

Pandemics and Sustainability of the Built Environment

The COVIDd-19 pandemic has made visible some important conflicts between 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 the 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 paper will occasionally be updated as more information becomes available and as our knowledge increases.

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

A. Context

All issues and responses to them are influenced by contextual factors. The COVID-19 pandemic has caused affected millions of people globally, and has demonstrated that societies and individuals of all classes undergo dramatic and rapid changes under pandemic conditions. The following context factors appear to be relevant:

1. Recent global events

- 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.
- 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.
- 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 plants², prisons, churches, sports stadia, conference centres and other places 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.
- Global carbon dioxide emissions have shown a drop of about 17% during early April 2020³. Most of the reduction has been within the industrial and transport sectors and not related to building operations. Much of this reduction is temporary and will rebound later in 2020 as societies and economies open up to normal levels of activity⁴.
- These 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 CO₂ reductions therefore carry a heavy price, and the disruption of commerce and daily life will not be tolerated for more than short periods.

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

- According to Oxfam, half a billion people (between 6 and 8 percent of the global population) could be pushed into poverty by the Covid-19 pandemic⁵. The World Bank estimates that the pandemic could push about 49 million people into extreme poverty in 2020⁶ 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 do not recognize 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

² 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.

³ 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>

⁴ <https://www.carbonbrief.org/analysis-what-impact-will-the-coronavirus-pandemic-have-on-atmospheric-co2>

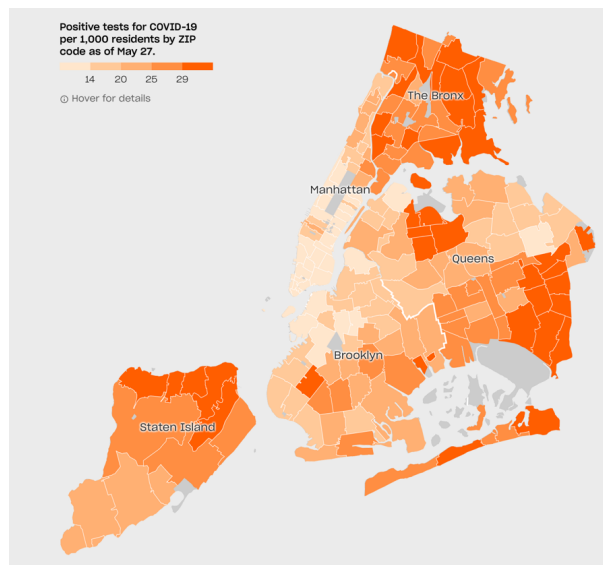
⁵ <https://www.oxfam.org/en/press-releases/half-billion-people-could-be-pushed-poverty-coronavirus-warns-oxfam>

⁶ 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>

constraints, violence, and overcrowding in slums make physical distancing and self-quarantine impractical, and the rapid spread of an infection highly likely. These 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 and water.

Impacts are likely to vary systematically by characteristics such as⁷:

- **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.
- **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. Disproportionately 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 US¹⁰.
- **Household composition.** Certain types of households are more vulnerable, such as those with children, elderly, or sick members.
- 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.



Positive tests for Covid-19 per 1,000 residents in New York City by ZIP code as of May 27¹¹

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

⁸ Recent data coming out of New York, Chicago, and Louisiana indicate that deaths from Covid-19 are disproportionately high among communities of color — black and Latino patients in particular. 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, is one of the world's leading nonprofit organizations dedicated to the support of AIDS research.

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

¹¹ https://projects.thecity.nyc/2020_03_covid-19-tracker/

3. Prospects for the future

- Spokespersons for the WHO expressed the view on May 13, 2020 that COVID 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.
- Governments are currently spending at a very high level for temporary income support programs, but are unlikely to be able to continue this pace over the next 3 to 5 years due to reduced economic activity, taxation revenue, and increasing indebtedness.
- 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.
- 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 EURACTIV¹². 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.
- The pandemic has exposed the limitations and rigidities of some aspects of building systems and designs, and the need to adapt and better address the universal design concept in the appraisal of spaces and in design in the built environment. The post COVID-19 presents the challenge of space management, be it a restaurant adapting to distancing regulations and therefore less patrons, to adaptability of spaces.

B. Individual Issues and behaviour

1. 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;
- There will be a greater need for home offices for work and/or home schooling purposes, which may require extra space and renovations. However, this may not be physically or financially possible in some cases, and that may result in home working or schooling not being possible, which leads to a need for community-based solutions, which are discussed in this paper;
- 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, young families and low-income groups such as students;
- There will be less international and inter-city travelling, and more use of country properties, municipal and regional parks, where they are open.

2. Physical distancing and space requirements in the built environment

A requirement for individuals, except those who are members of a single household, 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 by type of building.

¹² <https://www.euractiv.com/section/energy-environment/news/leaked-europes-draft-green-recovery-plan/>

3. Scheduling or time shifting

Physical (aka social) distancing is a well-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.¹³

4. 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.

5. Demand for electric power and internet bandwidth.

- The use of home video conferencing, general home office 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 and peak shaving and resiliency in community 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 users¹⁴.

6. Some 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 construction 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 home insurance costs to unacceptable levels.

¹³ To simplify matters in this report, we refer to either physical or temporal distancing, or a combination of these, as distancing requirements.

¹⁴ https://www.researchgate.net/publication/339784437_5G_deployment_and_urban_sustainability_09Mar20

C. Buildings and building systems

1. Key requirements for all building types

- 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.
- Wash basins or sanitizer stations should be provided at frequently used building entries.

2. Key specific requirements for various building types

2.1 Multi-unit residential buildings (MURBs)

- Large MURBs (more than 50 units) should be provided with an extra suite on ground or G+1 floors. Such a suite can be used for guests or for isolation. It could also serve as a shared office for building occupants (but physical distancing requirements must remain). Additional materials, energy, emissions and water would be required, but it could reduce the need for individual home offices.

2.2 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.
- In Canada, 82% of all COVID-19 deaths during the March-April period have been at long-term care facilities¹⁵. The most significant factor appears to be more a matter of poor management than the physical facilities. The issues 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 found. A national newspaper has published a story¹⁶ 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 Guardian reported¹⁷ that:

- In Sweden, about 90% of the 3,700 COVID-19 fatalities were over 70, and half were living in care homes;
- More than three-quarters of deaths in Belgian care homes (77%) are suspected cases;
- Between Madrid and Catalonia, care home deaths in the two regions account 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 died¹⁸. ... such deaths now account for more than half of all fatalities in 14 states, according to the Kaiser Family Foundation...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 isolation¹⁹.

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

¹⁵ Data from National Institute on Aging, quoted in Toronto Star, May 7, 2020

¹⁶ <https://nationalpost.com/news/companies-managing-troubled-ontario-long-term-care-homes-run-dozens-more-make-millions-in-profits>

¹⁷ <https://www.theguardian.com/world/2020/may/16/across-the-world-figures-reveal-horrific-covid-19-toll-of-care-home-deaths>

¹⁸ <https://www.worldometers.info/coronavirus/>

¹⁹ Curtains between beds are an alternative if they are effective in limiting transmission of aerosols or droplets and can be effectively cleaned.

2.3 Hotels

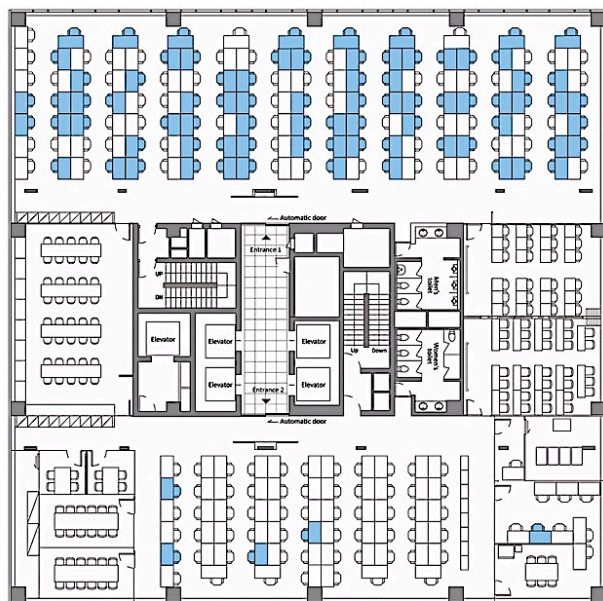
- Hotel food service is a complicated problem since, as in restaurants, it involves food and cold storage with staff and processing zones in tight spaces.
- During pandemics, hotel rooms may be used for persons undergoing a 14-day isolation period. There may be a need to sanitize rooms after the person ends the isolation period and departs.

2.4 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 remain to be seen, but is likely to result in a surplus of office space.
- A recent newspaper story²⁰ 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....*

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 Asia²¹... *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 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.*
- An excellent overview of some recent and forthcoming pandemic issues related to office space is provided by CityLab²², a workplace information service operated by Bloomberg. The review covered the spread of COVID-19 in a Seoul office building and also deals in depth with reconfiguration requirements in a post-pandemic phase.
- Coverage of the Seoul COVID-19 outbreak is of considerable interest. The call center on the 11th floor of this 19-story office building in downtown Seoul had ...long rows of shared desks line each side of the open floor, with a handful of smaller meeting rooms and



²⁰ <https://www.theglobeandmail.com/business/article-shopify-to-close-offices-until-2021-with-most-employees-expected-to/> Globe & Mail, May 21, 2020

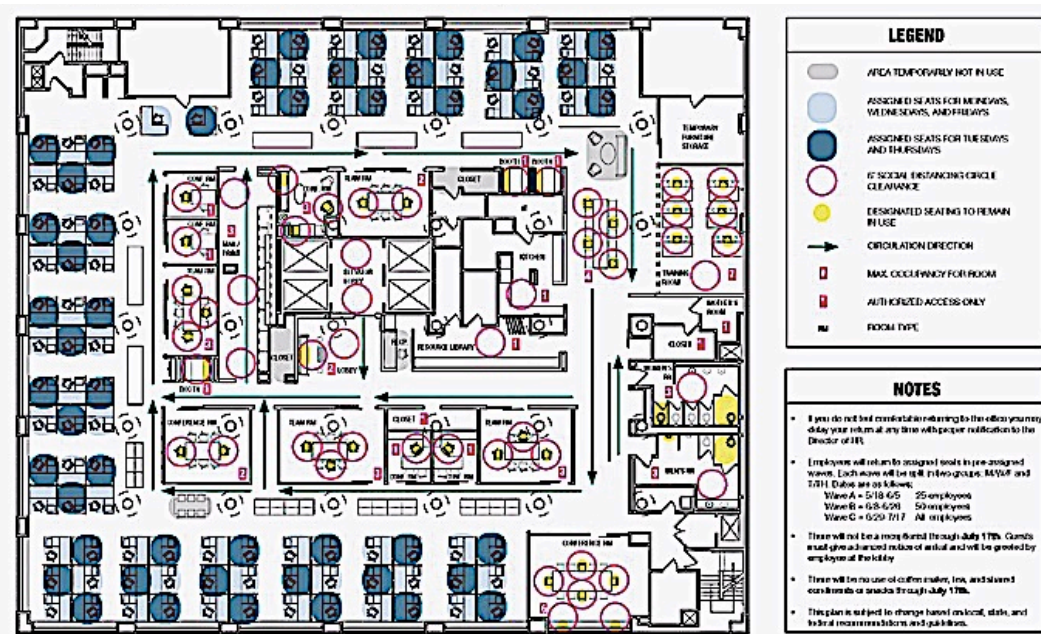
²¹ *The challenges of physical distancing, 36 storeys up in skyscrapers*; Globe and Mail, 04 May, 2020

²² <https://www.citylab.com/life/2020/05/open-office-design-coronavirus-risk-safe-workplace-health/611299/> Even the Pandemic Can't Kill the Open-Plan Office, Sarah Holder, May 14, 2020

private offices tucked into the corners. On February 25, one of the 216 people who worked on the floor started experiencing symptoms of coronavirus. Swiftly, a cluster of cases began to ping-pong across the office, until the government learned of the outbreak and the building was shut down.

The *Korea Centers for Disease Control and Prevention* tracked down anyone who lived in, worked in, or had visited the office and apartment development, revealing the path of the virus as it leapt from warm body to warm body. Of the more than a thousand people they tested, 97 had contracted Covid-19. Nearly all of them worked together on the 11th floor. An infection map released by researchers showed that one side of the room, filled with lines of tables where at least six employees sat on each side, was hit hardest. In all, 94 of the 216 densely-packed employees tested positive for the disease, the cases scattered across the office like a checkerboard.

- The solutions arrived at for post-pandemic offices include very complex time-shifting as well as physical distance 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-desking²³ 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 devices²⁴;
- 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 B3.

2.5 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.

²³ Wikipedia - Hot desking is an office organization system which involves multiple workers using a single physical work station or surface during different time periods

²⁴ see *Cone of Silence* from the TV show *Get Smart*

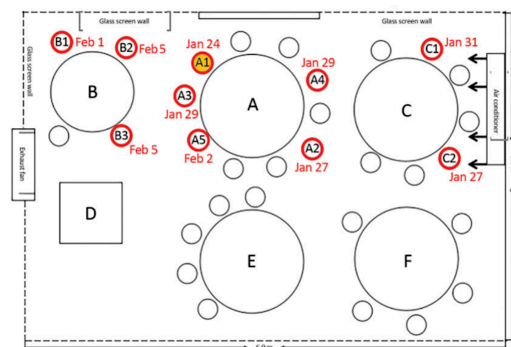
- In a retail shop, consumers have short-term exposure risk, but clerks and other staff have all-day exposure, so they must be given added protection in the form of protective barriers and ventilation systems that can be altered in rate and direction of flow.

2.6 Food processing plants

- Food 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 problematic in Europe and North America, and creates conditions for pandemic outbreaks.
- Slaughterhouses are a special category of food processing that constitutes a major source of COVID-related infections and deaths. Relevant factors appear to 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 can be useful in solving this problem.

2.7 Cafés and restaurants (includes such facilities if part of other occupancies)

- In larger facilities continuous monitoring of occupancy density should be possible.
- Seating density in eating areas must be adjusted to respect the 2 m. distancing requirements. The importance of spacing, especially in an indoor restaurant, is illustrated in this sketch of seating in a restaurant that experienced COVID transmission²⁵ (in this case, the original source was seated at place #1, and others were infected by speech and/or effects of the ventilation system. Dates of infection are also shown.



- 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.

2.8 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 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 students who are receiving home schooling.



Pupils sit at desks with dividers set up to combat the spread of COVID-19, at Dajia Elementary school in Taipei, Taiwan, on March 13, 2020. Ann Wang/Reuters

- 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.

2.9 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 yelling (sports fans) or singing (choirs) results in virus particles being spread much further and wider than is the case for speech. This, combined with seating distance issues, is the main reason why most health authorities have closed down such venues during the pandemic.

²⁵ COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020; Research Letter, CDC Vol. 26, No. 7, July 2020

- Conferences and smaller meetings have been identified as an effective arena for virus 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 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. Another problem with videoconferencing pointed out in the on-line journal *Buildings & Cities*²⁶, is that it limits or prevents the informal exchange of information between colleagues that take place in live events.
- Perhaps all the issues outlined for these assembly occupancies will lead to more use of outdoor locations, where weather conditions permit.

2.10 Universities or residential schools

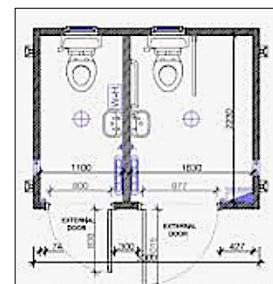
- Settings like these share some characteristics of MURBS, office buildings, commercial retail, sports, conference and other assembly occupancies.
- Problems arise in the conflict between the new emphasis on remote teaching and the required hands-on teaching of applied science, technologies etc. Staggered 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.

2.11 Community Refuge Centres

- Other types of community emergencies include weather-related emergencies such as flooding or windstorm or heat waves, earthquakes or large-scale fires.
- Neighbourhood health and pandemic screening centres can provide venues for quick and inexpensive viral screening and/or treatment of local population and also to support non-pandemic medical needs. Providing local treatment reduces demand for transport to distant health centres.
- The refuge function is especially important for low-income households, who may be homeless in the short term or who lack air conditioning for heat waves, or alternate accommodation for isolation during pandemics. 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.
- Such community refuge centres must provide support facilities such as nursing stations, publicly-accessible washrooms, kitchens and supply storage areas.
- 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;

3. Public washrooms and bathrooms

- Public 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.
- 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.



²⁶ *Scientific conferences and the pandemic*, 24 March 2020, Buildings & Cities; www.buildingsandcities.org

- 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 household²⁷.
4. **High-touch surfaces in washrooms, office, public and commercial buildings**
- 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 surfaces²⁸ and automatic (hand wave based) paper dispensers. Japanese washlet toilets are another option, which also reduces use of toilet paper. Sarah Bookman²⁹ 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...*
5. **Private open space in residential buildings**
- 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 balconies³⁰. 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.
6. **Operable windows and natural ventilation**
- Natural ventilation with outdoor air may be provided through the use of operable windows in buildings with where the depth of the ventilated zone to windows is less than about 7 m.
 - 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.
7. **Limiting virus transmission in tall residential buildings.**
- In the 2003 SARS epidemic the virus was transmitted in a Hong Kong apartment tower through faulty plumbing, according to the World Health Organisation³¹ (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 Control³² provides an excellent summary of issues primarily related to operation and viral transmission issues in MURBS, and also covers some design and operational issues.
8. **Safety and service quality of 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 that³³ ... *The company is working on a physical distancing plan for elevators, lobbies, washrooms and other*

²⁷ <https://www.citylab.com/design/2020/04/bathroom-home-design-history-disease-hygiene-coronavirus/609745/>

²⁸ <https://academic.oup.com/cid/article/58/6/848/340734>

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

²⁹ Sarah Bookman, Auckland University, in the Guardian, 03May20.

³⁰ <https://www.citylab.com/life/2020/04/apartment-design-balcony-private-outdoor-space-zoning-laws/610162/>

³¹ <https://www.who.int/mediacentre/news/releases/2003/pr70/en/>

³² 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>

³³ Newspaper interview with Cadillac Fairview spokesman, Globe and Mail, 02 May 2020

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...

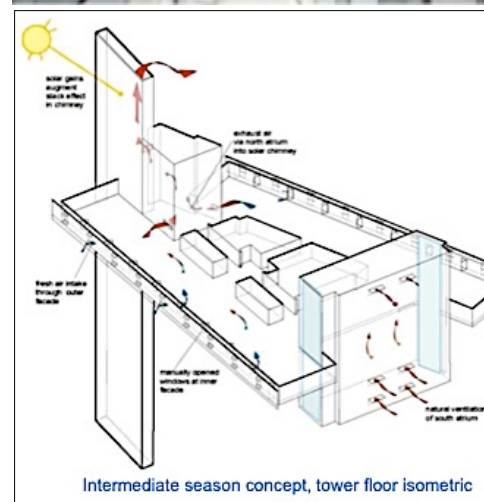
- Similar spacing issues arise with escalators.
- Individual employees may have to arrive and leave at staggered hours to reduce crowding of lifts, lobbies, garages and public transport. Similar staggered lunch hours may be needed. These measures increase lift use and result in more energy consumption and a decreased service frequency level.

9. HVAC systems in residential buildings.

- Where MURB public areas and corridors do not have 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. 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.
- 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.

10. HVAC systems in commercial office and retail buildings.

- To reduce the risk of infection, an increase in the Air Change Rate per hour (ACH) in public and office areas may be advisable. Direction of airflow is also important and may need alteration for both air supply and extraction, ceiling fans, etc.
- Ultraviolet light is mainly used to purify water supplies, but germicidal lamps that emit ultraviolet C (UVC) light can be used in HVAC systems. Wikipedia states that³⁴ *...this short-wave ultraviolet light disrupts DNA base pairing, causing formation of pyrimidine dimers, and leads to the inactivation of bacteria, viruses, and protozoa.* It can also be used to produce [ozone](#) for water disinfection... Recent developments in [light-emitting diode \(LED\)](#) technology have led to the commercial availability of UVC LED sources. It should be noted that there is no official endorsement by WHO for UVC technology in fighting COVID-19.
- 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. Although more energy-intensive. In low- and mid-rise office buildings, 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 building³⁵ in Winnipeg, Manitoba. The drawing shows the system that was subsequently constructed in 2008.



11. Provision of rain-water storage and separate grey-water supply

- Conserve potable water by using grey water for toilets and irrigation. This measure is not suggested because of pandemic needs but because of general benefits in reducing water consumption, in regions where potable water deficits occur.

³⁴ https://en.wikipedia.org/wiki/Germicidal_lamp

³⁵ Manitoba HQ building, Winnipeg. Architects Kuwabara, Payne, McKenna, Blumberg and Smith Carter Searle.

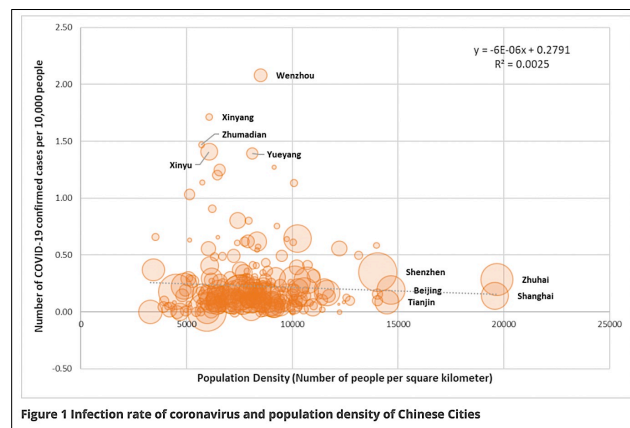
D. Urban Issues and systems

1. The COVID-19 pandemic vs. 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^{36 37} -

- The World Bank has published a study on the relationship between urban population density and the spread of the COVID-19 pandemic³⁸ ...*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 we've found does not support the argument that density is a key determinant of coronavirus transmission risk. As illustrated by Figure 1, 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 kilometer.

2. Demand for private auto usage v. policies to promote use of public transport

The number of people that can be safely transported within a given time frame will decrease, due to the need for maintaining some physical distance 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. When personal mobility and the use of private vehicle will again be unrestricted, the use of cars may increase, which will lead to continuing pressure for parking space and will continue current levels of fossil fuel consumption and NO₂ emission rates.

Local governments generally wish to support increased use of public transport to rationalize urban transportation systems and to land use 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.

³⁶ <https://www.vox.com/2020/5/20/21265194/coronavirus-deaths-us-singapore-case-fatality-rates>

³⁷ <https://www.statista.com/statistics/1100120/south-korea-coronavirus-cases-by-province/>

³⁸ <https://blogs.worldbank.org/sustainablecities/urban-density-not-enemy-coronavirus-fight-evidence-china>

Vancouver provides one of the few sources of real data on this subject. According to a recent newspaper report³⁹...*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.*

- Public transport system operators will need to convince the travelling public that their health and safety measures are sufficient;
- Public transport 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.

3. Facilitating walking, bicycling and landscaping or trees in neighbourhoods.

- Even in pandemic lockdowns people are encouraged to walk and exercise for physical & mental health. Area used for streets or parking areas can be used for other purposes. More foliage reduces pollution and noise.
- Ensuring that pedestrian walkways allow people to pass each other safely is more than ensuring a width of 2 m+. Complicating factors 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.
- Provide walkways or group areas to allow a minimum of 2 m. spacing between individuals.



4. Paved roadway areas, green spaces and parks

- 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.⁴⁰
- Incorporate sustainable land use management principles in the design and operation of large park areas, to ensure that storm water management and soil permeability is considered. Even where paving is required, permeability is possible.

5. Community vegetable gardens within neighbourhoods.

Reduces travel / shipping energy and emissions (but for small scale production only); also good for exercise and mental health, as long as distancing requirements can be maintained.

6. Continuous monitoring and analysis of wastewater to detect coronavirus traces

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-2⁴¹. 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.

³⁹ Vancouver increases space for walking and cycling through introduction of slow streets; Globe and Mail; 13 May 2020

⁴⁰ B. Dousset, ESA user consultation meeting, Athens, June 2007

⁴¹ From Nature, 03 April, 2020, <https://www.nature.com/articles/d41586-020-00973-x>

E. Impact of the COVID pandemic on climate and environmental action

1. Survey of international finance officials and experts on impact of COVID-19 on policies for climate change actions.

A forthcoming paper⁴² 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:*

- * *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. The authors suggest that emissions will rebound once mobility restrictions are lifted and economies recover, unless governments intervene. *There are reasons to fear that we will leap from the COVID frying pan into the climate fire. 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 (Jacobs⁴³). 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-Peltier⁴⁴). In the long run, these public investments offer high returns by driving down costs of the clean energy transition (Henbest⁴⁵). Harnessing more of these opportunities could result in ‘kick starting the green innovation machine’ (Acemoglu et al.,⁴⁶) and driving an efficient, innovative, and productive economy, with higher spill overs that benefit the wider economy (Aghion et al.,⁴⁷).*

⁴² 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.

⁴³ 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.

⁴⁴ 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.

⁴⁵ 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.

⁴⁶ Acemoglu, D., P. Aghion, L. Bursztyn, and D. Hemous (2012), ‘The Environment and Directed Technical Change,’ *The American economic review*, 102(1), 131–166.

⁴⁷ 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.

2. Plans for European investments in deep green renovations⁴⁸

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 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.*⁴⁹

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 says... *As Europe is discussing the scale of an unparalleled recovery programme to mitigate the damage of the Covid-19 pandemic, 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.*

⁴⁸ http://bpie.eu/wp-content/uploads/2020/05/Recovery-investments-in-deep-renovation_BPIE_2020.pdf

⁴⁹ 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.

F. Summary table of key relationships

Summary of key COVID pandemic requirements and implications for the built environment

Item / Issue	COVID pandemic aspects	Building requirements	Net effect
Floor space requirements in MURBs	In large MURBs, a small extra unit should be provided for occupants who need to isolate.	More space results in increased capital and operating costs and energy consumption.	
Changing floor space requirements in office areas	More space is needed in lobbies, open offices, corridors and washrooms, to respect 2m.distance. More staff working from home may balance this.	If extra 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.	
Industrial building space requirements	In meat processing plants, close spacing of workers on production lines appear to be a factor. In all industry types, noisy environments are an indirect factor in spreading airborne disease.	Increased space results in increased capital and operating costs and energy consumption, and most industrial workers cannot do their work from home.	
In ground-oriented residential units, private open space should be provided	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.	There are indirect benefits from natural space cooling in summer in temperate climates. In areas with cold winters, balcony slabs need thermal breaks.	Increased capital cost. Little net difference in operating cost, unless the need for thermal breaks of balconies in cold climates is ignored.
Provide more single-occupancy rooms in long-term care homes	Occupancy by 2 or more occupants appears to be linked with a higher rate of viral transmission.	This will increase overall building area and also requires more bathroom facilities	Increases capital and operating costs
MURBs and buildings should be provided with no-hands operation of doors and sanitary equipment in public areas (entries, lobbies, laundry rooms, recreation facilities and parking facilities). Provide thermographic scans of persons entering the building.	No-hands operation of doors and sanitary equipment is needed to minimize viral spread; Thermographic scans provide triage measure; Continuous monitoring of occupancy numbers and density is optional in some key facilities	Except for thermographic scans, the other measures are common in high-end (Class A) office buildings.	Added capital cost and some added operating cost
Mechanical ventilation systems	Systems to be capable of 100% outdoor air (OA) supply, and for positive pressure conditions in public areas	Minimize need to cool OA in hot weather or to heat OA in cold weather via heat exchangers	Consumes more energy than systems with recirculating air
To reduce the risk of infection, an increase in the Air Change Rate (ACH) may be required in buildings accessible by the public.	May be needed in case of severe virus outbreak.	High ventilation rates will be wasteful under normal conditions	Increases energy requirements if the higher speed setting is used.
Positive air pressures in public areas of mechanically ventilated buildings	Prevents migration of air from contaminated rooms to public spaces or other areas	This is a normal approach in most buildings with mechanical ventilation	No change

Item / Issue	COVID pandemic aspects	Building requirements	Net effect
Natural ventilation with outdoor air may be provided through the use of operable windows in spaces where the depth of ventilated area is less than 7 m.	<p>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.</p> <p>Depending on their orientation and exterior wind and noise conditions there may also be a psychological benefit.</p> <p>Where air-cooling systems are provided, they should be automatically switched off when operable windows are open, in order to maintain HVAC efficiency.</p>		
Widen sidewalks and walkways	Need to facilitate 2 m. distance	Where roadways can be narrowed, this is a good solution	
Neighbourhood Refuge and Support Centres	Provide medical screening and refuge for local residents during pandemics, wildfire, heat waves, flood and earthquake, also provides storage for emergency food and medical equipment.	Allow for temporary shelter in secure facility with food and health service.	The extra financial and energy costs are justifiable in view of multiple needs.
Community gardens within neighbourhoods	Allows residents without cars to grow local produce	Space required in urban planning schemes.	Cost-benefit to be estimated
Provide continuous monitoring and analysis of local wastewater.	Analysing wastewater ... is one way that researchers can track infectious diseases excreted in urine or faeces, such as SARS-CoV-2	None	to be determined
Urban public transport	Reduced capacity for public transport	Less mobility in cities, but increased accessibility through working from home, walking and cycling	Decreased passenger revenues. Extra financial support needed to ensure public transport system survives.

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