

Pandemics and the Built Environment

17 September 2020

The Covid-19 pandemic has made evident some important conflicts between respiratory pandemic health requirements and the ability to satisfy these in buildings of various occupancy types. Some requirements can be satisfied with changes in the way that buildings are managed, or with minor renovation; but others require more substantial changes which may not be easy to implement in the short- or mid-term.

Other issues move beyond the scale of buildings into urban scales, and then there are even larger questions of state/provincial and/or national governments taking up the task of post-pandemic reconstruction.

*The point of departure in launching this enquiry was our concern that the immediate need to deal with the adaptation of buildings to the pandemic might take our collective eye off the **equally crucial but less immediately visible issues** of sustainability performance of the built environment and climate change action.*

The document consists of a combination of referenced sources and more subjective inputs, reflecting the recent and fast-moving nature of the issue.

The discussion in this document is focused on respiratory disease issues that have emerged with Covid-19, but many of the ideas and suggestions proposed may also apply to other bacterial or viral diseases that will emerge in the future.

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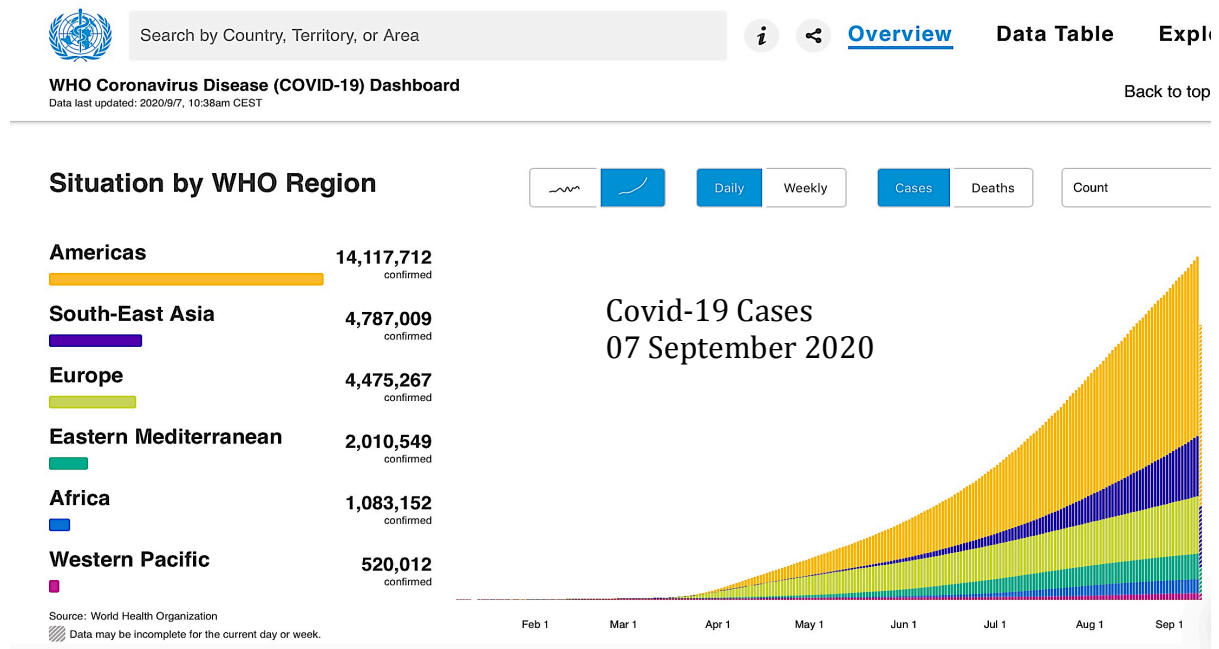
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¹ http://bpie.eu/wp-content/uploads/2020/05/Recovery-investments-in-deep-renovation_BPIE_2020.pdf

A. Context

The Covid-19 disease² began in Wuhan, China, and cases were then reported from Thailand, Washington State, Korea, Italy, and then onwards to include most countries in the world. Covid-19 was declared by the World Health Organization (WHO) to be a global public-health emergency on 30 January 2020, and then on 11 March it was declared to be a pandemic.



Covid-19 is only the latest in a long series of pandemics

We are currently focussed on Covid-19, which is a "novel" respiratory coronavirus that apparently emerged in 2019³. There have been many epidemics and pandemics in the past, several of which have had profound impacts on human civilization and events, and there is no reason to think that this pattern will not continue.

Partial historical list of major epidemics and pandemics caused by infectious diseases (excerpt from 244 events listed by Wikipedia ⁴)				
Event	Date	Location	Disease	Death toll (estimate)
Antonine Plague	165-180	Roman Empire	unknown, possibly Smallpox	5 to 10 million
Plague of Justinian	541-542	Europe and West Asia	Bubonic Plague	25 to 100 million (40%-50% of European population)
Black Death	1346-53	Europe, Asia and North Africa	Bubonic Plague (Yersinia Pestis)	7 to 200 million (up to 60% of European pop.)
Cocoltzli Epidemic	1576-80	Mexico	Possibly <i>Salmonella enterica</i>	2 to 2.5 million (50% of population)
Wyandot people epidemics	1634-40	Wyandot people in U.S. and Canada	Smallpox and influenza	15,000 to 25,000 (total pop. at first contact in 1615 was about 16,000 to 50,000) ⁵ .

² The name Covid-19 comes from Coronavirus Disease 2019

³ https://covid19.who.int/?gclid=EAIaIQobChMIhpLw7N316gIVSr3ACh102A1fEAAyAAAEg11HPD_BwE

⁴ https://en.wikipedia.org/wiki/List_of_epidemics

⁵ <https://www.wyandotte-nation.org/culture/history/published/native-peoples/>

Europe smallpox epidemic	1870-75	Europe	Smallpox	500,000
Sixth cholera epidemic	1899-1923	Europe, Asia, Africa	Cholera	800,000+
"Spanish flu"	1918-20	Worldwide	Influenza A virus subtype H1N1	17 to 100 million
Typhus epidemic	1918-22	Russia	Typhus	2.5 million
Asian Flu	1957-58	Worldwide	Influenza A virus subtype H2N2	1 to 4 million
Hong Kong Flu	1968-70	Worldwide	Influenza A virus subtype H3N2	1 to 4 million
Swine flu pandemic	2009-10	World-wide	Influenza A virus subtype H1N1	264,000 (151,700-575,400)
U.S. Flu season ⁶	2017-18	U.S.A.	Seasonal influenza	61,000 (46,000-95,000)
Covid-19	2019-	World-wide	Covid-19 / SARS-CoV-2	500,000 deaths (10+ million cases)

Immediate effects and impacts on individuals and society

Transmission of Covid-19: Initial assessments by the *World Health Organization* (WHO) and national health authorities focused on viral transmission by airborne droplets generated mainly by speech, coughing, sneezing, and this led to the almost universal consensus that a 2 m. distance between individuals, along with face masks, would reduce risks of viral transmission to an acceptable level, except where cheering (sports) or singing (choirs) take place. More recent assessments have pointed to the possibility that smaller droplets could remain airborne for a considerable time, especially indoors, and that mechanical ventilation systems could be complicit in spreading the virus in such a circumstance.

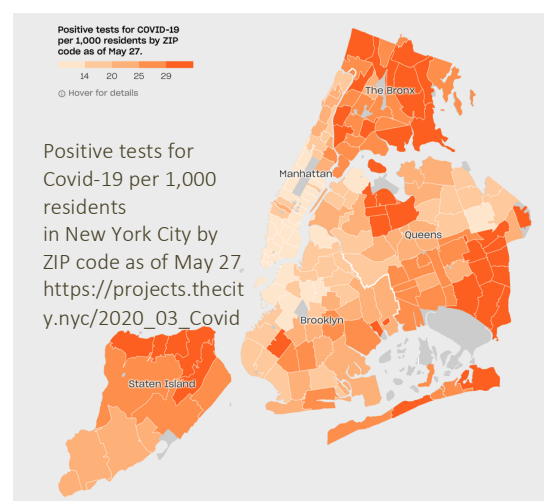
Impacts are likely to vary systematically by characteristics such as⁷:

Geographic Variation. Covid-19 has had a great variation across space within cities and has impacted disproportionately the poorest neighborhoods. For example, in New York City, one of the world's hardest hit city - with 197,351 NYC confirmed cases and 21,362 deaths - as of May 24, 2020, the Bronx had the highest rate of COVID-19 cases per 100,000 people, that is the double of Manhattan.

Age. Children and youth suffer schooling interruption, adults are most likely to suffer employment loss, and the elderly face higher risk of severe health outcomes from Covid-19.

Gender. Women have specific vulnerabilities, since (a) school closures and elderly care tend to burden time use of women; (b) women are more exposed to infection due to larger share of women in health and service sectors; (c) women face a higher likelihood of domestic violence during home confinement; and (d) some of the service sectors most affected by the economic shock have higher concentrations of female employment. On the other hand, men appear to be more vulnerable than women to suffer serious effects of the coronavirus infection, including hospitalization and death.

Household composition. Certain types of households are more vulnerable, such as those with children, students, elderly, or sick members.



⁶ Included because it is relatively recent.

⁷ <https://www.worldbank.org/en/topic/poverty/brief/poverty-and-distributional-impacts-of-covid-19-potential-channels-of-impact-and-mitigating-policies>

Socioeconomic status. Vulnerable groups such as migrants, refugees, and ethnic minorities, and more generally, households with lower levels of income and education face greater challenges in accessing services such as health, education, and infrastructure. The disparities in access will be exacerbated by the pandemic. Evidence now suggests that the coronavirus is disproportionately affecting black Americans in some U.S. cities⁸.

An amfAR⁹ study shows disproportionate impact of Covid-19 on black Americans. Primarily black counties, mostly in the Southern U.S., have significantly higher rates of infection and mortality. A range of social and built environment conditions such as being uninsured or unemployed, household crowding, poor air quality, and reduced ability to practice social distancing tend to be more common in disproportionately black counties and explain this disproportionate impact. Black workers are also expected to feature disproportionately in the 26 million recent unemployment claims in the U.S.¹⁰.

Lock-down: In many countries, large sections of populations have undergone several weeks of isolation in their homes, while operators and staff of commercial enterprises, schools, universities and other institutions have also been forced to cease activity. There have even been closures of public parks and playgrounds. This period of "lock-down" is having a major negative impact on the economic and social life of affected middle-class countries. In developing or impoverished countries or regions, citizens may not possess homes to be isolated in, and that is a much bleaker prospect.

Vectors: The pandemic has shown that occupants and staff of nursing homes and long-term care facilities are especially vulnerable to Covid-19. Other extremely dangerous virus "hot spots" are meat-processing plants¹¹, prisons, churches, sports stadia, conference centres and other facility types where a large number of people are closely packed together for several hours or more. Loud singing in choirs or chanting and cheering in sports facilities appear to be especially problematic in disseminating virus particles. Unfortunately, refugee camps also offer good prospects for the spread of Covid-19.

Economic and social impacts: The reductions in emissions are correlated with major losses in employment and income by large portions of the population, and also with major disruptions in educational and training activities. These temporary CO2 reductions therefore carry a heavy price, and the disruption of commerce and daily life will not be tolerated for more than short periods.

Issues of special relevance to low-income areas and developing countries

According to Oxfam, between 6 and 8 percent of the global population could be pushed into poverty by the Covid-19 pandemic¹². The World Bank estimates that the pandemic could push about 49 million people into extreme poverty in 2020¹³ and that many of the new poor will likely be in cities. Covid-19 has affected urban dwellers differently according to the wealth and level of development of cities and to the socio-economic characteristics of people within the same city. Any responses to Covid-19 that ignore the realities of urban inequality will further jeopardize the survival of large segments of the urban population globally.

Nearly 1 billion people around the globe are currently living in urban slums, where physical space is scarce and social distancing impossible, and many rely on daily wage labor for survival. Space constraints, violence, and overcrowding in slums make physical distancing and self-quarantine actions impractical, and the rapid spread of an infection highly likely. Slum populations are uniquely vulnerable to Covid-19, but suffer under shelter-in-place restrictions that can often limit their access to basic needs like food or water.

⁸ Though blacks are only 22% of New York City's population, as of mid-April they constituted 28% of fatalities from the virus. In Chicago, where blacks are 30% of the population, they comprise 70% of those killed by Covid-19. In the state of Louisiana, blacks are 32% of the population but 70% of those dead from the disease.

<https://hbr.org/2020/05/the-disproportionate-impact-of-Covid-19-on-black-health-care-workers-in-the-u-s>

⁹ amfAR, The Foundation for AIDS Research.

¹⁰ <https://www.theguardian.com/us-news/2020/apr/28/african-americans-unemployment-Covid-19-economic-impact>

¹¹ Note also that the low temperatures in meat packing plants (and presumably ice hockey arenas) provide a more stable environment for a virus and therefore increases its effectiveness.

¹² <https://www.oxfam.org/en/press-releases/half-billion-people-could-be-pushed-poverty-coronavirus-warns-oxfam>

¹³ A large share of the new poor will be concentrated in countries that are already struggling with high poverty rates, but middle-income countries will also be significantly affected. Almost half of the projected new poor (23 million) will be in Sub-Saharan Africa, with an additional 16 million in South Asia. At the same time, 22 million of the projected new poor will be in middle-income countries.

<https://blogs.worldbank.org/voices/Covid-19-will-hit-poor-hardest-heres-what-we-can-do-about-it>

Prospects for the future

Spokespersons for the WHO expressed the view on May 13, 2020 that Covid-19 is likely to become endemic. If this becomes the case, there will be a recurring need for more contact tracing, or lock-downs of homes, schools, factories and offices, along with physical distancing and occasional isolation, whenever there are significant waves of cases. These impacts reinforce the importance of adopting at least some of the measures outlined in this discussion paper.

B. Individual Issues and behaviour

Changes in personal and household behaviour under pandemic conditions.

The Covid-19 pandemic has demonstrated that societies and individuals of all classes can undergo dramatic and rapid changes under pandemic conditions.

There may be a need for 14-day isolation periods for households and/or for individuals within households and hence a spatio-temporal re-arrangement of the “home” spaces between different individuals of the family.

High-stress conditions may cause social conflicts and hence effects on the mental health of individuals and groups (families), either living together under the same roof, or in different locations.

There will be a greater need for home offices for work and/or home schooling purposes, which may require extra space and renovations. This may not be physically or financially possible in some cases, and that may result in home working or schooling not being possible, leading to a need for community-based solutions.

Home working and/or home schooling will lead to an increased use of (and reliance on) high-speed internet and video conferencing. In some North American rural areas, internet speeds are relatively low (<50 Mbps) and this limits the ability to carry out business or schooling activities in such areas.



There will be employment and educational disruptions during recurring Covid-waves, which will damage career prospects and create psychological problems for all, but especially for women, students, young families and low-income groups.

There will be less international and inter-city travelling, and more use of country properties, municipal and regional parks, where they are open.

Spatial distancing and space requirements in the built environment

A requirement for individuals, except those who are members of a single household, and who are not under an isolation requirement, is to maintain a distance of at least 2 m from other people. This measure has been adopted by health authorities in almost all countries and regions. Other new health requirements lead to larger floor areas, to accommodate some larger spaces, added rooms, wider corridors etc. These measures have implications for types and functions of open spaces and buildings, and are difficult to achieve without expensive additions or rebuilding efforts.



Schedule or time shifting

Spatial (aka social) distancing is becoming an accepted concept, but an analysis of the situations in which this may be implemented rapidly leads to the realization that scheduling (or time) separation is also a necessity in many situations. For example, arrival to and departure from work settings can be staggered to reduce crowding in lobbies, check points, corridors and lifts. The concept can be extended further to reduce line-ups for

cafeterias. There are limits on how far these principles can be applied in large organizations, but it should also be noted that some firms have already reduced their on-site workforce or are planning to do so soon.

The time shifting concept fails to solve the issue of attendance at meetings, conferences or concert presentations because such events all have fixed start times. Here the only feasible solution is virtual attendance via videoconferencing. All of these ideas have been partly implemented before, but the need now is to apply the ideas widely and consistently.¹⁴

Increased use of smart phones for population track and trace requirements.

There will be a new reliance on the use of smart phones, due to governmental track and trace rules to monitor and track movement and personal contacts in the built environment. People without smart phones may not be able to move within the city, go into shops, etc. This will disadvantage some demographic and socio-economic groups, such as old people and the homeless, and will also alienate others who find such tracking to be an intrusion into private lives.

Demand for electric power and internet bandwidth.

The use of home video conferencing, home telework use, and growth of electric auto sales are likely to increase daytime and peak electricity use. More availability of local renewable power will therefore have significant benefits for total demand, peak shaving and resiliency in local microgrids or synergy zones.

Regarding internet usage, the March 20 issue of Forbes magazine reported that under pandemic lock-down conditions, presumably in USA, *...total internet hits have surged by between 50% and 70%, according to preliminary statistics. Streaming has also jumped by at least 12%, estimates show... an increase is not surprising with so many people ordered to stay at home...*

Finally, the shift from 3G or 4G to 5G internet systems will certainly greatly increase power consumption, mainly because 5G signals are easily interrupted by blocking elements such as buildings, walls, trees, leaves, and even rain, which reinforces the need for many cell towers to ensure the continuity of signals for mobile users¹⁵.

Management and other non-material issues

It should be recalled that the building industry is not just a matter of concrete, steel, masonry and wood. Many jobs will be permanently lost, and many more workers will telecommute than in the past. New commercial (especially office) construction may be completely unnecessary, particularly if there is more office “hoteling” as well as stacking of uses. Avoided new construction is important inasmuch as embodied emissions of new construction can represent 50% to 80% of carbon footprint of buildings in the first 10 years of their lifespan – and the next 10 years are critical for planetary climate stabilization.

- The construction industry in many countries depends on (both unskilled and skilled) people from elsewhere. If construction workers return to their home countries there will be labour shortages in construction, and a lack of workers would have major impacts on scheduling and cost of construction.
- The provision of spatial separation on construction worksites is difficult, and hand-washing stations, personal protective equipment (PPE) and clear guidance must be provided and maintained.
- Insurance rates for various occupancies, such as the large-scale implementation of home offices, may increase the cost of home insurance to unacceptable levels.

¹⁴ To simplify matters in this report, we refer to either spatial or temporal distancing, or a combination of these, as distancing requirements.

¹⁵ https://www.researchgate.net/publication/339784437_5G_deployment_and_urban_sustainability_09Mar20

C. Urban Issues and systems

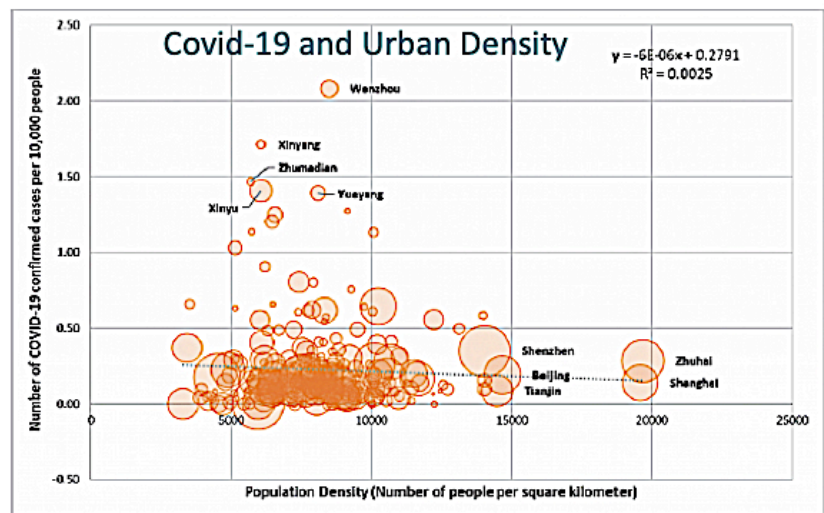
Urban density, location of jobs and residential areas

The long-standing issue of whether it is better to live or work in high-density urban areas or low-density suburbs has not been resolved by the Covid-19 pandemic. The data on Covid infections are confused by the fact that some of the regions or cities with high rates of infections (e.g. Milan, New York) were at the leading edge of the pandemic wave. Other locations with very high population densities and poor sanitation, e.g. refugee camps or low-income neighbourhoods in third-world cities, are also susceptible. Finally, large religious, sports or social group meetings are also effective incubators for the virus, because of the very close proximity of participants over a period of several hours.

However, the vulnerability of such locations is not due to their urban density, as evidenced by the modest infection and death rates in some major urban areas^{16 17}.

The World Bank has published a study on the relationship between urban population density and the spread of the Covid-19 pandemic¹⁸. *To find out whether or not population density is a key factor in the spread of the coronavirus, we collected data for 284 Chinese cities on two relevant indicators: (i) the number of confirmed coronavirus cases per 10,000 people; and (ii) the population density in the built-up urban area.... The evidence does not support the argument that density is a key determinant of coronavirus transmission risk. As illustrated, cities with very high population densities such as Shanghai, Beijing, Shenzhen, Tianjin, and Zhuhai have had far fewer confirmed cases per*

10,000 people. We notice that the group of dense cities are also the wealthier ones (with bigger bubbles), making them more able to mobilize enough fiscal resources to cope with the coronavirus. This partly explained their low infection rates. On the contrary, cities with the highest coronavirus infection rates were those with relatively low population densities, in the range between 5,000 to 10,000 people per square km.



Notwithstanding the World Bank study, there are indications of a cultural difference leading to other choices in urban areas of U.S.A. The Guardian reports¹⁹ that real estate brokers in the greater New York region ... *are describing a boom in demand for homes north of the city and on Long Island – and especially those that offer space for home offices. Competition is so fierce, says Madeline Wiebicke, a real estate broker in New City, an affluent hamlet some 20 miles from Manhattan, that city dwellers are snapping up suburban properties in bidding wars, often after just a video tour. Demand for homes, say brokers, is fuelled not only by fears that coronavirus infections in densely populated urban areas could rise again next winter, but also by fundamental shifts in demand from in-office to remote workers...According to the Pew Research Center, over 40% of jobs could be performed remotely, yet only 7% of American workers had the option to telecommute as a benefit before the Covid-19 pandemic. A separate survey produced by Redfin found that 50% of respondents in cities like New York, Boston, San Francisco and Seattle said they would consider moving out of the city if remote working becomes permanent.*

¹⁶ <https://www.vox.com/2020/5/20/21265194/coronavirus-deaths-us-singapore-case-fatality-rates>

¹⁷ <https://www.statista.com/statistics/1100120/south-korea-coronavirus-cases-by-province/>

¹⁸ <https://blogs.worldbank.org/sustainablecities/urban-density-not-enemy-coronavirus-fight-evidence-china>

¹⁹ *So long, New York: pandemic and protests spark new exodus to suburbs*; The Guardian, 12 June 2020.

We can conclude that the post-pandemic offers the prospect of a more decentralized pattern of working and living to employers and workers alike and with benefits to both groups. Explicit efforts will be needed to reconfigure urban areas as mixed-use neighbourhoods, with easy local access to jobs and housing and without relying on the use of private vehicles.

Urban transportation

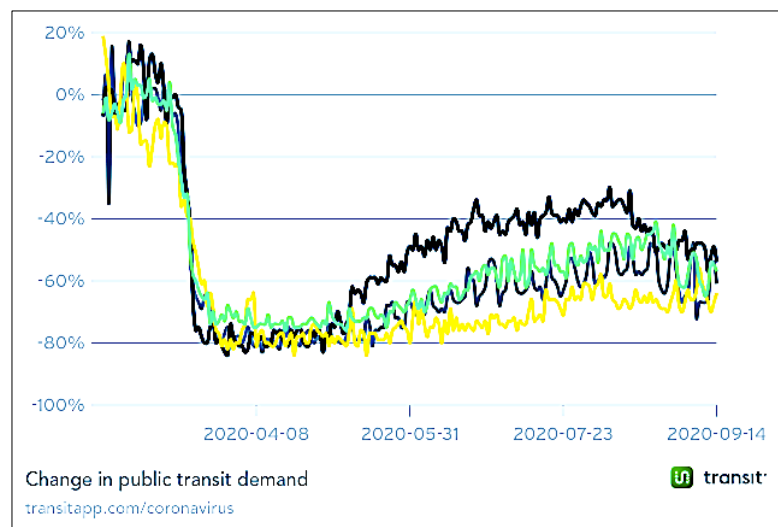
The number of people that can be safely transported within a given time frame will decrease, due to the need for maintaining some spatial distancing on platforms and inside train carriages or buses, e.g. a bus that normally holds 80 people may be restricted to 15 people. The consequence of a partial lockdown with spatial distancing will be, at least in the short term, reduced capacity in public transport.

Under pandemic conditions, there may be an increased demand for use of private vehicles because this provides a reduced risk of contact with the public, leading to lower possibility of viral transmission and enhanced safety for occupants. The CityMapper Mobility Index²⁰ notes that the lockdown measures brought about by the Covid-19 pandemic have led to large-scale reductions in urban public transport activity: the number of trips in most cities has reduced by more than 50%. Even after lockdown measures are relaxed, use of urban public transport may remain low due to social distancing needs and passengers' health concerns.

According to the American Public Transportation Association: *when the economy begins to recover, transit agencies will still be challenged with severe fiscal restraints. These constraints stem from social distancing that reduce vehicle capacity, increased costs of facility and vehicle cleaning and disinfection, and some displacement of ridership resulting from greater acceptance of decentralized work locations adopted during the pandemic.*



Data from a global transit information organization²¹ shows that, in 4 major world cities, the use of urban public transport systems decreased by 70% to 80% during the mid-February to early April period and, as of early September, has only partly climbed back.



Local governments generally wish to support increased use of public transport to minimize land used for roads and parking, and to reduce GHG, NO₂ and particulate emissions, the latter being linked to air pollution and increased rates of viral transmission and of mortality. Reduced household incomes also point to more use of public transport.

Vancouver provides one of the few sources of real data on this subject. According to a recent newspaper report²²...*The city has essentially been in pandemic mode for two months. It saw an 80-per-cent drop in transit use and, in the early weeks of the pandemic state of emergency, about half of the normal car traffic. Cycling is also lower than it was, because schools and many workplaces are closed. But the drop has not been as significant as other modes of transportation, as people have turned to bikes for errands, commuting, fitness and recreation.* Certain conclusions can be drawn:

²⁰ Citymapper (2020), Citymapper Mobility Index (database), <https://citymapper.com/cmi>. Ecocompteur (2020), Understand the impact of the pandemic on cycling, <https://www.ecocompteur.com/en/covid19-dashboard/>.

²¹ see <https://transitapp.com/coronavirus>

²² *Vancouver increases space for walking and cycling through introduction of slow streets*; Globe and Mail; 13 May 2020

- In temperate climates and during favourable weather conditions, bicycling is likely to become more widely adopted. It will be important for local governments to facilitate this by constructing dedicated bicycle paths. The Municipality of Paris has constructed an additional 50 km. of bicycle routes during the pandemic period²³. The success of this "15-minute city" initiative was greatly helped by the dense urban fabric of Paris, and it would be difficult to achieve this goal in low-density suburban areas of North America.
- Public transport system operators will need to convince the travelling public that their health and safety measures are sufficient;
- Stops, platforms and waiting areas need to provide enough area for safe distancing of passengers;
- Continuous monitoring of embarking or disembarking passengers will be needed to avoid overcrowding of platforms, buses or trains;
- The reduced passenger densities under pandemic conditions will reduce the energy and cost efficiency of public transport.

Neighbourhood features to support outdoor activities.

Even in pandemic lockdowns people are encouraged to walk and exercise for physical & mental health. Part of the area now allocated for streets or parking areas can be converted to such uses. More foliage reduces pollution, noise and ambient summer temperatures. Specific ideas:

- Provision of outdoor area for local residents to relax and to exercise is especially important if residential unit areas are diminished. Public parks are a more efficient way of providing green space for local residents compared to private open space belonging to each dwelling unit, although a combination of both private and public green space is ideal. There are practical benefits, since trees and vegetation reduces ambient temperatures, mitigating the heat island effect.²⁴
- Major public media have noted the general decline in availability and quality of maintenance of public washrooms in major western cities over the last 100 years. The pandemic has brought this lack to a crisis point, since cafés, restaurants, community centres and libraries have been closed, and local residents are therefore unable to relieve themselves.
- Sustainable land use management principles in the design and operation of large park areas should be incorporated to ensure that storm water management and soil permeability is considered. Even where paving is required, permeability is possible.
- Complicating factors in maintaining safe 2m-distances include couples or groups walking together, adjacent parked cars making it difficult to make detours around other pedestrians, joggers breathing heavily as they pass.
- High-risk elements include drinking fountains and play areas.



Community vegetable gardens within neighbourhoods.

Local vegetable gardens can reduce travel / shipping energy and emissions (but for small scale production only); and is also good for exercise and mental health, as long as distancing requirements are maintained.

Monitoring and analysis of wastewater to detect coronavirus traces²⁵

More than a dozen research groups worldwide have started analysing wastewater for the new coronavirus as a way to estimate the total number of infections in a community, given that most people will not be tested. So far, researchers have found traces of the virus in the Netherlands, the United States and Sweden. Analysing wastewater ... is one way that researchers can track infectious diseases excreted in urine or faeces, such as SARS-CoV-2. We do not yet have scientific studies that definitively show a link between the trace viral amounts and actual outbreaks of COVID in the community.

²³ see the excellent BBC podcast *Will Covid-19 Change Cities?*. <https://www.bbc.co.uk/programmes/w3cszl3h>

²⁴ B. Dousset, *ESA user consultation meeting, Athens, June 2007*

²⁵ From *Nature*, 03 April, 2020, <https://www.nature.com/articles/d41586-020-00973-x>

D. Buildings and building systems

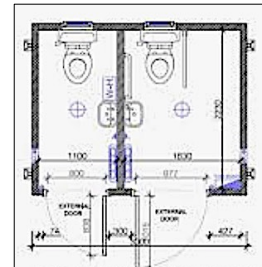
1. Issues and proposed actions for all building types

Entries and shared facilities

- All buildings accessible to the public should be provided with no-hands operation of doors and sanitary equipment in public areas, such as entries, lobbies, laundry rooms, recreation facilities and parking facilities.
- An option to carry out thermographic scans of persons entering the building should be in place and, where local laws and customs permit, mobile phone data should be collected to support track-and-trace operations..
- Wash basins or sanitizer stations should be provided at frequently used building entries.
- Surfaces in public areas that are frequently touched by users (and are therefore prime candidates for spread of virus) include entry/exit and washroom doors and washroom sanitary fixtures. Solutions include sensors for taps, toilets, automatic doors and self-cleaning surfaces²⁶ and automatic (hand-wave based) paper dispensers. Where manual door handles are needed, lever types should be used to minimize contact risk.

Washrooms and bathrooms

Publicly-accessible washrooms will require more floor area than current standards, because of a need for 2 m. spacing between urinals, toilets and washbasins. There is also the question of more floor area required to maintain a safe distance between several users. If conventional washrooms are planned, toilet compartment doors should extend to the floor and an automatic cleaning system should be installed for each compartment. Each toilet compartment should have a mechanical exhaust, located directly above the toilet.



- Considering all these factors, it may be easier to install unisex bathrooms (a single toilet and small washbasin), as well as a self-cleaning mechanism activated between users. In existing office or public occupancies, this may be difficult and expensive to achieve, but will help to overcome the usual problem of conventional women's washrooms being notoriously deficient in numbers of toilets.
- Japanese washlet toilets are an option, which also reduces use of toilet paper. Sarah Bookman²⁷ states that... *entirely self-cleaning toilets that sanitize the cubicle when a door is shut could be installed in greater quantities ... Our current toilet practices are not sustainable...*



Lifts in high-rise buildings

In pandemic conditions, restrictions are placed on lift passenger capacity, such as reducing capacity of small lifts (capacity up to 9 persons) to one person, or a maximum of 2 or 3 passengers in larger lifts. This reduces the quality of service and increases energy related to more frequent use.

A spokesman for a real estate developer with a large commercial portfolio, recently stated that²⁸ ... *The company is working on a spatial distancing plan for elevators, lobbies, washrooms and other high-traffic common areas... CF wants to ensure there are no more than three to four people in an elevator; employees will wait in specific lines to catch them...* Similar spacing and/or time shifting issues arise with escalators.

- Individual employees may have to arrive and leave at staggered hours to reduce crowding of lifts, lobbies, garages and public transport. Similar staggered lunch hours may be needed. These measures increase lift use and result in more energy consumption and a decreased service frequency level.
- We suggest that passenger capacity of lifts should be planned to ensure that passengers are spaced with a minimum of 3 m² per person

²⁶ <https://academic.oup.com/cid/article/58/6/848/340734>

<https://pubs.rsc.org/en/content/articlelanding/2012/NR/c2nr30388d#divAbstract>

²⁷ Sarah Bookman, Auckland University, in the Guardian, 03May20.

²⁸ Newspaper interview with Cadillac Fairview spokesman, Globe and Mail, 02 May 2020

Natural and hybrid ventilation

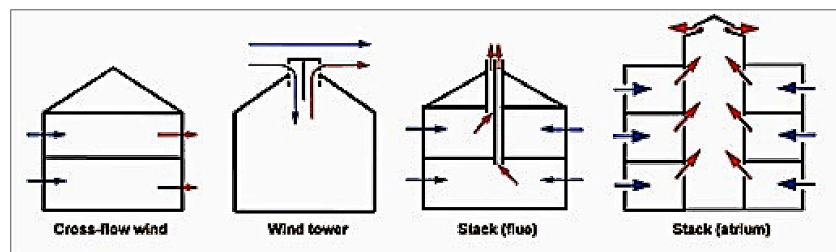
Natural ventilation with outdoor air may be provided through the use of operable windows or other types of openings in buildings. The World Health Organisation (WHO) has developed guidelines²⁹ on these matters, which are primarily applicable to health care facilities in developing countries in warm climates, but still have much to offer to other building types in temperate climates.

Natural ventilation with outdoor air and cross-ventilation will reduce or eliminate need for mechanical cooling and ventilation except in extreme summer and/or noise conditions, thereby reducing energy consumption, GHG emissions, capital and operating costs. Depending on their orientation and exterior wind and noise conditions, operable windows also allow better contact with the external environment in low- to mid-rise buildings, which provides occupants with a psychological benefit. Where air-cooling systems are provided, they should be automatically switched off when operable windows are open in order to maintain HVAC efficiency.

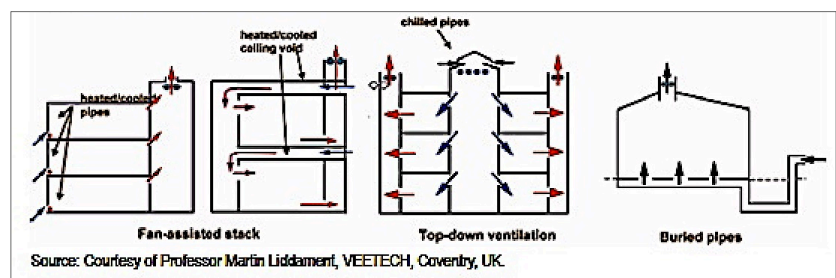
An advantage of natural ventilation is that a high rate of air change is easy to achieve, which is an important factor in ensuring a healthy environment and the dispersal of pollutants. Natural ventilation is free and requires no motive energy, and large exterior openings can provide added daylight. However, its effectiveness depends on several factors, including:

- a building location that provides the possibility of ambient air movement during all seasons
- feasibility of placing openings on more two sides of the building, or one side and roof exhausts, so that cross-ventilation can be achieved
- exterior conditions that ensure an adequate quality of pollutant-free outdoor air
- orientation of the building to maximize potential air flow through the building
- interior layouts and functions that are compatible with inevitable natural variations in air flow rates
- where full cross-ventilation is not feasible, a shallow floor plan with interior spaces no further than 7 m. from exterior openings
- acceptable ambient maximum noise levels
- design and construction of windows that ensure a high level of thermal performance and security against entry when closed

Four concepts for natural ventilation, from the WHO guideline



Four concepts for hybrid ventilation, from the WHO guideline



Source: Courtesy of Professor Martin Liddament, VEETECH, Coventry, UK.

Natural ventilation will not be feasible in situations where the driving forces are not adequate to ensure sufficient air flow to the building openings, or to specific areas within it under certain conditions, e.g. seasonal periods of little wind, or certain internal spaces or rooms that require constant or higher ventilation rates, or differential pressure regimes. In such situations, a hybrid or mixed-mode ventilations system may be a better solution, combining operable exterior windows with an interior mechanical ventilation system as a supplement in all or parts of the interior.

²⁹ Natural Ventilation for Infection Control in Health-Care Settings; WHO Publications, 2009, ISBN 978 92 4 154785 7

Mechanical heating, ventilation and cooling

A problem inherent in mechanical ventilation systems under respiratory pandemic conditions is that recirculation of ventilation air increases the likelihood of infection, since occupants are exposed to infected air repeatedly and for a long period. This situation can be alleviated by ensuring that most (preferably all) of incoming air is directly supplied from outdoor sources.

The *American Society of Heating, Refrigerating and Air-Conditioning Engineers* (ASHRAE) is

recognized as one of the pre-eminent sources of expert knowledge and opinion about HVAC systems in buildings, and we provide some relevant extracts from their publications in this section: In the *ASHRAE Position Document on Infectious Aerosols*, the following statements are relevant³⁰:

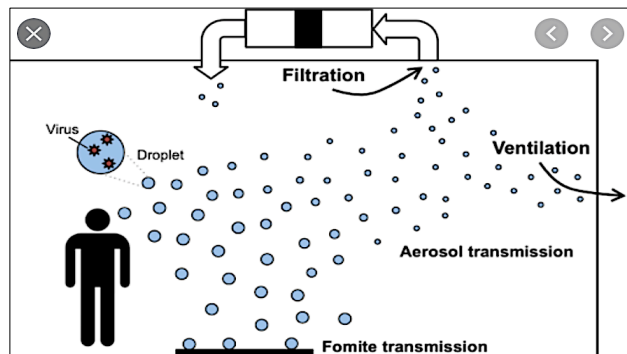
- ... Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled.
- Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.
- ... Ventilation and filtration provided by heating, ventilating, and air-conditioning systems can reduce the airborne concentration of SARS-CoV-2 and thus the risk of transmission through the air. Unconditioned spaces can cause thermal stress to people that may be directly life threatening and that may also lower resistance to infection. In general, disabling of heating, ventilating, and air-conditioning systems is not a recommended measure to reduce the transmission of the virus.
- Building science professionals must recognize the importance of facility operations and ventilation systems in interrupting disease transmission. Non-HVAC measures for breaking the chain of infection, such as effective surface cleaning, contact and isolation precautions ... Dilution and extraction ventilation, pressurization, airflow distribution and optimization, mechanical filtration, ultraviolet germicidal irradiation (UVGI), and humidity control are effective strategies... in buildings and transportation environments.³¹
- ... HVAC system cannot control all airflows and completely prevent dissemination of an infectious aerosol or disease transmission by droplets or aerosols. An HVAC system's impact will depend on source location, strength of the source, distribution of the released aerosol, droplet size, air distribution, temperature, relative humidity, and filtration. Furthermore, there are multiple modes and circumstances under which disease transmission occurs. Thus, strategies for prevention and risk mitigation require collaboration among designers, owners, operators, industrial hygienists, and infection prevention specialists.

ASHRAE has recently issued an advisory guideline, *ASHRAE-reopening-schools-and-universities-c19-guidance*.

See the *Universities or Residential Schools* section on page 19 for more information.

In summary we suggest that 3 air change rates (ACH) should be considered a minimum, with the system having a capacity of providing 100% outdoor air and provided with HEPA filtration systems. Mechanical ventilation systems using all or part re-circulated air provide pathways for virus distribution and non-recirculating systems with 100% outdoor air should therefore be required under pandemic conditions. HVAC systems should always be designed to exhaust contaminated air as close as possible to the source.

ASHRAE is pre-eminent in North America, but Covid-19 guidance suited to the context of India is also available in the *Indian Society of Heating, Refrigerating and Air-Conditioning Engineers*³² (ISHRAE), and the UK *Chartered Institution of Building Services Engineers* (CIBSE) issued guidance in the CIBSE Journal³³.



³⁰ ASHRAE Position Document on Infectious Aerosols, pg. 2, April 14, 2020

³¹ ASHRAE Position Document on Infectious Aerosols, pg. 5-7, April 14, 2020

³² ISHRAE COVID-19 Guidance Document for Air Conditioning and Ventilation, ISHRAE, April 13, 2020

³³ <https://www.cibsejournal.com/technical/cleaning-the-air/>

Building management systems (BMS)

Computer-controlled BMS systems are required to ensure the efficient operation of building systems, to conserve energy, and to ensure that occupants can live or work safely and comfortably within the parameters established. The size and complexity of the building and its functions will determine the scope and sophistication of the BMS system, but the need to manage building systems efficiently during pandemic conditions emphasize their importance³⁴.

A factor directly related to the control of pandemics is information about the population density of occupants in public occupancies. Depending on the culture, personal information on health status of individuals (from their smart phones) may be integrated.

Impact of the pandemic on large and specialized building types

Certain very large and specialized buildings are now dysfunctional. Conventions and conferences of any significant size have a very uncertain future, as do large-scale sporting events. The pandemic has reduced international and inter-city domestic air and rail travel to a shadow of the pre-Covid level of activity. Several aviation industry publications have published information about the rapid decline of air passenger traffic, but there has been little discussion of the major energy and other operating losses that are likely to be incurred before we enter a post-pandemic era. Similar issues are applicable to other large structures that are now largely abandoned.



These considerations lead to questions about what to do with such facilities while waiting for the situation to resolve itself: should parts of airports, train terminals and convention centres be closed off, or should they be re-purposed and, if so, for what purposes? These are major questions and lie beyond the scope of this document.

Requirements for post-Covid changes in configuration, layout and technical systems of buildings will occur at different levels of intensity and urgency, and strategies should be developed for each of these.

- Minor changes, such as changes in internal layouts and furnishings can be accomplished in the short term with minor costs and disruptions.
- A second and more demanding level of intervention, e.g. changes to internal fixed partitions, upgrading of building control and information systems, modifications of HVAC systems etc., can be accomplished with minor physical changes and additions to structure and technical systems, although costs may be considerable.
- When the most demanding level of change is needed, such as enlargement to the total floor area, different internal layouts or functions, larger washrooms, new types of fenestration, a new HVAC system, or more sophisticated building control and information systems, a major retrofit and renovation must be considered, or else replacement of the existing building must be considered.

In all cases, the professional management of buildings is likely to require considerable changes that will involve a greater understanding of the relationship between respiratory diseases and building operations, more knowledge of occupant activities, and more control of their movements and activities in buildings. Such restrictions may create opposition by tenants or occupants.

³⁴ A list of systems that may be monitored or controlled by a BMS are shown in Appendix 1.

2. Issues and proposed actions related to specific building types

Multi-Unit Residential Buildings (MURBs)

- Large MURBS (more than 50+/- units) should be provided with an extra suite on ground or the G+1 floor. Such a suite can be used for guests or for isolation. It could also serve as a shared office for building occupants (but spatial distancing requirements must remain). Additional materials, energy, emissions and water would be required, but it could reduce the need for individual home offices.
- In residential occupancies, dwellings with at least two bedrooms should be provided with a secondary bathroom (toilet, shower and wash basin) to allow for isolation of one person in the household³⁵.
- Private open space for all residential units is a highly-valued feature in urban areas with temperate climates, and is needed to endure lockdown conditions. In ground-oriented residential units, the need can be met by gardens or courtyards, and in mid- to high-rise apartment buildings by balconies³⁶. There are indirect benefits from natural space cooling in summer in temperate climates. In areas with cold winters, balcony slabs will become a source of heat loss unless architectural detailing provides thermal breaks.
- In the 2003 SARS epidemic the virus was transmitted in a Hong Kong apartment tower through faulty plumbing, according to the World Health Organisation³⁷ (WHO). Other research confirms viral transmission through trapped air in the plumbing and wastewater systems in tall buildings, and associated negative pressure caused by bathroom exhaust ventilation. Risk identification is needed along with retrofit measures. More recently, a publication from the *B.C. Centre for Disease Control*³⁸ provides an excellent summary of issues primarily related to operation and viral transmission issues in MURBS, and also covers some design and operational issues.
- Where MURB public areas and corridors lack exterior windows, mechanical ventilation will be required. Public areas should operate under positive pressure, to minimize migration of contaminated air into common areas or from one unit to another.
- Note that many condominium MURBs have individual HVAC systems in each dwelling unit. This adds a layer of complexity to the issue.
- Maintenance of HVAC systems to ensure safe and efficient operation requires professional intervention at the building level, and hands-on coaching at the level of dwelling units.

Long-term residential care buildings

The majority of Covid-related deaths in Canada and in several other countries have occurred in long-term residential care homes. Both residents and staff have been affected.

- A recent report by the Canadian Institute for Health Information³⁹ provides an overview of the situation in Canada compared with 18 OECD countries....*As of May 25, 2020, the number of reported COVID-19 deaths among LTC (Long-term Care) residents varied substantially, from 28 in Australia to 30,000 in the United States, with more than 10,000 in France, Italy, Spain and the U.K. The number of LTC residents who had died of COVID-19 in Canada (5,324) was similar to the average of OECD countries.*
- *While Canada's overall COVID-19 mortality rate was relatively low compared with the rates in other OECD countries, it had the highest proportion of deaths occurring in long-term care. LTC residents accounted for 81% of all reported COVID-19 deaths in Canada, compared with an average of 42% in other OECD countries (ranging from less than 10% in Slovenia and Hungary to 66% in Spain).*

³⁵ <https://www.citylab.com/design/2020/04/bathroom-home-design-history-disease-hygiene-coronavirus/609745/>

³⁶ <https://www.citylab.com/life/2020/04/apartment-design-balcony-private-outdoor-space-zoning-laws/610162/>

³⁷ <https://www.who.int/mediacentre/news/releases/2003/pr70/en/>

³⁸ *COVID-19 Precautions for Multi-unit Residential Buildings*; Angela Eykelbosh, 31 March 2020, <https://www.nccch.ca/sites/default/files/COVID-19%20Precautions%20for%20Multiunit%20Residential%20Buildings%20-%20March%2031%202020.pdf>

³⁹ Canadian Institute for Health Information. *Pandemic Experience in the Long-Term Care Sector: How Does Canada Compare With Other Countries?*. Ottawa, ON: CIHI; 2020.

- The most significant factor appears to be more a matter of poor management than the state of the physical facilities. The issue has come to a head after a contingent of Canadian Armed Forces (CAF) provided emergency support to 5 Ontario long-term care homes, and on May 26, the CAF released a report on what they found⁴⁰. A national newspaper has published a story⁴¹ on the situation that contains troubling information on an extreme lack of care for elderly residents, coupled with very high levels of profits for the private-sector firms owning these facilities.

At the international level, The Guardian⁴² reported on May 16 that:

- In Sweden, about 90% of the 3,700 Covid-19 fatalities were over 70, and half were in care homes.
- More than three-quarters of deaths in Belgian care homes (77%) are suspected Covid-19 cases.
- Between Madrid and Catalonia, care home deaths in the two regions accounted for more than a third of all the coronavirus deaths in the country.
- Italy's higher health institute found that between 1 February and 17 April 2020 there had been 6,773 deaths across all care homes, 40% of which were due to Covid-19.
- U.S. nursing homes have accounted for a staggering proportion of Covid-19 deaths in the US, where more than 102,000 people have died⁴³. ... such deaths now account for more than half of all fatalities in 14 states....but only 33 states report nursing home-related deaths...
- It appears that part of the health hazard for residents may be due to the sharing of rooms by 2 or 4 persons. Changing to single occupancy would undoubtedly reduce the health risk, but would add costs, energy and other operating costs for added room areas and additional bathrooms. Single occupancy would also create conditions for psychological problems caused by isolation⁴⁴.

A distressing lack of care for residents of long-term care facilities seems to be common in many western countries, especially when operated by private-sector firms. This report cannot delve deeply into management issues but at least in Canada, it seems evident that the problem is largely due to a low ratio of staff to residents and very low rates of pay.

Hotels

In-house conference and meeting facilities will clearly play a more limited role in hotel operations in the future because of more difficult travel, the shift to virtual meetings and requirements for spatial distancing on site.

Hotel food service is a complicated problem since, as in restaurants, it involves food and cold storage with staff and processing zones in tight spaces.

During pandemics, hotel rooms may be used for persons undergoing a 14-day isolation period. There may be a need to sanitize rooms after the person ends the isolation period and departs.

Office buildings, or office areas in public buildings

A reduction in occupant density caused by distancing requirements is clearly required, but a counteracting factor is a probable permanent reduction in staff size caused by employees who will continue to work from home, or find other jobs, after the initial Covid crisis is resolved. The net effect of the interplay of these two factors remains to be seen, but is likely to result in a surplus of office space.

A recent newspaper story⁴⁵ reports that... *Facebook Inc. and Ottawa e-commerce company Shopify Inc. both said on Thursday that significant numbers of employees could continue working from home after the pandemic subsides. The Silicon Valley social-network company expects that half of its nearly 50,000 employees will be working remotely by 2030, while Shopify said most of its 5,000-plus staff would continue to do their jobs from home while it also adjusts its workflow and office-space needs...*

⁴⁰ <https://www.tvos.org/article/covid-19-read-the-canadian-forces-report-on-long-term-care>

⁴¹ <https://nationalpost.com/news/companies-managing-troubled-ontario-long-term-care-homes-run-dozens-more-make-millions-in-profits>

⁴² <https://www.theguardian.com/world/2020/may/16/across-the-world-figures-reveal-horrific-Covid-19-toll-of-care-home-deaths>

⁴³ <https://www.worldometers.info/coronavirus/>

⁴⁴ Curtains between beds are an alternative if they are effective in limiting transmission of aerosols or droplets and can be effectively cleaned.

⁴⁵ <https://www.theglobeandmail.com/business/article-shopify-to-close-offices-until-2021-with-most-employees-expected-to/>
Globe & Mail, May 21, 2020

A recent story in The Guardian⁴⁶ reports that a London-based financial consulting firm with 65 staff has given up its head office. The financial savings for firm and staff are substantial, despite the firm paying for desks, laptops, dual screens and printers for staff to use at home, as well as a virtual office to provide a downtown address. Another firm that trains graduates for banking positions has also given up its head office. The CEO has found generally positive results and access to a "workplace club" allows the firm to use meeting rooms and lounges on an occasional basis.

A reduced demand for central-area office space may lead to a series of linked effects such as:

- In the short term, a reduction in office building operating costs, energy and water use.
- A possible reduction in office buildings asset values.
- Conversion of office space to other uses, such as hotels or condominiums.
- Extensive construction and renovation activities related to the above.

A specific example comes from KPMG in Asia⁴⁷ ... *About half of KPMG's Asia-based staff have returned to their offices, to varying degrees, and the transition back was tightly structured. Returns were scheduled by floor, start times are staggered and employees come in on different days of the week. Inside the offices, KPMG tracks occupant movements using data from pass cards, and has cordoned off some desks and offices. Meetings in person are limited to four people, who must each be two metres apart. And employees work in teams that rotate between offices and their homes so that if a staff member catches the virus, their team can be isolated and another can step in to help clients.*

The solutions arrived at for post-pandemic offices include very complex time-shifting as well as spatial distancing considerations. One example cited in the CityLab report is ... *Bergmeyer, a design collaborative with open-plan offices in Boston and L.A., is currently planning to invite employees back... in phases. In the Boston office, people will come back in three waves, over three-week cycles. About a third of the office will be sorted into each wave, and divided in two again: half will come in Mondays, Wednesdays, and Fridays and the other half on Tuesdays and Thursdays. If people want to avoid rush hour on public transit, managers are suggesting people stagger their arrivals each day...from 11 a.m. to 4 p.m. Eastern time, when workers on both coasts are online.*

Hot-desking⁴⁸ in open offices may decline because of reduced occupant load (staff working at home), and because of the need to sanitize furniture after each use. There is likely to be an increasing use of small, compartmented work spaces or even personal devices⁴⁹.

Public washrooms in office occupancies are likely to need renovation and refit, to respect distancing requirements (more space between urinals and sinks, and possibly between toilet compartments). This will require that washrooms be enlarged, but declining staff numbers on site may help to reduce this need. An alternative of conversion to unisex washrooms is explained in C1.2.

Retail commercial

In high-occupancy environments (supermarkets, banks etc.) one-way flow for shoppers and visitors is needed to reduce interaction between people, especially where passageways are narrow.

In a retail shop, consumers have short-term exposure risk, but clerks and other staff have all-day exposure, so they must be given added protection in the form of protective barriers and ventilation systems that can be altered in rate and direction of flow.

Food and meat processing plants

Processing of perishable crops requires that seasonal workers be provided with housing, sanitary and cooking / dining facilities close to the processing facilities. The quality and space allocated for such accommodation is a problem in Europe and North America, creating conditions for pandemic outbreaks.

⁴⁶ <https://www.theguardian.com/business/2020/jun/27/why-the-home-working-boom-could-tumble-londons-skyscrapers>

⁴⁷ *The challenges of physical distancing, 36 storeys up in skyscrapers*; Globe and Mail, 04 May, 2020

⁴⁸ Wikipedia - Hot desking is an office organization system which involves multiple workers using a single physical work station or surface during different time periods

⁴⁹ see *Cone of Silence* from the TV show *Get Smart*

Meat processing plants are a special category of food processing that constitutes a major source of Covid-related infections and deaths. A hygiene and public health expert at the University of Bonn has recently stated that⁵⁰ ... *Air cooling systems used at abattoirs could be an overlooked risk factor accounting for Covid-19 outbreaks, according to scientists who have studied conditions at a meat processing plant at the heart of a cluster of infections in Germany. Martin Exner, a hygiene and public health expert at the University of Bonn, spent two days analysing the plant in Gütersloh, a western German city sent back into lockdown this week after around 1,500 employees were infected with coronavirus.*

At a press conference, Exner said the air filtration system in the slaughter area had contributed to the spread of aerosol droplets laden with the virus. The area of the plant where animals are slaughtered, gutted and cut to pieces is kept at a cool 6-10 °C degrees. To do this, the cooling system circulated the same unfiltered air, thus keeping aerosols in motion, Exner said. A filter fitted to the cooling system was not able to keep out the virus, his analysis found.

Relevant risk factors in meat processing plants include low ambient temperatures, which is a more stable environment for viruses, and high-density seating of workers, aggravated by high noise levels which cause workers to speak very loudly to communicate. Individual Bluetooth communication devices may be useful in solving this problem.

Cafés and restaurants

Seating density in eating areas must be adjusted to respect the 2 m. distancing requirements. Commercial kitchens, food storage, washrooms and other support areas pose a challenge, especially when renovations are required that might require an increase in floor area.

Primary and Secondary Schools

Preventing the spread of respiratory disease in a school environment is of major importance. Young children may find it difficult to fully implement the need for distancing, control of sneezing and frequent hand-washing. Teachers and other staff who work in close contact with children are also vulnerable in such settings.

As in all occupancies, distancing requirements lead to a need for more space. In the case of schools, the number of post-Covid students on site may be reduced by the absence of those who are receiving home schooling.



Many complex educational and social issues are involved in a shift from face-to-face to remote teaching, and it is not yet clear if the major challenges can be overcome.

Universities or residential schools

Settings like these share some characteristics of MURBS, office buildings, commercial retail, sports, conference and other assembly occupancies.

Problems arise in the conflict between the new emphasis on remote teaching and the required hands-on teaching of applied science, technologies etc. Staggered or time-shifted attendance times while distancing would lead to multiplication of courses or a limitation on the number of students. Either option may be prohibitively expensive for the institutions and for students.

Architectural Design Studio (ADS) teaching for example will face huge disturbance if adopting full-remote distance learning. The physical component of ADS is of great importance, and a hybrid approach of teaching (Virtual/In-person) is necessary. Spatial and temporal adjustment of the studio spaces is a must while maintaining high standards of health and safety.

⁵⁰ *Abattoir air cooling systems could pose Covid-19 risks, expert warns*; Philip Otterman in The Guardian, 25 June 2020

ASHRAE has very recently issued an advisory guideline⁵¹, *ASHRAE-reopening-schools-and-universities-c19-guidance*. The guide is meant to provide practical information and checklists to school district and university campus environmental health managers, facility managers, administrators, technicians, and service providers to prepare educational buildings for the resumption of classes. The guideline contains much practical information that is relevant to an American context, but some general recommendations have a broader relevance and is certainly worth reviewing by those trying to re-launch their school systems in other countries.

Prisons

The incarceration of large groups of prisoners at high densities of accommodation and for long periods provides valuable experience and data about conditions conducive to the spread of Covid-19. The U.S. experience is especially useful because of the large prison populations there, 2.3 million people in 2016⁵². According to the New York Times⁵³ *...the number of infected inmates and workers has exceeded 70,000, the count doubled between mid-May and mid-June — and there have been at least 627 virus-related deaths*. In a related court case, the judge noted that *... the inmate “remains in regular and close contact with other inmates and prison staff. ... He lines up with other inmates in proximity in order to receive food and medication multiple times per day. He also shares communal spaces like toilets, sinks, and showers with dozens of other people. The prisoner was not even housed in a cell by himself; he shared one with another prisoner.*

Sports, concert, conference and other assembly occupancies

Seating density in assembly areas must be adjusted to respect the 2 m. distancing requirements. Considering row as well as sideways spacing, this is an extremely difficult challenge.

An aggravating factor in sports and concert halls is that cheering and chanting (sports fans) or singing (choirs) appears to result in virus particles being spread much further and wider than is the case for normal speech. This, combined with seating distance issues, seems to be the main reason why most health authorities have closed down such venues during the pandemic.

Religious assemblies, conferences, and smaller meetings have also been identified as effective arenas for viral transmission, leading health officials in many countries to establish limits on group meetings, for both public and private events. Sweden has established a maximum group size of 50 persons for meetings, and restrictions like this have led to the cancellation of many religious, sports, concert and conference events. In the case of small (less than about 20 persons) interactive meetings, videoconferencing can work well, but this is not a viable solution for larger events. Perhaps all the issues outlined for these assembly occupancies will lead to more use of outdoor locations, where weather conditions permit.

Community Service Centres

Other types of community emergencies include weather-related emergencies such as flooding or windstorm or heat waves, earthquakes or large-scale fires. Given the possible confluence of pandemics and extreme weather generated through climate change, it may be time to think ahead about community requirements under future pandemic conditions. A Community Service Centre would be a new type of public facility that can be purpose-built, or located in existing schools, auditoria or hotels for shorter periods.

- A purpose-built Service Centre should be designed to be easily adapted to changes in functions.
- Such a facility provides temporary shelter for households with temporary food and support services
- Specific functions will depend on location, but will probably include:
 - Medical screening and/or treatment of local population and also support for non-pandemic medical needs. Providing local treatment reduces demand for transport to distant health centres.
 - Isolation for local residents during pandemic lock-downs.
 - Protection for those relocated by wildfire, flood and earthquake.
 - Cooling, for persons without air conditioning during heat waves.
 - Warming, for people without proper heating systems during cold winter periods.

⁵¹ <https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf>

⁵² Incarceration in the United States - Wikipedia.

⁵³ <https://www.nytimes.com/2020/06/25/opinion/coronavirus-prisons-compassionate-release.html>

- Sanitary facilities (public washrooms, WCs and showers).
- A community kitchen.
- Storage for emergency food and medical equipment.

The refuge function is especially important for members of low-income households, who may be homeless in the short term or who lack air conditioning for heat waves. Community cooling centers⁵⁴ have been established in some urban areas in U.S.A. to provide relief during heat waves. These facilities can also provide heat-wave shelter during pandemics, although a number of special factors should be considered according to the *Centers for Disease Control and Prevention* (CDC)⁵⁵.

The design and operation of such facilities must take into consideration the likely mix of ages, illness and mental as well as physical distress of the displaced people who need to make use of the facility.

Existing community buildings with suitable site locations, structures, space and equipment, can serve this purpose well on a short-term basis during pandemics or other disasters, but the shift in function must be rapid.

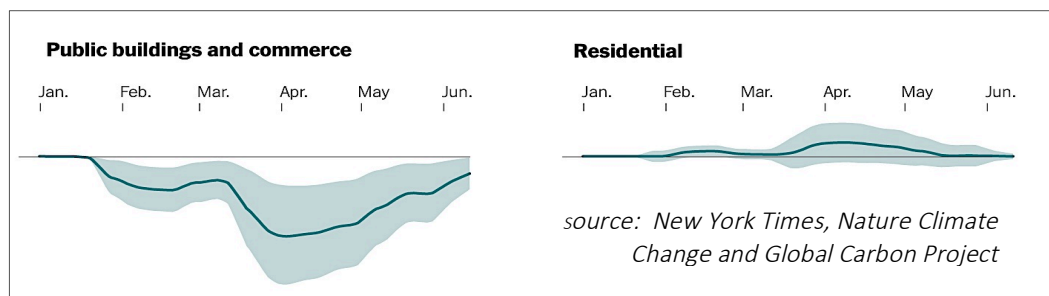
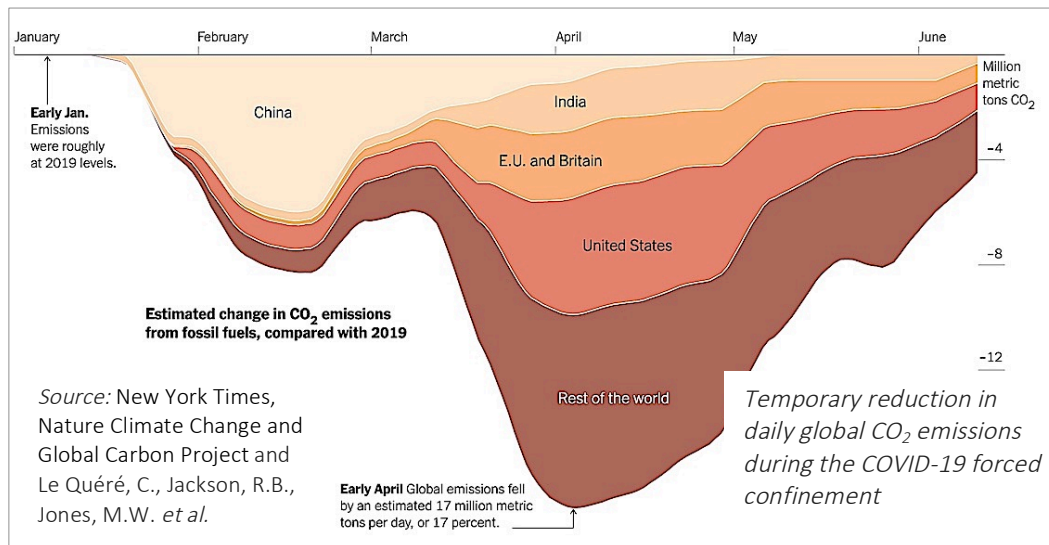
⁵⁴ https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/heat/cooling-centers.page

⁵⁵ <https://www.cdc.gov/coronavirus/2019-ncov/php/cooling-center.html>

E. Impact of the pandemic on climate and environmental actions

Effects and impacts on atmospheric emissions

Global carbon dioxide emissions have shown a substantial drop during early April 2020⁵⁶. Most of the reduction has been within the industrial and transport sectors and not related to building operations. The reduction is also likely to be temporary⁵⁷ and will rebound later in 2020-21 as economies open up to normal levels of activity.



Plans for European investments in deep green renovations⁵⁸

The European Commission (EC) is currently working on a green recovery plan that will focus on building renovation, renewables and hydrogen as well as clean mobility and the circular economy, according to a leaked working document obtained by EURACTIV⁵⁹. This approach is intended to provide synergy between economic recovery and climate action efforts, and is in contrast with the lack of action in North America in this regard.

In other regions and countries, economic recovery plans related to the built environment are not yet defined, because the pandemic has not yet run its course in these areas, but it is likely that there will be difficulties in raising the massive amounts of capital that are likely to be needed.

The Buildings Performance Institute Europe (BPIE) has published an analysis of the economic opportunity for Europe's building sector, which could help mitigate economic damage of the Covid-19 pandemic. According to BPIE... *the findings show that the total amount of public funding required to trigger a significant scaling up of the renovation rate and depth would add up to €90 billion annually until 2050, with €76 billion annually allocated in support of building renovation, and an additional €14 billion/a should be provided in an innovation fund to scale*

⁵⁶ Le Quéré, C., Jackson, R.B., Jones, M.W. *et al.* Temporary reduction in daily global CO₂ emissions during the COVID-19 forced confinement. *Nat. Clim. Chang.* (2020). <https://doi.org/10.1038/s41558-020-0797-x>

⁵⁷ <https://www.carbonbrief.org/analysis-what-impact-will-the-coronavirus-pandemic-have-on-atmospheric-co2>

⁵⁸ http://bpie.eu/wp-content/uploads/2020/05/Recovery-investments-in-deep-renovation_BPIE_2020.pdf

⁵⁹ <https://www.euractiv.com/section/energy-environment/news/leaked-europes-draft-green-recovery-plan/>

*up serial renovation of buildings on an industrial scale. The total investment opportunity for deep renovation of Europe's buildings is estimated at €243 billion per year.*⁶⁰

A clear picture of the financial requirements for Europe's building sector is of high political relevance...The European Commission (EC) is ... preparing to put at least €1 trillion into a broad stimulus programme expected to be presented next week (June 25-29). In addition, the "Renovation Wave" strategy for buildings, proposed by EU Commissioner for Energy, Kadri Simson, has been deemed a priority for economic recovery and will be released this September.

Oliver Rapf, Executive Director at BPIE states... it has become clear that renovation of the European building stock would create a triple benefit. It would lead to an increase in economic activity, retaining and creating employment; it would support the achievement of Europe's climate and energy targets, and it would provide Europeans with better and healthier buildings.

Views of IEA and IMF on a sustainable recovery

A recent IEA-IMF special report⁶¹, prepared in collaboration between the International Energy Agency and the International Monetary Fund (IMF) outlines the views of these two major organizations on the prospects for a recovery from the economic collapse that has resulted from the Covid-19 pandemic. A special concern of the IEA is to consider energy and emissions issues in designing and supporting such a recovery. A covering press release, dated 19 June notes that ... *the set of policy actions and targeted investments over the 2021-2023 period that are outlined in the Sustainable Recovery Plan could:*

- *boost global economic growth by an average of 1.1 percentage points a year*
- *save or create roughly 9 million jobs a year*
- *reduce annual global energy-related greenhouse gas emissions by a total of 4.5 billion tonnes by the end of the plan*

In addition, the plan would deliver other improvements to human health and well-being, including driving a 5% reduction in air pollution emissions, bringing access to clean-cooking solutions to around 420 million people in low-income countries⁶², and enabling nearly 270 million people to gain access to electricity.

Achieving these results would require global investment of about USD 1 trillion annually over the next three years. This sum represents about 0.7% of today's global GDP and includes both public spending and private finance that would be mobilised by government policies.

Buildings:

- *According to IEA/IMF, ...the Covid-19 pandemic is resulting in drastic declines in construction and investment in the buildings sector because of disruptions to on-site working conditions, labour availability and material supply chains. More than 25 million jobs across the sector have been lost or are at risk in 2020. However, measures to improve the efficiency of buildings and appliances could be implemented quickly, in some cases with very short payback periods, creating 10-15 jobs per million dollars invested.*
- *For investment measures, energy efficiency in buildings and industry together with solar PV create the most jobs per million dollars of investment: on average, these three measures create between 10-15 jobs for every million dollars. Energy efficiency measures tend to be labour intensive, and the jobs involved tend to pay relatively low average wages, while the rapid cost reductions in solar photovoltaic (PV) in recent years means that labour now represents a much larger portion of total costs than was the case in the past.*

Evaluation of possible recovery measures

- *Investment in energy efficiency in buildings is expected to fall by nearly 15% in 2020 from around \$150 billion in 2019. With buildings accounting for more than 30% of global energy use today and 30% of energy-related CO2 emissions, investment needs to accelerate significantly if the world is to meet its sustainable development goals.*

⁶⁰ One of our editorial contributors Giancarlo Mangone <mangoneg@gmail.com> strongly disagrees with the wisdom of this policy and has volunteered to launch a discussion group on the subject.

⁶¹ World Energy Outlook Special report, in collaboration with the International Monetary Fund, June 2020

⁶² In this report, we will only deal with aspects related to the built environment

- **Retrofit existing buildings and more efficient new constructions:** We estimate that 9-30 jobs would be created for every million dollars invested in energy efficiency measures in the buildings sector. Measures in this area often have short lead-times: existing efficiency programmes, for example, can be rapidly expanded and new projects can be shovel-ready within weeks or months. ...Government investment in accelerating energy efficiency in buildings would bring long-lasting benefits: it would reduce energy bills for consumers, reduce energy poverty, improve health and comfort, and improve resilience in the face of climate events and price shocks.
- **More efficient and connected household appliances:** Lower household incomes, disruption to global supply chains and the closure of retail outlets have resulted in the deferral or cancellation of many appliance purchases. This has slowed the rate of improvement in energy efficiency. Action to support the replacement of old appliances with new, highly efficient and connected appliances would create 7-16 jobs for every million dollars spent.

Retrofit of existing buildings and more efficient new construction

The Covid-19 pandemic is drastically reducing global construction and retrofit activity in the buildings sector. Investment in building construction may decline by 20% to 30% in major advanced economies in 2020, while also falling in China and India. About 250 million people are employed in construction across the world: estimates suggest that over 10% of jobs have been or will be lost in 2020, and up to 80% of workers have been furloughed in some countries.

In some countries, existing buildings are expected to account for up to 80% of the stock in 2030; retrofits have an especially important part to play in improving energy efficiency. In countries where the building stock is expanding rapidly, it is particularly important to ensure that new buildings are constructed as efficiently as possible. Delays to construction and renovation activity will slow energy efficiency improvements, affecting energy use and related CO₂ emissions in the buildings sector. This is especially the case for space heating and cooling, which account for almost 40% of energy use in buildings today and for 42% of CO₂ emissions and over 60% of direct CO₂ emissions in the sector.

Retrofits for existing buildings and efficient new constructions are the primary means of reducing energy demand in the sector. Where retrofits are needed, they are most effective at reducing demand and emissions when improvements are made to the building envelope... and when there is a shift to more efficient equipment, such as heat pumps or heat solutions based on renewable resources, and to digital energy management.

Building efficiency measures are central to achieving near zero energy building status in both new and existing buildings. Average annual energy retrofit rates in buildings are currently less than 1% in most major markets, which is well below the level required to achieve sustainability objectives. Most buildings in advanced economies – where heating demand is concentrated – were built before there were effective building codes. Even today, less than one-third of countries globally have mandatory energy-related codes for new construction.

Policy approaches to address the current Covid-19 crisis-related circumstances include:

- Increase incentives for building efficiency improvements, smart energy management solutions and on-site renewables, including by reducing administrative and processing times for approvals and addressing shortages of skilled providers.
- Target efficiency improvement measures on those households and businesses most impacted by the crisis, such as low-income households, small businesses and hotels.
- Use public procurement to catalyse activity, for example by commissioning efficiency retrofits of public assets such as social housing, schools, offices and healthcare facilities.
- Provide guarantees to encourage energy service companies to invest in retrofits.
- Accelerate or expand existing and planned efficiency programmes.

Deep energy retrofits of old buildings can reduce energy demand linked to space heating by two-thirds or more: they can also reduce or eliminate emissions where they involve switching to renewables or decarbonised electricity. Retrofitting 20% of buildings in advanced economies over the next five years would reduce CO₂ emissions from space heating by around one-fifth. Major cost-effective gains can be achieved by improving insulation and installing heat pumps.

More efficient buildings help to improve the security and resilience of energy systems by reducing energy use. Retrofits and efficient construction that encourage electrification and the use of smart energy management systems strengthen the security and resilience of electricity systems, boosted by the use of smart devices and on-site renewables that facilitate load management and support increased integration of variable renewables into electricity networks.

Survey... on impact of Covid-19 on policies for climate change actions.

The current focus on the Covid-19 pandemic as a threat to global health and to social and economic order results in less political will available to pursue issues related to the serious need for climate change mitigation and adaptation, and/or pursuing improved sustainable outcomes in construction. We must recognize that climate change unfortunately lacks the clarity and immediacy of the pandemic threat in the mind of the public, but it remains an existential threat to the planet and the people on it.

A forthcoming paper⁶³ on the relationship between global Covid-19 fiscal recovery packages and progress on climate change actions ... *is based on a survey of 231 central bank officials, finance ministry officials, and other economic experts from G20 countries on the relative performance of 25 major fiscal recovery archetypes across four dimensions: speed of implementation, economic multiplier, climate impact potential, and overall desirability....* The authors identify five policies with high potential on both economic multiplier and climate impact metrics including: *clean physical infrastructure, building efficiency retrofits, investment in education and training, natural capital investment, and clean R&D.*

In lower- and middle-income countries (LMICs) rural support spending is of particular value while clean R&D is less important. These recommendations are contextualised through analysis of the short-run impacts of Covid-19 on greenhouse gas curtailment and plausible medium-run shifts in the habits and behaviours of humans and institutions. ..However, the crisis has also demonstrated that governments can intervene decisively once the scale of an emergency is clear and public support is present. Covid-19 has precipitated a major increase in the role of the state (Helm, 2020). Decisive intervention has begun to stabilise infection rates, prevent health systems being overwhelmed, and save lives...The climate emergency is like the Covid-19 emergency, just in slow motion and much graver...

The authors propose three key insights for policy-makers...

- * Recovery policies can deliver both economic and climate goals
- * Co-benefits can be captured.
- * Policy design (timeliness and flexibility) is important

The authors make interesting observations related to the role of the construction industry in a pandemic recovery period... *Green construction projects, such as insulation retrofits or clean energy infrastructure, can similarly deliver higher multipliers. These large construction projects are less susceptible to offshoring to imports (Jacobs⁶⁴). Clean energy infrastructure is also helpfully very labour intensive in the early stages – one model suggests that every \$1m in spending generates 7.49 full-time jobs in renewables infrastructure, 7.72 in energy efficiency, but only 2.65 in fossil fuels (Garrett-Peltier⁶⁵). In the long run, these public investments offer high returns by driving down costs of the clean energy transition (Henbest⁶⁶).*

Harnessing more of these opportunities could result in ‘kick starting the green innovation machine’ (Acemoglu et al.,⁶⁷) and driving an efficient, innovative, and productive economy, with higher spill overs that benefit the wider economy (Aghion et al.,⁶⁸).

⁶³ Hepburn, C., O’Callaghan, B., Stern, N., Stiglitz, J., and Zenghelis, D. (2020), *Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?*, Smith School Working Paper 20-02.

⁶⁴ Jacobs, M. (2012), ‘Green Growth: Economic Theory and Political Discourse,’ GRI Working Papers No. 92, Grantham Research Institute on Climate Change and the Environment, London.

⁶⁵ Garrett-Peltier, H. (2017), ‘Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model,’ *Economic Modelling*, 61, 439–447.

⁶⁶ Henbest, S. (2020), The First Phase of the Transition is About Electricity, Not Primary Energy, <https://about.bnef.com/blog/the-first-phase-of-the-transition-is-about-electricity-not-primary-energy/>, accessed April 27, 2020.

⁶⁷ Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous (2012), ‘The Environment and Directed Technical Change,’ *The American economic review*, 102(1), 131–166.

F. Conclusions

- The Covid-19 pandemic has been an undoubted global health, social and economic disaster.
- Even if a vaccine is developed, a vaccination program is not likely to be widely implemented until late 2021, and it appears likely that the disease will remain in an endemic form for several years.
- Global economies have also been badly damaged, and a rebuilding program is likely to involve trillions of Euro or equivalent, and require a decade of effort.
- However, such efforts will offer great opportunities to integrate health and economic goals with those of climate action, and the next 3 to 5 years are our last chance to take strong action to deal with climate change.

⁶⁸ Aghion, P., Hepburn, C., Teytelboym, A., & Zenghelis, D. (2014). 'Path dependence, innovation and the economics of climate change'. Centre for Climate Change Economics and Policy/Grantham Research Institute on Climate Change and the Environment Policy Paper & Contributing paper to New Climate Economy.

G. Key Covid-19 requirements and implications for the built environment

Urban issues and systems: <i>note that this analysis must be carried out separately for different regions and climates</i>		
Urban development pattern	<ul style="list-style-type: none">■ Barriers to working in formal office settings and easier internet-based work will cause middle class to move away from urban dwellings to larger suburban houses, which are larger, have gardens and are less expensive.■ Manual, industrial and some retail workers will not be able to take advantage of this new pattern.	<ul style="list-style-type: none">■ Some of the population movements (to the centre or to the periphery) are not yet resolved.
Local transport	<ul style="list-style-type: none">■ Use of public transport has collapsed.■ Personal car usage may increase■ Bicycling will increase, but only where climate and weather is suitable and local governments take appropriate measures.■ Walking in local areas will also increase, partly because home-based workers need to exercise.	<ul style="list-style-type: none">■ The struggle between personal cars or public transport is also unresolved, but it is clear that bicycling and walking is gaining in popularity where climate and weather is suitable and vehicle traffic is kept separate.
Neighbourhood development	<ul style="list-style-type: none">■ Trend towards mixed-use urban neighbourhoods continues■ Area currently used for vehicle traffic and parking will be reduced to provide more space for café and restaurant terraces, bicyclists, pedestrians, greenery and trees.■ High-risk elements: drinking fountains and play areas.	<ul style="list-style-type: none">■ The economic collapse of retail commerce caused by the Covid-19 pandemic provides an opportunity to rebuild according to mixed-use, with low-energy building and transport systems, and with more emphasis on preserving and enhancing ecological systems.
Green spaces, parks and gardens	<ul style="list-style-type: none">■ Sustainable land use management principles in the design and operation of large park areas will ensure that storm water management and soil permeability is considered.■ Even where paving is required, permeability is possible.■ Community vegetable gardens are needed for residents to grow local produce within walking distance of homes.	
Key requirements for multiple building types		
Item / Issue	Suggested measures	Comments
Building entries and shared facilities	<ul style="list-style-type: none">• No-hands operation of doors and sanitary equipment is needed to minimize viral spread in frequently used locations, such as entries, lobbies, laundry rooms, recreation facilities and parking facilities.• Access and use by disabled persons must be considered.• Thermographic scans provide triage measure;• Data collection from mobile phones for track-and-trace, where local laws and customs permit.• Provide wash basins or hand sanitizers stations at entries.• Continuous monitoring of occupancy numbers and density is optional in some key facilities	<ul style="list-style-type: none">■ Except for thermographic scans, the other measures are common in high-end (Class A) office buildings.■ There are moderate equipment costs and some added operating costs
Public washrooms and bathrooms	<ul style="list-style-type: none">• Convert male and female washrooms to unisex WCs with small wash basins;• Provide self-cleaning mechanism;• Japanese washlet toilets are an option;• Exhaust fans should be located directly above the source of contamination.	<ul style="list-style-type: none">■ Unisex WCs are desirable but may require more total floor area than conventional washrooms, which would require major renovations
Lifts in high-rise buildings	<ul style="list-style-type: none">• Spatial distancing leads to limited no. of passengers per lift;• An option is to install additional or larger lifts in an expanded or new building.• A mechanism to establish time shifting is needed.	<ul style="list-style-type: none">■ Larger lifts are a difficult and expensive option in existing buildings.

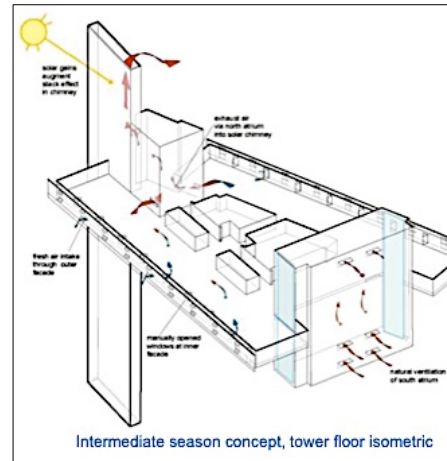
Natural ventilation	<ul style="list-style-type: none"> • Applicable where the depth of ventilated area is less than 7+/- m. and where exterior noise and pollution conditions are acceptable; • Where air-cooling systems are provided, they should be automatically switched off when operable windows are open, in order to maintain HVAC efficiency. • Natural ventilation with outdoor air will reduce or eliminate need for mechanical cooling and ventilation, except in extreme summer and/or noise conditions, thereby reducing energy consumption, GHG emissions, capital and operating costs. 	<ul style="list-style-type: none"> ■ This is easy to achieve in new buildings, and can result in reduced operating costs; ■ Depending on orientation and exterior wind and noise conditions there may also be a psychological benefit
Mechanical heating, cooling and ventilation systems	<ul style="list-style-type: none"> • In general, ASHRAE or iSHRAE or CIBSE or equivalent guidance should be followed; • Systems should be capable of 100% outdoor air (OA); • An increase in the Air Change Rate (ACH) should be possible to reduce risk of infection; • Provide positive air pressures in public areas to prevent migration of air from contaminated spaces; • Minimize need to cool OA in hot weather or to heat OA in cold weather via heat exchangers 	<ul style="list-style-type: none"> ■ OA consumes more energy than systems with recirculating air; ■ Increases energy requirements if the higher speed setting is used.
Building management systems (BMS)	<ul style="list-style-type: none"> • Compared to normal BMS systems, more information on occupants is needed, probably linked to mobile phones. 	<ul style="list-style-type: none"> ■ Local cultural values and privacy concerns may determine extent of links.
Rain-water storage and separate grey-water supply	<ul style="list-style-type: none"> • This measure is focused on reducing water consumption in regions where potable water deficits occur; • Greywater can be used for toilet flushing and for irrigation. 	<ul style="list-style-type: none"> ■ Surface areas available for rainwater collection is a practical limit.

Specific Building or Occupancy Types		
Item / Issue	Suggested new measures	Comments
Multi-Unit Residential Buildings (MURBs)	<ul style="list-style-type: none"> ■ In large MURBs, a small extra unit should be provided for occupants who need to isolate; ■ Dwelling units with 2 or more bedrooms should be provided with a secondary bathroom; ■ All dwelling units should be provided with private open space (POS); ■ Minimize risk of floor-to-floor virus transmission through plumbing systems; ■ Dwelling units with individual HVAC systems need control systems that warn of inefficient operation. 	<ul style="list-style-type: none"> ■ Items 1, 2 and 3 result in increased capital and operating costs and energy consumption; ■ The value of private open space depends on the pollution, noise and visual attributes of the immediate surroundings.
Long-term residential care buildings	<ul style="list-style-type: none"> ■ Shared rooms should be avoided; ■ Provide single-user unisex WCs with toilet and small sink, and separate shower / bath room; ■ Natural ventilation with outdoor air and no recirculation is highly desirable. ■ Permanent staff is needed to ensure high quality service, and that means that staff must be permanent employees and operated by a government or non-profit organization. 	<ul style="list-style-type: none"> ■ Occupancy by 2 or more residents is linked to a higher rate of viral transmission. ■ This will increase overall building area and also requires more bathroom facilities. Increases capital and operating costs
Office buildings	<ul style="list-style-type: none"> ■ More space is needed in lobbies, open offices, corridors and washrooms, to respect 2m distance. ■ Provide a ground floor meeting area with a street entrance where staff doing work at home can come in for occasional meetings; 	<ul style="list-style-type: none"> ■ It is unclear if increased spacing requirements will balance the reduction of on-site staff caused by employees working at home.

	<ul style="list-style-type: none"> ■ In open office areas, time shifting can be used in addition to space distancing; ■ Natural or mixed-mode ventilation is highly desirable; ■ Provide single-user unisex WCs with toilet and small sink plus a shared shower/bath room. 	<ul style="list-style-type: none"> ■ If extra floor space is needed, there will be increased capital and operating costs and energy consumption. ■ The percent of staff working at home is a key variable.
Retail commercial	<ul style="list-style-type: none"> ■ Provide one-way flow for shoppers and visitors, and screens to protect staff; ■ Direct entry to shop from the street is desirable, to reduce exposure to indoor recirculated air. 	<ul style="list-style-type: none"> ■ Retail chains may survive the economic collapse, but small retail shops will need to be re-established, perhaps in a better way.
Food processing plants and worker accommodations	<ul style="list-style-type: none"> ■ Most industrial workers cannot do their work from home, so the problems have to be solved on site.. ■ In meat processing plants, close spacing of workers on production lines is a factor in virus transmission. ■ In all industry types, noisy environments are an indirect factor in spreading airborne disease. 	<ul style="list-style-type: none"> ■ Increased space results in increased capital and operating costs and energy consumption
Cafés and restaurants	<ul style="list-style-type: none"> ■ Provide spatial distancing and/or time shifting; ■ Ensure that spatial distancing is considered in kitchens; ■ Provide single-user unisex WCs with toilet and small sink. 	<ul style="list-style-type: none"> ■ As with small retail, there will be major rebuilding required.
Primary and secondary schools	<ul style="list-style-type: none"> ■ More space is needed in lobbies, corridors, classrooms and cafeterias, to respect 2m.distance. ■ Time shifting can be used in addition to spatial distancing; ■ Natural or mixed-mode ventilation is highly desirable; ■ Provide single-user unisex WCs with toilet and small sink 	<ul style="list-style-type: none"> ■ Increased space results in increased capital, operating costs and energy consumption,
Universities or residential schools	<ul style="list-style-type: none"> ■ Problems arise in the conflict between the new emphasis on remote teaching and the required hands-on teaching of applied science, technologies etc. Staggered or time-shifted attendance times while distancing would lead to multiplication of courses or a limitation on the number of students/ ■ Universities are likely to adopt of a small number of small live events, along with large virtual teaching sessions. ■ Architectural Design Studio (ADS) teaching for example will face huge disturbance if adopting full-remote distance learning. The physical component of ADS is of great importance... 	<ul style="list-style-type: none"> ■ These institutions are likely to have large amounts of unused space, at least during the next few years, and this means wasted energy & operating costs. ■ Some less-specialized facilities may be leased out or converted to other uses. ■ Universities may begin to resemble mixed-use communities.
Prisons	<ul style="list-style-type: none"> ■ Focus more on tracking and controlling behaviour of indicted persons, and less on incarcerating them. This is socially and economically superior to the alternative of building more prisons. 	
Sports, concert, conference and other assembly occupancies	<ul style="list-style-type: none"> ■ Entry and exit areas and seating density in assembly areas must be adjusted to respect the 2 m. distancing requirements. Considering row as well as sideways spacing, this is an extremely difficult challenge. 	<ul style="list-style-type: none"> ■ A major problem is to resolve the economics of spatial distancing.
Community Service Centres	<ul style="list-style-type: none"> ■ In many urban areas, extreme events such as pandemics, flooding, windstorms or major fires, will impose difficult conditions on residents, especially low-income or elderly. ■ A local service facility provides temporary shelter for households requiring temporary shelter, food and support services 	<ul style="list-style-type: none"> ■ The extra financial and energy costs are justifiable in view of multiple needs.

during the 1990s, and it exceeded the energy performance requirements of that program by a wide margin, showing that hybrid ventilation in an office building can support very high performance.

Air distribution for heating and cooling systems provide pathways for virus distribution. Non-recirculating systems capable of 100% outdoor air supply are therefore essential for control of viral transmission in such occupancies. Operable windows are desirable if HVAC systems are linked. Mixed-mode ventilation can be achieved based on a passive double-skin façade, such as that used in the Manitoba Hydro headquarters building⁷² in Winnipeg, Manitoba. The drawing shows the system that was subsequently constructed in 2008.



4. Building management systems in office buildings

A list of systems that may be monitored or controlled by a BMS are excerpted below⁷³:

Illumination (lighting) control

[Heating, ventilation, and air conditioning](#)

[Access control](#)

[Lifts, elevators](#) etc.

[Closed-circuit television](#) (CCTV)

PA system

Electric power control

Security and observation

[Fire alarm system](#)

[Plumbing](#)

Control Panel

Security Automation

⁷² Manitoba HQ building, Winnipeg. Architects Kuwabara, Payne, McKenna, Blumberg and Smith Carter Searle.

⁷³ https://en.wikipedia.org/wiki/Building_management_system

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