IANAS Energy Committee

RETHINKING CITIES

The role of cities in meeting the Sustainable Development Goals

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July 2021

Research assistance and technical support by Eng. Kevin Rodriguez and Englebert Davis, administrative support by Kadian Roberts-Martin, Nadene Sherlock and Sandra Gayle of the University of the West Indies, and especial thanks to Maite Pérez García, the Secretary of IANAS. Professor Beatriz L. Caputto, the Executive Director of IANAS, Professor Jeremy McNeil the Co-Chair of IANAS, Professor Manfred Horn, the Co-Chair of the IANAS Energy Committee, and to the Caribbean Academy of Sciences.

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The current world population is about 7.9 billion. It is projected to reach 9.7 billion by 2050, and 10.9 billion by 2100 (UN Department of Economic and Social Affairs 2019[i]). The growing population will be increasingly urban; about 55% of the world's population currently lives in urban areas, but this is projected to increase to 68% of world population by 2050, which will add another 2.5 billion people to urban populations (UN Department of Economic and Social Affairs 2018[ii]). This will require the equivalent of 110 new cities each with over 20 million inhabitants (approximately the size of Mexico City today), which would involve building 3 or 4 new cities every year between now and 2050.

The US DESA World Urbanization Prospects 2018 report notes that this growth is driven by a number of factors, including a surplus of births over deaths in urban areas, domestic migration from rural to urban areas in search of economic opportunities, international migration (which is predominantly into urban areas) and the urbanization of formerly rural areas[iii]. The UNEP report 'The Weight of Cities: Resource Requirements of Future Urbanization'[iv] notes that over a third of the projected urban growth will be happen in just three countries: India, China and Nigeria, and that India's urban population will increase by 404 million, China's by 292 million and Nigeria's by 212 million. The most urbanized regions today include North America (82% urban), Latin America and the Caribbean (81%), Europe (74%) and Australia and the Pacific Islands (68%). Asia (50%) and Africa (43%) are presently the least urbanized but about 90% of the total projected increase in the urban population will be on these continents.

The US DESA report notes that there are now 33 megacities (a city with more than 10 million inhabitants), containing about 12% of the world's urban population. By 2030, there will be about 43 megacities, most of them in developing countries. However, much of the urban expansion is likely to be in smaller and mid-sized cities. Today, almost 50% of the world's urban dwellers live in cities with fewer than 500,000 inhabitants, and this pattern is likely to continue, as these smaller cities are still large enough to offer many of the economic and social attractors that drive urban growth.

These attractors include a younger, more diverse and better-educated workforce, a much higher concentration of businesses, schools and colleges, and proximity to markets, commerce, offices of government and transportation links. These support the rapid sharing of knowledge and information, and provide the infrastructure necessary for successful entrepreneurship and technological innovation. Cities are also more likely to provide better-paid jobs, adequate housing, better access to education and health-care, more cultural opportunities, and higher-grade infrastructure such as roads, piped water, electricity and public transport.

Urban growth is not a universal pattern, and some cities have lost population and declined economically. Most of these are in low-fertility countries in Europe and Asia, where the national population is also declining, but some have shrunk as a result of the loss of major industries or natural disasters. There are also possible countervailing factors, including pandemics, which might lead people to flee cities (although rural settings may be no less vulnerable), and better digital technologies, which would support a move to distributed patterns of working.

Overall, however, the demographic pressures will probably predominate, so it is still likely that there will be a large increase in urban population, which will result in both a significant expansion of existing cities and the construction of new cities. As a result, material consumption by urban areas will grow rapidly. The 'Weight of Cities' report notes that without a new approach to the management of urbanization, material consumption by the world's cities will grow from 40 billion tonnes in 2010 to about 90 billion tonnes by 2050. This includes the materials used in the construction and operation of cities and to support urban lifestyles, such as coal, oil and gas, sand, aggregate and cement, tar, aggregate and steel, wood and water and food. The report points out that the total urban demand for raw materials will far exceed sustainable limits before 2050, and concludes that a new model of efficient urbanization is essential to contain resource consumption and CO_2 emissions. The report also notes that the trend to urban de-densification (urban sprawl), currently running at about 2% per year, will increase global urban land use from 1 million km^2 to over 2.5 million km^2 by 2050, which will threaten agricultural land and could put food supplies at risk. The current model of urbanization is failing in another regard, about a third of the current urban population lives in slums and informal settlements, without access to proper housing and basic services, and this proportion is likely to increase significantly as a result of a combination of poor planning, weak governance and corruption, high fertility rates and rural-urban migration in the most rapidly-growing developing countries.

Cities and metropolitan areas are the main drivers of economic growth, contributing 60% of global GDP, but they also account for 70% of global carbon emissions, 75% of natural resource consumption, and 50% of global waste. Rapid and chaotic urbanization is resulting in a growing number of people living in slums, inadequate and overburdened infrastructure and worsening air and water pollution. About a billion urban dwellers live in informal settlements in developing countries, with low quality, overcrowded housing; poor provision for sanitation, drainage and waste collection; a lack of safe water supplies; and limited access to healthcare, emergency services, schools and policing. Global poverty will be increasingly concentrated in these vulnerable settlements. These problems will be compounded by the Fourth Industrial Revolution; over 80% of the jobs in some low-income countries could be now be done more cheaply by AI, robotics and automated systems. This will undermine the case for outsourcing and the associated flows of investment capital and skills into developing countries, and displace many low-skilled and entry-level opportunities, which will make it harder for poor people to integrate into the formal economy. The combination of climate change, rising temperatures and sea levels, increasing water scarcity, crop failures and the loss of critical infrastructure in coastal areas is likely to result in forced migration, raising the risk of civil unrest, conflict and terrorism. In the absence of effective action, these challenges will become increasingly intractable.

However, cities also offer the greatest opportunities to move the world to a more sustainable development trajectory. Cities provide the population densities needed to make energy and resource-efficient systems economically viable. Cities make it possible to operate mass transit systems, provide large markets for food, manufactures and other goods with significant economies of scale, support high-density energy, water and sanitation grids, enable bulk waste recovery and recycling, and provide large markets for many other services for a far lower *per capita* cost of delivery. A policy-driven transition to more sustainable patterns of production and consumption still has to be translated into sector-specific goals, such as energy-generating buildings, efficient transport systems, effective water and resource management, waste minimization, environmental remediation, increased resilience and reduced vulnerability to storm surge, flood, earthquake and other disasters, and integrated urban planning and building design systems that contribute to physical and social well-being and help to reduce conflict and crime.

Cities are also hubs of trade and commerce and offer access to a much larger set of educational and work opportunities, a combination that fosters the development of the new skills and technologies needed to decarbonize and reconstruct the global economy on a more sustainable basis. The challenge now is to find ways that cities can achieve far higher standards of energy and resource-efficiency while also maintaining economic competitiveness and the ability to attract investment and skilled human capital. This will require facilitating investments in the next generation of communications, energy, water and transport infrastructure, and fostering human capital and attracting investment to create dense knowledge networks that can sustain high rates of innovation, increase efficiency and reduce costs. Cities are major consumers of goods and services, so procurement can be used to engage suppliers, purchasers and consumers in the drive towards more sustainable patterns of production and consumption.

City ordinances and building codes can ensure that buildings are designed to deliver higher standards of energy and water efficiency, with built-in recovery loops for energy, water and materials. The promotion of fabricator-based manufacturing would allow cities to develop an internal industrial base, reducing the volume of freight, while autonomous vehicles, telecommuting and distributed modes of working would significantly reduce both the need to commute and the number of vehicles on the roads. Cities also have the concentration of supply and demand needed to support a transition to a circular economy, with resources continuously recovered and returned into productive use, in contrast to the current model which is based on a linear flow of resources and a single pass through the economy before disposal.

The majority of the Sustainable Development Goals (SDGs) now depend on progress to more sustainable patterns of urban living. One of the SDGs - SDG11 – refers specifically to cities; the goal is to make cities 'inclusive, safe, resilient and sustainable'. However, this broad concept has social, economic, cultural and environmental dimensions, which means that it includes a number of cross-cutting issues. 'Inclusive' and 'safe' are relevant to SDG1 (poverty), SDG2 (hunger), SDG3 (health), SDG4 (education), SDG10 (inequality), SDG8 (work and growth) and SDG16 (peace and justice). 'Safe' is also related to SDG6 (water and sanitation), while 'resilient and sustainable' are related to disaster risk reduction (also implicit in SDG3) and SDG12 (sustainable production and consumption patterns). This means that over half of the SDGs are linked to SDG11, and the number and strength of these cross-linkages will increase in future as a result of further population growth and urbanization[v]. Cities have served as engines of development for centuries, but their increasingly complex multi-functional role is now crucial to achieving the Sustainable Development Goals.

The problems of urban poverty, violence and squalor are real, but so is the enormous potential to use cities as drivers of change and the means to achieve the SDGs. The difference between cities as *problems* and cities as *opportunities* is determined largely by the quality of planning and governance needed to deliver better systems of housing, transport, food, water, sanitation, work and living. This requires a planning framework designed to deliver the optimal combination of economic development and growth, rising incomes, high environmental standards, strong protection for important ecosystems, effective management of natural resources, low rates of crime and an improved quality of life.

The goal of this project was to produce policy briefs in key relevant areas, including:

- Planning, construction and the built environment
- Urban energy, food, water and waste management systems
- Logistics and transport systems
- Manufacturing, consumption and the circular economy
- The digital economy and society

This involved analyzing global trends to 2050 and beyond in relevant sectors of the global economy, including the process of technological innovation, development and dissemination and the implications for the future management of energy and resources, the future of the built environment, transport and manufacturing, and the future of work, education and training.

Planning cities for the future

The period to 2050 will be a time of exceptional turbulence. The world is being transformed by the accelerating scientific advance and technological innovation of the fourth industrial revolution, the transition to a more crowded world with a population that will be significantly older, more urban, and predominantly Asian and African, the shift in the geopolitical balance of power towards Asia, increasing inequalities of wealth, increasing pressure on water, energy, land and natural resources, and the potentially massive disruptions of climate change (Clayton, 2020[vi]). Technological change will drive a transformation of education, healthcare, lifestyles and patterns of work. By 2050 there will be about 6 billion people in the global workforce, of whom just 1 billion will be doing jobs that exist today.

The future will therefore be determined by a complex combination of interacting variables, including demographic change, economic development, increasing competition, market liberalization or closure, environmental impacts, political dynamics, scientific advance and technological innovation. Success is not guaranteed, as the examples below illustrate.

Box 1: Urban crises and failures

Detroit, USA

The population of the city of Detroit grew from 285,000 in 1900 to 2 million by 1950, largely because it became a hub of automobile manufacture. As a result of deindustrialization, automation and the relocation of factories into cheaper locations, the population of the city began to shrink again. By 2010 the population of the city was 700,000, a decline of 61% from the peak. This has left Detroit with large areas of urban decay, abandoned houses and offices, and some of the highest crime rates in the USA. In 2013, the city of Detroit filed for bankruptcy, and required financial restructuring.

São Paulo, Brazil

In 2014, the mega-city of São Paulo (population 20 million) almost ran out of water. The main reservoir was down to just 3% of its capacity, which meant that the city had less than 20 days' water supply. The immediate cause of the crisis was a sustained period of drought, but this was greatly exacerbated by the fact that 31% of the water supply was being lost to theft and leaks, and because the city's two central reservoirs had become too polluted to use. Extreme water restrictions were required to deal with the crisis, and 80% of the water utility company's customers had to be given financial incentives to reduce their consumption. The utility had to extend their pipelines to tap into additional rivers, and pump water from further away, at a cost of nearly US$1bn.

Part 2: Policy Briefs for future cities

The UNEP report 'Sustainable Urban Infrastructure Transitions in the ASEAN Region: A Resource Perspective' proposes a set of strategies to retain the advantages of urbanization while reducing the environmental costs, as follows:

- Use enforced urban boundaries to protect important environmental and agricultural sites around cities and increase urban – rural permeability (with e.g. urban wetlands to absorb flooding, and wildlife corridors used to support biodiversity) in order to strengthen resilience against natural disasters.
- Develop a compact, inclusive and resource-efficient urban form within cities, with a mixture of high density, multi-storey construction and lower density, vernacular buildings.
- Promote diverse sustainable urban mobility and transit systems. This starts with high-density, well-designed urban development, which is more energy and resource-efficient, and reduces the demand for travel within the city, thereby reducing pollution, congestion, delays and traffic accidents, while good street-lighting, tree cover, traffic controls and pedestrian-friendly streetscapes also encourage walking and cycling, and clean, safe and efficient mass transit systems give people a better alternative to private vehicles.
- Promote energy-efficient buildings and neighbourhoods, and integrate renewable energy generation in cities. Existing buildings can be retrofitted to reduce energy use by 30-60%, provided that the necessary standards are incorporated into building codes. New-build can incorporate passive design features (such as orientation) that reduce energy consumption while increasing comfort. New technologies like autonomous micro-grids can support the development of renewables. Rooftop PV panels and solar water heaters can be incorporated into building designs. In coastal areas, seawater can be used for cooling.

- Prevent slum development and promote the rehabilitation and reintegration of existing slums. It is important to provide space for the urban poor inside the cities while preventing slum formation and unplanned urban sprawl. Building and construction codes can be used to ensure energy efficiency and disaster risk resilience. Integrated urban planning can be used to encourage socially diverse mixed-use neighbourhoods.
- Improve resource efficiency at the whole city level through integrated urban-industrial symbiosis. This involves the exchange of materials and energy to provide energy, water, heat, materials and waste management services in cities. For example, waste heat from industry can be used to heat water and cool homes, municipal solid waste can converted into useful products, including the conversion of plastic waste into decking, organic waste into compost and so on. This can be encouraged with the development of eco-industrial parks and urban industrial symbiosis infrastructure networks to transport waste water, heat and materials. This approach can be extended to the entire urban metabolism, which involves modeling the flows of complex urban systems (including e.g. food supplies and modes of transport) to identify the opportunities to reduce waste and recover energy and materials.

The UNEP ASEAN report argues that these strategies are the basis for a roadmap for developing inclusive and resource-efficient cities, which would improve both human wellbeing and environmental sustainability, thereby achieving multiple Sustainable Development Goals. This is consistent with the goals of UN Habitat's New Urban Agenda (2017)[vii] and the International Guidelines for Urban and Territorial Planning (2015)[viii].

The strength of the UNEP model is that it integrates social, environmental and economic factors, while the roadmap can be used to shape the urban environment toward greater energy and resource-use efficiency, lower carbon intensity and greater social cohesion. In this approach, traditional city planning becomes part of a higher-level decision-making process that is aimed at realizing a combination of economic, social, cultural and environmental goals, which are then translated into spatial visions, strategies and plans.

At a national level, the development of a new city can be both economically and environmentally positive. The UNEP ASEAN report notes that channeling investment into a new city can relieve pressure by easing the demand for housing, water and roads in existing cities, it can help to balance development across the country, and - if the new city also develops different economic specializations - it encourages inter-city trade and the development of business corridors. It the new city is also designed and built to higher environmental standards, the total environmental cost of urban living can be reduced at the same time.

The transition to this new model of urban development depends on good governance and planning. The transition pathways from the current *status quo* to the new approach have to be planned on a multiscale continuum, from international frameworks to national legal and planning laws, from national to local government level, and from local government and city down to neighbourhood level. It is particularly important to ensure that the plans at each level are consistent with the plans at the other levels. It is also important to ensure that the governance is inclusive in order to address the local issues and preferences that tend to get overlooked in top-down planning. Finally, planning and regulatory organizations must have the necessary capacity to plan and the ability to enforce if these ideas are to be delivered.

Global risks

The World Economic Forum Global Risks Report 2019[ix] identified the ten greatest risks facing the world today. The top five risks in terms of probability in the next 10 years were:

- Extreme weather events with major damage to infrastructure and loss of life.
- The failure of climate-change mitigation and adaptation measures by governments and businesses.
- Major environmental disasters resulting from criminal behavior or negligence, including e.g. oil spills and radioactive contamination.
- Major biodiversity losses and irreversible ecosystem collapse.
- Major natural disasters, including earthquakes and tsunamis.

Other risks included the slowing rate of global growth, the combination of high levels of debt with tightening financial conditions; the increasing tension between the globalization of the world economy and growing nationalism (which may make it harder to deal with global challenges), technology risks (including cyber-fraud, fake news, identity theft, loss of privacy and cyber-attacks on critical infrastructure), increasing concerns about the way that complex social, economic and technological transformations impact on people's lives, the associated sense of loss of control, and the implications for social cohesion and politics, and biological threats (including epidemics caused by natural or weaponized pathogens).

The implications of global risks for urban development

The WEF report noted that several of these global risks could be compounded and would then impact significantly on urban development. For example, about 800 million people live today in some 570 coastal cities that will be vulnerable to a sea-level rise of 0.5 meters by 2050, and the number and size of these vulnerable cities will increase with further urbanization which means that many more people will then be affected by extreme weather events and rising sea levels. This alone calls for a radical change in the planning and construction of cities, as the current pattern of urbanization is concentrating more people and property into some of the most vulnerable areas. The current pattern of urban development usually compounds these risks further by destroying coastal mangroves, draining wetlands, felling forests and increasing the strain on groundwater reserves, all of which decrease urban resilience and make cities increasingly vulnerable to flash flooding and the associated consequences, including damaged infrastructure and contaminated water supplies.

At a global level, the WEF report concluded that it is likely that intensifying impacts will render an increasing amount of land uninhabitable before 2050, which will force mass migration from the affected areas.

There are several possible strategies for survival. With regard to rising sea levels, for example, existing cities have three possible strategies:

- Engineering projects, such as berms and barriers to keep water out.
- Nature-based defences, such as the development of wetlands and water meadows to absorb storm water.
- Social strategies, including zoning developments out of the most vulnerable areas and gradually moving households and businesses to safer ground, and investing in social capital to make the most flood-risk communities more resilient.

The best strategy for new cities is to not build in vulnerable areas, but also to incorporate some of the above measures anyway to allow for the possibility of even more extreme conditions later in the century.

The implications of technological change for urban development

Technological development in key areas such as food, automation and transport will change the pattern of urban development. As the examples below suggest, technological change over the period is likely to have radical implications for the form and nature of cities in future.

Cities and the future of food

The UNEP report cited earlier assumed that there could be a trade-off between urban development and agricultural production, especially if new cities are built on land that has good agricultural potential. There is an important question, therefore, as to whether technological change could alter the significance of this problem.

Shapiro (2018) notes that agriculture is about to undergo profound disruption and radical transformation[x]. One of the key disruptive technologies is cellular agriculture, which involves taking cells from a single animal, usually in a small biopsy of muscle or liver, then culturing them in a nutritional solution of glucose, amino acids, minerals and growth factors. The cells can then be stimulated with electrical impulses until they form muscle fibers.

The main obstacle to scaling-up production, at present, is the need to reduce the cost of the nutrients and growth factors. Once these issues are resolved, it will be possible to produce high-quality fish, beef, chicken or other meats in bioreactors on a large scale. This will be significantly more resource-efficient and safer than conventional meat production. Tuomisto and Teixeira de Mattos (2011) estimated that cultured meat requires 7–45% less energy, 99% less land, 82-96% less water and causes 78–96% fewer greenhouse gas emissions than conventionally produced meat[xi].

Another disruptive technology is 'ferming'; using fermentation to rapidly multiply particular micro-organisms to make food products. This does not involve cells taken from animals, but bacteria. The goal is to modify these to produce carbohydrates, or the specific proteins needed to make meat or milk, or edible oils and long-chain omega-3 fatty acids. If successful, this would require just 0.005% of the land currently needed for the equivalent output of protein from conventional agriculture.

Either of these technologies would eliminate the production of methane (farm animals are a major source), deforestation (ranching is a major driver of deforestation), nitrate, phosphate and pesticide contamination, reduce the rate of soil erosion and eliminate the transmission of diseases such as BSE, TB and avian flu from animals to humans. The food is likely to be healthier, as it would not contain pesticide or hormone residue, most allergens and also saturated fats.

Livestock production currently requires about 80% of the world's agricultural land (including grazing and feed crops), so the replacement of extensive farming by cellular farming will allow most of the world's agricultural land to be converted for other purposes. This would allow rewilding and restoration of biodiversity, while reafforestation would draw down large quantities of carbon from the atmosphere. Cities could grow their own food, and surround themselves with forests and parks while still maintaining a high level of food security.

Current projections suggest that the cellular industry will scale up to commercial production by about 2025, and displace a significant part of conventional meat production by about 2030, while proteins from precision fermentation are projected to be the cheapest available by about 2025, and around 10 times cheaper than animal protein by 2035 (Monbiot, 2020)[xii]. This will result in the demise of most of the livestock industry and other forms of conventional agriculture, and remove the need for farm subsidies (the current world total of farm subsidies is about US$600bn).

Much of the immediate disruption and transformation of agriculture is expected to become apparent in the period 2025 – 2035. This particular concern, therefore, is likely to reduce over time, which would mean that it would then no longer be necessary to preclude the development of cities on land that is currently designated for conventional agriculture. This in turn means that city boundary restrictions could be relaxed in future with regard to agricultural land, although it is important to note that this land would then be needed for environmental restoration and development to increase urban resilience (such as the wetlands and forests mentioned earlier).

Automation[xiii]

For most of the last 10,000 years, most of humanity has worked in agriculture, because relatively low productivity meant that it was impossible to generate a sufficient surplus to support a large number of people in other sectors. A large modern economy such as the USA, however, now has less than 0.5% of its workforce in agriculture. Mechanization has replaced labour, which has generated enormous agricultural surpluses, allowed almost the entire workforce to migrate from the land into other forms of employment, and thereby created a vast amount of additional wealth.

To date, the process of innovation and technological development has created far more jobs than it has destroyed. There is no fixed amount of labour in any economy, as people have always found new ways to add value, and create goods and services for which there is a demand.

What is changing, however, is the speed of change itself. The automation of primary industries such as agriculture happened over many generations, the automation of secondary industry happened within one or two generations, and neither process is yet complete. However, the next wave of automation could replace most existing jobs within just one or two decades. The McKinsey Global Institute estimates that artificial intelligence is now driving a transformation of social and economic systems that is “happening ten times faster and at 300 times the scale, or roughly 3,000 times the impact” of the first Industrial Revolution [xiv].

In previous waves of technological change, jobs were created in new sectors of the economy at a pace that could absorb much of the labour that was being displaced. The next wave will be too swift to allow an easy transition for much of the current workforce[xv]. As many formerly middle-class jobs have become unnecessary in the post-industrial societies, many of the people that used to hold those jobs did not move into more highly skilled jobs, but shifted into lower-paid work, mainly because they did not have the training to make the transition to a job at the same rate of pay[xvi]. This suggests that there is a rapid change happening in terms of the kind of skills that people need, and that the education system is lagging behind the trend and failing to give people the skills sets and adaptability that are now required. Demand is growing for highly skilled, highly educated workers, but declining for those with low to moderate levels of education, which means that these people are more likely to be displaced downwards or out of the formal economy entirely[xvii]. For many people, the future will involve doing work that is more interesting and fulfilling than today, using machines to enhance and extend their skills[xviii] [xix], but for those that are not well-placed to make this transition, the future may look bleak. For many societies, it may become necessary to develop new forms of economic activity with equally unprecedented speed – or else face the risk of rising unemployment, rapidly increasing inequality and potentially serious social dislocation and civil unrest[xx].

This problem is likely to be compounded by the fact that while many people expect that the future will involve far more automation than today, relatively few expect it to replace their jobs. A report by the Pew Research Center (2016) found that most Americans expect significant levels of workforce and job automation to occur over the next 50 years, but that most of today's workers did not think that their own jobs or occupations would be affected; 36% of workers anticipated that their current jobs or occupations would 'definitely' exist in their current forms five decades from now, while an further 44% expected that their jobs would 'probably' exist in 50 years[xxi]. This means that this group is unlikely to make the necessary investment in retraining.

Automation could now rapidly replace most remaining routine tasks, while the next wave of development will see AI systems replace many skilled processes, even in areas such as medicine, law and finance. This is being driven by the 'Fourth Industrial Revolution', which involves the integration of previously separate fields such as artificial intelligence, robotics, nanotechnology, 3D printing, genetics and biotechnology. This is likely to destroy 'old' jobs with unprecedented speed. Frey and Osborne (2013) suggested that almost half of the current jobs in the USA could now be automated[xxii]. Additive manufacturing could replace factories, construction workers and architects[xxiii] [xxiv]. Online courses could allow universities to operate with far fewer teaching staff, while online services could allow governments to operate with a much smaller civil service. Many low-paid jobs will be vulnerable; as the former CEO of McDonald's pointed out recently, it is now 'cheaper to buy a $35,000 robotic arm than it is to hire an employee who's inefficient making $15 an hour bagging French fries[xxv].' The cost savings will be dramatic. The Bank of America Merrill Lynch predicts that by 2025 the annual savings from the replacement of employees by artificial intelligence will reach US$9 trillion, with an additional cost reduction of US$8 trillion from efficiency gains in manufacturing and health care, and a further US$2 trillion in efficiency gains from the deployment of self-driving cars and drones[xxvi].

Most of the studies in this area assume that repetitive, manual tasks will be the first to be replaced. However, the greatest economic return is by replacing skilled tasks, of the sort that normally require extensive training. Genetic algorithms used for medical diagnosis are now 'as capable of diagnosing diseases as accurately as an experienced paediatrician' (The Lancet, Vol. 1 May 2019)[xxvii], and algorithmic systems can deliver 'a range of benefits, such as efficiency, efficacy, auditability, and consistency' in legal and paralegal services (The Law Society, 4 June 2019).[xxviii]

A recent Millennium Project report suggests that by 2050, of the 6 billion people who will then be in the workforce, just 1 billion will be in a job that exists today, and that elite professionals will use AI to effectively augment their intelligence so they can carry out knowledge-specific tasks (The Millennium Project Team, 2019[xxix], and as reported in the Financial Times, 4 November 2019)[xxx]. Most of them will be working in the gig economy, as freelancers, working from home on multiple projects with many different teams and companies. This will increase the importance of collaborative working and professional networks. It will also flatten the traditional hierarchies in organizations, as most of the people doing high-value work in the economy will no longer have a designated boss or supervisor. Traditional ideas of promotion will also disappear, as status and reward will be determined by the strength of the influence that people have in their networks, not by progress up an increasingly slender management chain.

As middle management roles disappear, much of the middle class will have to make a difficult transition. Some will migrate successfully into the people-oriented, skills-based networked economy, but many will fall back into less well-paid jobs. The employees most likely to succeed will be those who are flexible, adaptable and creative, and who can work well in a more diverse organization with a flatter structure.

An alternative future scenario is much more dystopian. With the loss of any real challenge to capitalism, such as socialism or strong unions, society will become increasingly unequal. Wealth will be accumulated by moving it offshore and concealing it in tax-free trusts, allowing it to become far more concentrated. Workers will be replaced, wherever possible, by automated systems, and the cost of any remaining welfare provision for those displaced will be borne by a diminishing tax base. This scenario is far more likely to lead to conflict.

Developing countries will be profoundly affected. For example, over half of all jobs in Angola, Mauritius, South Africa and Nigeria, up to 85% of all jobs in Ethiopia and almost 90% of the 400 million jobs in low-income countries could be now be automated[xxxi] [xxxii]. This means that the traditional path to growth (which involved moving workers from agriculture to more productive jobs in factories) may not be available to today's low-income countries.

In order to avoid the most dysfunctional scenario, it is important to make a much stronger commitment to human capital development, as skilled jobs are less susceptible to automation, but this requires a coherent strategy for change; there is no point in investing in skills in an area that is about to become redundant. In general, jobs that require originality, social and creative intelligence, perception of irregular spaces and manipulation are very difficult to automate and are therefore at low risk of replacement in the near future. These areas do not, however, provide the kind of mass employment opportunity that can create livelihoods for millions of people.

The profound challenge, therefore, is to identify new growth areas, to develop the research, education and training programs needed to prepare an entire generation for new modes and models of work, and to create environments that will attract an increasingly mobile, skills-based, networked workforce.

If the world fails to find viable and economically attractive solutions, then the likely outcome is extreme polarization between a small global elite and an increasingly disadvantaged underclass, with a corresponding increase in the risk of civil unrest, crime and terrorism.

Transport

A number of firms are developing driverless vehicles, and a range of countries (including the UK and various states in the USA; California, Florida, Michigan and Utah) have started the process of legalizing their use on the roads. This has revolutionary implications for road transport; it will make it much cheaper, safer and more reliable. At present, about 75% of the cost of shipping goods by road across the USA is the cost of the labour involved, so eliminating the workforce will reduce the cost by the same percentage. In addition, driverless trucks can work for 24 hours per day, while drivers in the USA are restricted by law from driving more than 11 hours per day (9 hours in the UK). This means that the shift to driverless trucks would double the capacity of the US road network while reducing the cost per load by 75%, giving an eight-fold improvement in the price-performance of ground transportation networks[xxxiii] [xxxiv] [xxxv]. Automated vehicles are also much more fuel efficient (as they can be programmed to run at optimal cruising speed). Similarly substantial savings will be made in other regions, such as Europe, where over three-quarters of all shipped goods are transported by road.

Autonomous transport will also be safer. At present, about 1.25 million people die in road accidents each year, with an additional 20-50 million injured or disabled. The total economic cost is US$518bn per year, about 1-2% of the GDP of most countries, and the cost of road accidents to low and middle-income countries is US$65bn annually (which exceeds the total amount that these countries receive in development assistance). Most of these accidents are the result of human error, so many of those lives could be saved, and the associated economic cost largely eliminated.

Autonomous vehicles could also reduce traffic congestion, which causes accidents, costly delays and air pollution. This problem is rapidly worsening; from 2010 to 2016 congestion rose in in New York by 30% and in Los Angeles by 36%. However, autonomous vehicles, including robo-taxis, autonomous shuttles, and autonomous buses can use AI to reroute and time journeys, and can also coordinate with rail transit timetables. A study by McKinsey (2019) estimated that this model of 'seamless mobility' could allow most cities to accommodate up to 30% more traffic while reducing average travel time by 10%[xxxvi], to give a total global saving of 1 billion hours per day as a result[xxxvii]. McKinsey therefore predict that by 2030, up to 80% of miles driven in the USA will be by autonomous vehicles.

Shipping represents a significant part of the cost of all consumer goods, so an eight-fold improvement in the price-performance of ground transportation means that consumers everywhere will see prices fall significantly and their standard of living rise commensurately. McKinsey estimate that if the United States fully adopted autonomous vehicles, the benefit would exceed $800bn a year by 2030.

The impact on employment, however, will be equally dramatic. About 1.6 million people in the USA work as truck drivers, which is about 1% of the workforce, and most of them would then become redundant, along with many of the jobs in support activities such as local deliveries, gas stations, diners and motels; a total of nearly 9 million people in the USA who would lose their current jobs[xxxviii].

Another defining future trend is that it will no longer be necessary to own a physical device to obtain a particular service. For example, Airbnb has become the world's largest hotel chain without ever owning a single hotel room[xxxix], while the transition to driverless cars will eliminate the need for both public transport and private car ownership. When ownership is decoupled from service, the intensity of use is typically higher, significantly improving efficiency. At present, most cars in the USA are parked for 95% of the time[xl], representing a very inefficient commitment of capital, but removal of the need for ownership could almost reverse that ratio. These innovations will generate extraordinary efficiency gains, but will also make car salesmen, driving instructors, car insurance salesmen, car park attendants, traffic police and many other associated jobs unnecessary.

The road to 2050

The previous section suggested that new industries and technologies will restructure most economies by 2050, which means that a number of existing sectors and occupations will have largely disappeared by then, at least in anything resembling their current form. This section examines the implications of some of these changes for a selection of key sectors.

Energy

Key change: the transition to renewable and low-carbon sources[xli], [xlii], [xliii],[xliv], [xlv],[xlvi],[xlvii]

A number of emerging trends are likely to transform the current system of electricity generation and distribution. The FAO reported in March 2021 that the incidence of climate change-related disasters has tripled over the last four decades, resulting in events such as the mega-fires in California, Canada, Siberia and Australia and the floods in Europe and China; this will eventually spur more effective government action to rapidly decarbonize the economy[xlviii]. The International Energy Agency stated in the World Energy Outlook 2020 that solar-produced electricity has fallen dramatically in price, it is already 20-50% cheaper than in 2019, which means that it is now the 'cheapest electricity in history'[xlix]. The development of perovskite solar cells, which promise to be both cheaper and more efficient than silicon, will bring substantial further cost reductions. Net Zero and Energy-Plus buildings could eventually make cities net exporters of power. The one-to-many grid model will be replaced by a many-to-many model, with the grid becoming a dynamic market place in which many people buy power when they need it and sell a surplus when they have it. The transition to electric vehicles will give every country additional storage capacity, with vehicles charging themselves when prices are low and retailing power when demand rises. These technological changes will allow even small island nations to separate electricity generation, transmission and distribution, and the grid may eventually consist of a number of interconnected microgrids, as this distributed model will give increased resilience and support the integration of diverse renewable energy resources.

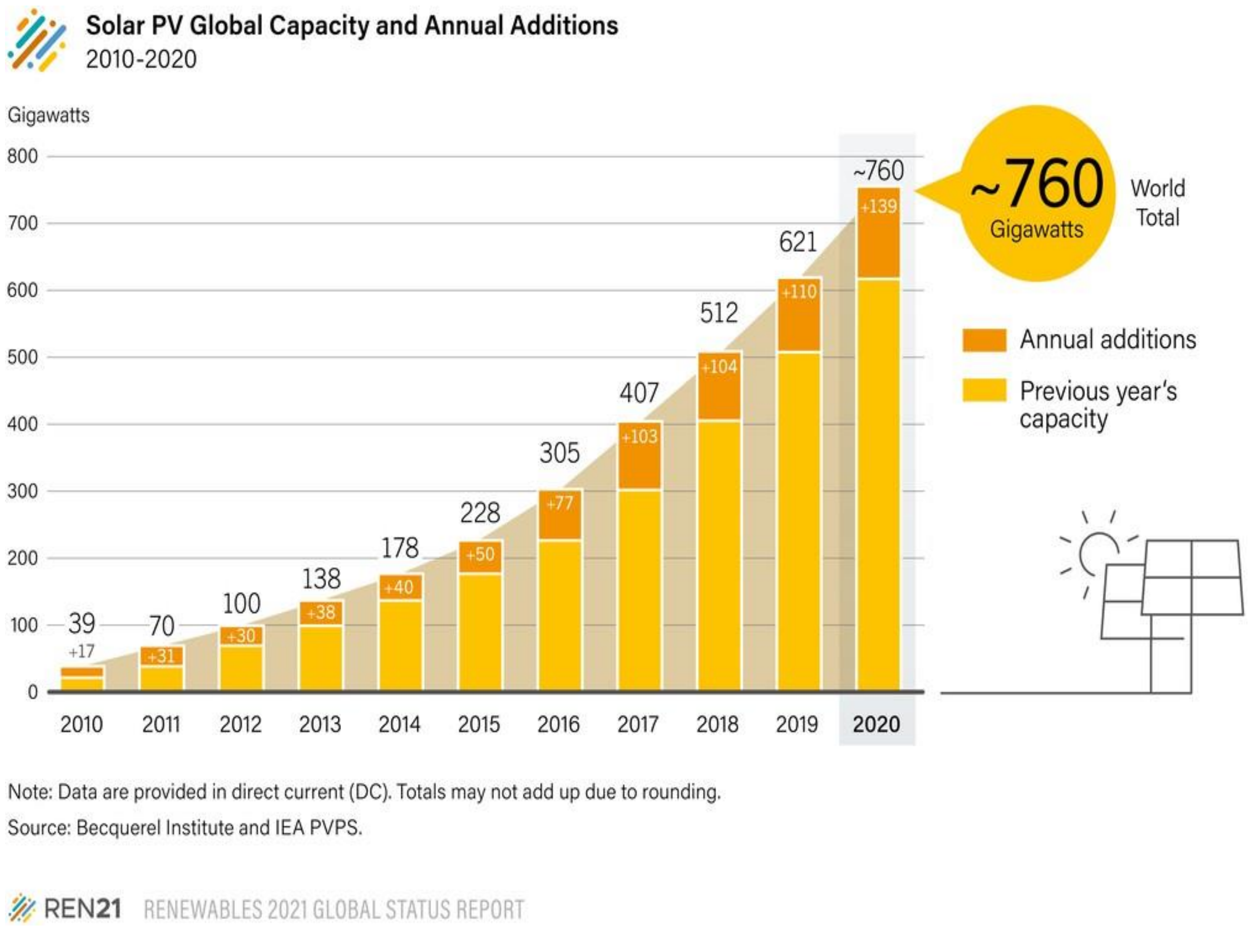
Drivers:

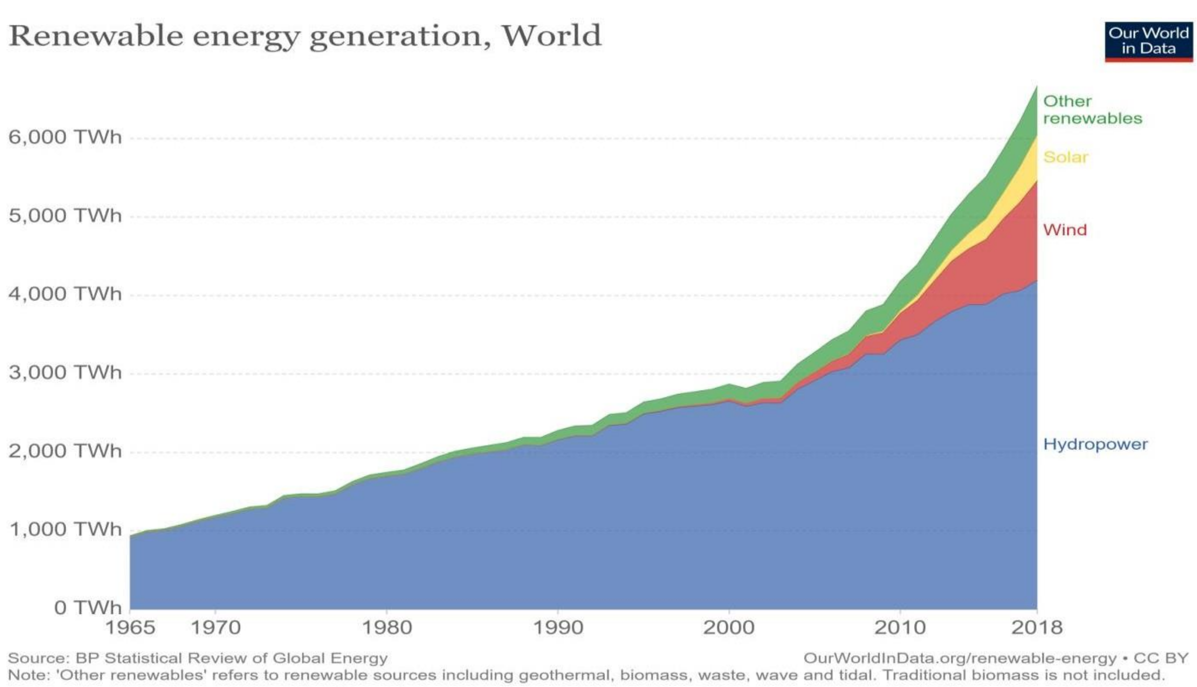
- The need to decarbonize the world economy.
- Renewables are price-competitive. It is now about 50% cheaper to generate electricity from renewables compared with fossil fuel plants[l].
- Fossil fuels are no longer competitive when environmental costs and subsidies are included.
- About two-thirds of the energy from fossil fuels is wasted, lost in mining, drilling, burning, converting, transmitting, using and waste disposal. Renewables involve no extraction, no combustion, fewer conversions, and so have lower losses.

The situation today:

- Nearly 20% of the energy used globally for heating, power and transportation is from renewables.
- Over 26% of global electricity generation is from renewables.
- Renewables could contribute almost 50% of global electricity generation by 2040, mostly from hydropower, wind and solar; see illustration 1 below.
- With sufficient policy push, renewables will be the largest source of power by 2050, mostly from hydropower, wind and solar. Solar is growing particularly rapidly; see illustration 1 below. Changes in government policies could significantly shorten the time to transition. The most important change would be removing the subsidies for fossil fuels, currently over US$300 billion/year.

Illustration 1: The transition to renewables[li]:





Current constraints:

- The intermittent nature of some sources means that energy storage is necessary, this tends to be expensive. However, advances in energy storage technology, the generation and export of power from sparsely-populated areas and the interconnection of grids will solve this problem.
- Transport (32% of world energy use) is still largely based on fossil fuels. Resolving this will require large-scale electrification of transport systems (which will be a component of the transition to autonomous vehicles; electric motors have few moving parts, higher efficiency and lower maintenance).
- The subsidies to fossil fuels and off-book environmental costs appear to make renewables uncompetitive. This can only be resolved by government policy changes.

Construction

Key change: Net Zero and Energy Plus Buildings[lii],[liii],[liv],[lv],[lvi],[lvii]

Net Zero buildings are designed to maximize energy efficiency, using orientation and insulation to minimize unwanted heat gain or heat loss, maximizing the use of sunlight for lighting, natural ventilation for cooling, and using energy-efficient appliances to reduce the need for air conditioning (see illustration 2 below). They use photovoltaics, biomass or other renewable energy source to meet demand. As the examples below demonstrate, buildings can now achieve Energy Plus status, where they export power. Buildings account for 25% of world power demand, so improvements in efficiency would substantially reduce the demand for energy. If buildings like this became standard, many power stations would become redundant.

Current constraints: It takes many decades for a country's entire building stock to be replaced (over 90 years in the UK), so it is important to upgrade existing buildings as well. In the EU, 75% of the building stock is energy inefficient, but only 0.4-1.2% (depending on the country) is renovated each year. Retrofit will therefore be slow, achieve less, and the investment may make it less likely that the building will be replaced. A transition to fabricated buildings would largely solve this problem.

The EU and UK are now both committed to achieving net zero carbon emissions by 2050. Buildings are the single largest energy consumer in Europe, accounting for 40% of energy consumption and 36% of CO_2 emissions. This means that the carbon target can only be achieved by going to Net Zero/Energy Plus buildings.

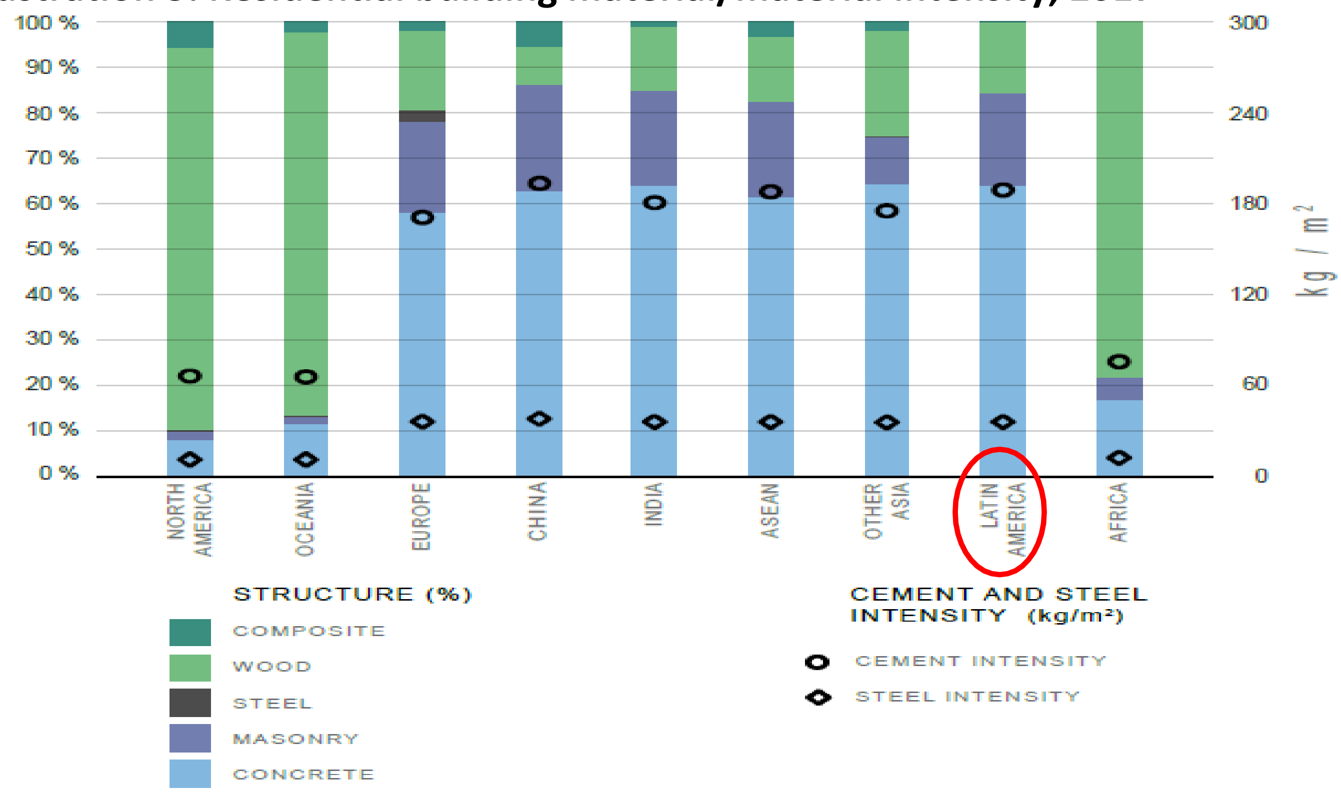
Illustration 2: The first net-zero energy building in the Caribbean

This building, on the Mona Campus of the University of the West Indies, is very energy efficient and has a solar roof. It generates more power than it consumes.

Building materials

The most commonly used material in construction is concrete; a mixture of cement, water and selected aggregates to produce a form of artificial stone. Cement is manufactured by heating a mixture of ground limestone, clay and sand in a kiln to temperatures of 1,450ºC, which is an energy-intensive process. Most construction today is based on cement and steel, and each of these industries contributes about 8% of world carbon emissions. Combined, these two industries are second only to the fossil fuel industry as the world's largest source of carbon emissions. The prevalent building type in Latin America and the Caribbean is largely dependent on concrete and steel for construction (see illustration 3), with a high thermal mass, and few are designed to minimize unwanted heat gain or to utilize passive cooling solutions. This means that they require constant cooling in order to remain at a tolerable internal temperature.

Illustration 3: Residential building material/material intensity, 2017[lviii]



Marginal reduction in CO_2 emissions is possible with increased energy efficiency, alternative fuels and clinker substitutes in the manufacture of cement. The greatest gains would be had with the use of carbon capture, use and storage; carbon-cured concrete and 3-D printing[lix]. Prefab and modular housing, with off-site production, also allows a more efficient use of cement. For example, according to the UK-based Waste and Resources Action Programme, the offsite construction of a modular building consumes 67% less energy compared to traditional on-site building work[lx]. Globally, modular construction was valued at USD 112.3 billion in 2018 and is expected to register a CAGR of 6.5% by 2025[lxi]. However, the combined gains to date are still far too marginal to achieve decarbonization goals.

It is therefore important to develop new construction materials and new models of building form and use which will have lower levels of embodied carbon, and give lower carbon emissions in operation. There are a range of possible candidates, including cross-laminated timber, which has the structural strength of steel, resists warping, allows buildings to be rapidly assembled from prefabricated sections and gives sufficient flexibility to allow the building to withstand an earthquake or hurricane[1]; bamboo strand lumber[2], plywood or laminates, which have high density and tensile strength, and are water and weather-resistant; and eco-composites, natural fibres in a biological matrix derived from plant starches or tree resins.

The use of engineered timber, bamboo and eco-composites would also offer completely new prospects for local agriculture. There is an immense potential market for such industrial crops, many of which could be advantageously produced and processed in tropical and sub-tropical regions. This would allow farmers to expand beyond their traditional role at the base of the food industry and evolve into key suppliers in a larger industrial complex producing building materials.

[1] Cross-laminated timber consists of pieces of softwood laminated together to become a larger structure, glued together in opposing directions to give extra strength. It is becoming popular as a result of its strength, durability and speed of construction [Cross-Laminated Timber - Status and Research Needs in Europe, 2016, Espinoza, Trujillo, Mallo and Buehlmann]. [Cross Laminated Timber Market Size, Share & Trends Analysis Report]

[2] Bamboo too is already being used in construction (Nogueira 2008) [Structural performance analysis of cross-laminated timber-bamboo (CLTB)]

> "If 10 percent of cement was replaced with CLT, carbon emissions would be reduced by up to 750 million tons each year (about 2 percent of global emissions). Regarding bamboo, an abundant natural resource in LAC - its structural properties and strength/density and stiffness/density ratios, its physical, chemical and mechanical characteristics indicate values that exceed wood and concrete, and in this aspect, it can be compared to steel" (Janssen 2000).

Fully decarbonizing the built environment will require developing concept and prototypes for buildings with highly efficient modes of construction and use that can be embedded in planning and building codes so that new solutions can be rapidly absorbed into the mainstream, amending legislation and regulation to mainstream and lock in these gains, and by reforming planning frameworks to ensure that future developments specify buildings with high energy and cooling efficiency.

Manufacturing and construction

Key change: Fabricators[lxii], [lxiii], [lxiv], [lxv], [lxvi], [lxvii], [lxviii], [lxix], [lxx], [lxxi], [lxxii], [lxxiii], [lxxiv]

Drivers:

- Many manufactured goods can now be made more cheaply and with less waste by 3D printers.
- Fabricators eliminate the need for tooling; it is now possible to go directly from design to manufacture. Designs can be downloaded, allowing for globally distributed manufacturing.
- Fabricators can make everything from micro-scale (e.g. precision medical implants) to the very large (e.g. entire ships and buildings).
- Modern fabricators can support a wide range of materials, including plastics, resins, ceramics, cement, glass, metals and metal alloys, rubber, pharmaceutical chemicals, both stable and dissolving gels, and thermoplastic composites infused with carbon

nanotubes and fibers. This allows the manufacture of a very wide range of products, including electronics, pharmaceuticals, engines and other complex multi-material components with many moving parts.

- The transition to fabricators will eliminate the competitive advantages currently held by countries with large, low-cost workforces.
- Fabricators can be used in all settings, from homes to factories. Domestic fabricators today are as easy to operate and refill as printers, and can be used for repairs, to replace small broken components and so on, with the costs now lower than the cost of purchase The most likely model, however, is localized facilities that would allow adjacent homes and business to send designs for manufacture.
- Semi-autonomous fabricators connected to the Internet of Things will be able to detect when components fail and automatically manufacture replacement parts.

Illustration 4: A 3D-printed heat exchanger[lxxv]

Fabricators allow buildings to be constructed quickly, accurately, cheaply and to a very high quality, and also to utilize waste materials as aggregate in the structures. This are compelling advantages, and the global 3D printing construction market size is projected to expand at a compound annual growth rate of 91.5% from 2021 to 2028[lxxvi].

Illustration 5: 3D-printed houses[lxxvii]

Implications for urban design: Fabricator centres will allow the localization of production; urban residents will be able to manufacture many products that currently have to be imported. Future cities will also be able to add or demolish and replace buildings quickly, cheaply and to a very high quality, without needing a large workforce. The key is therefore to ensure that future cities include fabricator centres and ICT systems to support the development, utilization and export of designs and manufactures.

The circular economy

Key change: Transition from the current linear economic model to a circular model, built on closed loops in which raw materials, components and products are continuously recovered and reused, and powered by renewable energy.[lxxviii], [lxxix],[lxxx],[lxxxi],[lxxxii],[lxxxiii]

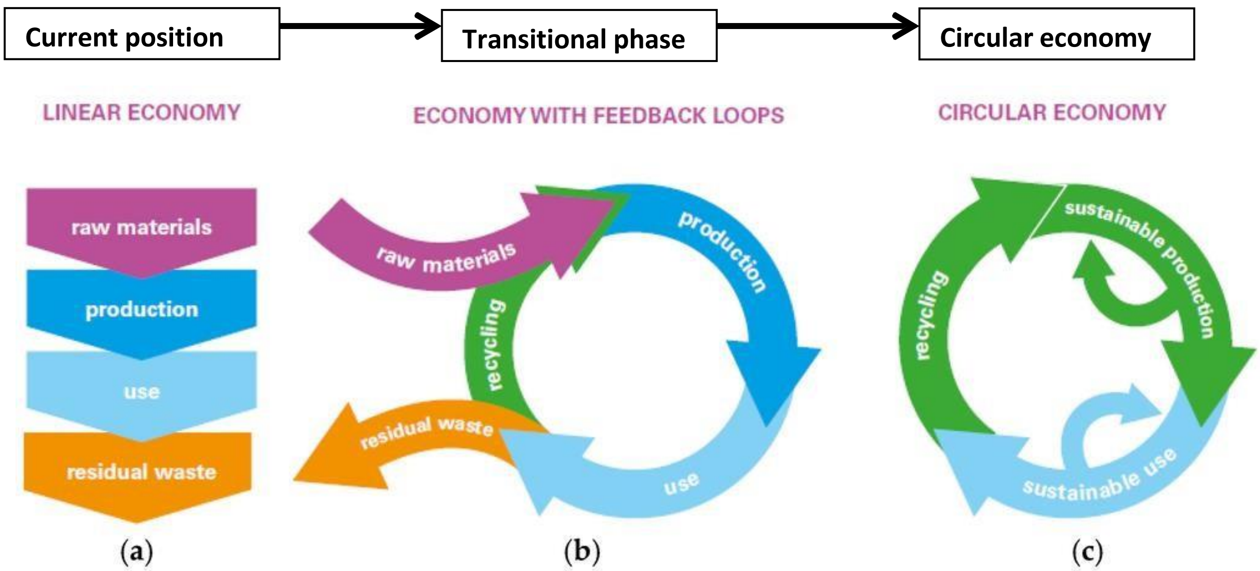
Drivers:

- Elimination of losses from material exiting the economy
- Elimination of wastes and waste disposal costs
- Substantial reduction in environmental impacts
- Reduced dependence on imported materials and energy
- Improved balance of payments
- Generation of local employment

Levels:

1. Refuse: preventing the use of raw materials.
2. Reduce: reducing the use of raw materials.
3. Reuse: product reuse (second-hand, sharing of products).
4. Repair: maintenance and repair.
5. Refurbish: refurbishing a product.
6. Remanufacture: creating new products from (parts of) old products.
7. Repurpose: product reuse for a different purpose.
8. Recycle: processing and reuse of materials.
9. Recover energy: incineration of residual flows.

Illustration 6: Transition to circular economy[lxxxiv]



The transition to a circular economy requires leadership from the private sector, technology, capital and political support, including legislation and regulation.

For example, the EU's current targets are that 70% of packaging waste should be recycled by 2030, and 65% of municipal waste should be recycled by 2035, with no more than 10% to go to landfill, while the Dutch plan is to achieve a fully circular economy by 2050.

Implications for urban design: Cities should be planned from the outset to move towards a fully circular economy as business and technological options become available. Businesses should be encouraged to operate on a net zero waste basis, with industrial symbiosis systems used to link flows of discarded materials with potential users.

Health and pandemic-resilience

Why pandemics could be more common in future

About 60% of all known human infectious diseases are zoonotic (diseases caused by pathogens that spread from animals to humans) (WHO, 2014)[lxxxv], (CDC, 2017)[lxxxvi]. The rate of outbreaks of new zoonotic diseases is increasing rapidly; 75% of the infectious diseases that have emerged in the past three decades are zoonotic (Smith et al, 2014)[lxxxvii]. The reasons for this include forestry, agriculture and mining in developing countries; these open up remote regions and exterminate the larger species, which allows smaller and more adaptable species such as rats and bats to flourish, and it is these species that carry the most pathogens. The populations of animals hosting zoonotic diseases are about 2.5 times higher in environmentally-degraded places (Carrington, 2020)[lxxxviii].

Bushmeat is another major source of infection. Animals such as gorillas, chimpanzees, squirrels, mongooses, bats, rodents and marsupials are hunted for food, mainly in parts of Africa, Asia and South America; somewhere between 1 and 5 million tonnes of bushmeat per year is eaten in West and Central Africa. This is probably how Ebola virus, HIV and the SARS-CoV-2 coronavirus were passed from animals to humans.

Wet markets (where live animals are sold and butchered) are another major disease vector; the wet market in Wuhan was the ground zero of the Covid-19 pandemic, and wet markets are common in west and central Africa.

These problems are compounded by urbanization and population growth, with about a billion people now living in informal settlements without proper sanitation, and by mass international travel, which allows an emerging virus to spread rapidly around the world. It is probable, therefore, that there will be more frequent outbreaks of zoonotic infectious diseases in future.

The scientific capacity to respond to pandemics has improved tremendously, but the chaotic situation caused by the Covid-19 outbreak in the USA, UK, Brazil and other countries indicates the harm that can be done by a weak policy response. It is therefore important not to rely on a policy response, and to consider ways that measures to limit the impact of pandemics can be incorporated into physical infrastructure.

Cities have responded to past pandemics by changing their physical structure. For example, the bubonic plague, which killed one-third of Europe's population in the 14th century, resulted in the urban improvements of the Renaissance. Cities cleared slum areas, opened larger public spaces and built more spacious settlements outside of the former city walls (Waller and Chakrabarti, 2020)[lxxxix]. Now that we are in an era of more frequent pandemics, however, it is important to ensure that future cities are designed on a preventative basis to ensure that they remain safe and habitable (Constable, 2020)[xc].

Making future cities pandemic-resistant

Densely populated cities with busy international transport hubs, crowded public transport systems, informal settlements and many venues for social gatherings offer an ideal environment for the rapid transmission of a droplet-borne virus. Some of these problems are baked in to the current infrastructure. For example, the roads prioritize motorized traffic over pedestrians and cyclists, making it much harder for people to choose alternatives to public transport (WEF, 2020)[xci].

It is therefore important that future cities are designed to mitigate the risks of pandemics. One possible response would be de-densification and disaggregation, to disperse the urban population over a much wider area, but there are two problems with this approach (Shenker, 2020)[xcii]. First, there wasn't a strong relationship between density and disease transmission in the Covid-19 pandemic; this was less significant than other factors (Holland, 2020)[xciii]

Secondly, this would conflict with the need to increase urban density in order to reduce environmental impact and increase the efficiency of energy, waste heat recovery, water, transport, waste recycling and other urban life-support systems (Leung, 2016)[xciv].

The optimal strategy, therefore, is to incorporate pre-emptive measures in city planning and building controls.

- Cities should be designed around multiple cores rather than a single core. For example, the 'twenty minute city' concept developed in Australia ensures that each core has work, exercise, recreation and shopping opportunities within twenty minutes walking distance. This minimizes the need for commuting on public transport systems.

- This approach could be supplemented by encouraging the rehabilitation of any adjacent towns into satellites to reduce the pressure on the urban hub (Moore, 2020)[xcv] and thereby allow for gradual de-densification while still retaining the advantages of the urban concentration. The satellite towns could be incorporated into a multi-core model by dispersing business, retail and work opportunities.
- City plans should also ensure that there are options to avoid crowded public transport (Connolly et al 2020)[xcvi]. This would include, for example, pedestrian and cycle ways (which also help to maintain health during a lockdown) (Halliday et al, 2020[xcvii], Rannard, 2020)[xcviii], which would require encouraging offices and businesses to include bicycle storage space to permit cycling, and having a low speed limit inside the city where vehicle and cycle ways must intersect. The city can also maintain high urban air quality by accelerating the move to electric vehicles and other low-carbon modes of transport (Factor CO^2, 2020), and by maintaining a healthy tree population in the city, with urban parks and orchards, street trees and green corridors (Smith, 2020)[xcix].
- Future cities could limit the density of socialization in a non-coercive way by ensuring a larger number of more diverse opportunities for socializing, moving to flexible working to extend the day and allow better time management; and ensuring there are options to avoid crowding, such as large parks, broad avenues and wide pavements to allow distancing (Stokes, 2020)[c].
- Cities should also specify that street furniture must allow distancing (e.g. benches and shelters with Plexiglas dividers), that large buildings have multiple lifts and staircases to reduce the density of use, and that building furniture in public spaces should be designed to reduce the number of hand-contacts (e.g. automatic doors and elbow-operated door handles).
- City plans should discourage the construction of office districts, with fixed, immobile single-purpose structures, as these are largely vacant during lockdowns (Wakefield, 2020)[ci]. Instead, city plans should encourage the development of adaptable and flexible

offices to allow for a combination of remote and in-office working, and ensure that there are some modular buildings that can allow for rapid changes of use[3].

- This approach can be supplemented by ensuring that houses are designed to function as combined homes, schoolrooms and work-places, so that online work and schooling can continue during lockdowns), and discouraging the development of high-density developments with small apartments, as these become less tolerable during a lockdown.
- Cities should ensure excellent ICT infrastructure to allow telecommuting (Hughes, 2020)[cii], as well as urban simulation platforms (Allen, 2020)[ciii], data mapping, contact-tracing and analysis of infection vectors, linking e.g. smart phones with city sensors (Klaus, 2020)[civ]. The city management systems should include sensors in sewers to detect pathogens and sensors in public places (e.g. automatic temperature readers in door frames in public places). This combination will allow the immediate identification and tracing of possible disease carriers and their contacts.
- Cities should be designed on the basis of a closed-loop economy for physical materials, with near self-sufficiency in food and water to allow an immediate shut-down of trade and travel in an emergency. City plans should therefore encourage vertical forests (where buildings are designed to support dense vegetation) and vertical agriculture, the use of recycled materials for construction, and passive design to improve energy efficiency (Zhang, 2020)[cv]
- Cities must also ensure reliable, high-quality water and sanitation, including rainwater harvesting and water storage capacity to ensure continuity of water supplies, and install hand-washing stations throughout the city.

[3] For example, the Nightingale Hospital in London was converted from an exhibition centre in just nine days to accommodate 4,000 patients. The space and capability to create rapid, temporary structures to absorb surges in cases requiring hospitalization is an important component of pandemic preparation.

- Cities should deploy social interventions to maintain relatively low levels of inequality, as high inequality is associated with poor-quality informal settlements and riskier behaviour.

Some of these improvements could be retro-fitted to existing urban areas, and so can be extended to any existing towns that become satellites of the Next City. For example, Freiburg, in Germany, is 900 years old, but has re-invented itself to become one of the world's most attractive and sustainable small cities (Barber, 2020)[cvi].

The digital economy and society

Key change: Transition to distributed working, education and governance[cvii,cviii,cix,cx,cxi,cxii,cxiii]

Background:

As the Covid-19 pandemic spread in early 2020, government restrictions in many countries forced all non-essential occupations to work from home. Before then, teleworking was not common. For example, about 11% of the workforce in Germany, 8% in Italy and 5% in the USA occasionally worked remotely, probably less than 1% in Jamaica. As a result of the pandemic, however, most countries moved government and corporate meetings online; school and university classes were taught virtually; and physicians consulted via social media platforms. In the USA, for example, teleworking has risen from 5% to 35-50% of the workforce. Many of these changes are likely to be irreversible, as there have been significant reductions in cost, gains in efficiency and substantial reductions in unproductive, time-consuming requirements such as commuting.

Some 40-60% of the workforce in a developed economy such as the USA could work entirely or part-time online. This includes people working in education, professional services (scientific, technical, ICT etc.), administration, office work, management, finance and insurance. In Germany, some 54% of businesses now plan to telework part of their operations. Twitter and Google have announced plans for their employees to continue working remotely. Facebook expects half the company's workforce to be working from home by 2030. Some businesses and other organizations will meet for key meetings but are likely to telework routine operations. However, some jobs will still require physical presence, including manual labour, low-paid service-sector activities such as transport, slaughterhouse work, couriers, construction, food services and retail (only 1% of the people working in those areas could telecommute), but also some high-skills occupations such as medicine and dentistry.

There will be far less demand for traditional office buildings, as there is little point in maintaining a large building that is only lightly used. The markets have realized this; between March and May 2020 commercial property investments in the EU fell by 44% on average, by 80% in Ireland. In the longer-term, however, there may be more demand for other facilities, such as shared meeting spaces for firms that need only occasional meetings.

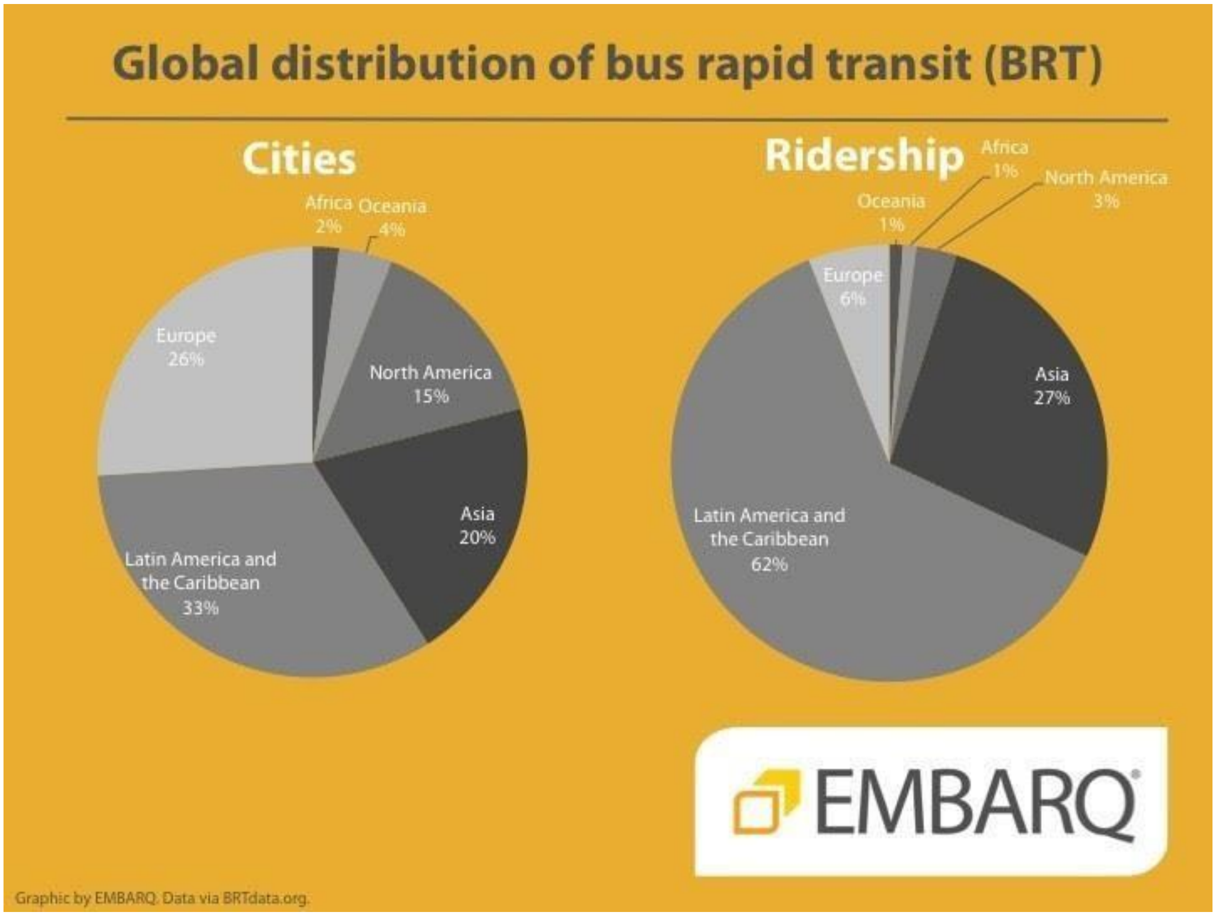
Implications for future cities: Good information systems are vitally important, as is universal media-literacy. So the migration to online teaching, conferencing and business should not be reversed, but extended after the crisis. This is a unique opportunity to migrate to an all-digital economy, which is an increasingly essential component of competitiveness in the modern world.

Mass transit

The growth of cities in Latin American and the Caribbean will create significant further problems of congestion and pollution. The challenge is to transform existing mobility systems in a way that capitalizes on emerging technology, incentivizes innovation, reduces traffic congestion, ensures greater road safety, reduces pollution and increases energy efficiency.

Latin America has an existing mass transit culture based on public and privatized bus, metro, taxi and ad-hoc minibus systems. The existing public transit and shared system comprises 68% of all passenger travel, one of the highest percentages in the world. See illustration 7.

Illustration 7: Bus rapid transit[cxiv]



There is also a growing automobile market, driven by increased per capita income and aspiration. However, private cars are costly in terms of capital commitment, with relatively low use, and a significant contribution to road congestion and traffic accidents.

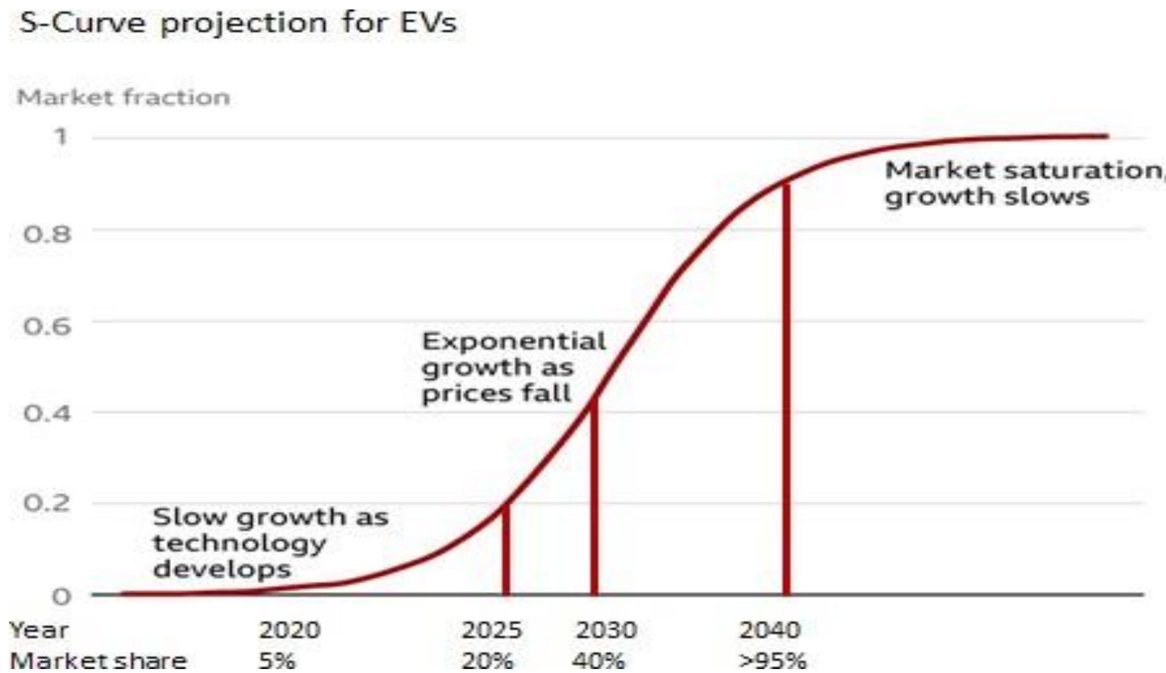
Most of the nations in Latin America and the Caribbean already have networks of public and private mass transit operators. Digitization could transform the efficiency of the mass transit system and make it more competitive with private cars. This could include, for example, ubiquitous mobile payment in public transit systems (cashless systems reduce the risk of assaults on drivers and passengers), connecting multiple different service providers through one payment system. With the collection of ticketing and passenger data, transit providers can also track dynamic changes in the system and adjust accordingly, using real-time pricing to spread passenger loads over time.

With digitization, service providers can provide on-demand transit and augment service in high-demand areas or in existing systems where peak saturation is downgrading rider experience. An on-demand system can help both public and private transit providers reduce areas of inefficiency; suggest alternative, more cost-effective transit options in areas with low ridership; and ultimately reallocate existing funding in the urban mobility system to key areas that need improvement.

The revolution in transport and the implications for the grid

Planning for transformative technological change requires trying to anticipate the point at which a technological solution will move into the mainstream. With electric vehicles, the main limiting factors included battery storage, durability, charging time, range, cost and legislation. These limits have been largely overcome, indicating that the transition to electric vehicles is now moving into the exponential growth phase (see illustration 8 below)[cxv].

Illustration 8: S-Curve projection for EV market share[cxvi]



Key indicators:

- Between 2010 and 2020 the cost of one kilowatt hour of battery power fell by 90%; it is now price-competitive with gasoline.
- The latest batteries are designed to last as long as the vehicle itself, about two million kilometers.
- Maintenance costs are much lower, mainly because there are about 20 moving parts in an electric vehicle, compared with about 2,000 in an internal combustion engine.
- A number of countries have now set provisional dates for the phase-out of internal combustion engines, including twelve US states, China, Japan, Canada, the UK, Iceland, Denmark, Sweden, Norway, Slovenia, Germany, France, the Netherlands, Spain, Portugal, Sri Lanka and Costa Rica. The UK, for example, will ban sales of new gasoline and diesel cars and vans in 2030.

Most vehicles in Latin America and the Caribbean are imported, so the pace of change in exporting countries will drive the pace of adaptation. For example, in May 2021 the Ministry of Finance and the Public Service in Jamaica concluded its review of the fiscal regime to develop Jamaica's e-mobility architecture; this is now seen as an important pre-emptive measure to prevent the import of vehicles that can no longer be sold in other jurisdictions[cxvii].

Many of these new vehicles will be autonomous. A number of firms are developing driverless vehicles, and a range of countries (including the UK and various states in the USA; California, Florida, Michigan and Utah) have started the process of legalizing their use on the roads. This has revolutionary implications for road transport; it will make it much cheaper, safer and more reliable. At present, about 75% of the cost of shipping goods by road across the USA is the cost of the labour involved, so eliminating the workforce will reduce the cost by the same percentage. In addition, driverless trucks can work for 24 hours per day, while drivers in the USA are restricted by law from driving more than 11 hours per day (9 hours in the UK). This means that the shift to driverless trucks would double the capacity of the US road network while reducing the cost per load by 75%, giving an eight-fold improvement in the price-performance of ground transportation networks[cxviii] [cxix] [cxx]. Automated vehicles are also much more fuel efficient (as they can be programmed to run at optimal cruising speed). Similarly substantial savings will be made in other regions, such as Europe, where over three-quarters of all shipped goods are transported by road.

Autonomous transport will also be safer. At present, about 1.25 million people die in road accidents each year, with an additional 20-50 million injured or disabled. The total economic cost is US$518bn per year, about 1-2% of the GDP of most countries, and the cost of road accidents to low and middle-income countries is US$65bn annually (which exceeds the total amount that these countries receive in development assistance). Most of these accidents are the result of human error, so many of those lives could be saved, and the associated economic cost largely eliminated.

Autonomous vehicles could also reduce traffic congestion, which causes accidents, costly delays and air pollution. This problem is rapidly worsening; from 2010 to 2016 congestion rose in in

New York by 30% and in Los Angeles by 36%. However, autonomous vehicles, including robo-taxis, autonomous shuttles, and autonomous buses can use AI to reroute and time journeys, and can also coordinate with rail transit timetables. A study by McKinsey (2019) estimated that this model of 'seamless mobility' could allow most cities to accommodate up to 30% more traffic while reducing average travel time by 10%[cxxi], to give a total global saving of 1 billion hours per day as a result[cxxii]. McKinsey therefore predict that by 2030, up to 80% of miles driven in the USA will be by autonomous vehicles.

Shipping represents a significant part of the cost of all consumer goods, so an eight-fold improvement in the price-performance of ground transportation means that consumers everywhere will see prices fall significantly and their standard of living rise commensurately. McKinsey estimate that if the United States fully adopted autonomous vehicles, the benefit would exceed $800bn a year by 2030.

When ownership is decoupled from service, the intensity of use is typically higher, significantly improving efficiency. At present, most cars in the USA are parked for 95% of the time[cxxiii], representing a very inefficient commitment of capital, but removal of the need for ownership could almost reverse that ratio. These innovations will generate extraordinary efficiency gains.

Developments in other jurisdictions

Other countries have already started moving in this direction. In May 2021, the UK energy regulator Ofgen approved the expenditure of US$425 million on the further extension of the national network of charging points, with another 1,800 ultra-rapid car charge points on motorways and an additional 1,750 charge points in urban centres, as well as funding to upgrade and decarbonize the grid, switching to low-carbon sources such as wind turbines (mostly offshore) and solar arrays[cxxiv]. A further US$57 billion of investment in the UK's power system is planned over the next seven years as part of the UK's plan to achieve net zero carbon by 2050. This is expected to unlock nearly US$1 trillion in new business opportunities.

Implications for the grid

The grid will have to adapt relatively rapidly to support this radical transformation of transport systems. It will require building out a network of charging points to replace filling stations. Autonomous vehicles will track their own battery levels, and will be able to self-connect to charging points. Dynamic pricing will allow the grid to constantly adjust the price in response to real-time supply and demand. Amazon uses dynamic pricing and updates prices every 10 minutes; dynamic pricing for electricity is likely to use a much shorter interval.

An even more profound implication is that vehicles will also be able to respond to price and demand, so that they could connect to a charging point and sell power back to the grid when prices were high and they did not anticipate needing the power in the immediate future, in effect making vehicles into spot market traders

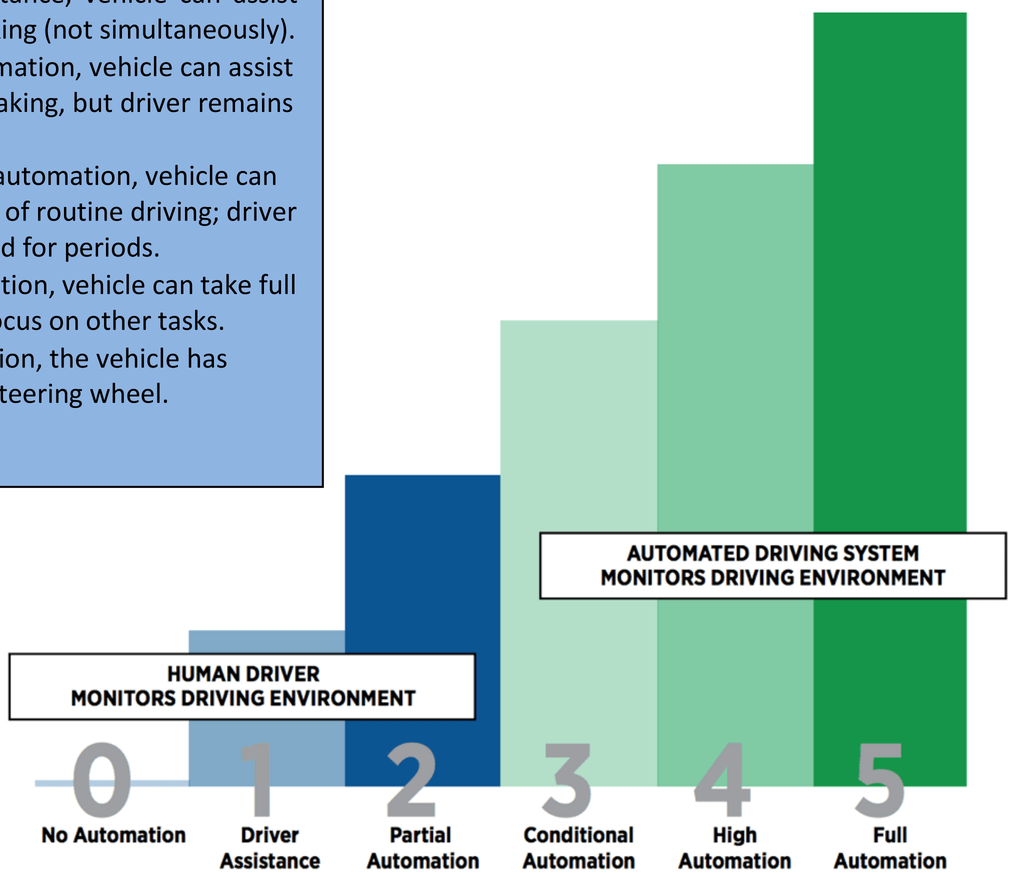
Autonomous vehicles

Key change: autonomous vehicles[cxxv],[cxxvi],[cxxvii]

Illustration 9: Stages of development in the driving environment[cxxviii]

Levels

- Level 1: driver assistance, vehicle can assist with steering or braking (not simultaneously).
- Level 2: partial automation, vehicle can assist with steering and braking, but driver remains in control.
- Level 3: conditional automation, vehicle can handle most aspects of routine driving; driver can take eyes off road for periods.
- Level 4: high automation, vehicle can take full control, driver can focus on other tasks.
- Level 5: full automation, the vehicle has control, there is no steering wheel.



- **Stage today:** Between Levels 2 and 3.
- **Current constraints:** poor quality roads (potholes, no lane markings etc.), legislation (with regard to e.g. traffic laws, responsibility, insurance etc.) has to be updated, smart vehicle infrastructure is not yet in place (vehicles must be able to communicate with each other, the road, and the satellite GPS). These are mostly government responsibilities, so do not depend on rate of technological development.

Implications for developing countries: It is likely that by 2050 there will be no non-EV/automatic vehicles available for import.

Illustration 10: Mercedes Benz F015 concept stage 5 driverless car[cxxix]

Logistics

Key change: autonomous shipping and logistics systems[cxxx], [cxxxi],[cxxxii], [cxxxiii]

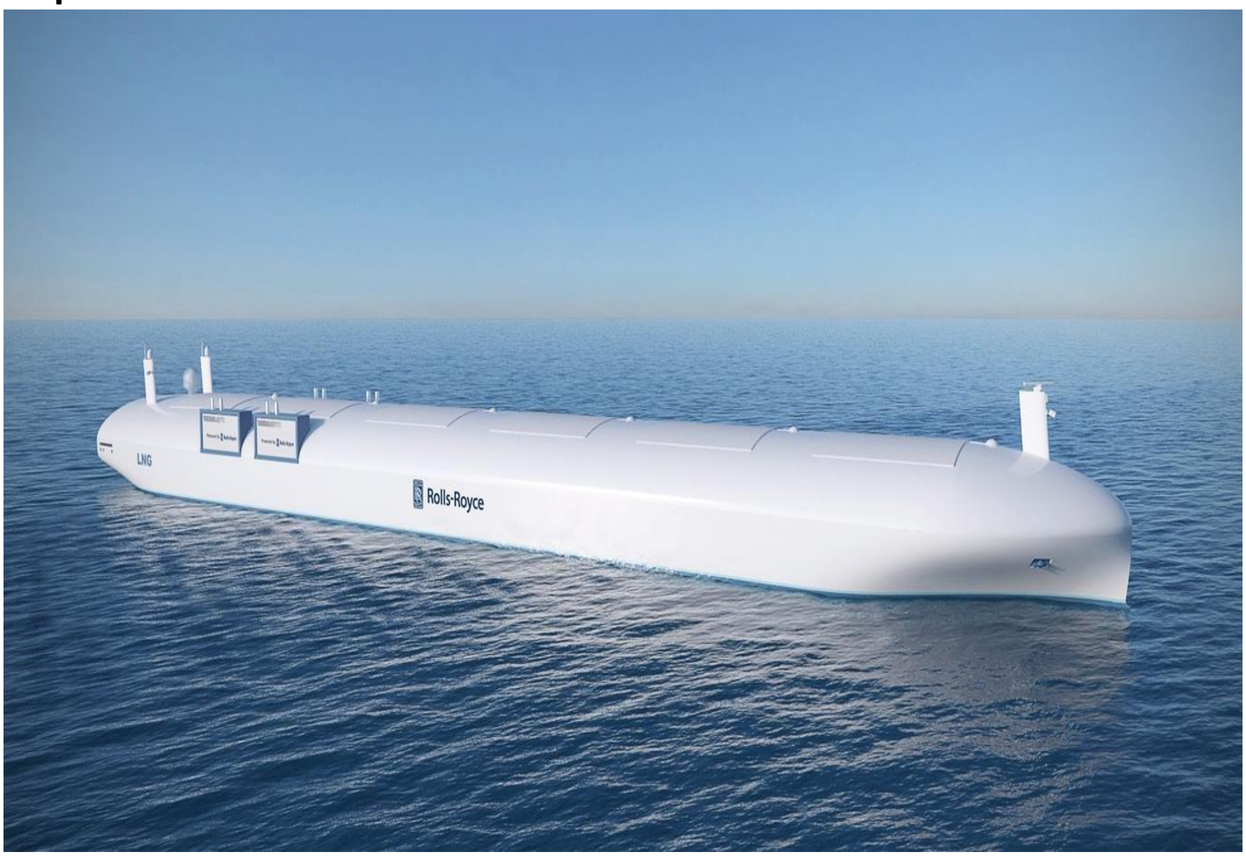
Drivers:

- Substantial reductions in time and cost, labour largely eliminated.
- Complex shipping and haulage operations can be coordinated by autonomous systems with multiple oversight points for security.
- Elimination of crew allows ships to be redesigned for much greater efficiency

- Expected 75-96% reduction in shipping accidents.
- Reduction of risk of piracy (no potential hostages on board)

2017: Rolls-Royce launched the world's first remote-controlled commercial ship.

Illustration 11: The world's first remote-controlled commercial ship[cxxxiv]



Estimated timeline:

- 2020: Remote-operated inshore vessels
- 2025: Remote-controlled coastal vessels
- 2030: Remote-controlled ocean-going vessels
- 2035: Fully autonomous ocean-going vessels.

By 2030 it might be possible for a control centre with a dozen staff to manage an entire fleet of large vessels with shipping operations around the world.

Illustration 12: Fleet control centre[cxxxv]

There are many implications for Latin America and the Caribbean. Shipping will be safer and cheaper, reducing the cost of both imports and exports, allowing e.g. automated trans-shipment operations to be established on islands in good strategic locations, such as Jamaica, which is near the entrance to the Panama Canal and the crossroads of four global maritime routes between Asia, the USA, South America and Europe. In conjunction with the move to fabricators, many of the cost disadvantages to e.g. manufacturing and processing operations on small islands will disappear.

Agriculture

Key change: fermentation bioreactors[cxxxvi], [cxxxvii] Micro-organisms can be fermented to make proteins; the inputs are CO^2, water, ammonia and electricity (used for water electrolysis to release hydrogen). The output contains protein, with all the essential amino acids, fats, carbohydrates and Vitamin B, and can be further processed into food products such as ice cream, meat-substitutes, bread or pasta. The production of 1kg of fermed proteins takes 0.06% of the water and 0.005% of the land needed for the equivalent output of protein from conventional agriculture, and the fermed proteins do not contain pesticide or hormone residue.

Illustration 13: Fermentation bioreactor[cxxxviii]

Current constraints: the technology still has to be scaled up, and has to compete against the subsidies for conventional agriculture (the current world total for farm subsidies is US$600bn).

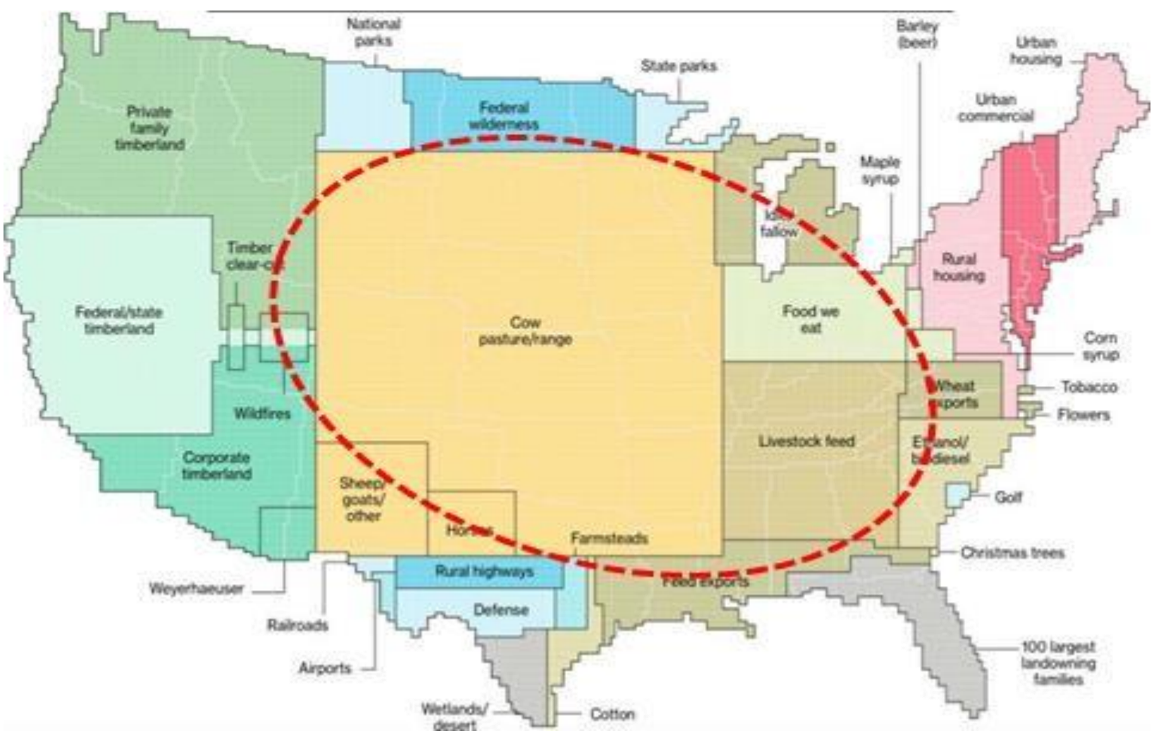
Estimated timeline

- **Time to price advantage:** By 2035 fermed proteins will be 1/10th the cost of proteins from conventional agriculture.
- **Time to start displacing livestock production:** 10 years, to 2030

- **Time to become dominant source of protein, fats and carbohydrates:** 15 years, to 2035.

Implications for urban design: It is no longer necessary to preclude the development of cities on land that is currently designated for conventional agriculture; existing agricultural land could be used for environmental restoration to increase urban resilience (e.g. wetlands and forests). With fermentation bioreactors, cities could feed themselves.

Illustration 14: Schematic representation of land no longer required for agriculture in the USA



Conclusion

It is important to think about the scale of the change and disruption between now and 2050. The transition to a circular economy, based on renewable energy, will change the geopolitics of the world. Artificial intelligence will change the way that we think about education and work, and the move to an immersive, all-digital environment will re-write the rules for the way that society works and culture evolves. Climate change disasters, such as the mega-fires in California, Canada, Siberia and Australia and the floods in Europe and China, will become increasingly frequent and severe. The period to 2050 is likely to be one of profound technological, social, economic and environmental change.

We need to do more to prepare people for the changes that lie ahead, and it is essential to map out strategies for survival. This report argues that with better planning, cities could be at the core of those strategies. The purpose of this report was to list some of the key drivers of change and set out an overall framework for rethinking cities.

Better governance, improved planning and regulation and targeted investment in infrastructure could be used to ensure that cities support the new models of urban living required to deliver far higher levels of energy and resource efficiency, minimize environmental impacts and footprints, generate employment opportunities, encourage social integration and cohesion, and use better design to make cities pandemic-resistant, with the remodeling of homes, offices and public spaces to allow distributed working and social distancing.

This combination of measures could resolve many of the problems of urban living, and turn cities into solutions to the major challenges of our time.

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