heat pumps, their modelling concluded that 'Canada would need to retrofit over 400,000 dwellings per year to fully electrify all dwellings by 2050 and meeting 2030 targets requires even more aggressive action: over half a million retrofits would be required per year' and 'meeting the 2050 target will cost between $4.5 billion to $6.3 billion per year'.

To balance this cost estimate it should be noted that multiple estimates of the economic benefits of general 'green buildings strategies' suggest significant new, skilled job creation and a substantial boost to employment and national income. Half a million jobs and a rise in GDP of around 1 per cent per annum for a decade into the 2030s are suggested by the Royal Bank of Canada (RBC, 2021).

DeLand and Vanderhoof (2022) also suggest that other measures to reduce GHG from housing will be needed, including raising energy standards of new homes, revising building codes and combining heat pumps with other energy sources. These are precisely the kinds of costed, targeted and modelled measures that should underpin Federal resource support for more local housing investment plans. There is no room for hot air in cross-order housing policy debates!

A central issue then becomes who pays for energy retrofit or the higher energy standards of new homes. Governments, anxious to see progress, may feel tempted to incentivise CO2 mitigation through subsidy and/or tax concessions on green energy systems. We return to this discussion of the choice of instruments and cases for support in the discussion below on policy and governance. But as energy prices rise, through 2021 and 2022, and seem likely to remain historically high, it becomes increasingly clear that, in many senses, reducing GHG emissions from residential energy use is relatively low hanging-fruit in the transition to net zero. First, it is clear that within shortening periods individual and collective investments pay-off, benefits exceed costs and increase net household incomes for many. For the majority of Canadian households who are owners of housing (owner occupiers and landlords alike) the issue becomes a financing question, namely how they source loan finance to undertake energy upgrading and not essentially a subsidy question (as long as new construction standards are set to achieve net zero). Past uplifts in-home asset values could also underpin or directly finance actions. For poorer Canadians, there is a resourcing issue of being able to pay for energy upgrades either as owners or as tenants and there is a direct challenge for CMHC to assess whether it will finance the housing energy transition for poorer Canadians and by what means.

Despite the costs and difficulties noted above, the GHG impacts associated with the old building stock need to be reduced through retrofitting to achieve the emission reduction targets of Canada (Feng et al., 2020; Ruparathna et al., 2017). Accelerating the adoption of high-performing retrofits and net-zero new construction (involving new technologies and low-carbon building materials) by raising developer and household awareness and innovative financing models could readily expand retrofit and upskill the next generation of energy efficiency workers (Natural Resources Canada, 2021).

Here is another important nexus of system interactions to be understood and governed involving housing, energy, industry, education, and skills silos. What is holding retrofit activity back? Extra short-term costs (with significant upgrading often taking 8-10 years to generate net savings, at least prior to 2021 increases in energy costs); lack of knowledge (sometimes on the part of contractors as well as households) about the technology associated with a net zero energy home; not knowing someone who owned a net zero energy home, were all significant barriers to accepting net zero energy homes (Singh et al., 2019).

Their results suggest that policymakers should promote the diffusion of net zero energy home technology by encouraging housing developers to include net zero energy homes in their collection of model homes, with an emphasis on quality design and construction. Furthermore, engaging in trust building initiatives such as education and knowledge about the technology, its related energy cost savings, and the environmental benefits would contribute to a greater acceptance of net zero energy homes (Singh et al., 2019). Given the importance of housing in future lives, the magnitude of energy costs and the damage that global warming will do through the lives of young Canadian 'managing the homes and its financing' could be a significant life skills course for senior scholars. Few such initiatives exist at present.

What Works for Consumers?

This seems to be a public acceptance that building energy retrofits are a potential key to realising climate mitigation goals in Canada (Zhang et al., 2021). There also now seems to be an awareness that emission reductions and cost savings are possible, even probable. A recent press report (Globe and Mail, April 2023) suggests that at least half of households want governments to act faster than present rates of progress. But are there financial and behavioural barriers to making the transition?

Some, important notes of caution need to be sounded. Some past studies suggest that the impact of household-defined retrofits can be rather small, because many 'retrofits' claimed by households are very small scale (Guler et al., 2001). They assess the impact of various energy efficiency upgrade scenarios on the annual energy consumption of the Canadian housing stock: including major retrofits, such as the improvement of the house envelope by adding insulation, and the replacement of the existing heating system and appliances by higher efficiency units, as well as minor retrofits, such as lighting fixture, thermostat, showerhead, and aerator upgrades that reduce energy consumption (see next section). The results indicate that the overall energy savings potential of the collection of retrofits resulted in savings of 0-8 per cent of the total energy consumption of the Canadian housing stock. They reported that most major retrofit upgrades are not economically feasible for households and can involve payback periods of more than 20 years (though the benefit/cost ratio for major retrofit changes has improved considerably over the last decade).

A little more recently, commentators argue that there has been considerable experience with and take-up, by Canadian households, of measures to improve energy efficiency and undertake building 'retrofits' (Karunathilake et al., 2018). Using 2011 data, they estimated that, 82% of all households engaged in at least one energy-efficient or conservation intervention, while 37% of homeowners had undertaken at least one significant energy-saving retrofit. The National Energy Board of Canada, using similar figures, projected that in the period between 2016 and 2040, the energy use per square metre of residential floor space will reduce by 0.7% annually, due to the increased use of efficient technologies (National Energy Board of Canada, 2016). These rates would miss all the relevant targets and it is likely that studies before 2018/19 will underestimate household incentives for change. They suggest, plausibly, that energy efficiency upgrades are more likely to be economically attractive if they are conducted as part of a major renovation project, or when replacing old equipment and appliances with new ones as they reach the ends of their useful lives (issues of 'equipment' are discussed below). BMO also notes that such investments are more likely when households, at least owners, move home.

Recognising the significance of natural capital and GHG costs in the housing sector has led to some new ways of thinking about the gains from retrofit, linking to circular economy concepts. For instance, Dahmen et al. (2018) present a statistical model called the Teardown Index, which indicates that replacing older poorly performing homes with new high efficiency homes in Vancouver will result in 1.3–2.8 million tonnes of additional carbon dioxide equivalent emissions between 2017 and 2050. The Teardown Index is indicative of the kinds of housing investment decisions tools that need to be developed when housing and environmental systems are co-considered. A recognition that reusing already embedded resources (in situ) reduces new natural capital demands extends systems thinking over time is ways that current assessment approaches avoid.

Other kinds of research, again somewhat dated highlights that a range of other factors influence household domestic energy demands and reinvestments. It would not be unfair to suggest that the major flourishing in technical research on residential energy systems have been matched by an, at best, modest scale improvement in understanding household, developer, and policymaker behaviours in this important topic area. In conducting review work for this paper there was a striking contrast between the range of recent, quality econometric studies of relevant household residential behaviours that OECD (2022) could cite for other economies that could not be found in Canada.

The, dated evidence, that exists confirms that consumption patterns of residential energy are impacted by a plausible set of factors. Young (2008) made a good summary of the possible factors that would influence consumers' energy use behaviours including socioeconomic factors and policies on income levels, demographics, occupancy levels, patterns in households, availability of information, as well as the environmental attitudes of users. Yamamoto et al. (2008) highlight that the awareness of energy efficiency and knowledge to make informed decisions are key factors in determining consumer behaviour towards energy-efficient appliances. The costs involved in purchasing, today, energy-efficient products with gains tomorrow are important (de la Rue du Can et al., 2014) as is the availability of technical support (Chen et al., 2016).

The most significant decision-makers in the housing supply chain are residential home builders, and as a result, they have the most control over how new housing responds to changes in technology, demographics, and housing policy (Singh et al., 2019). Most, but not all, builder recognise that net zero energy home is a realistic proposition,(for them and buyers), especially if the prospective buyer is pleased with the home's construction and design (Singh et al., 2019). Additionally, promoting trust by educating people about the technology, the associated energy cost savings, and the environmental advantages would help them accept net zero energy homes more (Singh et al., 2019). Much stronger, contemporary market evidence of behaviours about and barriers to residential energy transition in Canada are urgently needed.

7. HOUSING ATTRIBUTES OUTSIDE THE HOME: NEIGHBOURHOOD AND LOCATION.

***Housing Decarbonisation and Location*.**

Debates and actions about 'decarbonisation' of the housing system typically, as this paper has done in sections 3-6, focus on either reduction in GHG in the construction of housing capital or in amending the attributes of dwellings to reduce residential energy demands and switching energy systems to use renewable energy (including self-sourced geothermal and solar power). That narrow focus and these issues are important, excluding other significant ways in which other chosen attributes of a home have a major effect on the emissions produced by households. Important elements of housing choices involve Location, Location and Location! Key, accessibility-related aspects of a home, are at the core of the ways households produce activities, and lifestyles, that are based around as opposed to within the home. Most household activities have a regularly repeated geography. Families with children have weekdays involving travel between home and schools and workplaces, and at weekends to shops, sports and socialisation sites. Travel connects home with activity sites and household travel using fossil fuels is a major element of household GHG emissions.

Too often in regional and metropolitan policymaking travel demands, and related congestion issues, and how to respond to or change them, are narrowly defined. Policy responses, despite a strong history of research exploring travel behaviours and transport-land-use interactions, are usually fashioned within transport silos that seek solutions in making transport investments and changing transport systems rather than changing the nature and frequency of the travel flows between the geographies of home and work/activity sites. The housing market shifts, the so-called 'search for space' that occurred in the first two years of the Covid-19 pandemic (see Paper 2) make this point strongly, even if 2023 sees a reversion to pre-2019 patterns.

Arguably, transport, infrastructure, and housing provision, which households see as an integrated system of connections in their daily lives, may be disconnected, and separated in siloed public policy decision taking.[3] In assessments of major public

[3] This has changed, but between 2005 and 2008 I was Chief Economist in the Federal Department for Infrastructure, Cities and Communities, concerned with urban infrastructures and policies. Papers on housing never crossed the Department's desk and there was little, voluntary, contact between officials

infrastructure investments transport silos will often argue the productivity gains of reducing travel distances and times. Housing silos never claim the equivalent productivity gains from constructing closer to employment nodes. A feature of metropolitan areas in this millennium has been increasing commuting times (and costs) for households decentralising from city cores to find cheaper homes. The propensity for older Canadians to continue to remain, often as single survivors, in what had been their peak value 'family home' long after children have left for other locations, largely because rising house prices makes their home their inheritance. In consequence, the effective supply of family housing closer to work and activity sites becomes reduced. The systemic effect is that the homes of the older deteriorate faster than they need to, older households use higher-than-needed domestic energy and younger families have to travel more to integrate the spatial points in their lives. And, of course, an adequate 'affordability' measure for their daily living system should include not just housing costs alone but the close substitute expenditures on travel and energy. These housing 'shortage' causes of additional GHG need to be identified and accounted for to decarbonise housing and cities.

In recognising the realities of the systems and spaces (and places) that households use to live and work, and their GHG consequences, policy framing and discussion have to move beyond the measures and methods of silo governance. Housing and Environment Ministers, in all governments, should be able to expect an informed answer to the questions: **Where should we locate housing investments to maximise emission reductions? What is the best mix and geography of homes, and related place-making, infrastructure investments that will minimise non-active travel demands and reduce reliance on carbon intensive travel modes?** Governments are struggling towards framing that 'cross-silo' question. The housing 'decarbonisation' discussion has, so to speak, focussed on the individual trees and little emphasised on the forest. And that needs to change.

Progress can be made by comprehending, as discussed in the introduction to Paper 1, the key elements of household activity patterns and how they are reflected, in aggregate, as functional structures within a metropolitan, or regional economy. That is, the 'big picture' functional areas are, for instance, travel to work areas (daily commuting) and

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in Infrastructure and Transport Canada and turf, or more appropriately tarmacadam, was resolutely defended.

housing market areas (based on local housing relocation patterns). Within these bigger functional system geographies, there is usually a mosaic of different kinds of neighbourhoods and within and between them there are spatial structures of movements connecting homes and the wider city. The housing system, and its sorting mechanisms, shape travel demands and patterns, and transport systems and structures shape housing choices too.

These patterns reflect ***HOUSING*** choices. As noted earlier, surveys of residential preferences and econometric analyses of the determinants of housing prices, confirm that choices of home, and the prices paid for them, reflect their accessibility to both wider metropolitan/regional locations and the quality and variety of amenities and infrastructures within the more immediate vicinity, or neighbourhood,[4] of the home. When the decarbonisation of housing is addressed choices and effects at multiple spatial scales have to be understood and connected across system levels. In dealing effectively with GHG, and indeed most other 'wicked' social and economic issues involving the housing sector, the systemic approach has to recognise and link global, national, regional-metropolitan, neighbourhood and individual dwelling level systems and effects. In this section, having emphasised the domestic system level above, the focus is on neighbourhood and city/metropolitan scales and how housing outcomes may shape, along with other key sectors and activities, better GHG outcomes. This brings the discussion of housing decarbonisation to a direct and important interface with emerging policy ideas about '10/15-minute neighbourhoods' and 'compact cites' as well as a range of more dispersed discussions about active travel and 'transport-oriented development' (also embracing the notion of 'development-oriented transport'!).

Separate papers could have been devoted to housing systems' roles in these (cross-silo) ideas and what follows is a heavily truncated discussion of key ideas. The discussion does not assume that metropolitan areas are, any longer, dominated by their CBD cores, and that significant centres of employment and retailing activity may be dispersed across wide metropolitan areas. This 'polycentric' structure has been well established and emerging for almost half a century and may have been accelerated permanently by

[4] The complexities in defining neighbourhood as a concept and defining workable boundaries are considerable (members of the same household, adults and children for example, may define neighbourhood scale and boundaries differently or similar age and activity group members may define areas that barely overlap, and looking at these 'perceived places' becomes bound up with similar challenges of identifying 'community' for real policy action (see Galster et al., 2012) .

the impacts of Covid-19 on geographies of working and living (Phelps, 2023). At the same time, there has been a continuing diversification of the physical and social structures of what, in an over-simplification, is called 'suburbia' (Phelps, 2023), as indeed there has been within core metropolitan areas, see, for instance, the identification of the emergence of '3 Torontos' (Hulchanski, 2010). Understanding the geography of the housing system, how it is changing and how it needs to change is an important first step, that perhaps Canada has omitted, in designing the linked economy-housing-transport-infrastructure strategies for change. That is, the 'map' for change that will reduce GHG and raise incomes and/or well-being needs to be discovered and drawn locally, because the outcomes matter nationally, and indeed globally.

<u>Neighbourhoods and GHG Reductions.</u>

Housing is always fixed in place. And, following the discussion above, it is fixed in place relative to not just other homes, but also other amenities and activities (public and private) and is more or less accessible to other major activity sites in a metropolitan area. It is also placed in visible, audible, and smellable local physical environments. Moreover, the age, diversity, styles, and cultures of neighbours all shape a neighbourhood social environment that may be more or less anomic or act as some form of a cohesive community. Households choose these sets of neighbourhood 'attributes' when they rent or buy a home. A century of housing research confirms that there are marked differences in preferences regarding these attributes across different household types and income ranges. However, it has become apparent in recent decades that there are also different lifestyle and location choices within age and income groups[5]. Inner Cities and Outer Suburbs are more diverse in quality and socioeconomic standing than half a century ago.

Creating housing unavoidably always creates places (more or less adequately). Housing actions, whether developing a new greenfield suburb or revitalising older localities, need to work in conjunction with other neighbourhood infrastructures and services to create places for people. Whether the neighbourhood is more or less adequate depends on both homes and other neighbourhood attributes meeting household demands (and needs). The neighbourhood is, for many households, the local system for living, it is

[5] A longer discussion would have reflected upon not just how 'neighbourhood' are demanded but how they are 'supplied'.

their functional place. Housing development needs to be transport oriented so that links beyond the local spatial system can be readily made, but also health centre, hockey hall, shopping mall, school, and much more, oriented too.

10- or 15-Minute Neighbourhoods

There is currently much discussion of the meaning, and desirability of creating, '10/15-minute neighbourhoods' as a basis for localising some aspects of household activity patterns and reducing fossil fuel consumption in everyday mobilities.[6] For instance, in the Canadian context, the City of Ottawa has embraced the concept of 15-minute neighbourhoods because it supports a variety of objectives, including but not limited to intensification, economic development, energy and climate change, gender equity, and culture (City of Ottawa, 2021). The City believes that 15-minute neighbourhoods are compact and well-connected places with a cluster of diverse services and facilities encapsulating a range of housing types, shops, services, local access to food, schools and day-care facilities, employment, greenspaces, parks and pathways. This kind of community supports active transport and transit, reduces car dependency, and enables people to live car-light or car free.

There is much to be learned from developing the core idea, namely that residential neighbourhoods well served by infrastructures and other amenities will increase active travel, reduce GHG and promote other health and community benefits. European planning professions have made 10/15 Minute Neighbourhood their mantra for localising aspects of life to move towards net zero. But often the ideas are not well thought through and need to be refined and rethought. The easy espousal of the ideas works for those who live in mixed neighbourhoods close to their walkable workplaces and higher-order urban services. This is unsurprising because these are often older core gentrified neighbourhoods that were actually 'supplied' as part of 'the walking city' up until the start of the 19th century (Ottawa Centre Town springs to mind). The concept's aims may well remain relevant in poorer places in job poor locations, but the realistic prospects do not. It is easy to recreate 10/15-minute places in older, central, now gentrified neighbourhoods, and much more problematic where poorer households have

[6] This discussion omits the practical problems of defining neighbourhoods 'functionally' identified in footnote 4 above.

been pushed to low amenity and job poor suburbs. How can the core aims be achieved and potential GHG gains secured?

It is important to stress that the, hopefully constructive, criticisms presented here in no way share the (seemingly born of ignorance) polemics swilling around social media that clamour that 10/15 neighbourhoods are a control conspiracy being foisted on citizens by metropolitan elites.

The main points to stress in contributing to an improvement in the concept and improving housing governance and investment for decarbonisation are:

- Recognise what has been learned from a century of successful joint provisions of housing investment and infrastructure for the poor in the social housing estates that have survived and even thrived over a century and for those that did not take the important lessons of almost half a century of major housing-led renewal programmes. The essential ideas are not new, and they did not originate in Paris in the 1990'. The early housing and planning thinkers in Europe and North America articulated the ideas of the Garden City, New Towns and Better Neighbourhoods over the last century; good town planning incorporated these ideas in Halifax in the 1920s, Toronto in the 1990s, (think Hydrostone, think Regents Park), and similar ideas can be seen across the nation where resources and imagination facilitated good planning. The better urban revitalisation strategies of the last half century have reported time after time the importance of creating the ranges of infrastructures and facilities within neighbourhoods that households require. Most evaluations have also stressed the importance of connecting poorer places to wider job and other opportunities across the city system. In stressing, predominantly, the local the new orthodoxy may needlessly disconnect 15-minute places with little to offer.

- City planning and housing programmes appear in some places to have forgotten the significance of local amenities, so the revival of the basic idea is important.

- The notion of specific 10- or 15-minute boundaries may be essentially a presentational gimmick (the fast and loose use of 10-, 15-, and 30-minutes neighbourhood, community and city in the concept label would suggest some fuzziness in the concept). Perhaps what is required is an audit of the missing amenities and infrastructures that will be important to people in particular places: adopting such an approach respects the nature of a place and its residents (rather than imposing planners' templates on boundaries and infrastructure mix) and it also underpins a coherent costing of infrastructure investments required to create a well-serviced neighbourhood than can function with active travel for most people for most activities. There are some major cities that have embraced the idea, and raised resident expectations, but had no metropolitan spatial strategy for 'big infrastructure' and no costed programme for neighbourhood infrastructure investment. CMHC, and the Department of Infrastructure could consider trialling infrastructure and housing mixes for neighbourhood scale changes that will connect to low carbon transport-oriented development.

- There needs to be a recognition that there is a cost and revenue logic to the efficient scale and location of not just private provision of retailing and entertainment facilities but to public provision. Service centres are not 'created equal' but have spatial, hierarchical patterns. Simply thinking about the internal functioning of neighbourhoods and not their effective connections to city-wide infrastructure and service systems is poor investment planning that may compromise achieving metropolitan growth and social well-being goals.
- The same point has to be recognised when required connection to metropolitan employment concentrations is considered. Home location, and modes of access to wider metropolitan geographies of other household activities, especially employment and post-school education sites, are also major influences on the carbon footprints of households.

The important systems thinking and housing policy lessons, to better achieve GHG reduction (and other 'wicked issue' progress) is to deconstruct 10/15-minute planning fad, to retain the key aims but see how neighbourhoods are best connected to, and comprise, the city they are set in. The key housing policy concerns must include:

a) Having a clear understanding of whom a neighbourhood serves and what it functions it serves in the wider metropolitan system (what is it for?).

b) A clear sense of mission for change, in relation to GHG, and other major goals

c) A collaborative approach with other policy agents to clarify not only what housing investment is needed but how it will work with other policy silos, and communities and private interests, to fashion an effective partnership for locally led change there needs to be a major place based investments are intended to do and how they will reduce CO_2 emissions; this is really about creating effective neighbourhood governance.

d) An integrated transport plan that raises active travel but ensures also that there is low carbon public transport wherever feasible and the facilitation of electric car usage, that is a low carbon transport and infrastructure strategy with which to embed energy efficient homes.

e) Similar remarks apply to how homes will be connected to higher-order service locations and employment cores within the city (not all jobs will 'spread' and not everyone will work from home).

f) There needs to be a more active consideration of how neighbourhood heating and energy production can be integrated with housing development to produce more effective outcomes: models exist in Canada but largely remain undeveloped.

g) Non-profit housing providers and other community bodies can play significant roles in energy descent strategies and partnerships of non-profits, financial institutions and energy providers have supported the installation of energy-efficient systems and smart metering in homes whilst in rural areas non-profits involved in community land transfers have used revenues from wind and solar energy to support affordable housing provision.

A recent report from Dühr et al. (2023) makes, in the Australian context, many similar points and stresses that governments are missing an important opportunity for sustainability strategies if they fail to recognise that the neighbourhood is a more efficient scale than single buildings by which to drive GHG reduction in the housing system and to link them to other essential investments. They also highlight the need to develop effective delivery vehicles for GHG reductions through housing not just on greenfield and brownfield sites but in more complex neighbourhoods where existing homes and infrastructures will remain in place as others are added and altered. This relates to two very obvious Canadian contexts. Many towns, within metropolitan hinterlands have seen growth in recent years but others, in remoter locations are still left behind. Within the largest metropolitan cities suburbs developed from the 1910s to the 1930s were populated by large homes with large lots, and many had neighbourhood shopping centres. In both these settings there are new opportunities to boost sustainable housing and infrastructure supply opportunities, albeit in different ways with different models. There are market failures and coordination issues in both settings that policies have largely ignored in the past and the present opportunities for denser, more affordable, and energy-efficient homes. A strategic review of 'rebuilding neighbourhoods' in Canada is long overdue.

The GHG reduction aims of the 10/15-minute neighbourhood lobbies and the message that housing, other infrastructure, and services need to be better integrated to shape better places for people are both important contributions to policy thinking. However, the fuzziness of the concept and unclear strategies and approaches to the delivery of the core ideas diminishes their applicability. Housing, Infrastructure and Transport Departments need to work together, and collaborate across Federal, Provincial and Municipal levels, to provide a framework for 'investment in better neighbourhoods' and to have a clearer conception of how such bottom-up approaches can be set within broader metropolitan strategies and their resource implications understood.

CMHC might wish to look at how the Dutch government have developed strong municipal and neighbourhood dimensions to their main strategy for decarbonising housing and cities (summarised in OECD, 2022). Such a perspective seems to be currently missing in Canadian approaches. The issues also speak to the ways in which Federal infrastructure and housing funds are allocated in cross stakeholder partnerships and this is discussed in the final Section.

Neighbourhood lives need to fit into spatially wider social and economic systems. It is not enough to organise the 'just transition' to 'localise' lives by delinking neighbourhoods from their wider city economic and society processes. The ideas of the '10/15-minute neighbourhood' and 'community wealth building' have relevance in particular settings but neighbourhood cannot be unlinked from city, and sustainability cannot be unhooked from productivity. Neighbourhood housing actions need to link to infrastructure and other systems that constitute the sub-system connectors within, and indeed between, city regions. Neighbourhoods nest into a wider metropolitan structure, and local plans and investments similarly have to cohere with some broader, spatially defined metropolitan/regional strategy. What city structures should housing system policy be supporting in order to best deliver net zero carbon?

Housing and More Compact Cities?

The fast absolute growth of the population of Canada in the 21st century has, as discussed in Paper 2 and in the paragraphs on commuting below, led to a growing population scale, and share, in metropolitan areas (and this is consistent with recent and future trends of for the OECD), an expansion of the geographic spread of functional metropolitan regions and a smaller, but positive, counter-flow to smaller towns and rural areas. In housing terms these processes have meant substantial shortages in metropolitan areas, growth pressures at the metropolitan edge and pressures in the towns and rural areas that attract those who leave Canada's cities. These geographies of population change imply new geographies of housing supply, and market pressures, and (even if every new dwelling were to be NZC in construction and subsequent energy use) new patterns of daily household movements and their associated carbon footprints.

There is an imperative for Canada to understand better 'where the country is going' and to understand the new residential geographies now beginning to emerge. Even if all neighbourhoods are well designed and operated, which places will household choose? Two major changes will drive these new residential geographies.

The first is, how new technologies in digital face-to-face communication and other service sector oriented innovations in artificial intelligence will underpin a continuing change towards working from home and how management systems and worker expectations will shape that process. There is still much uncertainty about how 'going to the office' will recover from the Covid-19 stay at home years. The notion of home as workplace (commonplace until the 18th century) has not yet shifted thinking about housing standards, space, and amenities. Will, in future, cities and towns be defined by their neighbourhoods rather than their busy cores, congestions and concert halls?

The second change is whether net zero carbon is achieved by reducing flows of connection, other than by active travel, or whether new energy systems for motor vehicles, private and public, can be close to net zero. Alternative energy sources for transport such as biofuels and hydrogen but particularly (battery stored) clean electricity are all being rapidly developed. And there is innovation too in the kinds of vehicles that can be used to connect city and suburbs, for instance within a decade hydrogen fuelled small air taxis (with vertical take-off and landing capabilities) will be technically possible and economically feasible. These developments have implications for how houses are built (fast electric charging points for homes, stronger flat roofs for taxis to land!).

Since 2021 the rise in the price of gas, and the emergent instability in sources of imported natural and oil transport have accelerated interest in more rapid expansion of electric vehicles. Recent, extensive subsidies for the development of electric vehicle production in the USA (in the Inflation Reduction Act) and, announced by the EPA in April 2023, intendedly high emission reduction standards required for vehicles will drive faster, lower cost production of electric vehicles. And where the USA goes on this issue economics dictates where Canadian car production will largely, have to follow.

Governments, and housing providers, in Canada have to grasp these changes, and how to govern them, quickly. And they have to have some strategic sense of the 'big picture' infrastructures and nodes in the metropolitan system within and around which more effective homes and neighbourhoods will be developed. This is not a minor but a major change in urban age, and it is full of dangers, opportunities, risks and uncertainties for households, developers, lenders, and governments. As noted in Paper 1, this is 'a change of age' as much as an 'age of change'. And a 'change of age', a systems paradigm, needs leadership, imagination and as much as innovation the discarding if old views and systems that don't apply anymore. What spatial structures for housing will work for Canada?

There is no space here to even begin to adequately address that topic. But some of the challenges and opportunities for housing system change can be illustrated by focussing on what we know about the key changing connection between homes and work.

Commuting: Connecting Housing and Work Choices

Commuting is a household activity that is required to reconcile the spatial distances between the residential and workplace locations chosen. It involves direct costs and time costs that reduce labour productivity and as it usually depends on the use of fossil fuels it creates a range of atmospheric pollutions as well as GHG emissions. Approximately 15.5 million Canadians commute to work. 9 displays the number of commuters by main mode of commuting in 2016, 2021 and 2022. Metropolitan-level data suggest that, to 2016, there had been significant increases in average commuting distances and a growing proportion of commutes longer than one hour (Statistics Canada, 2022). While the pandemic affected commuting in 2021, commuting returned to pre-pandemic patterns by the spring 2022 (Statistics Canada, 2022).

Number of commuters by main mode of commuting, 2016, 2021 and 2022

	Driver/passenger in a car	Bus	Subway	Train	Walk	Bicycle	Motorcycle
2022 (thousands)	12,768	797	271	103	726	215	37
2021 to 2022 (% change)	18.3	17.5	14.4	32.6	11.6	57.4	83.8
2016 to 2022 (% change)	2.5	-32.7	-48.1	-58.3	-14.5	-2.1	43.9
2021 (thousands)	10,790	678	237	78	651	137	20
2016 (thousands)	12,454	1,184	523	248	849	220	25

Note(s): The census data exclude First Nations reserves, full-time military and the territories.
Source(s): Census of Population, 2016 and 2021 (3901), and Labour Force Survey, 2022 (3701).

Figure 93. Number of Canadian commuters in 2016, 2021 and 2022

Source. Statistics Canada (2022).

Using data from 1996 and 2016 Census of Population, Savage (2019) examines the commuting patterns in Canada's eight largest census metropolitan areas and finds that with more people and businesses located in suburban areas, commuting choices and patterns have changed in the past two decades. Five categories have been identified: within the city-core commuters, traditional commuters, reverse commuters, short suburban commuters, and long suburban commuters. Many CMAs still have a significant number of traditional commuters, ranging from one-fifth in Toronto to one-third in Ottawa-Gatineau. Nevertheless, commute types have shifted, accompanied by a decline in within-city core commuters and a rise in traditional, reverse, and short suburban and long suburban commuters between 1996 and 2016. Especially, there were a large number of long suburban commuters, about half of all the commuters in Toronto and one-fourth in Winnipeg.

These changes have been influenced by housing system imbalances and commuting patterns have a significant impact on energy consumption and greenhouse gas emissions. Transport-related emissions have been growing faster than the emissions of any other sector (Natural Resources Canada, 2018). And now constitute about one-third of the total secondary energy use and GHG emissions in 2018 (Natural Resources Canada, 2018). Passenger transportation (mainly commuting) accounts for more than half of the total energy consumption in the sector in 2018 (Natural Resources Canada, 2018) and increases in passenger numbers were responsible for a 38% in sector energy use and GHG emissions between 2000 and 2018 (Natural Resources Canada, 2018).

Per capita residential energy use in Canada, as discussed above, is the highest in the OECD but it has started to decline with changes in energy systems and alternative energy uses. Road transport emissions per capita in Canada's urban areas are the second highest in the OECD and are higher than similarly dense urban areas in other OECD countries (OECD, 2012). Harcourt and Maclennan (2007) reported Canada's high and dirty footprint for residential development and highlighted the need to change. The reaction of the Federal Government of the day was to, imperiously, bury the report and fiddle whilst the fossil fuels burned. Most Canadian governments now support the NZ goal for 2050 and notably, major cities have set themselves faster energy descent targets (as has happened in comparable countries). What are the big ideas for change?

Suburbanisation, urban sprawl, and the compact city

Among all the factors contributing to energy use and GHG emissions in the transport sector, urban form/spatial structure is regarded as the main determinant of transport-related GHG emissions (Newman & Kenworthy, 1999; Zahabi et al., 2017). For the development of practical solutions to achieve environmental targets, a deeper knowledge of the relationship between urban form, energy, and the environment is essential (Anderson et al., 1996; Norman et al., 2006) and that puts housing system outcomes at the centre of change. As Figure 10 shows, in Canada, two-thirds of the population lives in some form of suburb (Gordon & Janzen, 2013), and that 93% of the population growth in CMAs between 2006 and 2011 took place in suburbs. This situation is especially true in mid-sized metropolitan areas. The total population in Active Core neighbourhoods for Canada's midsized metropolitan areas increased by less than 1% between 2006 and 2016, compared to 11% for the large metro areas (Gordon et al., 2019). Within these mid-sized areas, 88% of the population lived in transit suburbs, auto suburbs, or exurban areas (Gordon et al., 2019).

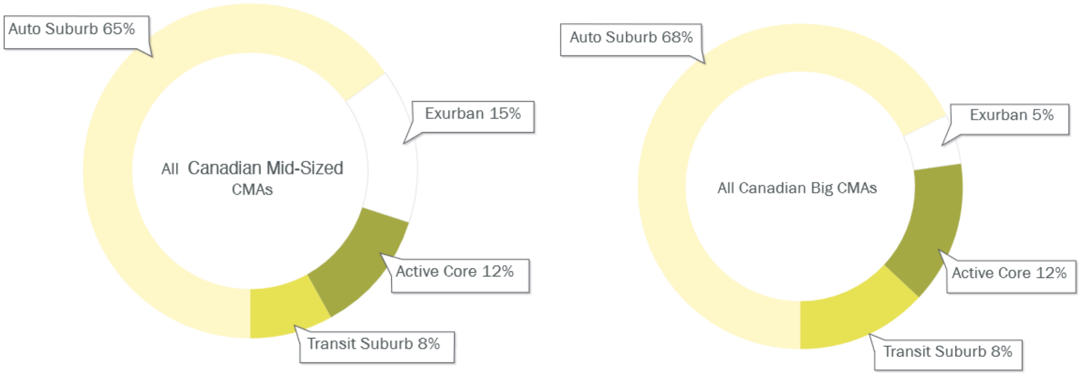

Figure 10. Canada: A suburban nation

Source: Gordon et al. (2019).

Across the OECD countries, Canada is the country with the lowest urban population density, at approximately one-third of the OECD average (OECD, 2018) (albeit with geographic differences among CMAs). Cities in Canada are on average more sparsely populated, compared to cities in European countries. Furthermore, urban population density in Canada exhibits the highest dispersion in the OECD study, about 2.3 times the OECD average. As a consequence, Canada is characterised by low density, highly auto-dependent, segregated land uses and insufficient infrastructure provision namely. These are the defining attributes of what is known as 'suburban sprawl'. It is widely considered to be an unsustainable form of urban development, and can have adverse impacts on economic, environmental, and public health indicators (Gurin, 2003; Jaeger & Nazarnia, 2016; OECD, 2014). In terms of environmental impacts, urban sprawl is associated higher with GHG and other noxious pollutants from road transport, loss of environmental amenities, and jeopardization of the biodiversity of natural habitats (OECD, 2018). Unfortunately, urban areas in Canada rank relatively high in multiple dimensions of sprawl (OECD, 2018). Where Canada builds homes and what it builds are central to these adverse environmental outcomes.

A number of studies have examined the impact of urban density on car dependency and related energy consumption and associated GHG emissions. For decades, research has shown that low urban density is strongly related to an increase in average trip lengths and high levels of private car usage since households depend predominantly on automobiles to commute to work (Newman & Kenworthy, 1999; Potoglou & Kanaroglou, 2008), which causes more greenhouse gas emissions (LSE Cities, 2014).

Almost two decades ago, Norman et al. (2006), using two case studies from the City of Toronto provided an empirical estimate of energy use and greenhouse gas emissions associated with high and low residential development. They concluded that the embodied energy and GHG emissions resulting from material production are about 1.5 times higher for the low-density case study than the high-density case study on a per capita basis. However, the result is quite different when the unit is changed from per capita to per living area. On a per capita basis, low-density developments used 1.8 times more energy for building operations than did high-density apartment developments. When measured by per square meter, single-detached dwellings and high-density apartment buildings are almost equal in yearly energy use. Per capita transportation related GHG emissions and energy use associated with low-density development are found to be 3.7 times higher than those associated with high-density development. Similarly, switching the functional unit from a per capita basis to a living area basis dampens the relative difference in transportation energy use and GHG emissions between low- and high-density developments.

In both case studies, the effects of resident transportation account for the majority of GHG emissions, whereas building operations account for the majority of energy use. Their results indicate that low-density suburban development is more energy and GHG intensive than high-density urban core development on a per capita basis.

This pattern is supported by VandeWeghe and Kennedy (2007), that described both the overall patterns of greenhouse gas emissions for Toronto, and also examined how these vary spatially throughout the Toronto CMA. As the distance from the central core rises, transport emissions begin to play a dominant role. Of all census tracts in the Toronto CMA, the top ten areas of GHG emissions are located in the lower-density suburbs, largely due to private auto use. It would be surprising if that observation no longer holds. Kennedy also, at the request of Infrastructure Canada, undertook a preliminary analysis of the infrastructure costs of developing low-density suburbs that revealed the high costs (and very high costs per capita) were not matched with higher local property tax revenues and, in effect were subsidised by other taxpayers. This result was not shared with Infrastructure Ministers at that time.[7]

[7] I commissioned the paper.

Recently, population density has been found to have a small but statistically significant negative impact on GHGs and car usage (Zahabi et al., 2015). More specifically, they find that a 10% increase in population density would reduce household GHGs by 2.08% and would reduce distance travelled by 2.20%. These effects are higher for households located in suburban peripheries and are largely attributable to daily commuting. Zahabi subsequently reported that a 10% increase in population density resulted in 3.5, 1.5 and 1.4% reduction in GHGs in Montreal, Quebec and Sherbrooke, respectively (Zahabi et al., 2017). Both changes in urban form and the replacement of fossil fuel energy sources are required for NZ's progress.

As older manufacturing cities began, in the 1980s, to make progress in dealing with 'inner city' decline, associated with deindustrialisation, the emerging evidence that low-density, auto-based suburbs could be problematic, led to the articulation of the 'compact city' as a spatial form for city development. The review of the concept by Haughton and Hunter (2004) placed the idea at the core of city planning education by the start of this millennium. The essential idea was that planning and housing development should strengthen densities city cores and secure per capita GHG reductions and infrastructure costs. The now growing body of literature on the compact city recognises its benefits for mitigating climate change through reduction in vehicle travelled and consequent reductions in energy use and greenhouse gas emissions (Angel et al., 2020). The compact city notion in the Canadian context occurs has been most usefully developed in Vancouver and Montreal (OECD, 2012). Canada knows the arguments for and against compact cities, but different provinces and cities have made different choices about how to create them, and Toronto and Calgary are sprawling contrasts to Vancouver and Montreal.

In many respects, Canada's carbon cat is already out of the bag. There have been 20 years of rapid suburbanisation in this millennium and the major potential for compactness and density may now not be pro-core growth and suburban restriction. The basic idea may need to be implemented in the different urban and semi-urban forms Phelps (2023) within the suburbs and rethink how housing and other land uses are linked to low-carbon transit systems and transport nodes. That is, Transit-Oriented Districts (TOD) of suburban centres.

Ali et al. (2021) reviewed the impacts of TOD on GHG and the environment. They found that more effective organisation of public transport enables TOD to reduce greenhouse gas emissions and building life-cycle energy consumption by 9%-25%. The overall reduction of GHG can be as high as 36%, through the proper planning of transportation and buildings. TOD is among the most popular interventions for reducing the mobility footprint, thus making it a critical component of smart growth and new urbanism (for a comprehensive definition, see Southworth, 2003). And as noted above, linking TOD to some of the basic ideas of 10/15 minute neighbourhoods keeps the latter connected to the cities they lie within.

Positive Thoughts.

Two decades ago, more national, and sub-national governments had begun to notice the global warming warnings of international organisations, notably OECD and the United Nations. A decade ago, many were fearful of the implications not just of rising global temperatures but of the perceived economic and political costs of acting to abate them. Yet a further decade on, there is now in many governments a recognition not only that urgent action is needed but also a sense that in many areas of human activity and government policy there are actions that can significantly abate GHG emissions. This is not a prompt to political complacency, but rather to observe that recognising 'new times,' and absorbing information and innovation are essential human traits in building new framings or paradigms for living. It is clear that the societal innovation process, with systems thinking emerging, has meant that changing housing is making substantial gains in reducing GHG emissions from the quotidian activities of living. More needs to be done to augment housing thinking and action, in conjunction with other infrastructure programmes, to reduce the GHG effects of housing location choices conjoined to the transport modes and miles that households undertake. There is much done, and lots still to do. And these tasks are urgent because climate change induced damage is accelerating.

8. RECURSIVE RELATIONSHIPS: CLIMATE CHANGE AND HOUSING SYSTEM IMPACTS.

Governments started to model some of the major consequences of climate changes at the start of this millennium and quickly became aware of how global warming would have significant effects for all but for particular regions and types of places. That modelling has become more sophisticated and specific in its projections with organisations such as the IPCC making increasingly firm and believed predictions about global system change for long periods ahead. More prosaically major insurance companies track, where possible, climate-induced catastrophes and recurrent damage.

The global insurers, Swiss Re Institute (2021) report on natural catastrophes and sub-divide catastrophes into natural events with serious consequences and man-made disasters. They recognise the approximate nature of such estimates. They note, given caveats, that man-made catastrophes fluctuate but are generally related to global population change and they have doubled since the 1970s. Natural catastrophe numbers, in contrast, have been trending steadily upwards over that half century. They have trebled Between 1970 and 2020. In 2022, natural disasters killed 33,000 people and man-made events under 3000. Catastrophe damage costs were 250bn $US. Insured losses met half of that total and the insured portion has been falling over time.

Leaving aside catastrophes the IPC say that in 2022, the 3rd worst year on record (and the other two postdate 2016), bad weather caused $3.1bn in insured damage and arose from a growing number of weather events. In these incidents, the costs are mainly due to water-related damage. Damage value, by 2022, was 4 to 5 times higher than in the first decade of the millennium. Aquanomics (2022) report that by August 2022 the broader costs of economic costs of disruption are $44 to$ 45 bn per annum in Canadian economy. The record floods that isolated the port of Vancouver in 2021 illustrate the economic damage of lost connectivity, power and water (including the lost output of those working at home).

Rural and urban regions all suffer from such processes. Personal property claims have tripled between 1996 and now, from $2.3bn to $7.1bn (Malik, 2021), based on Ratesdot.ca figures. As a consequence of these weather damage effects, average costs of home insurance continue to rise and indeed rose from $1000 in 2021, and around $1300 at the end of 2022. CMHC is undertaking a separate review of changing relations between the housing and fiancé sectors. Given the mortgage insurance and market roles of CMHC there are clearly important implications in relation to risks associated with existing loans as well as much consideration to be given loan allocations and insurance coverage for future CMHC-supported initiatives. This theme is not developed further here. However, an integrated view of how climate change will impact the price, quality and running costs of housing. Energy use may go up unduly hot and cold phases of weather and urban heat islands raise housing costs.

There is also a much more serious and sometimes unrecognised housing system risk from climate change, even where damage processes operate gradually rather than chaotically. An important, recent study by Gourevitch et al. (2023) explored and estimated the 'Unpriced climate risk and the potential consequences of overvaluation in US housing markets'. They made econometric estimates of the extent to which climate risks derived from climate change modelling, and estimated for particular localities throughout the US, were actually reflected in housing values. They estimated a considerable divergence between risk efficiency and actual prices and found '*that residential properties exposed to flood risk are overvalued by US$121–US$237 billion, depending on the discount rate. In general, highly overvalued properties are concentrated in counties along the coast with no flood risk disclosure laws and where there is less concern about climate change. Low-income households are at greater risk of losing home equity from price deflation, and municipalities that are heavily reliant on property taxes for revenue are vulnerable to budgetary shortfalls. The consequences of these financial risks will depend on policy choices that influence who bears the costs of climate change'*.

Their model suggests that New England coast is most likely to be affected, and the Province of Nova Scotia will no doubt be reading the study with interest. Aside from their important recursive finding, which really stresses the value of housing systems thinking, Gourevitch et al. make very important policy points and explore different policy scenarios to avoid housing market damage on a systemic scale. The worst (of four) strategies is for governments to conceal the damage risk estimates but warn when a significant damage event does occur expectations of further future may drive prices quickly down. The best strategy is to have a full revelation of damage estimates in a non-disaster context with supportive mitigation strategies in mind. Damaged property markets imperfectly understood and badly governed may be a major concern and task for CMHC, unless Federal Canada wants to be seen to be leaving ‘damage victims’ to deal with the consequences of local and personal actions.

In the next, final, section we place that role for CMHC alongside a wide range of governance and policy issues that have arisen in drafting this report.

9. THE GOVERNANCE HOUSING SYSTEMS FOR NET ZERO.

An 'Iniquity' of 'Wicked Problems'.

People and politics in all the advanced economies are facing futures of dealing with a diverse 'Iniquity' of multiple systems, an interaction of 'wicked' problems. This paper focussed on how increasingly dysfunctional housing systems and policies are producing outcomes that have generated greenhouse gas emissions and exacerbated global warming. This paper has been about exploring how two systems, the environment and housing, are in linked crises. It has also made clear how by changing housing systems outcomes, through reconstructing system governance as well as raising investment levels, it is not just possible but feasible to improve both housing and environmental outcomes.

In the introductory Preface to these papers, on economic and environmental outcomes of housing policies, the aim of signposting ways to improve housing 'governance' was stressed and Paper 4 offers some high-level recommendations for change in the Canadian context. 'Governance' looks at the high-level ways in which governments, and organisation, shape their aims, principles, visions, 'problem framings and understandings', and their management styles and approaches to developing 'missions', strategies, and delivery arrangements, including their approaches to partnerships, vehicles and policy instruments used.

As a conclusion to this paper, and to shape the agenda for Paper 4, a number of the ways in which governance aspects of the Canadian housing system might impact GHG outcomes are summarised.

Progress in Government.

The recognition that adverse environmental outcomes, not least GHG emissions, originating in local housing systems have a global and national impact that requires action by all orders of government. The mantra, still heard on Parliament Hill, that housing is a social policy concern for Provincial action, is for climate change governance deniers. The in the transition to net zero, the Federal Government has a critical funding, influencing and integrating role to play in shaping better housing outcomes for all of Canada and all Canadians. Housing is local. Canadian Housing outcomes are always more than local and, demonstrably, can be global.

It is clear that within Federal government there is clarity on the importance and urgency of GHG reduction. There is less obvious clarity on the required instruments for change. An integrated statement on the tax arrangements (particularly carbon taxation), expenditure-subsidy packages, standards and regulatory choices intended to achieve the green transition would help policymakers in specific policy areas, and in different orders of government, to make better-detailed policy choices with more certainty. OECD (2022) impressively summarises the ways in which arrays of different policies impact key GHG goals and the GOC might usefully develop such a matrix of the likely effects of each of the (wide) array of instruments of policy used.

This observation also implies to the housing system effects on monetary and prudential borrowing policies that are critical influences on individual housing investments, including green upgrading. So called 'green finance' is available on capital markets and through other arrangements in increasing flows. Federal government has the general policy responsibility for the design and stability of the financial system. CMHC as a major mortgage insurer has a major policy interest in such concerns and will be a leading channel by which the Canadian mortgage market and housing system are impacted by climate change in general and specific events in particular. Will environmental 'lending' criteria be added to the sector stability aims associated with CHMC financial actions? Is CMHC more than a quasi-commercial mortgage loan insurer? A separate review is examining these issues and they are not discussed further here.

There does not yet appear, to be a fully developed interface between federal housing, infrastructure, transport, and energy policy actions to reduce GHG and the new location of housing policy within Infrastructure offers much potential for better policy integration of housing policy to achieve GHG reductions. Much Federal discussion on housing issues is about the provision of 'defensive actions' to abate sustained criticism from traditional housing lobbies to meet 'housing needs'. Responding to these social needs to be complemented with a new clarity on how housing policies, particularly when integrated with transport (TOD) and other infrastructure packages (15-minute neighbourhoods) lead to environmental improvements and better housing outcomes. Net Zero Canada needs an effectively 'more localised' aspect of daily living and it is housing and infrastructure programmes that will ensure that outcome. Housing policy objectives in Federal, and Provincial Canada, are not adequately framed to capture

GHG, and other environmental effects. If these gains from integrated, better, policy actions are not delivered and recognised, housing policy debate will remain a narrative about failure to meet social housing needs. Whilst in no way diminishing the importance of meeting these needs, federal housing systems policy, needs strategic aims and actions to improve the economy and the environment.

An immediate concern for achieving the housing sector's contribution to achieving Net Zero, that touches almost all the important missions of the federal government, and other orders too, but particularly the work of the Ministry for Labour, is the urgent need for and real prospect of rapid retrofitting of Canada’s older homes. That retrofitting won’t be done by robots nor by older construction labourers or with traditional skills and designs. New construction skills, of a high order, will be required with a massive step-up in construction employment (from currently near peak employment levels). Skilled construction labour for retrofitting, resolving the current shortages of housing, keeping pace with growing demands, and rising volumes of essential immigration will be the major constraint in the Canadian housing system from now until at least the 2030s. Right leaning, as opposed to right thinking, policy commentators in Canada lay the responsibility for the sluggish housing supply at the door of municipal planning authorities. Inflexible planning systems have some role in some places but amongst a wide range of other influences on housing investment supply chains. However, it is construction labour shortages that, if left unaddressed by policy now, will inflate retrofitting costs, slow progress to Net Zero and increase voter resentment at any imposed new residential energy standards. Yet, with effective coordination across housing, infrastructure, construction labour and immigration policies more, greener homes (and buildings) are a major opportunity. Independent estimates (see above) of the economic opportunity of producing a Canada of green buildings could create up to half a million jobs and raise GDP by 1pc per annum over the next decade.

There is a strong case to be made that the federal government should immediately establish, in a Federal-led task force to work with Provinces and cities, private and non-profit developers, and relevant experts and serviced by CMHC. An immediate audit of housing and retrofit supply shortages and an action plan to reducing barriers (reviewing labour and materials shortages, the case for modular homes, converting redundant downtown office spaces to apartments, raising the input of public land, inclusionary zoning, incentivised removal of planning barriers) should be developed and report before Budget 2024. There may then be merit in creating a follow-on Canadian Housing Supply Council, located within, and serviced by, CMHC to monitor progress and any barriers emerging. Solving the housing/retrofitting supply issues and driving GHG emission reductions through greener homes are two sides of the same coin. These issues need more than commentariat consensus that ‘supply is the problem’. They need Federal-led action now.

The recent innovative wave of creative work in building materials, housing construction processes and energy systems and sources in Canada reflects a major uptick in research in multiple branches of science and engineering. Changing environmental and housing behaviours can be as important in some aspects of energy descent and ‘just transition’ as new applied science. Whilst there is some useful work on ‘buildings’ there is no coherent economic and social research programme in Canada on the environmental outcomes of housing systems and the transformation of housing systems, behaviours, and policies to foster net zero goals. Searching for applied economics research on the contemporary Canadian housing system is a daunting and often unproductive task (in contrast to conducting equivalent research in Australia, the USA, and the UK).

Government has fashioned effective forms of partnership working in multiple policy fields in Canada. That could be strengthened by embedding systems thinking around areas of Federal policy development financed and their integration with other partners and orders of government. Collaborative governance with synergistic power sharing to achieve goals and missions is important within and beyond the Federal government. A critical outcome from such a process would be for senior officials to understand that multiple departments have key influences on housing system outcomes and that other departments recognise how better outcomes facilitate their own goal achievements. Three decades on from the early advocacy of whole of government approaches Federal Canada needs to rethink roles in reducing adverse housing outcomes. Housing policymakers need their stakeholder and synergy makers maps at the front of action. And so do Ministers in improving national housing outcomes. Reducing the dirtiest environmental footprint of residential development in advanced economies is a subject worthy of continuing cabinet attention, for example.

There is much more to be said about Federal governance, and embracing the other non-GHG ‘wider goals’, of housing policies and their delivery. A key task in that process is to recognise the potential importance of its national housing agency in that process to reshape it to meet the housing crises and opportunities of the 2020s rather than let it struggle into that future whilst seen primarily as an agent for contracting federal housing actions and spending (downturns excepted) and sponsoring low-income housing programmes that are often overwhelmed by other key policy actions. A federal agency will be a critical integrating device for systems governance of housing policies within and across other orders of governance.

Other Orders, Not Just Following Orders.

Provinces are critically important in the multi-order governance of the housing system and that applies to environmental as well as social outcomes. Many of the observations regarding research gaps, collaborative culture and thinking about the housing system also apply at that scale. Two particular themes seem provincially pertinent. Provinces play key roles in planning and building regulations as well as land and property-related taxes. There is a complex array of different tax and regulatory arrangements across and within Provinces and their mesh with Federal tax and regulations to promote better environmental and GHG outcomes is, arguably, unclear in relation to the fiscal efficiency and fairness of 'transition' aims and processes. Provinces could lead the rethinking of better systems of regulatory and fiscal measures to promote zero carbon emissions, collectively engaging with the Federal government on its fiscal/regulatory settings and using CMHC understanding of housing systems to help better inform policy settings that could better serve both environmental and housing outcomes.

Provinces have the presence and capacity to frame regional/ multi-regional spatial strategies to secure better economic, environmental, and social outcomes. Within such strategic frameworks they require a coherent housing-system strategy, and a clear articulation of how strategic housing actions will achieve major policy goals. For instance, some major Canadian cities have embraced faster achievement of net zero than the Provinces they are located within. Why? Is it simply 'politics' or are there gaps in thinking? And does it hamper the strategic alignment of municipal and provincial policies, not least as Canada's future housing growth and housing-led carbon mitigation and adaptation activities will continue to be in the major metropolitan areas?

Provinces need to lead the transformation from the social/affordable framing of housing policies to a wider strategic housing system management and investment strategy.

Federal government investment support to Provinces should, in part, be delivered on the basis of such strategic plans for the housing sector. CMHC should have a role in supporting Provinces, with limited resources or a capacity for mutual learning, to implement best practices to shape the decarbonisation of local housing systems.

Provincial strategic actions need to be based on strong collaborative actions with municipalities. Where Provinces are home to multiple CMA's that geography should be reflected in Provincial processes and plans with the major metropolitan areas playing leading roles in delivering better GHG outcomes. There may be a strong case for major investment programmes to be constructed as 'Cleaner Canada Deals', not imitating, but building on the lessons of Australian and UK city deals, as major, strategic investment partnerships funded and resourced by all orders of government. For instance, at present, how many governments demand full market price for land that is to be deployed in 'affordable/zero carbon' housing? How often are small tranches revitalised to meet housing objectives when bundles of such parcels of land could be integrated into more efficient city/region-wide housing and infrastructure programmes?

When looked at from abroad, a great deal of policy energy and political effort appears to be dissipated in bargaining and manoeuvring in regard to flows of programme funds across orders of government (and silos of policy spending) rather than improving outcomes. Often other Canadian governments rather than greenhouse gases appear to be seen as the existential threat. And a response to political risk aversion and low trust in allocating funds from federal to more grounded scales of government is to fund projects and not investment strategies and to concentrate on onerous application systems but, at best, modest assessment of outcomes. Modern governance of the housing system needs strategic support and clear monitoring and quick evaluation of how spending reduces GHG and provides better homes.

It also needs engagement and support from citizens, consumers, and communities. Housing outcomes, and not just because of their environmental consequences, are so crucial to the wellbeing, prosperity, and productivity of all Canadians that missing education about the housing system, in schools, colleges and universities remains a mystery. Learning how to thrive differently with zero carbon has to be a priority for all age cohorts, and a 'greener future does not have to be meaner times'. More compact living in cities within well-served local neighbourhoods in homes that are net clean energy producers is already a feasible proposition for Canada.

Governance that serves the future rather than pays homage to policy history is required. Energy experts have now designed flooring and sidewalk materials that capture the kinetic energy embedded in human footfalls to create clean energy for other uses.

In a similar vein, the energies and activities used in governance systems for housing in Canada need to be recaptured and directed towards a better strategic management of housing polices and systems. More resources, and there will never be enough, and more rights, and they will never be realised, directed to current approaches to housing polices will not resolve the emerging crises in the Canadian housing system. Rethinking housing systems, recognising what they do and revitalising their governance might give rights and resources a serious chance to improve housing outcomes.

Duncan Maclennan and Jinqiao Long,
16th April,2023.

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