Managing the Transition to a Climate-Neutral Economy in Cities and Regions

Ralph Chapman
School of Geography, Environment and Earth Sciences, Victoria University Wellington
ralph.chapman@vuw.ac.nz

This paper investigates how cities can manage the critical transition to carbon neutrality. First, and in the light of the most recent evidence on climate science, the role and responsibility of cities and their regions in mitigating climate change are identified, together with factors that could hold cities back, and characteristics of cities, which can facilitate their contribution to the transition process. Second, a framework for considering the desired contribution is developed, focusing on how policy can be more coherently framed around well-being and the sustainable development goals, moving away from a narrow cost-benefit analysis to emphasise co-benefits, while recognising the complexity and constraints of urban systems. A key part of the argument is that the transition process can and must involve signalling such an early and profound shift in expectations and priorities for investment and behaviour that an endogenous process of system transformation takes place in which the costs of change fall dramatically. The last part of the analysis argues that political and governance processes will not succeed without giving attention to ensuring the transition is just.

Four key themes emerge. First, a rapid and far-reaching transition is essential to preserve as much climate stability as possible, but will be disruptive and politically demanding. Second, in the context of urgency, effectiveness becomes more salient than efficiency. Third, the shift from a framework focused on optimising for economic growth to one based on the purposeful pursuit of well-being, including climate stability, has major implications for the way that mitigation is framed for cities. Fourth, the systemic nature of cities has a profound effect on the nature of the policy approaches required to mitigate urban emissions, and the means by which we can overcome barriers to mitigation along a carbon-neutral transition path.

Background information

This paper was prepared as a background document for an OECD/EC high-level expert workshop on "Managing the transition to a climate-neutral economy for regions and cities" held on 17 May 2019 at the OECD Headquarters in Paris, France. It sets a basis for reflection and discussion. The background paper should not be reported as representing the official views of the European Commission, the OECD or one of its member countries. The opinions expressed and arguments employed are those of the author(s).

Managing environmental and energy transitions for regions and cities

The workshop is part of a five-part workshop series in the context of an OECD/EC project on "Managing environmental and energy transitions for regions and cities". The five workshops cover "Managing the transition to a climate-neutral economy, "Managing environmental and energy transitions in cities", "Managing the transition to a circular economy", "Managing environmental and energy transitions in rural areas", and "Financing, scale-up and deployment". The outcome of the workshops supports the work of the OECD Regional Development Policy Committee and its mandate to promote the design and implementation of policies that are adapted to the relevant territorial scales or geographies, and that focus on the main factors that sustain the competitive advantages of regions and cities. The seminars also support the Directorate-General for Regional and Urban Policy (DG REGIO) of the European Commission in work of integrating sustainability transitions in the next generation of European Union Cohesion Policy programmes 2021-2027, as well as to support broader discussion with stakeholders on managing long-term environmental and energy goals in EU regions and cities. The financial contributions and support from DG REGIO are gratefully acknowledged.

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1 Introduction and key themes

In 2018, the IPCC released a report on climate change (2018a), which provides an authoritative overview of the scale of transition necessary internationally if catastrophic climate risks associated with global warming above the 1.5-2°C range (relative to pre-industrial levels) are to be avoided:

'Pathways limiting global warming to 1.5°C… would require ***rapid and far-reaching transitions*** in energy, land, urban and infrastructure (including transport and buildings) and industrial systems (high confidence). These systems transitions are ***unprecedented in terms of scale***, but not necessarily in terms of speed, and imply ***deep emissions reductions in all sectors***, a wide portfolio of mitigation options and a significant upscaling of investments in those options (medium confidence).' (IPCC, 2018b, p.17); emphasis added.

Others echo this language, many seeing the transition challenge as part of a wider ecological sustainability crisis. For example the Institute for Public Policy Research in the UK approach the transition challenge from the perspective of avoiding a wider environmental breakdown: 'Preventing environmental breakdown requires rapid transitions of unprecedented scale across all economies.' (Laybourn-Langton, Rankin, & Baxter, 2019)

Ideally, any transition, even if unprecedented in scale, would be measured, rather than rushed: 'Transitional policies should aim to enable a steady transition – one in which emitters are neither overly disrupted nor so protected that there is no incentive to change.' (Upton, 2019, p.11). However, 30 years of policy prevarication have left little time in which to make this transition of unprecedented scale, without significant disruption. Reputable climate scientists have warned that 'responses based on marginal changes to the current trajectory of the human enterprise— "fiddling at the edges"—risk the collapse of large segments of the human population or of globalised contemporary society as whole' (Steffen et al., 2011). Carbon emission reductions of at least 5% per year (i.e. a halving each decade) may appear rushed in some sectors, but are now required.

The 2018 IPCC report on 1.5 degrees of warming points to accelerated emission reductions of about 45% by 2030, i.e. over about a decade, followed by further reductions aiming at close to zero carbon by 2050. Economists such as Burke support this by pointing to large gains from hewing as close as possible to the Paris targets, and large losses if temperatures rise. Kormann (2019), citing Burke (2018), writes that 'if nations met their [current] commitments under the Paris Agreement, the world would still see the average global temperature rise by two and a half to three degrees Celsius which…would result in a fifteen-to-twenty-five-per-cent reduction in per capita output by 2100.'

The actuality of such economic and social disruption will be layered on top of the impacts due to climate disruption that are already 'baked into' the climate system. Disruption from mitigation itself can be minimised by thoughtful (but urgent) policy measures, compensation for those most disrupted and accelerated investment in innovative practices and technologies.

We have already seen political resistance among some affected by the likely stranding of their assets as transition gets underway. Further, more intense resistance is inevitable, threatening successful transition, but will need to be faced down if enormous environmental, economic and social damage is to be avoided. A ***first theme*** of this paper is that a 'rapid and far-reaching' transition is essential to preserve what we can of climate stability, but will be a disruptive, hotly contested, politically demanding and uncertain process.

A key consequence of a compelling need to reduce emissions by enough to have a strong chance of averting catastrophic climate change is that policy **'effectiveness'**, in relation to reducing carbon emissions needs to become a higher priority than efficiency. This is the **second theme** of this paper. Effectiveness amounts to emissions abatement potential. At any time, with limited policy maker attention, it makes most sense to focus first on policies which can cut emissions a lot. For example, in the short run, encouraging a switch to electric vehicles is an effective policy, probably more effective than reshaping cities to be more compact and improve mobility and access. EV promotion might not be highly efficient, as EVs may often simply perform unnecessary trips with lower emissions, creating negative effects such as congestion and the validation of sprawl (Rees, 2014), but it can be effective in the short term. In the medium to longer run, policies to reshape cities and improve public transport will be more efficient, taking into account the co-benefits of more compact cities. Harvey, Orvis et al. (2018) estimate that 'urban mobility' policies would be more effective in generating carbon savings over 2020-2050 than vehicle electrification. So reshaping cities is vital, but should be recognised as a medium to longer-term contribution to the mitigation challenge, even if it needs to get underway before long given the implementation lags involved. Privileging effectiveness points to an initial emphasis on policies with immediate effect, while longer-term policies are developed to improve the efficiency and quality of life of city regions.

Romer's endogenous growth argument is important here (Zenghelis, 2019a): in short, optimising future policy pathways via 'integrated assessment models' of estimated income, cost and 'efficiency' is misleading, as it is difficult to accurately predict the costs of mitigation, including how the global economy will adapt and innovate to limit costs. The costs could be significantly less than a number of modellers have projected since, if a climate-effective path is adopted, innovation and growth will develop around (become endogenous to) that path. In simpler language, 'the lesson of the last decade is that costs fall when there is a concerted effort to act' and that the economic impact of reducing emissions to net-zero 'are likely to be small globally and in the UK and could turn out to be positive' (CCC, 2019). An example of this is the prospect that transport will see net savings, rather than costs, in the transition to net-zero: electric vehicles are likely to have lower upfront and lifetime running costs in roughly a decade (Carbon Brief, 2019).

Conversely, pessimistic estimates of mitigation costs would discourage businesses and governments from investing in new technologies, slowing the rate at which costs come down, and making decarbonisation more costly.

A **third** and related theme is that the shift from a framework focused on optimising for economic growth to one based on the purposeful pursuit of **well-being**, including climate stability, as outlined in the sustainable development goals, also has major implications for urban transitions, and the way that mitigation is framed for cities. The framing in the past has been narrow. For example, historically, the policy direction in transport for cities has been expressed in terms of supporting mobility for economic growth, sometimes with social progress (including health) identified, but often with externalities such as climate change seen as a lower priority consideration (Government Office for Science, 2019, p.112). That order of priorities is not consistent with guaranteeing a transition to zero carbon. A framing around well-being directs attention to impacts of mitigation policies on different income and social groups (Banister, 2018), with the policy implication being that adjustment assistance to those most affected is essential. There has been a dearth of research on who gains and who loses from the urban politics of mitigation (Bulkeley, 2010). A focus on equity as part of well-being is central to good design and management of the transition process.

A **fourth** theme is that the systemic nature of cities has a profound effect on the nature of the policy approaches required to mitigate urban emissions, and the means by which we can overcome barriers to mitigation. This is most evident when we consider the co-benefits of carbon emissions mitigation. For example, a systems approach suggests that policies to adjust urban form can contribute not only to mitigating transport emissions, but also to important goals such as improved health and the quality of life of local communities. The state of understanding of co-benefits is inadequate -- the IPCC comments that 'societal co-benefits of the modelled transformations remain largely unaccounted for' (IPCC, 2018c, p.32). This means that more work on co-benefits is urgent. It does not mean that they can be ignored; they can

be critical to the transition. Improving health, in particular, is a strong motivator of emission reductions (Bain et al., 2016; Myers, Nisbet, Maibach, & Leiserowitz, 2012) and action is less likely to occur in the absence of health arguments.

The remainder of this paper develops these themes in reverse order across several sections, structured as follows. The next section (Section 2) starts with the fourth theme, taking a systems perspective and ***considering how cities*** (i.e. cities and their regions) contribute to the climate change problem, the key role they can play in the mitigation solution, what is special about cities, the barriers faced by cities, and broadly how a climate-neutral urban transition can be facilitated.

Section 3 focuses on how urban mitigation can be made more ***coherent and purposeful***. It develops the third theme by addressing how rethinking the cost-benefit analysis of policy measures in an urban context can make an important contribution, especially when critical co-benefits are considered. In addition, it addresses the question of how to shift other aspects of the current policy framework towards one better suited to transition. Section 4 addresses the ***role of policy instruments and infrastructure investment***, contributing to the second theme around policy effectiveness, and harking back to the first theme of unprecedented disruption. Section 5 departs from the four themes, discussing ***governance and institutional dynamics*** and the critical question of the distributional impacts of transition policies.

A word on this paper's scope. This analysis focuses on mitigation in the city-focused domains of energy, transport and buildings. For example, it includes aspects of the energy sector (while recognising that much energy is generated outside city regions), but excludes food production and industry, sectors which are largely outside the regulatory domain of cities.[1] While most examples of mitigation are from OECD countries, many of the policy messages are also relevant to other countries, whose actions will often weigh the most in terms of overall global emission reductions.

2 The role of cities and regions in the necessary transition

> *"Nations talk; cities act."– Michael Bloomberg, former Mayor of New York City*

2.1 Cities are a major part of the carbon emissions problem, but the problem is systemic

Cities and city regions contribute disproportionately to CO_2 emissions: it is estimated that the total greenhouse gas (CO_2, CH_4, N_2O and SF_6) contribution of urban areas globally was between 37% and 49% of total global greenhouse gas (GHG) emissions in 2000 (Seto et al., 2014, p.927). However, for CO_2 alone, the responsibility of cities is probably closer to 76% (*ibid*), greater than cities' share of global population. In considering this, it is important to note that there is debate about the effective boundaries of cities. The OECD has suggested an economic emphasis in defining cities, arguing that 'urban areas can be characterised by densely inhabited "urban cores" and "hinterlands" whose labour market is highly integrated with the cores'; i.e. they are 'functional economic units' (OECD, 2012). Socio-cultural factors such as a sense of place are also important in defining cities.

In considering the emissions intensity of city dwellers compared to those in rural areas or small towns, the latter's emissions are often comparatively high: one expert puts it that, generally, 'wealthy households living in small urban centres or rural areas have higher carbon dioxide emissions per person than households with the same level of wealth living in cities (because of, for example, more automobiles, more automobile use and larger, worse-insulated houses).' (Satterthwaite, 2008, p.541). This is supported by other sources. A key factor is the type of urban form in question: even within one nation, some large cities (e.g. New York) have lower emissions per capita than smaller, more suburban cities, such as Oklahoma City (Glaeser & Kahn, 2010). The disparities in emissions are also a matter of 'development' and incomes; in poorer countries, emissions per capita are low in rural areas, but tend to rise as populations urbanise. Cities typically have bigger concentrations of higher income groups with higher emissions.

Cities depend on long supply chains, often global in nature. Therefore, when determining their emission reduction strategies, cities and their regions also need to consider their carbon footprint from a consumption perspective. In other words, cities need to take account of the footprint of imported goods and services, and ways to reduce these. Gothenburg in Sweden set a consumption based emissions target in 2014, one of the first to do so (Falk, Gaffney, & colleagues, 2018).

Given the interdependence of cities, their hinterlands and the wider economic system, the allocation of responsibility for emissions among cities, their regions and other regions is ultimately less important than understanding how emissions can be most effectively reduced in each component, i.e. the solutions available. Furthermore, decarbonisation solutions for cities – such as electrification of much transport – may compete against solutions in other parts of the economic system. For example, decarbonisation of most industrial products (e.g. cement, steel, ethylene, ammonia) is likely to demand a great deal of low-

cost electricity, especially where those industries do not face environmentally realistic carbon prices (de Pee, Pinner, Roelofson, & colleagues, 2018).

2.2 Why is the contribution of cities so critical?

Crosscutting policy instruments such as a price on carbon are usually implemented at the national level (or state level, in federal countries such as the US). Cities nevertheless provide critical emission reduction opportunities, as cities typically have jurisdiction over some sectors such as buildings and parts of transportation, and other local infrastructure. Importantly, cities are usually able to take mitigation action independently of, and more rapidly than, national level governments. They are also motivated to take action as many of the co-benefits of mitigation accrue locally.

Cities are the pre-eminent spaces of innovation in the global economy. Since they generate higher incomes than rural or semi-rural areas in most countries, they tend to have the resources and the scale to get change underway. The very reasons why cities exist, to allow easier social and economic exchange – yielding 'gains from agglomeration' -- mean ideas proliferate and develop more readily in urban environments. Nimbler responses are also facilitated by cities being centres of innovation, and testbeds for mitigation experiments and pilots (Castán Broto & Bulkeley, 2013). They can deploy their significant procurement powers, but in addition, they can support smart city technologies and set an example of progressive emission reduction targets. In a world in which the exact shape of dynamism and disruption is not foreseeable, what is clear is that we are likely to be pleasantly surprised by the capacity of cities to generate, develop and implement technological and social innovations, from e-scooters to local housing intensification strategies.

The main reason cities are so critical at this moment is because of lock-in. Cities can make a huge contribution, on the upside, to enabling a zero-carbon transition, but on the downside they also have the potential for locking in a pattern of energy-, building- and transport-related carbon emissions that cannot be easily undone. Urbanisation is currently so rapid that the shape of future cities is literally being set in concrete, decade by decade, as urbanisation proceeds. Typically, this urbanisation is unnecessarily diffuse: urban land cover is expanding at twice the rate of urban population growth (Global Covenant of Mayors, 2018). The problem of lock-in is, of course, not limited to cities, but cities' form and infrastructure represent the longest-living economic asset that humanity has, over the centuries, constructed: few large assets have endured nearly as long as cities such as Athens and London. Early action on sprawl is critical to minimise lock-in. The long service life of buildings, transport systems and other infrastructure means they are costly to reconfigure.

Moreover, given that carbon emissions must be reduced overall to net zero by around 2050 to minimise the risk of global warming of more than 1.5C (Global Covenant of Mayors, 2018), inadequate mitigation by cities would imply greater pressure for action falling on other parts of the economic and social system, such as food production in the rural economy, energy generation, and industry.[2] This pressure would increase as climate change intensifies. We could also expect political tension -- resentment of and resistance to any special pleading by cities, and potentially a reduced willingness of those outside cities to act. Some trade-exposed industry (e.g. food exporting sectors) under pressure to make rapid emission reductions would likely be resistant to change, due to their greater competitiveness challenges, relative to 'sheltered' sectors such as urban transport. Inadequate action by cities might cause an undermining or fracturing of carefully constructed coalitions for climate action. In short, we could expect a range of negative consequences from cities not 'pulling their weight' in terms of mitigation.

2.3 What could hold cities back?

The nature of cities as complex systems means mitigation strategies face the difficulty of working across sectoral and political boundaries; strategies have to struggle to be congruent with a wider set of objectives, and city or regional policies have to be reconciled with state and national policies where at all possible. System effects within cities can also create trade-offs. For example, promoting electric vehicles may act to the detriment of urban public transportation, creating conditions which are less conducive to wider goals such as reduced urban congestion and adequate physical activity. Another example is that simply relocating a polluting industry (to the benefit of a city's carbon footprint) may have zero effect on overall emissions if the industry simply moves elsewhere in the country (Bai, Dawson, Ürge-Vorsatz, Delgado, & colleagues, 2018). System interactions might also mean other sectoral policies, such as for electricity generation, could cut across urban decarbonisation goals. Notwithstanding falling prices over time for renewable power generation in many countries, strong upward pressure on energy prices in some instances could limit short-run electric vehicle take-up. In a world of falling 'energy return on energy invested' (EROEI), and increasing competition among sectors for energy and capital resources, the energy transition could be characterised by rising energy prices and downward pressure on incomes (Režný & Bureš, 2019).

Acknowledging the multi-level systemic nature of cities means recognising that city governments have a complicated governance task. First, even aside from the challenges of policy alignment beyond their jurisdiction, they need to manage and balance the aspirations of multiple sectors, which they regulate or support, through instruments such as building efficiency regulation and land use management. This can be complex where building standards are set nationally but affect local building outcomes, and local councils have legal responsibilities for monitoring and compliance. What local government does here can ripple through markets for years after implementation: for example, land use regulation that impedes intensification can mean that public transport investment is less economic, discouraging and slowing a transition to lower-carbon transport, increasing energy use and raising carbon emissions.

Second, cities need to recognise that their constituencies are increasingly turning from one-dimensional outcome measures (such as economic growth) to a richer set of outcome measures, including addressing inequality and enhancing resilience and sustainability, as embodied in the UN's Sustainable Development Goals (SDGs). Cities' tasks require wider competency and encounter more complex challenges of coordination and integrated management. This change builds on a shift 'from traditional conceptions of [and preoccupation with] agglomeration economies to the capacity of urban areas to adopt a sustainable model for their natural resources and to reduce income disparities and marginalisation.' (OECD, 2012)

An important part of this more challenging task, in the context of a zero-carbon transition, is a more sophisticated consideration of co-impacts of mitigation and attention to equity impacts. Understanding and profiling co-benefits and equity-enhancing dimensions of policies is necessary to support change makers' ability to summon sufficient political support for a coherent mitigation strategy.

2.4 How can urban transitions be facilitated?

In thinking about strategies and transition pathways that work well for complex systems, attention is usefully directed to both ***leverage points*** and ***barriers***. Leverage points are 'places in the system where a small change could lead to a large shift in behaviour.' (Meadows, 2009), and provide critical opportunities. These are discussed below in section 3.5 in more detail.

In the energy sector, for example, high leverage opportunities arise in the transition to renewables. A wide variety of low-income communities are gaining access to renewable energy resources, such as biomass, wind and solar power. An International Council for Science report noted that 'progress in making use of those potentials could help to reduce poverty, as long as the benefits accrue to local suppliers.' (M Nilsson,

Griggs, McCollum, & Stevance, 2017, p.131). Leverage strategies that facilitate investment in such resources could unleash economic opportunity and reduce poverty as well as assisting in emission reduction.

A second example of a leverage point is infrastructure renewal opportunities, to improve building energy (and carbon) efficiency. New York City recently passed a bill to require building energy efficiency measures cutting 50,000 large buildings' carbon emissions by 20% by 2030, on track in principle to 80% cuts by 2050. Building owners will be eligible for modest incentives, such as low-interest loans and, for buildings with clear track records, less frequent façade inspections, saving them resources which could be reallocated to the energy efficiency improvements (A. Howden-Chapman, 2018; Urban Green Council, 2018).

A rather different instance of leverage is where a few key opinion-leading cities take mitigation action, encouraging others. Such tipping effects can work at country level, with just a few trendsetter nations which exemplify change causing a qualitative shift in the investment environment (Sterl, Hagemann, & colleagues, 2017). There is no reason why such behaviour should not be similarly transmitted among and from leading cities. Cities can lead through such programmes as San Francisco switching its large buildings to 100% renewable electricity by 2030 (Fracassa, 2019); and community solar, the aim of which is to reduce the upfront cost barriers to low-income households contributing to a community investment process which pools modest investment sums to achieve more rapid solar growth (Galluci, 2019).[3]

In the transport sector, greater leverage is realised when a wider range of policy tools is used more or less together. Transport experts note that transport policies can behave in complementary ways to reinforce desired effects such as making active travel attractive (Pucher, Dill, & Handy, 2010; Scheepers et al., 2014). Moreover, it is difficult to disentangle the effects of individual policy measures when they are implemented as part of a systemic programme. Additionally, where multiple aims (health, environmental, etc.) are being sought, intersectoral collaboration is beneficial (Scheepers et al., 2014).

The other side of positive points of leverage in the transport sector is the political reaction by those fearful of any eclipse of established development patterns. Filion warns about political resistance to moving away from a suburban/ex-urban dominated model of land transport investment focused on highway construction ('suburban inertia') (Filion, 2015).

One possible alternative to relying on leverage points is to place reliance on 'big bang' solutions. However, Levin et al. argue that 'one-shot ''big bang'' policies for super wicked problems, which require behavioural change by all relevant populations immediately, either fail to garner adequate support or, in those rare cases where such policies are adopted, are likely to produce societal ''shocks'' that hamper implementation and compliance, derailing a policy no matter how well designed. Even if such a policy survives, rarely do decision makers assess how the policy might be designed to ratchet up over time to become more ambitious.' (Levin, Cashore, Bernstein, & Auld, 2012)

2.5 The context in which cities must act: urgency and capacity

In thinking about urban changes necessary to establish a credible transition pathway, it is important to have a clear understanding (even if provisional) of the implications of the ambition and pace of mitigation required.

'Climate neutrality' implies, for consistency with the IPCC (IPCC, 2018c), '**net** zero', i.e. allowing for negative emissions technology such as bio-energy with carbon dioxide capture and storage ('BECCS'), or very extensive afforestation. It implies that global net anthropogenic CO_2 emissions decline by about 45% from 2010 levels by 2030. The IPCC notes that reliance on carbon dioxide removal technology is a 'major risk' (IPCC, 2018c, p.32), and others note the likelihood of delay in ramping-up carbon capture and storage (Rockström et al., 2017; Smil, 2011), so the intergenerational ethical case for such reliance is questionable.

Net zero implies, then, a less demanding goal than zero gross carbon emissions by 2050 since it enables gross emissions to fall somewhat more slowly when they can be offset by growth of removals by sinks.[4] However, it is nevertheless a very demanding goal. A trajectory towards 1.5°C (the aspirational goal of the Paris agreement) 'implies very ambitious, internationally cooperative policy environments that transform both supply and demand (high confidence)'(IPCC, 2018c). Moreover, if developed countries take into account the need for more atmospheric 'head room' for developing countries to make a slower transition to zero carbon, there is a corresponding implication that they should reduce their own emissions more rapidly. The UK's CCC was cognisant of its global role (and historical responsibility) when it recently recommended to the UK government that the UK adopt a 100% by 2050 mitigation commitment.[5]

There are undoubtedly questions about the capacity of the global governance and political system to effect the needed carbon transition in an appropriate timeframe. It has been estimated, using a Bayesian analysis focusing on carbon intensity and GDP, that the likelihood of staying within 1.5°C by 2100 is around 1%, and the likelihood is less than 5% for staying within 2°C (Raftery, Zimmer, Frierson, Startz, & Liu, 2017). No one can entirely rule out staying within such limits, but achieving such goals, they argue, would 'require carbon intensity to decline much faster than in the recent past.' (p.637). On governance capacity, the IPCC note that 'lack of global cooperation, lack of governance of the required energy and land transformation, and increases in resource-intensive consumption are key impediments to achieving 1.5°C pathways. Governance challenges have been related to scenarios with high inequality and high population growth in the 1.5°C pathway literature' (IPCC, 2018c), but are not limited to such countries.

Juat as there is wide variance among countries and cities in their capacity to mitigate carbon emissions, so there is among cities and regions. These differences in capacity interact with perceptions that major inequity has developed over time among and within countries in terms of historical carbon emissions per capita. This uneven history and uneven 'ambition' may be important in the motivation of transitions (UNEP, 2018). Less developed cities and regions may be les motivated to invest in rapidly mitigating emissions before comparatively rich cities and nations have demonstrated high commitment to policy action and engaged in appropriate technology transfer. In this context, efforts by all countries to be transparent about the strategies which they and their cities are adopting will be important in encouraging greater efforts.

3 Ensuring coherent and purposeful urban transition policies

3.1 Ensuring the strategic framework is coherent

The IPCC suggests that governments' strategic framework choices in the past may not have been entirely appropriate: '…large system transformations, similar to those in 1.5°C pathways, require prioritizing an evolutionary and behavioural framework in economic theory rather than an optimization or equilibrium framework as is common in current IAMs [Integrated assessment models].'

Certainly, there is a strong argument that an economic optimisation framework is not well suited to discussing transformative changes of the scale involved in effective climate change mitigation, whether for cities, regions or nations. An optimisation framework became inappropriate as the world moved, after WW2, out of the equilibrium of the Holocene, in which a small perturbation in climate conditions could be imagined and managed, and into the Anthropocene (Hamilton, 2016; Steffen et al., 2011). An optimisation approach founders on the complexity of the systems at issue, uncertainty in climate damage cost curves and in abatement cost functions, and the deliberate nature of the transition needed to a zero carbon economy. The challenge now is to stabilise as much as possible the rate of growth in global temperature, by constructing a purposeful transition involving carbon reductions of around 50% per decade (Rockström et al., 2017). However, in these circumstances, it is by no means clear that moving to an 'evolutionary and behavioural' framework, as the IPCC suggests, is an optimal or indeed safe prescription.

Evolutionary processes are ones in which there is a steady process of reproduction, variation and selection. Evolutionary policy learning can certainly help with purposeful strategies for mitigation, through encouraging diverse innovations, and learning what policy measures work, via policy experiments that reflect on system behaviour and desired social outcomes. But an evolutionary framework is more suitable for characterising processes of change in the past rather than establishing those needed today, in the face of a need for accelerated change (R. Chapman, Howden-Chapman, & Capon, 2016). It is now more widely accepted that public policy must play a central role 'in shaping the directionality of transitions through environmental regulations, standards, taxes, subsidies, and innovation policies.' (Köhler, Geels, Kern, & colleagues, 2019). Loorbach suggests that this process might be accelerated by phasing out undesired practices and technologies.[6]

The enormity of 50% per decade emission reductions across the economy, including cities, and the need to maintain social cohesion during this process, mean that neither a minimal-government 'wait and see' stance, nor the market-based pursuit of individual consumer lifestyles (Jackson, 2009), are now acceptable. Instead, a focused role for government in ***purposefully shaping*** collective behaviour towards consumer and environmental restraint (fossil energy use restraint in particular) and the pursuit of a rapid but just transition seem more reasonable.

What sort of policy processes could accelerate purposeful change? Costanza (2014) argues that tools such as scenario planning can encourage people to envisage and design more sustainable futures, including a future for commons such as the atmosphere. It would require the design of 'rules, norms and

institutions' to guide the transition we wish for, 'motivated at the individual level by a vision of a better life.' The IPCC also supports the contribution of a vision-led path: 'Pathways that encompass joint, iterative planning and transformative visions, for instance… in urban contexts, show potential for liveable and sustainable futures (high confidence).' (IPCC, 2018c, p.46).

While vision-led scenario planning is less likely to be feasible politically at higher levels, i.e. for the city region and nation, it can work well at the local community and arguably the city level. Ostrom's effective governance criteria of appropriate group size and cohesion are relevant (Ostrom, 2010). There are frequently opportunities presenting themselves at city level, which can help urban communities to shape their future.

However, even if vision-led local processes can be established as a guide for purposeful urban transformation, there is too much at stake in terms of the necessary speed and reach of the transition process for it to be left by central government to local government alone. Business, households, NGOs, and unions can all play valuable roles, responding creatively to the vision and goals of the transformation. Establishing a broadly accepted vision is a key multi-level process, but will not be easy. In many cities and countries, a transition vision is so far little more than rhetoric (Klinenberg, 2016). We address below (section 5) some of the options for shaping this process to be more democratic.

As well as a guiding vision, an important element will be taking advantage of opportunities that occur month by month and year by year, driven by exigencies other than climate risk. Older cities have to keep updating infrastructure and, where cities are urbanising rapidly, there are critical opportunities for design of appropriate, sustainable infrastructure (Ernst, de Graaf-Van Dinther, Peek, & Loorbach, 2016; The Global Commission on the Economy and Climate, 2014, 2018).[7] This includes investment in zero- or low-carbon infrastructure such as efficient public transportation and distributed renewable energy generation, and a determination to avoid the lock-in of high-carbon infrastructure (Seto et al., 2016; Unruh & Carrillo-Hermosilla, 2006). Infrastructure updates can be aligned with introduction of other urban policies such as congestion pricing, motivated largely by non-climate goals, as in New York (Komanoff, 2018; Paybarhah, 2019), a workplace parking levy (Breach, 2018), or improving underground transport systems (Calma, 2019).

3.2 From incremental opportunism to a cohesive investment strategy

To date, it can be argued that such opportunities, often presented under the rubric of 'eco-efficiency', have not been taken up fast enough. There have been steady gains in the urban or wider economy (e.g. in the falling cost of battery electric vehicles; better waste management) but rarely have such gains added up to the scale of change needed. A notable standout has been efficiency measures since the 1970s in California – a study found that had the other 49 states reduced fossil fuel use relative to economic activity at the same pace as California, nationwide carbon emissions would have been lower in 2016 by 1.2 billion tonnes, or 24 percent (Komanoff, Cavanagh, & Miller, 2019) – although the report notes that the US will have to reduce its fossil fuel dependence more than three times as fast as the California rate to meet its Paris climate commitment. Moreover, '[t]here is a risk that … [seeking efficiency gains] will simply embed unsustainable practices. Fuel-efficient motor cars are not enough, for example. To make sufficiently deep cuts in land transport emissions we will need alternatives to the automobile…' (Woodward, 2019, p.13).

Romer's endogenous growth theory is valuable here in developing a view of the economy (including the urban economy) as a dynamic whole, where innovation is critical. As introduced in section 1 above, appraising future policy pathways via elaborate but essentially static models focused on estimating income, cost and 'efficiency' impacts is misleading, as the economy is constantly and dynamically adapting and innovating (Zenghelis, 2019b). With a static view of the economy, the costs of decarbonising appear very large. Yet there have been huge reductions in the cost of critical resources such as renewable energy and battery storage in the last decade.[8] This transformation is not simply because incremental change can add

up to major gains over time in practice and expertise when innovation incentives are very strong. There is also a powerful dynamic interaction among these factors, which can also be boosted by public investment. The IPCC notes that '[a]ccumulated know-how, accelerated innovation and public investment play a key role in (rapid) transitions (Geels et al., 2017; Michaelowa et al., 2018)'. The IPCC (IPCC, 2018, p.2-76) and Mazzucato (2018) also point out that public investment has usually been critical to successfully and innovatively steering in a new direction.

There is a deeper process going on – system transformation. Zenghelis notes that '[n]one predicted that renewables would become the dominant source of energy investment in the first quarter of this century – or the expansion in LED lighting from less than 5 per cent to more than 40 per cent of the global market in the past six years.' These dynamics are difficult to predict, but they are the result of market actors and governments sensing change and investing accordingly, even while some resist change at the risk of locking in outdated assets and stranding their investments. Indeed, this is in the face of arguments and modelling 'that overstate the cost of decarbonisation [and] discourage businesses and policymakers from investing in renewables and energy efficiency. This slows the rate at which the costs come down, making decarbonisation harder.' (Zenghelis, 2019a). Acemoglu and others also underline the important role of the state and municipality in supporting change and innovation (Acemoglu, García-Jimeno, & Robinson, 2015).

For ***cities***, what is required is a set of policies and measures that powerfully reinforce significant changes in related parts of the urban system, so that the transformation of the whole becomes greater than the sum of the changes in the parts. As noted above, this process of mutually supporting innovation is likely to take place faster in cities than elsewhere, because of cities' high degree of internal interconnection. Historically, the emergence of the Renaissance in Florence is a pre-eminent example of such fertile transformation (Weiner, 2016). With modern information and communications technology, such changes are likely to be more rapid. An incipient transformation also has a chance of generating a supporting sense of social and cultural change to a better quality of life. An important localised example of mutually reinforcing change is where changes in urban form and transport infrastructure, shaped by the local government, reinforce a reduction in use of private fossil fuelled vehicle transport, and a sea change in the practices of living in a city, such as the mutually reinforcing and congestion-reducing take-up of walking, cycling and public transport, alongside e-bikes and e-scooters.

3.3 Growth, well-being and the SDGs

Economists such as Romer and Nordhaus have largely been focused on economic growth impacts when carbon mitigation is at issue, along with many national leaders and international voices concerned with least cost interventions. However, a major shift is starting to occur in policy makers' objective functions: a shift from growth goals to wellbeing-related goals, including climate change (Gurria, 2017; Daniel W. O'Neill, Andrew L. Fanning, William F. Lamb, & Julia K. Steinberger, 2018; Robertson, 2019).

It is not as clear, now, that economic growth necessarily contributes to wellbeing. In the ongoing debate about this, one stance is that 'We can have growth that is strong, sustainable, balanced, and inclusive' (The Global Commission on the Economy and Climate, 2018, p.1). Another stance, that of Herman Daly and others is to question 'whether ever-rising incomes for the already-rich are an appropriate goal for policy in a world constrained by ecological limits' (Jackson, 2009, p. 6). This raises distributional issues of who benefits from growth. However, a helpful way of framing this debate may be to adopt the approach of van den Bergh, who argues 'that "a-growth," i.e. being indifferent about growth, is a more logical social aim to substitute for the current goal of economic growth, given that GDP (per capita) is a very imperfect indicator of social welfare' or well-being (Van den Bergh, 2011). He argues that an explicit focus on critical goals such as environmental and social sustainability should be foremost.

Focusing on both environmental goals and limits – especially those already being transgressed (Daniel W O'Neill, Andrew L Fanning, William F Lamb, & Julia K Steinberger, 2018) -- ***and*** socioeconomic foundations

leads us to the conclusion that all nations need to do better at avoiding the sacrifice of environmental systems for short-term economic gains. It is clear that 'no nation is providing an adequate socioeconomic foundation while keeping environmental impacts to within sustainable limits' (Laybourn-Langton et al., 2019, p.25; Daniel W O'Neill et al., 2018). This message is underlined by the recent report of the UN's IPBES on the critical rates of loss of biodiversity (UN IPBES, 2019). As cities are central to all nations' economies, this observation applies as much to cities as to nations. Cities can and must do better in providing critical socioeconomic foundations while minimising environmental impacts.

The UN Sustainable Development Goals are a convenient if diffuse way of aiming to ensure that the full range of socioeconomic and environmental foundations are protected. For current purposes, the critical SDGs aside from climate action (SDG13) are sustainable cities and communities (SDG11), affordable and clean energy (SDG7), and good health and well-being (SDG3) (M. Nilsson, Griggs, Visbeck, Ringler, & McCollum, 2017). The UN argues that the SDGs are integrated and indivisible; certainly, there are strong interactions among the SDGs above (P. Howden-Chapman et al., 2017).

For example, measures to clean up air pollution can also mitigate climate change. Haines *et al.* make the point that mitigation of short-lived climate pollutants (SLCPs) such as methane, black carbon and HFCs can 'reduce the rate of global warming and protect against the increasing impacts of climate change' during the near term (Haines et al., 2017, p.868). Reduction of SLCPs can reduce immediate damage but this is not an argument for delays in carbon mitigation policies (Shoemaker & Schrag, 2013). Measures that are particularly important in cities include the reduction of black carbon from diesel fuel use by deploying Euro VI standards and diesel particulate filters for on-road and off-road vehicles. SLCP measures can contribute directly to achieving SDG target 3.9 to reduce the number of deaths from pollution by preventing around 2.4 million deaths related to outdoor air pollution annually by 2030 (Haines et al., 2017).

3.4 Rethinking cost-benefit analysis to facilitate the transition; the role of co-benefits

The mitigation policy debate to date has largely been framed in terms of cost-effectiveness – i.e. what is the comparative cost of various policies in achieving a tonne of carbon dioxide reduction at the margin? This has led to an undue focus on comparative costs without sufficient attention to benefits of different policies, most often because good data are not available about those benefits.

The most obvious example of this has been the usefully simplifying construct of the marginal abatement cost (MAC) curve, e.g. as produced by McKinsey and Co since 2007 (McKinsey & Company, 2009). The assumption is that a country should move incrementally up its MAC curve, starting with negative cost opportunities, until the targeted level of abatement is reached. Little consideration has been paid to co-impacts of mitigation, a crucial oversight where the co-impacts are significant. Consideration of them can change the order and rapidity with which abatement takes place. For example, as more is learnt about the drastic health costs of poor air quality, it becomes clearer that there are substantial co-benefits from abating power plant emissions in many countries, lowering both carbon emissions and air pollutants. One estimate is that in 'the 15 countries with the highest greenhouse gas emissions, the damage to health from poor air quality, largely associated with the burning of fossil fuels, is valued at an average of over 4% of GDP' (The Global Commission on the Economy and Climate, 2014, p.7).

There is a strong tactical case for identifying and emphasising these 'co-benefits'. Most people do not place climate change high in terms of everyday salience (Crawley, Coffe, & Chapman, 2019). They tend to focus instead on concerns such as health and education and well-being. Appealing to people to tackle climate change by cutting emissions will leave many of those people unmoved, but asking them to act to improve their health and well-being is much more likely to be motivating.

The IEA also notes that non-economic barriers to exploiting negative cost options can impede adoption of optimal mitigation policies. Supportive policies to remove barriers are therefore also required, to 'unlock cost-effective energy efficiency' potential (IEA, 2017). While the IEA's report on real-world policy packages for sustainable energy transitions mentions some barriers, such as lack of EV charging infrastructure, behavioural and social practice barriers are barely discussed.

As to research evidence, stronger empirical links between low carbon lifestyles and health are emerging (Gouldson, Sudmant, Khreis, & Papargyropoulou, 2018; P. L. Howden-Chapman, Keall, Conlon, & Chapman, 2015; Ürge-Vorsatz et al., 2016; Zapata Diomedi, Giles-Corti, Veerman, & Gunn, 2019). For example, a recent UK study establishes that residents of medium or higher-density urban areas, typically close to the inner city, are more active, more socially engaged, and less obese than people who live in low-density sprawling suburbia (Sarkar, Webster, & Gallacher, 2017). According to Sarkar, 'as cities get more and more compact, they become more walkable.' Denser residential areas tend to have destinations that are more attractive. People living in such areas are less dependent on cars, use public transport more, and walk more.

While emphasising co-benefits of (and surmountable barriers to) mitigation action is important, some argue that is unwise to place too much reliance on such an agenda (Woodward, 2019). Climate mitigation and health enhancement strategies do not align perfectly – there can be trade-offs as well as synergies. For example, the planned production by China of coal-based synthetic natural gas (SNG) as a substitute for coal fired power production, partly in order to reduce air pollution and improve health, is estimated to release significantly more CO_2 per kWh of electricity than existing coal-fired plants (Woodward, 2019), although this can be mitigated by carbon capture and storage (Qin et al., 2017). Woodward also warns that:

> *'… many of the examples of co-benefits apply to incremental changes. This may not be enough. Transformation of cities, energy, building styles, mobility and food systems may be required, in which case it is less clear how one would achieve health and climate savings simultaneously.' (ibid, p.10)*

However, this may be too cautious as a general prognosis. Other literature suggests powerful long-run linkages between more sustainable urban form and emissions reduction when key urban form drivers of carbon emission, such as density, land use mix, connectivity and accessibility, are considered, and in most cases, these changes will contribute to health and well-being. For example, the IPCC's 2014 report distilled solid evidence that 'co-locating higher residential densities with higher employment densities, coupled with significant public transit improvements, higher land use mixes, and other supportive demand management measures can lead to greater emissions savings in the long run…. (robust evidence, high agreement)' (p. 928). This implies that the way we build or upgrade cities, including where and how we put roads, and where we put what sort of building, deeply influences how much carbon is emitted in the longer term, largely because of transport (and sometimes-other energy use) choices, which can have significant health benefits.

The 2014-15 Global Commission on the Economy and Climate focused on global urbanisation and reached similar conclusions. The Commission concluded that well managed urban growth is critical for aligning well-being and prosperity with climate stability. Cities should be able to expand but should be as compact as possible, with higher densities, mixed neighbourhoods, be walkable and of human scale, redevelop brownfield sites, and ensure green space. Connected infrastructure, including smarter public transport, cycling, car sharing, electric cars and efficient buildings, have a strong complementary role. Too often, cities expand inefficiently, locking in inefficient infrastructure. This in turn can lock in emisisons for the future. As an example, the Commission contrasted costs of transport in compact Copenhagen (about 4% of its gross domestic product) with that of sprawling Houston, where transport costs about 14% of its GDP and generates much higher emissions. They pointed out the large health gains and carbon savings possible from a scenario based on compact cities with connected infrastructure (e.g. global transport emissions could be cut about 1.5 billion tonnes per year).(Floater, Rode, Zenghelis, & Tonkiss, 2015).

The overall picture of transition within the energy, transport and buildings sectors in cities is that in some subsectors considerably more than incremental change is occurring: truly transformational change is taking place. However, two major problems remain. First, because of the nature and complexity of some of the subsystems – for example, energy systems in small buildings where owners are often small, fragmented and undercapitalised -- the pace of change in some subsectors appears to be still too slow to be consistent with the required pace of change for urban carbon emissions as a whole (about 50% per decade). Second, innovations that increase efficiency or new technologies tend to add capacity to the system rather than reducing overall emissions. The following section explores these matters further, noting areas for both optimism and caution.

3.5 Transition opportunities and limitations in urban systems

Energy opportunities

Developments in national energy generation systems make a large difference to carbon emissions from urban areas. For example, as the proportion of national electricity generation that is renewable increases over time, the gains from electric vehicle take-up rise proportionally.

Battery storage of electricity combined with advances in demand response management now present an important opportunity for cities to decentralise energy supply and improve resilience They enable big enough cost reductions that decentralised renewables generation (with electricity storage) becomes economically competitive even where carbon prices are low (the advantages over gas, for example, are higher when carbon prices rise). For example, incremental cost reductions for batteries have been fast – around 75% in the 'levelled' cost ('all-in' average annual cost) of lithium-ion battery storage since 2012 (Henze, 2019). This increases the potential for dispatchable solar and wind power generation (using 1-4 hour storage capacity), reducing dependence on gas peakers in the generation system, and improving the attractiveness of grid-edge decentralised renewable generation in cities (Finkelstein, Kane, & Rogers, 2019).

It is unclear whether countries and cities are driving a sufficiently rapid reconfiguration of electricity generation to be on a 1.5°C-consistent transition path. Some indications suggest not – such as the US reaching its highest ever energy consumption in 2018, of which 80% was fossil fuels (US EIA, 2019). Others point to the pipeline of coal fired power stations still being constructed (Mirabile & Calder, 2018). On the other hand, another assessment, drawing on the work of IPCC scientists, concluded that 'There are signs that a systemic transition consistent with a 1.5°C pathway may be underway in the electricity generation sector.'(Global Covenant of Mayors, 2018). Only if cities, nation states and business invest with resolve in renewables is it likely that a successful transition in this sector will gather the necessary momentum.

Transport opportunities

Emissions from the transportation sector – already at 23% of global energy-related CO_2 emissions – could double by 2050 in a worst case (Creutzig, Jochem, & colleagues, 2015), although available policy options mean this is by no means inevitable. What is striking about transportation is the co-existence to date of rapidly changing technologies, offering the potential for mode switching as well as greater efficiency, alongside the evident difficulty of cutting emissions. In the medium to long run the best answer to this conundrum may be a major rethink of the need for mobility, with a shift to an emphasis on access (R Chapman, 2018). In the meantime, expectations of achieving zero carbon in this sector are lower than for most sectors. One estimate is that the share of low carbon fuels (electricity, hydrogen and biofuel) for 1.5°C 'no or low overshoot scenarios' would need to be 12% in 2030 and 55% in 2050 (Global Covenant of Mayors, 2018), although fuel decarbonisation by no means exhausts the policy options for this sector.

To summarise first the main visible technological changes, rapid changes are occurring in vehicle and ride sharing; the development of autonomous vehicles; and electrification of cars, bikes and scooters (McKinsey and Co, 2019). There is potential for this to reach far further than seen to date, with development of various linked concepts, such as 'mobility as a service'. One estimate is that global adoption of shared, autonomous electric vehicles could cut the world's vehicle stocks by one-third (Bai et al., 2018). However, there are real risks in relation to congestion and energy use with autonomous vehicles if these are not shared (Calthorpe, 2017).

in a recent analysis of opportunities for carbon mitigation by cities, one of the four priority action areas identified was enabling 'next generation' mobility, through building 'complete, compact communities that meet the mobility needs of residents and business' (McKinsey Center for Business and Environment, 2017, p.7). Central aspects are transit-oriented development, and initiatives to encourage walking and cycling, alongside enabling uptake of next generation vehicles. Outcomes expected include reduced congestion and air pollution, more equitable access to mobility and better quality of life. McKinsey concluded that densification (see next section) was one of the biggest opportunities to reduce transportation emissions, especially in fast-growing cities.

The main limitation of this analysis, however, is that it emphasises mobility rather than improving access. Access goes beyond mobility. Walking and cycling (active travel) has huge co-benefits, given that the physical inactivity death toll globally is more than 3 million deaths a year, and is amenable to reduction (Brown, Diomedi, Moodie, Veerman, & Carter, 2016; R. Chapman et al., 2018). A recent Lancet Commission underlined that more exercise can reduce the incidence of major non-communicable diseases such as ischaemic heart disease, stroke, diabetes, colon and breast cancer, Alzheimer's disease, and depression (Whitmee et al., 2015). In short, many urban policies, which reduce emissions, especially those encouraging active travel, are also very important for health and well-being.

Urban planning opportunities

It is apparent that achieving sufficiently low-carbon urban transport is very difficult without assistance from urban planning. Conventional emission reduction scenarios focus on gains from energy efficiency and from the carbon intensity of fuels (gCO_2/MJ), but tend to underestimate the long-term emission savings possible from reducing transport demand growth via better urban planning, and from associated mode shifting. WHO researchers, Creutzig and others instead emphasise savings via a package that includes densification and other measures -- 'compact urban development, [as well as] bus rapid transit, bicycle highways and telecommuting' (Creutzig et al., 2015, p.911; WHO, 2011).

Decomposing urban form, Seto *et al.* (2014, p.927) argue that key 'urban form drivers of energy and GHG emissions are density, land use mix, connectivity, and accessibility (medium evidence, high agreement)'. Other authors support this, noting that density is not the only factor, and pointing to the interconnections between energy, transport, planning and built form. What this means is that strategies, which address several of these factors together – for example, by supporting compact urban development for a range of income groups at accessible locations, linked to quality transport infrastructure – will achieve greater leverage and co-benefits for health, quality of life and equity, as well as emission reductions. More recently, organisations such as the IEA have acknowledged the important role of urban form and planning in transport emission reduction (IEA, 2017, p.33).

As many scholars and policy advisers point out, adapting urban form is seldom easy. It requires concerted policy attention over years and decades. It also requires strategic investment in infrastructure at the regional level, in transport, energy, water and waste systems. None of this new infrastructure can now afford to be significantly carbon emitting.

For example, intensified housing infrastructure investment at nodes and along corridors, as well as additional 'transition arenas' in established suburbs, needs to be substantial in order to effect 'greyfield

transitions' (Newton, 2010). Significant planning and political challenges with greyfields (under-capitalised intermediate urban areas which are not greenfield or brownfields) include engaging effectively with neighbourhoods where change is expected, and how to change building and planning regulations that inhibit intensive development (Newton & Glackin, 2014). Resistance is to be expected in the form of NIMBYism ('not in my backyard'), protection of local character, and demands for local planning control. Such resistance often ignores the interests of younger generations seeking an affordable place to live (taking into account both housing and transport costs), or others who would prefer higher density housing to a long commute. But in addition, the displacement, exclusion and loss of community often caused by gentrification (Weller & van Hulten, 2012) needs to be directly addressed, through the inevitably political processes of planning and redistributional policies that recognise the need for support for low-wage workers who keep the city region running (Stein, 2019).

Hall and Banister (Hickman, Hall, & Banister, 2013), in the UK context, have cautioned that effective urban planning for low-carbon development is not straightforward. Low-carbon urban strategy development, funding and implementation, they argue, 'seems beyond the realms of the current governance structures' in the UK (Hickman et al., 2013, p.218) They note three requirements:

- a strong regional and sub-regional urban planning framework, where integrated strategies can be developed and pursued;
- an adequate funding stream and devolved financial power (at the city region level);
- land acquisition power and use of development value uplift, so that the public sector can buy the land before development occurs and gain from the value uplift, allowing the infrastructure investment to be paid for.

In many countries, like the UK, the separation of powers between local and national levels has made strategic urban and transport planning complex. This is amplified when urban form planning is weak, and/or separated from regional transport development. A change-resistant government at either level can veto effective, long-term transport or urban development investment, locking the urban system into a car-dependent pattern of development (R. Chapman, Howden-Chapman, Whitwell, & Thomas, 2017; Hickman et al., 2013). To overcome this requires consistent forward-looking and long-term urban planning and transport investment choices to be made which consciously prioritise climate change mitigation.

Even in a world of policy activism, it is clear that dramatic reductions in transport emissions in cities will be difficult to achieve. Some experts point to a 'combined mitigation potential in urban transport via spatial planning, transport pricing, and behavioural options amount[ing] to 20 to 50% between 2010 and 2050, compared with baseline.' (Creutzig et al., 2015). Ewing *et al.* (2007), in a US analysis, points to similar magnitudes of change. This is likely to mean a major shortfall relative to meeting the level of reductions envisaged by the IPCC 1.5-2C goal for 2030. It is evident that governments will need to adopt much more concerted and intensive urban planning measures, integrated with transport sector actions, to achieve credible reductions in the transport sector.

Other building sector opportunities

The global building stock in place in 2050 will need to have 80 to 90% lower emissions than 2010 levels to achieve a 1.5°C-consistent pathway (Global Covenant of Mayors, 2018). Moreover, such a pathway requires a minimum 5% annual rate of energy retrofits of ***existing*** buildings in developed countries, as well as all ***new*** buildings being built fossil-free and near-zero energy by 2020 (*ibid*). These are very ambitious requirements. It is not clear that any building codes for new buildings, for example, meet these standards – even in New York City, where buildings are estimated to be responsible for almost 70 percent of the city's greenhouse gas emissions, and which now claims to have the 'largest carbon reduction effort by any city' (see section 2.4 above).[9]

The IEA notes that in the buildings sector, changes in the demand for electricity on the part of buildings 'are primarily driven by standards and regulation. In these sectors, a high carbon price plays a supportive role, but given lower price elasticities of demand they also require strong and complex packages of regulations and government investment to drive change.' (IEA, 2017, p.6).

Other analyses support this, pointing to the incentive barriers (landlord-tenant split incentives) in the residential and commercial building sectors, the slow pace with which programmes of insulation retrofitting have proceeded to date, and the high transaction costs for government of implementing upgrade requirements across a highly fragmented and distributed sector.

The C40 Cities Climate Leadership Group also sees local government as having a high degree of control over municipal buildings, such as city halls, government offices, hospitals, schools, libraries and museums, but also as providing a 'powerful opportunity to improve energy efficiency and reduce carbon emissions'. Moreover, municipal building energy efficiency improvements 'serve as a model for private buildings and inspire owners to take action.' (C40 Cities Climate Leadership Group, 2016) and may well stimulate the development of companies and individuals with valuable skills and expertise, e.g. in integrated energy systems.

4 Aligning the framework for transition: Instruments and infrastructure

4.1 Instruments: Pricing, regulation, first-best policy instruments and their limits

Having considered the systemic issues and barriers characteristic of urban systems, and how to make mitigation in cities more coherent, we return to a more general discussion of crosscutting policy instruments and institutions necessary for a zero-carbon transition. This section contributes to the second theme around policy effectiveness, and harks back to the first theme, of unprecedented disruption (Section 5 will deal with governance and political change.)

When effectiveness is critical, under conditions of urgency, there is a stronger argument that price instruments and indeed voluntary measures should defer to regulation, even if there are arguments that a carbon price is 'first best'. Consider the historical example of CFCs -- ozone-depleting substances whose increasing production and use especially in the 1970s put the health and safety of millions of people at risk. When it was confirmed in the 1980s that CFCs directly and rapidly damaged the ozone layer, it was widely accepted in most countries that, while a price instrument (such as a cap and trade system for CFCs) or voluntary regulation were feasible in principle, they were not optimal policy instruments in achieving a goal of a very rapid decline in CFC production and use. They essentially entailed sufficient uncertainty that the desired outcome could not be guaranteed in the time available. Interestingly, the European Community initially opted for a voluntary plan, but it proved ineffective, and in most nations a phase-down, and in short order a ban, were implemented (Doniger, 1988). There are of course major differences between the CFC history and that of fossil fuels, and the relative merits of instruments in terms of encouraging innovation are important. In general, more stringent regulation applying to fossil fuel use needs to be concentrated in the array of areas where there are ready alternatives in production or consumption, and where sectors are price-sensitive.

It is interesting to consider the choice of primary instrument adopted by New York City in mitigating carbon emissions from large buildings. As noted earlier, NYC's 2019 law mandates reductions in carbon emissions from the heating of large buildings of 40% by 2030. While carbon pricing could have been adopted (and in fact there will be limited trading for compliance flexibility under the law), the judgement appears to be that presenting building owners with a clear regulatory limit and timeframe will be more effective than a price on carbon emissions (or a price on fossil energy use).

Regulatory limits have the presentational advantage of making it evident to the public that action is being taken – i.e. demonstrating effectiveness. More importantly, they are likely to be more effective in the building sector because that sector is prone to market barrier issues such as the split incentives already

mentioned (e.g. tenants do benefit from insulation while landlords benefit little, but tenants are not in a position to invest the capital to improve building fabric and equipment). In such contexts, performance standards, especially ones that require regular upgrades, have been demonstrated to be effective (Harvey et al., 2018).

While, at a time of 'climate emergency' strict regulation of carbon emissions within particular sectors such as buildings has multiple attractions, a significant price on carbon may nevertheless be desirable in sectors such as transportation as a complementary step to motivate individual consumption decisions and constrain carbon emissions. Harvey et al. point to the proven effectiveness of vehicle performance standards in several countries, but combining such regulation with a carbon price so as to incentivise innovation may be still more effective (Acemoglu, Aghion, Bursztyn, & Hemous, 2012). Where there is a limited price elasticity of demand, the carbon price signal may have to be very high to significantly affect consumption and investment decisions. While it is widely accepted that confidence in rising future carbon prices can be a strong driver for long-lived low-carbon investment (such as switching to an electric vehicle) and for clean energy research, development and demonstration (IEA, 2017, p.12), such confidence generally does not yet exist. A sufficient carbon price trajectory is something of a chimera in most countries.[10]

Moreover, there is evidence that carbon prices in most countries are currently too low to reflect the full (global) social costs of carbon. A recent analysis (Ricke, Drouet, Caldeira, & Tavoni, 2018) suggests that the global social cost of carbon (the damage cost of another tonne of CO_2 emitted) is around US$400 per tonne: no current carbon tax or emission trading scheme price approximates this, in practice, to date. Without a price on carbon fuels approaching this level, many critical transportation, building and energy decisions in cities (of both an investment and operational nature) will continue to be severely distorted in favour of carbon-intensive choices.

A word of caution on carbon pricing is important. Even if some urban policies took into account a price on carbon of say US$400 per tonne, the value of carbon savings would sometimes still not be sufficient to change a given policy or investment decision. This is because other factors, for example congestion savings or health savings/dis-savings or labour productivity impacts might be big enough to swing a given decision in the carbon-intensive direction (R. Chapman et al., 2018). However, this need not matter greatly if many or most investment decisions are reoriented towards a significantly less carbon-intensive trajectory.

In practice, a price on carbon will in the short run not be enough, given two things. One is the weak state of policy coherence, and only slowly growing public acceptance of the need for vigorous mitigation action, in most countries. For example, a UNEP study, the 2018 Emissions Gap report, reported on a survey of domestic policies among G20 members. This survey found that reducing transport-related fossil fuel subsidies is covered by only 38% of G20 countries' policies. The OECD has underlined for around a decade that 'removing subsidies to energy consumption in a number of emerging and developing countries could drastically reduce their greenhouse gas emissions, by as much as 30% in some regions in 2050 compared to business-as-usual, and also contribute to increased economic efficiency.' (Gurria, 2009). The same UNEP report noted that overarching carbon pricing for the electricity sector was covered by only 44% of G20 countries (UNEP, 2018). [11]

If we pull back for a broader overview of the energy sector, it is evident that, despite the introduction of some carbon pricing and complementary policies in the last two decades to encourage low-carbon energy generation, overall environmentally significant progress has been glacially slow. Wallace-Wells notes that in the 25 years since the early 1990s, the proportion of global energy use derived from renewables has not grown (Wallace-Wells, 2019b, p.178). Primary energy consumption reached a record high in 2018 (US EIA, 2019). The questions about such patterns, then, are 'Why so slow?' and whether the forces impeding stronger policies are diminishing.

One analysis suggests that political economy factors, such as governmental rents from fossil fuels and jobs in the fossil fuel industry, significantly affect electricity emissions, slowing mitigation. Moreover,

addressing vested interests in fossil fuels would assist in any decarbonisation strategy (Röttgers & Anderson, 2018). There is clearly a basis for concern about coherent governance, the strength of political resistance to change, and whether, more latterly, countries are doing more than paying lip service to the Kyoto and Paris agreements.

Second, a price on carbon will not be enough by itself since it is clear that innovation responds strongly to non-price factors. A strong argument can be made that 'climate policy requires direct research subsidies for inducing and/or diffusing clean innovations, combined with carbon pricing (whether by taxes or trading).'(Aghion, Hepburn, Teytelboym, & Zenghelis, 2014). This arises because technological and social innovation is a path-dependent process; and history and expectations matter greatly in determining costs and outcomes, as noted earlier. The policy conclusion is that policy (such as energy subsidies policy) must address relevant knowledge externalities. In practice, this suggests measures such as favourable tax treatment for firms involved in clean technology, and the underwriting of green infrastructure projects.

Aghion *et al.* also make the useful point that certain features of cities, such as density, can affect the effectiveness of carbon pricing: denser cities can more readily respond to carbon pricing by investing in effective public transport or induce travellers to take up public transport, for instance. Thus, path dependence can make it easier for relatively low-carbon cities to decarbonise further.

4.2 Infrastructure investment

It is estimated that 'around 60% of GHG emissions are hard-wired into existing infrastructure' (OECD, 2017, p.95). Accordingly, as much infrastructure investment as possible, preferably all, will need to be zero-carbon, given that some residual emissions will continue from costly infrastructure unlikely to be phased out by 2050. Moreover, the 'New Climate Economy' reports note the risk of poor urban management, including misguided infrastructure investment, locking in lower productivity, higher carbon emissions and social costs for decades to come (Floater et al., 2015). Zero-carbon infrastructure decisions made over the next decade or so are central to moving to, and locking in, a zero carbon, more productive, healthier urban system (Gouldson et al., 2018).

The OECD's modelling[12] for G20 countries suggests that a focus on low-carbon public transport infrastructure investment integrated with land use planning can significantly reduce overall infrastructure costs relative to a 'business as usual' scenario centring on motorised mobility. The two alternative scenarios reported yield reductions of 34 - 50% in transport carbon emissions by 2050 (OECD/ITF, 2017), even while infrastructure investment costs are reduced.

Given these cost estimates, and given the critical need for emission reductions, how directive should governments be in signalling the need for, and investing in, zero-carbon and integrated infrastructure? It was noted earlier that there is a strong case for policy that in a transparent, non-discriminatory way, supports green infrastructure projects (Aghion et al., 2014). However, this is still a recommendation that supposes a degree of neutrality (avoiding picking winners), and assumes that there is time for infrastructure policy to falter or fail, and be corrected, over a period of decades. The climate crisis now implies there is no remaining window for such evolutionary experimentation.

Moreover, by analogy with the argument about the economic spillover benefits of technological innovation, it can be argued that there are strong spillover benefits of zero-carbon social and economic practices and behaviours, which green infrastructure supports. For example, investment in public transport systems is likely to encourage innovation around complementary zero-carbon practices and technologies such as bike sharing, scooter sharing systems, and – in future – 'last-mile' autonomous vehicles connecting to public transport nodes. Complementary low-cost investment in well-located and high quality green space can also encourage innovation in higher density, zero-carbon buildings and practices of urban living.

At present, there are major risks of infrastructure investment being distorted by decisions that favour traditional carbon-intensive incumbents. This is most evident in the energy sector, where there is continuing pressure for the use of gas to replace coal, even though the emissions footprint of fracked gas is often worse than that of coal (McKibben, 2018).[13] In Germany, a plan for transition of the coal sector during the 2030s has been agreed and represents Germany 'getting out of coal', but according to a climate expert on the Coal Commission, H J Schellnhuber, the transition is not sufficiently rapid to be consistent with the Paris agreement (Stratmann, 2019).

A similar pattern has long been evident in urban development. Newton, commenting on Australian cities, and incentives to invest in greyfield suburbs (existing suburbs which are neither greenfield development areas nor brownfield redevelopment sites), notes a pattern of government-driven 'pricing and incentives that favour centralized water and energy utilities, and high levels of urban resource consumption which encourage comparatively inefficient greenfield development while greyfield areas continue to operate without significant renewal' (Newton, 2010, p.86). And a comparable pattern is seen in New Zealand, where considerable highway investment and urban development has been occurring on the assumption that greenfield sprawl or low-density suburbs will remain viable in future, whereas their higher infrastructure costs (Adams & Chapman, 2016) and carbon footprints mean they will very likely become unsustainable as carbon prices and other policy signals change in future. Mature cities in rich countries should be expected to lead the way in adjusting to a very much lower-carbon pattern of development (Floater et al., 2014) through processes such as re-densification.

A related argument is that the sort of infrastructure investment chosen as part of sustainability-focused integrated urban planning has a strong path-dependent impact on climate outcomes. One expert's comment on such urban planning is that 'they who fail to plan, plan to fail' (Hickman et al., 2013). A particular sort of planning is evidently needed – to favour zero-carbon infrastructure, technologies and practices, such as low-energy buildings and human scale local built environments, favouring active and public transport. Such integrated planning has the best chance of eliciting the necessary innovative co-investment from the private sector to match government investment.

A similar argument for integrated infrastructure investment is made in the New Climate Economy reports, which conclude on the need for three Cs: compact urban growth, connected infrastructure, and coordinated governance (Floater et al., 2015). These reports emphasise the long life span of urban infrastructure such as roads and buildings, of 30-100 years or more. Critical infrastructure includes Bus Rapid Transit, cycle superhighways, smart grids, energy efficient buildings and essential water, sanitation and waste infrastructure (Floater et al., 2014), and supporting policies extend to public transport and the electric vehicle recharging network.

In some city regions, the transition in this direction is now underway. Newman's perspective is that the 'modernist manuals' of infrastructure planning need to be or are already being rewritten with the new model being a more distributed and participatory energy system; a polycentric transport system based largely on rail connections (and possibly trackless trams) plus walking and cycling; and water and waste systems based on reducing demand, reusing water, and recycling, supported by new, smart technologies (Glazebrook & Newman, 2018; Newman, 2016). It is critical that the pressure be ramped up in all cities for zero-carbon infrastructure to become not just desirable, but the accepted standard.

5 Governance and political change

In any radical transition, probably the greatest governance challenge lies in ensuring the population is aware of the pressing need for action and is prepared (and in some instances resigned) to facing disruption in the short term for the sake of longer-term gains, or indeed survival in some cases. Awareness of risks has to be balanced by a strong, positive narrative of change, to enable people to imagine a positive future. Without this support, no government will have the mandate to regulate self-interested actions by both adversely affected individuals and major market players who, understandably, would prefer to defer action or resist the stranding of their assets.

As well as requiring high levels of political awareness, electoral support for change requires more future focused, connected institutions; inclusive, democratic processes which engage a broad range of actors (NGOs, business, unions, consumers) during the transition; and government preparedness to address inequalities and assist those disadvantaged by change through the process of adjustment, for example with transition assistance – in short, ensure a 'just transition'. Athanasiou has underlined the point that '[o]nly by attacking climate and inequality together can we hope to find a new solidarity for the 21st Century, and thus a way forward' (Athanasiou, 2007), and Stern has made a similar point, noting that reducing poverty and achieving a form of development that is clean, sustainable and inclusive go hand in hand (Stern, 2018). Whether societies go the extra mile and 'use energy transitions as opportunities to rethink dominant political, economic, and social institutions' (Howe & Boyer, 2016) is an open question. Given that the elite, the most wealthy 1% in most societies, is strongly associated with fossil fuel interests, and their wealth is often heavily invested in current forms of infrastructure, it can be argued that without such rethinking, the necessary transition may ultimately be harder to make.

5.1 Working with public perceptions

In cities particularly, we are beginning to witness strong political momentum for mitigation action, and the start of an awareness that we are engaged in a race against time (Gurria, 2017). Ensuring that the public is better informed than currently, about both the risks associated with climate change and the implications of an ambitious mitigation strategy, is central. Among business and economic experts, the global risk perception picture is now dominated by climate-related risk (World Economic Forum, 2019).[14] In the wider context, risk perceptions and views of social commentators matter (Bain et al., 2016; Monbiot, 2017, 2019; Wallace-Wells, 2019a) and changing public perceptions appear to be intensifying calls for more rapid mitigation. Already, we see public perceptions of urban quality of life going beyond socio-economic well-being, to encompass a lower environmental burden (Gudipudi, Lüdeke, Rybski, & Kropp, 2018). This will increasingly be true as climate impacts such as heat and flooding progressively affect more cities. Urban governments will need to invest heavily in ambitious planning for energy, transport, housing, urban development and other investment, if citizens are not to be disappointed in their calls for effective mitigation action. This need will coincide with increasing demands on urban governments to plan for adaptation, and implement protective strategies.

Signposting significant changes will be important for managing perceptions that city and national governments are developing credible plans. Transparent sectoral commitments -- such as those by New York City to reduce large buildings' carbon emissions by 40% by 2030 and 80% by 2050 (Urban Green

Council, 2018), or by cities, car companies or countries to ensure petrol and diesel car production or imports cease by dates such as 2025, 2030 or 2035[15] -- are vital in creating a sense of momentum, as long as the commitments are specific and not too distant in time. Similarly, a helpful signpost is San Francisco's announcement of a plan to ensure all very large buildings are powered by renewable electricity by 2030.

Many already believe that local government is part of the answer in terms of action on climate change. In the US, when asked 'How confident are you that people like you, working together, can affect what your local government does about global warming?', 50% of registered voter respondents say 'a great deal'/'a lot'/'a moderate amount'. The corresponding figure for the federal government is 38% (A. Leiserowitz et al., 2019, p.19).

However, there is no doubt that some population segments, not only in developed countries such as the US but also in developing countries remain relatively poorly informed about the impacts of climate change (e.g. only 48% of Americans in December 2018 thought that 'people in the US are being harmed by global warming "right now"')(A. Leiserowitz, Maibach, E., Rosenthal, S., Kotcher, J., Ballew, M., Goldberg, M., & Gustafson, A. , 2018, p.14). In addition, fewer than half of Americans perceive social norms for taking action on global warming (*ibid,* p.19). Ongoing educational efforts are important to target such groups.

Support for a comprehensive policy package to address climate change is now relatively high in developed countries, although support for particular policy measures affecting particular sectors and groups is usually softer. In the US, the 'Green New Deal' policy package is garnering some support. It has been described as a 'massive program of investments in clean-energy jobs and infrastructure, meant to transform not just the energy sector, but the entire economy' and amounting to a 'choice between changes that seem impossible and a future that seems unthinkable.' (Roberts, 2019). In December 2018, a national US survey (A. Leiserowitz et al., 2019, p.19) investigating support for the package found 81% support among registered voters (n=966).[16] However, given that 82% of Americans had heard 'nothing at all' about the Green New Deal, it is unlikely that such a level of support will be sustained as partisan divisions emerge around specific policies in future. Much of the package would directly involve cities and regions in components such as upgrading the 'energy grid, buildings, and transportation infrastructure', improving energy efficiency; and investing in 'training for jobs.'

Despite general support for government action on mitigation, climate policy has not been a ***priority*** among the public, compared to other policy issues. For example, climate change and environmental issues were not priority issues among the general public in France, Germany or the UK at the time of polling in mid-2016, although climate change's ranking was higher in Norway (Steentjes et al., 2017). Accordingly, ensuring sufficient cross-party support will continue to be a potential stumbling point for progressive mitigation policy, not only in the US, but also in liberal-democratic countries such as the UK, Australia and New Zealand. The argument for ensuing cross-party support is principally that without both (or all) major political parties being on board, there will be a lack of sustained investment in long-lived assets (Fallow, 2018). The UK has been a leader in terms of cross-party support for its mitigation legislation.

At present there appears to be trade-off in some countries between policy and legislative durability on the one hand, and policy ambition on the other. Nevertheless, to the extent that there is an ongoing shift in public opinion towards stronger policy action, there is a case for governments to invest in planning measures that push beyond the 'current' political middle ground. Failing to be prepared for strong mitigation measures as opinion develops runs a major risk of missing critical opportunities to avoid carbon lock-in.

More pessimistic assessments of citizen preparedness (and government support of citizen education for change) are not unusual. For example, the UK's Institute for Public Policy Research states: 'It is unclear whether adequate efforts are being made to sufficiently prepare populations to navigate the radical social and economic transitions needed to prevent catastrophic environmental breakdown while ensuring they remain resilient to the growing negative impacts of breakdown ' (Laybourn-Langton et al., 2019)

Social acceptance and institutional ***trust*** are critical to public acceptance of rapid change, especially when driven by disruptive policy measures. Trust has been shown to vary significantly across countries. For example, Steentjes *et al*. (2017) found that institutional trust was higher in Germany and Norway than in the UK and France. Part of building acceptance and trust is the development of a compelling, coherent and positive narrative, explaining the need for policy and behavioural change, and setting out the evidence linking all aspects of mitigation to improved well-being.

Over the next 30 years, the world will change dramatically for a range of reasons, including climate change impacts, population movement partly driven by climate change, changes in regional economic activity, and changes in technology and social practice. Many of these changes will materially alter cities. Climate change is already starting to have impacts on migration, for example (Gleick, 2014).[17] If a projected 150-200 million possible climate refugees by 2050 (IOM (UN Migration), n.d.) leads to proportionate dislocation and social and economic responses, then the political landscape over the next three decades will likely be one of growing turmoil. It is important that governments anticipate the risk of destabilised political conditions and, to the extent possible, support rational policy programmes as long as possible.[18]

5.2 Future focused, connected institutions

There has been little research on how governments can best re-orient institutions in the face of barely tractable, complex problems. One analysis (Levin et al., 2012) suggests building 'forward-looking path dependence'. Levin et al. argue for an 'applied forward reasoning approach', which identifies 'ways in which interventions might create particular policy pathways that move toward preferred outcomes.' (p.131). At the urban level, this implies developing some shared understanding of a transition process across a multi-level governance system (with both vertical and horizontal linkages) which can act as a basis for a programme for purposeful change. It also implies working harder to connect different parts of government.

A related challenge is how to 'bind our collective selves' in the face of short-sightedness on the part of electorates and institutions which, of course, reflect 'ourselves'. Keeping important goals and performance indicators under review can help, but in the case of climate transition, those indicators – such as the UK's and New Zealand's climate budgets and emission trajectories – require real determination to adhere to. Levin *et al.* observe that 'rarely do decision makers assess how …policy might be designed to ratchet up over time to become more ambitious' (Levin et al., 2012, p.125). Yet this is precisely what is expected of signatories to the Paris agreement, which includes a ratchet mechanism for increasing ambition over time (Bodansky, 2016).[19]

Other writers have suggested forward-looking 'policy binding' mechanisms. Boston (2017), for example, suggests improved reporting on progress towards long-term government goals, giving greater weight to path dependence and irreversibility in policy analysis and decision-making, applying lower discount rates in cost-benefit analyses (especially for periods exceeding thirty years and when there are risks of catastrophic or irreversible consequences), and enhancing deliberative mechanisms for decision making.

5.3 Inclusive, democratic processes

Inclusion is critical, if disruption due to mitigation is not to compound the unfairly distributed emerging effects of climate change (with the most extreme consequences largely falling on the Global South, but with some falling on low-income populations in the Global North). The IPCC observes that 'inclusive processes can facilitate transformations by ensuring participation, transparency, capacity building and iterative social learning (high confidence).' (IPCC, 2018).

SDG16 ('Peaceful and inclusive societies for sustainable development, and inclusive institutions at all levels') highlights the importance of democratic participation as a goal.[20] Democratic participation can in

turn support the achievement of other sustainable development goals, although it may come under time pressure during a rapid transition process. Given the limitations of representative democracy, deliberative democracy may be one of the most effective tools available to generate an effective conversation and manageable democratic process (Taylor & Runciman, 2018) on large, long-term matters such as stabilising and then reducing consumer demand in rich countries.

It is easy to imagine there will be significant public support for policy measures where demonstrable gains, such as health benefits as well as emission reductions, clearly outweigh the costs of action. But because of loss aversion (Kahneman & Tversky, 1984), even modest policy adjustments, such as the provision of bike lanes in cities with the purpose of increasing active travel and reducing car use, will be vigorously resisted by some who are concerned by a loss of conventional (if recent) patterns of activity. One way to manage such resistance is through early, inclusive and democratic planning processes involving communities, and workers in carbon-intensive industries. It is no easy political task to manage such change, and rapid change across multiple domains of a city or region is considerably more challenging.

There is no substitute for ongoing political awareness raising and education about the purpose of such changes, incremental introduction of and experimentation with appropriate policies, evaluation of performance and celebration of successes, emphasising their contribution to the longer-term trajectory of change. This needs to involve the public, debating and building the case for both individual and collective (policy) action, and the nature of that action. It also needs to engage local business and community partners in the process of change. The IPCC notes that '[r]e-examining individual and collective values could help spur urgent, ambitious and cooperative change (medium evidence, high agreement).' (IPCC, 2018c, p.46). However, while such reflection on the values involved is desirable, it is only part of a multi-dimensional process needed at the level of local government action.

A significant risk during a period of disruptive transition is in maintaining democratic responsiveness and engagement. One risk is that of losing democratic control to well-resourced special interests as demonstrated even by the more confident and less hurried processes of previous technological transitions. An example is the transition from a pedestrian and bicycle based urban mobility system in cities around 1900 to a private vehicle based mobility system by the 1930s. In countries such as the US, Australia and New Zealand, this process was one in which local democratic control of cities' land use (mainly streets) became dominated by the interests of the automobile industry, leading to an accelerated and problematic displacement of pedestrians and bicycles by cars (Tolley, 2019). One of the consequences of the imbalance that developed was an over-emphasis on roads and facilities for vehicles (including parking) at the expense of more compact human-centred urban design.

It would be naïve to suppose that special interests with large influence, such as the fossil fuel 'oligarchy', or those with powerful ownership interests in the current transport system, for example, would be accommodating to the necessary changes in cities, or indeed to changes in the wider economy. The difficulty is that this resistance poses dangers for democratic urban (non-oligarchic) governance, leaving aside its significance for national governance (MacKay, 2017).[21] It is likely to be manifest in a range of ways, such as resistance to the repurposing of car-dominated land use arrangements, for example, or to the widespread decentralisation of electricity generation. As MacKay argues, control over much societal decision-making by a small, self-interested elite can make it difficult for society to make rational and long-sighted decisions in the face of major threats like climate change.

A potential antidote to the resistance by established interests to municipal democratic reform of urban planning, transport and energy systems is to ensure that sustainability-conscious horizontal networks of democratic cities are built and utilised. Networks of cities – e.g. C40 cities; ICLEI -- have proven useful in constructing knowledge of, and sharing, promising urban sustainability practices. The Global Covenant of Mayors for Climate & Energy, for example, has been signed by around 9,200 cities representing about 813 million people worldwide or almost 11 percent of the global population[22] (UNEP, 2018). Despite its impressive coverage and apparent ambition, the covenant lacks cut-through and specificity. One

manifestation of the ongoing power of elites is in the way city networks seem to be operating. Johnson makes the powerful point that city networks such as ICLEI and C40 Cities may come close to jeopardising their intellectual independence: '[They] have become highly dependent upon the contributions of private corporations and corporate foundations, such as Bloomberg Philanthropies, the Rockefeller Foundation and Arup, suggesting a possible limitation on the ability of city-networks to develop an autonomous climate policy agenda.' (Johnson, 2018, p.152)

The point is often made that local government is typically a creature of national power, with national government able to abolish local government, or trim its powers and resources. For example, the Conservatives abolished the Greater London Council in 1986; however, it was reinstated, if altered, as the Greater London Authority, in 2000. The State of New York blocked – until recently – plans for New York City to introduce congestion pricing.[23] As an OECD analysis remarks, 'local governmental authority to act in areas related to climate change is often "nested" in legal and institutional frameworks at higher scales' (OECD, 2010, p.173).

Ultimately, in an era of nation states and partial globalisation, the power of cities tends to be significant but limited (R. Chapman et al., 2017; Johnson, 2018). Cities may be prompted to action by an 'action gap' at the national level (Engel, 2009; Gore, 2010). The local level is an appropriate level for some mitigation policies, as cities normally have high energy consumption (as noted earlier) and waste production, as well as considerable influence over key areas such as transport (Puppim de Oliveira, 2009). Although cities can have influence and may even be highly motivated, factors such as a lack of coordination and/or capacity (Aylett, 2014) may constrain them. At the least, it makes sense to exploit opportunities from better vertical and horizontal policy integration (Corfee-Morlot et al., 2009; Newman, Beatley, & Boyer, 2009) and exploit concrete areas where cities can effect change (Committee on Climate Change, 2012).

Developing and sharing intellectually independent, critical knowledge about the priorities for climate mitigation policies of cities is important if we are to learn as rapidly as possible about effective mitigation strategies. This includes understanding lessons from existing literature, which is rapidly growing; and making those lessons digestible for policy makers. As noted earlier, making use of networks of cities (e.g. C40 Cities; ICLEI) which are already active in this space could increase the efficiency with which best practice can be disseminated and refined, but it will be vital to safeguard the independence of such networks from established interests.

5.4 Addressing inequalities and distributional issues

As noted above, the IPCC links governance challenges to scenarios with high inequality. Specifically, the IPCC in its 2018 SR1.5 report couches this as follows:

> *'The design of the mitigation portfolios and policy instruments to limit warming to 1.5°C will largely determine the overall synergies and trade-offs between mitigation and sustainable development (very high confidence). Redistributive policies that shield the poor and vulnerable can resolve trade-offs for a range of SDGs (medium evidence, high agreement).'(IPCC, 2018c, p.45).*

This raises questions of how, within countries, redistributive protective policies or compensatory policies might be effectively articulated and introduced (and whether all are necessarily justified, including for example, compensation for property owners having to relinquish property privileges). It is important also to bear in mind that there are high transaction costs for any government in working through questions of redistribution, given that alterations in the current distribution of power and resources may be disproportionately resisted.

It is widely accepted that emissions are at present very inequitably distributed; for example, Wallace-Wells notes that 'If the world's richest 10% were limited to the average European footprint, global emissions

would fall by a third.' (Wallace-Wells, 2018). A more specific and local analysis by Brand and Boardman suggests that a disproportionate share of the UK's transport emissions is produced by the wealthy:

> *'There is a highly unequal distribution of [travel] emissions amongst the population, independent of the mode of travel, location and unit of analysis. The top 10% of emitters are responsible for 43% of emissions and the bottom 10% for only 1%. Income, economic activity, age, household structure and car availability significantly influence emissions levels.' (Brand & Boardman, 2008)*

Governments, both nationally and locally, seeking to constrain emissions of the population as a whole will in some form have to face the question of what they propose doing to regulate the very high emissions of the well-off, while at the same time ensuring that the transition process does not leave vulnerable groups worse off. One perspective on this is that dealing with the justice aspects of climate change is a pre-condition for proceeding in a responsible way with the climate transition (Perkins, 2019). However, a rigid rhetorical position on this could stymie climate action. A perhaps more pragmatic position is that in any emergency, such as wartime, greater material sacrifices are expected of those with greater resources, and progressive taxation to finance mitigation investment is justified. At the time of writing, the UK House of Commons has just declared a formal environment and climate change emergency and this initiative shows signs of spreading globally.[24]

In any one urban domain, such as transport, or energy, or urban planning, the pursuit of more just and equitable policies and resource allocations is a formidable social and political task. In the transport domain, Banister translates concerns about the challenge of developing equitable transport systems into some key principles for equitable, sustainable transport:

- It should promote the means to reduce inequality through investment and subsidies that meet the needs of the disadvantaged;
- It should address the rights of all to live in a clean, healthy, safe and quiet environment;
- Transport should be seen as cutting across all related policy sectors (e.g. housing, employment) so that it can provide connectivity between them, and contribute fully to raising human capital. (Banister, 2018)

One view is that advancing these principles while rapidly mitigating climate change, as well as providing effective urban governance to deal with climate adaptation and resilience building, will be very demanding. A counter position is that the experience of the yellow jackets in France shows that without addressing the first principle above, mitigation will be unattainable due to popular resistance.[25] The debate therefore goes well beyond the minimal presumption that mitigation policies of cities should not make the distribution of resources more inequitable. Rather, wherever possible, complementarities and alignment should be sought so that distributional gains can accompany or be generated by mitigation policies.

There is no doubt that the transition away from fossil fuels will have a major disruptive effect on certain regions and communities, such as those where fossil fuel extraction and processing continues today. However, not to adapt also promises stranded communities in future. Both promise and challenge lie ahead in this aspect of transition. The 'greening' of the labour movement offers important promise for transition, but continuing support for the transition requires major investment in local economies dependent on extraction, before major disruption occurs, alongside a determination that any negotiated outcome respects the necessities of climate science, as noted above in the context of the German coal transition.

5.5 Knowledge gaps

A last consideration is knowledge gaps. A recent literature survey noted that 'locating research efforts, stakeholder engagement and policy advocacy in growing cities and developing regions will be instrumental to avoiding lock-in and realising compact, low-carbon urban forms that can tackle the coming mitigation

challenge' (Lamb, Creutzig, Callaghan, & Minx, 2019). They also note that 'more attention should be given to learning from case studies', alongside 'increased ambition in comparative research, and more comprehensive reviews of the case study literature.'

This echoes one of the findings of the New Climate Economy researchers five years ago, that a major challenge for analysing carbon emissions at the city level is the lack of robust, comparable data. They also found that 'only around 40 cities were found to have published carbon emissions [data] over the last three years, and only 12 of these provided a clear breakdown of emissions for key sectors of the economy' (Floater et al., 2014).

Putting research questions back into the wider frame, we end by paraphrasing and focusing the IPCC's questions (IPCC, 2018c, p.43) about remaining research and knowledge gaps, as applied particularly to cities and regions:

- How can rates of change for urban areas be accelerated and scaled up?
- How much can be realistically expected from innovation and behavioural and systemic political and economic changes in cities, to reduce carbon emissions?
- What is the outcome of realistic assessments of mitigation transitions that are consistent with sustainable development and addressing inequality?

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[1] As a matter of practicality, it also excludes waste management, although much of this occurs in cities, on the basis of materiality: the waste management sector is responsible for only ~ 1.5 $GtCO_2$/y in 2010 compared, for example, with the transport sector at 6.7 Gt, globally: see IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change.
[2] https://climateactiontracker.org/publications/the-ten-most-important-short-term-steps-to-limit-warming-to-15c/

[3]In Washington, D.C., nearly 100 households are each saving $250/year on their electric bills thanks to a 182-kW project by New Partners Community Solar, a nonprofit developer that offers free subscriptions to low-income residents (Galluci, 2019).

[4] Some sources (e.g. a report in the New York Times) confuse the concept of climate neutrality, explaining it (for example) as when a jurisdiction generates more renewable energy than the 'dirty' energy it consumes --see (Sengupta, 2019).

[5] The Climate Change Committee (May 2019) noted that current pledges of effort from countries across the world would lead to warming of around 3°C by 2100. The UK CCC's recommendation is consistent with a 1.5°C trajectory, and its intent to 'identify a UK target that is within reach and best supports an increase in global effort.' (p.13). Moreover, the 'net-zero target for all GHGs would imply that the UK will be actively reducing its large historical contribution to global warming.'(p.17).

[6] Comment by Derk Loorbach at OECD workshop, 17 May 2019.

[7] Estimated infrastructure investment is of the order of US$90 trillion in the period to 2030, according to Global Commission on the Economy and Climate (2018) Unlocking the Inclusive Growth Story of the 21st Century: Accelerating Climate Action in Urgent Times Report.

[8] The organisation which came closest to predicting this in the case of wind power was probably Greenpeace [Pers. Comm.: Eric Martinot].

[9] https://grist.org/article/new-york-citys-newly-passed-green-new-deal-explained/

[10] For a discussion of a European minimum carbon price proposal, see https://www.pik-potsdam.de/news/press-releases/klimaplan-fur-deutschland-okonomen-schlagen-co2-preisreform-vor

[11] It also found that support schemes for using renewables in buildings' heating and cooling systems were covered by only 19 percent of G20 members.

[12] Based on an International Transport Forum analysis for the period 2015-2050.

[13] See also the comment above on SLCPs (short lived climate pollutants), one of which is methane.

[14] Disasters triggered by climate and weather-related hazards are responsible for an increasing toll, estimated at US$320 billion in losses in 2017: (The Global Commission on the Economy and Climate, 2018)

[15] However, the dates in question matter: '2040 is too late for the phase-out of petrol and diesel cars and vans, and current plans for delivering this are too vague.' (CCC, 2019) The goal set by Norway to cease sales of conventional cars by 2025, and Paris's commitment to banish all petrol and diesel cars from the city centre by 2030 are more timely: (Gurria, 2017).

[16] The description of the policy was summarized from a 2018 policy report: "the Green New Deal will produce jobs and strengthen America's economy by accelerating the transition from fossil fuels to clean, renewable energy. The Deal would generate 100% of the nation's electricity from clean, renewable sources within the next 10 years; upgrade the nation's energy grid, buildings, and transportation infrastructure; increase energy efficiency; invest in green technology research and development; and provide training for jobs in the new green economy."

[17] A plausible view is that climate played a significant role in the onset of the Syrian refugee crisis, contributing to the 1 million or so refugees who crossed into Europe from around 2014, in turn contributing to anti-immigrant sentiment in Europe and fuelling political reactions such as Brexit.

[18] Steentjes et al. found that in the four countries surveyed in 2016 (Germany, Norway, France and the UK),'a majority disputed any link between climate change and the 2016 refugee crisis in Europe, [but] about one third of respondents (and one half in Norway) did think that climate change will lead to more migration to their own country in the future.' (p.37).

[19] The Marrakesh Declaration reinforces the commitment to increasing ambition in mitigation: 'We call for urgently raising ambition and strengthening cooperation amongst ourselves to ***close the gap between current emissions trajectories and the pathway needed*** to meet the long-term temperature goals of the Paris Agreement.' (emphasis added): (UNFCCC, 2016)

[20] Goal 16.7 is 'Ensure responsive, inclusive, participatory and representative decision-making at all levels.': https://sustainabledevelopment.un.org/sdg16

[21] https://www.resilience.org/stories/2018-09-25/the-ecological-crisis-is-a-political-crisis/

[22] Covenant website, accessed May 2019: https://www.globalcovenantofmayors.org/news/

[23] https://www.theguardian.com/politics/2008/apr/08/congestioncharging.pollution but also https://www.nytimes.com/2019/03/26/nyregion/what-is-congestion-pricing.html

[24] https://www.theguardian.com/environment/2019/may/01/declare-formal-climate-emergency-before-its-too-late-corbyn-warns

[25] Some behavioural economics evidence suggests that when inequality is such that resource endowments are unequal and impacts of climate change tend to fall on the poor, it is difficult to achieve cooperation and success in mitigation. (Burton-Chellew, May, & West, 2013)