Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Impact of COVID-19 pandemic on socio-economic, energy-environment and transport sector globally and sustainable development goal (SDG)

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ABSTRACT

The United Nation's Sustainable Development Goals (SDGs) want to have a peaceful world where human life will be in a safe, healthy, sustainable environment without any inequalities. However, the year 2020 experienced a global pandemic due to COVID-19. This COVID-19 created an adverse impact on human life, economic, environment, and energy and transport sector compared to the pre-COVID-19 scenario. These above-mentioned sectors are interrelated and thus lockdown strategy and stay at home rules to reduce the COVID-19 transmission had a drastic effect on them. With lockdown, all industry and transport sectors were closed, energy demand reduced greatly but the time shift of energy demand had a critical impact on grid and energy generation. Decreased energy demand caused a silver lining with an improved environment. However, drowned economy creating a negative impact on the human mind and financial condition, which at times led to life-ending decisions. Transport sector which faced a financial dip last year trying to coming out from the losses which are not feasible without government aid and a new customer-friendly policy. Sustainable transport and the electric vehicle should take high gear. While people are staying at home or using work from home scheme, building indoor environment must specially be taken care of as a compromised indoor environment affects and increases the risk of many diseases. Also, the energy-efficient building will play a key role to abate the enhanced building energy demand and more generation from renewable sources should be in priority. It is still too early to predict any forecast about the regain period of all those sectors but with vaccination now being introduced and implemented but still, it can be considered as an ongoing process as its final results are yet to be seen. As of now, COVID-19 still continue to grow in certain areas causing anxiety and destruction. With all these causes, effects, and restoration plans, still SDGs will be suffered in great order to attain their target by 2030 and collaborative support from all countries can only help in this time.

1. Introduction

RNA-enveloped coronaviruses ranging from 60 nm–140 nm in diameter along with a crown-like appearance, can be witnessed in humans, other mammals, and birds which reasons respiratory, enteric, hepatic, and neurologic diseases (Lu et al., 2020). They are well-known to mutate and recombine (Zhou et al., 2020) to create human diseases including 229E, OC43, NL63, HKU1, severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) (Baghizadeh Fini, 2020). Among them, the first four are common and elicits simple cold symptoms while the severe SARS-CoV and MERS-CoV have a zoonotic origin that cause fatal illness. Previously, in 2002–03 because of SARS, more than 8000 people suffered serious sickness while 774 people died. Further, in 2012, MERS-CoV instigated 2494 infections, with over 858 deaths worldwide (Chakraborty and Maity, 2020). SARS-CoV-2 has 88–89% resemblance to bat-SL-CoVZC45 and bat-SL-CoVZXC21 (two bat-derived severe acute respiratory syndrome-like coronaviruses) (Lai et al., 2020) and, 79% and ~50% similarity to SARS-CoV and MERS-CoV respectively (Lu et al., 2020).

In December 2019, patients suffering from pneumonia, known to evolve from an unknown cause, which has its epidemiological link with

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the wet animal wholesale market, was reported in Wuhan, Hubei Province, China. Wuhan, the capital city of Hubei province and one of the largest cities in central China, located in the middle of the Yangtze River delta, experiences subtropical humid, warm summer, cold winter, and monsoon climate with a population of 10 million as of 2017. On Jan 9, 2020, World Health Organisation (WHO) identified the mysterious cause of the disease to be the coronavirus and on Jan 12, 2020, WHO officially avowed this fast-spreading virus as "2019-novel coronavirus (2019-nCoV), which was further reformed to be SARS-CoV-2 on Feb 11, 2020, and also officially professed this disease to be COVID-19 (CO-Corona; VI-Virus; D-Disease; 19: year) (Tay et al., 2020). This was declared as the sixth public health emergency of international concern following H1N1 in 2009, polio in 2014, Ebola in 2014 in West Africa, Zika in 2016 and Ebola in 2019 in the Democratic Republic of Congo (Chakraborty and Maity, 2020).

Eventually, the market of Wuhan was shut down from Jan 1, 2020, as part of efforts to contain the outbreak, however, a large number of patients still confirmed to have COVID-19 even without exposure to the market but either had a travel history from Wuhan or any close physical connexion with a COVID-19 patient (including health-care workers). This proposed a strong human-to-human transmission of the virus, thereby leading to 162,506 infections by Mar 12, 2020, worldwide. Thus, on Mar 11, 2020, WHO announced this to be a pandemic, when in that very same day a total number of confirmed cases reached 118,319 including 4292 deaths, worldwide.

Recessions, down-turns, wars, revolutions, earthquakes, and volcanos seemed like minor blips when it was compared to the global lockdowns, an expensive state interventionism on a scale previously witnessed not for a millennium. Quarantine, lockdown, and social distancing are few of the popular terms, which soon gained recognition during this pandemic.

Researchers started focusing on writing articles about different sectors of society, which were severely affected due to COVID-19. More than 66,000 articles have been published between Dec 2019 and Jan 2021 (web of science), concerning the rise of this pandemic. A major section of the researches includes the medical approaches or pathological findings to study the clinical characteristics of the corona virus, its clinical course, risk factors, association or similarity with previously occurred diseases, case study of various patients with COVID-19 and other diseases, treatment or clinical trials of hydroxychloroquine and azithromycin for the cure of COVID-19 and vaccine development. Also, researches were made on various strategies to diagnose patients with COVID-19 at early stages either clinically, statistically or computationally by studying and finding correlation between environmental changes and the number of patients in each area, or scrutinizing community and localities such as employing wastewater management to detect coronavirus. Apart from the medical study, researchers also studied widely on various sectors of society, which are greatly damaged due to COVID-19 pandemic. Researchers also greatly indulged themselves in scrutinizing how COVID-19 and its associated system of lockdown or social distancing affected economy of each nation (Ghosh et al., 2020c), tourism, science (Zhu et al., 2020), community, work, family life (Lehmiller et al., 2020), nationalism (Woods et al., 2020), politics, relationships (Brown et al., 2020), physical activities, pollution (Zheng et al., 2020), mental health (Killgore et al., 2020), food behaviour (Smith and Wesselbaum, 2020), education sector (Ahimi et al., 2020), etc.

This work tried to highlight how COVID-19 propagated around the world creating a drastic impact on human social life, economy, environment, and secondary fields like transport and energy, which were reviewed elaborately. Adverse impacts of COVID-19 could compromise to achieve UN's 2030 SDGs Agenda. Recent progress in terms of vaccine and treatment was also briefly discussed. For this work, we searched relevant databases, including, Google Scholar, Science Direct, Web of Science, to investigate published literature in the past few decades. The search keywords were COVID-19, SARS-CoV-2, Pandemic, COVID and environment, Economy, Energy and Transport. However, because of the diverse terminology, we also employed other terms to obtain more work to review which were included and investigated for this work. The rest of the paper is structured as follows. Section 2 explores the Chronological history for COVID-19. Section 3 discusses the affected area due to the COVID-19 including human social life, environment, economy, energy, transport. Finally, section 4 summarises the discussion and section 5 draw the main conclusions.

2. Methodology

The systematic literature review method is always better than a traditional review because it helps to identify the gaps in studies and provides information on areas where the majority have been undertaken. However, these COVID-19 cases and associated incidents are very new and at the time of the first submission, it was only 6 months happened after COVID-19. Thus, most of the information was covered including either government documents, quick submission or the different published research article. It was not either very clear at that time how and for how long the global impact will remain active. However, after the first revision and during the time of the second submission, it was clear that the impact of COVID-19 remained drastic and aligned with the previous work. For the discussion section, a wider review has been included which has an immense influence on building energy has been included. In our study, we did not investigate more on details of COVID-19 virus. Fig. 1 illustrates the mechanism of performing this review work. At the first step keywords such as COVID-19- energy, COVID-19 –social, COVID-19-environment, COVID-19-transport, COVID-19 –economy, COVID-19 sustainable were employed to obtain published work. Details of the COVID-19 virus and its genetic structure and comparative relation between the genetic structures of other SARS viruses were excluded. This information was added only in the introduction section to start the topic. For the 2nd steps publication period between 2020 and 2021 was included. In this process, we excluded the work, which was based on perspective and added only which included real time data analysis. However, to make a clear and positive discussion more relevant work in the building sides were included and for them, publication ranged varied between 2015 and 2021 however priority was given to the most recent updates for each specific topic.

3. A chronological history of COVID-19

3.1. Spread of COVID-19

Established on rudimentary observations on 1099 COVID-19 confirmed patients, it was recognized that COVID-19 undertakes 14 days (median time) to transfer from symptom onset to death. SARS-CoV-2 has a briefer median incubation period than SARS (4 days) (Lessler et al., 2009) and MERS (7 days) (Cho et al., 2016) but high latency period of maximum 24 days (Wang et al., 2020e), encouraging high COVID-19 transmission risk (Wang et al., 2020c). Also, coronaviruses are stable and can be detectable on aerosol (3h), copper (4h), cardboard (24h), and on stainless steel and plastic (2–3 days) (Doremalen et al., 2020). These results demonstrate crucial information about the stability of these pathogens which implies that transmission/infection is conceivable to people from touching of contaminated objects along with human-to-human transmission via droplets or direct contact, and this type of infection has revealed a basic reproduction number of about 2.24–3.58 (Remuzzi and Remuzzi, 2020). Starting from China (Lau et al., 2020a), COVID-19 spread out more rapidly around the world primarily through the air travel (Nakamura and Managi, 2020) and cruise travel (Ito et al., 2020). Fig. 2 shows the present COVID-19 cases in the world (230 countries infected due to COVID-19) and Figs. 3 and 4 show the chronological event of COVID-19 cases globally. Now globe is suffering from the hit of second wave (Hafeez et al., 2021).

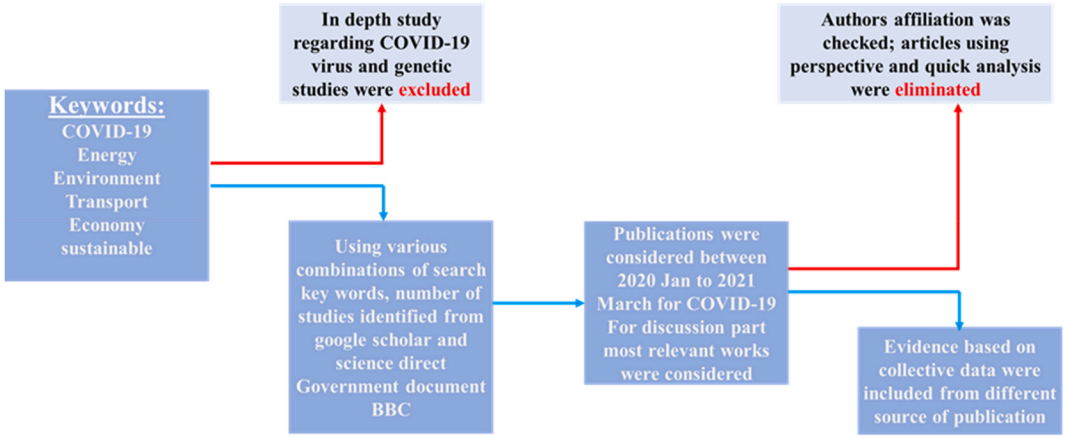

Fig. 1. Employed literature search approach in the selection of reviewed studies. (Red arrow indicates exclusion and sky-blue arrow indicates inclusion of study).

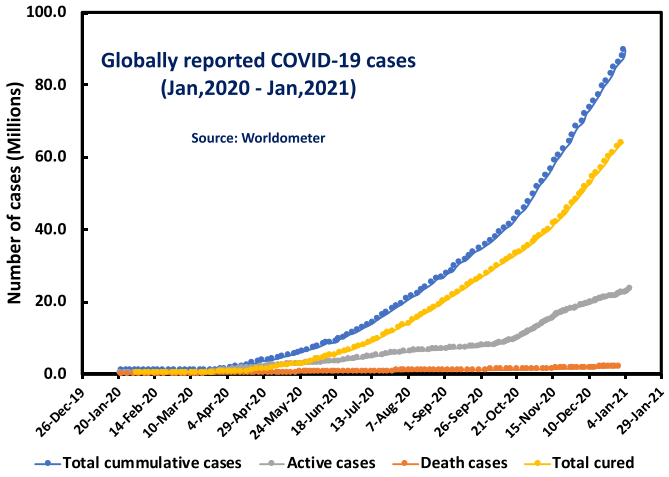

Fig. 2. Cumulative number of COVID-19 cases in the world for a time period of 1 year: Total number of cases, number of active cases, number of death cases and total number of cured cases daily.

3.2. Techniques to combat with COVID-19 transmission: social distance, lockdown, and sewage management

To inhibit the spread of the infection, standard recommendations including regular washing of hands, mouth, and nose during coughing and sneezing and usage of masks outdoors were implemented. Another commendation is to maintain 1–2 m of social distance to avoid close contact with anyone showing symptoms of respiratory illness. Thus, social distancing became a highly recommended and appreciated practice to eliminate unnecessary transmission spread (Wilder-Smith and Freedman, 2020) (Sen-Crowe et al., 2020). Over a hundred countries in the world started lockdown to combat with COVID-19 at the end of March (BBC, 2020a). Wastewater management in different localities became one of the means to detect early COVID-19 and prevent its spread in the community.

Even though the social distance measure designed by the WHO for influenzas was 1m, different distance measures are employed worldwide: the UK and New Zealand held 2 m, while 1.8 m, 1.5 m, and 1 m were exercised in the USA, Australia, and Singapore, respectively. COVID-19, not being a flu, all the distance measures the different country adopted were not considered scientific. It is still not explicit how far an infectious droplet can travel. Real-time experimental data is not accessible as analysis includes the presence of several variables: the number of infectious particles and their airborne survival, humidity and the speed of expulsion, thereby making the process complicated. Still, for the secure side, all countries enhanced the measurements. Australia executed the distance based on the length of the available shopping trolley in the market. In the UK, national health services and other health bodies adopted higher distance criteria for more safety precautions. The USA previously estimated that a safe distance of 1.8 m, declines the flu transmission. However, during activities such as running and exercising, a safe distance of 5 m, while 20 m for cyclists or usage of personal protective equipment (PPEs) amongst Chinese health care workers led to the merest spread of the ongoing coronavirus within hospitals (Brook, 2020). Furthermore, >25% of health care workers in Sweden suffered severe infection due to the lack of PPEs. Additionally, it is also critical that healthy individuals remain disease-free to curb the pandemic. Therefore, the application of facemasks is empowered as proactive protective measures to safeguard health care personnel, patients, and healthy individuals during not only this pandemic but applicable for future viral outbreaks. Prevention of spreading the virus from infected people is possible by using facemasks.

The first countries to initiate mobility prohibitions to colleges, universities, and apply telework due to the COVID-19 situation were: Mongolia and China. South Korea methodically controlled this outbreak and stood as an epitome for the world to learn from their techniques that they have experienced and developed during the MERS outbreak back in 2015, which had 19% fatality and 40–90% infection rate (Her, 2020). Brazil declared a public health emergency on Feb 3, along with social restriction set up in two most populous states, São Paulo and Rio de Janeiro. In Rio de Janeiro, a series of events took place. From 21st March, partial lockdown was started when schools and universities were closed, bars, restaurants, beaches, shopping centres, and commerce in general (except for food and medicines) were closed, public events were cancelled, public transport within the city was limited and work at home was recommended. The first lockdown on Feb 22, order issued in a cluster of cities in Lombardy and Veneto regions in the north, which further expanded till March 8 to all of Lombardy and 14 other northern provinces (Ren, 2020). By March 9, lockdowns began to be applied in other countries, where, not all countries carried out a lockdown, there were some exceptions such as Kazakhstan (Astana), Romania and Indonesia, where a state of emergency was declared by March 15, March 24, and on April 2, respectively. However, some countries eased the lockdown with restrictions. Slovakia (Bratislava) allowed its people to walk or exercise outdoors with mask protection. Mexico City declared a voluntary quarantine, whereas Bangkok (Thailand) and Belgrade (Serbia) declared a curfew since April 4. Saudi authorities reported its first COVID-19 case on March 2. This case was imported by a Saudi national returning from Iran via Bahrain. The Saudi Ministry of Sports announced, all sports competitions to be indoors from March 7, in addition to the suspension of the 2020 Saudi Olympics Games, planned to start on March 23, 2020. March 8, the Saudi Ministry of Education

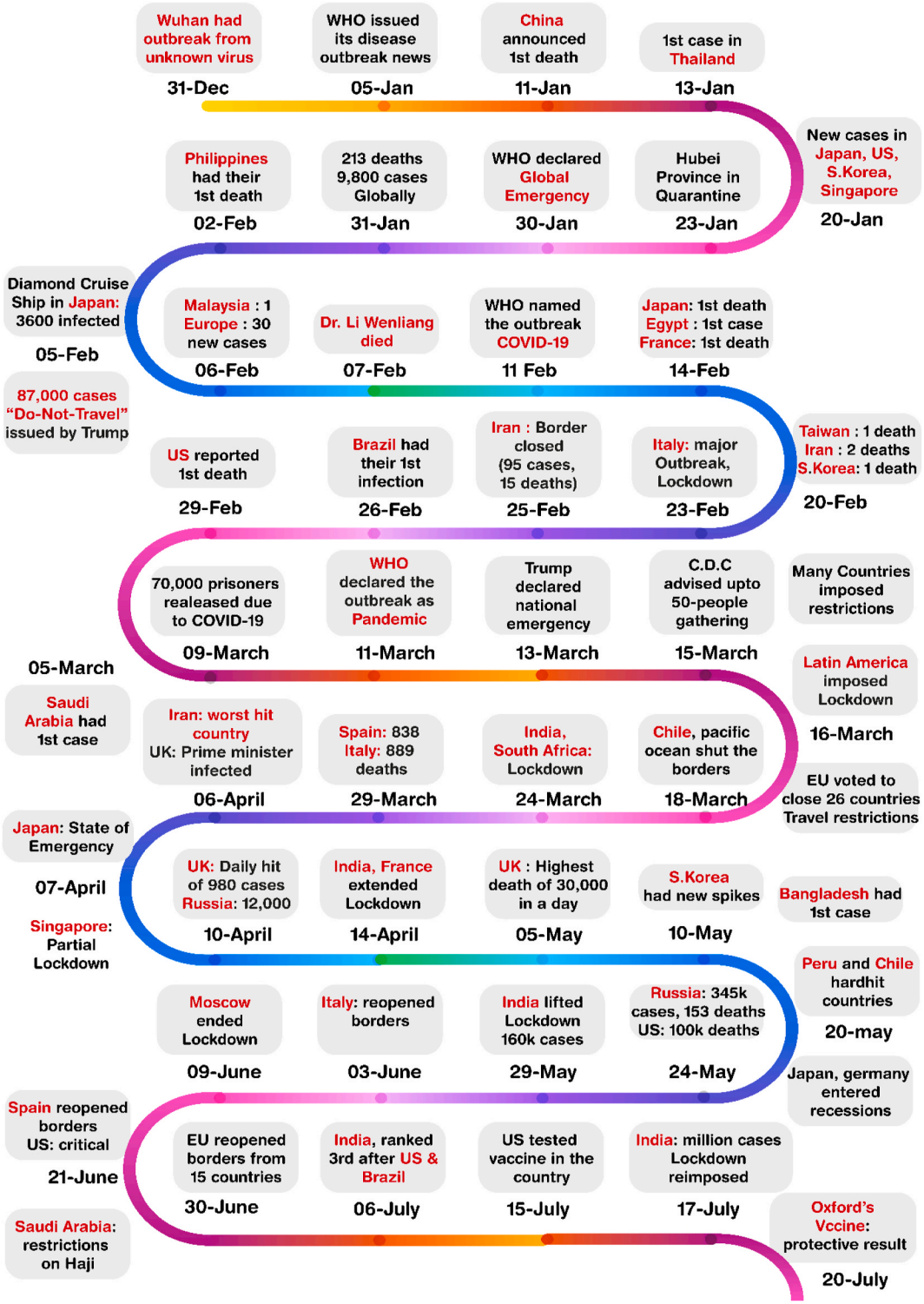

Fig. 3. Chronological major event for COVID-19 globally (from Dec 2019–July 2020).

declared the closure of schools and on March 20, they suspended all domestic public transportations: flights, trains, buses, and taxis in a heightened effort to stop the spread of the virus (Yezli and Khan, 2020). Lockdown measure was announced in the UK, on March 23, except essential businesses. People were only allowed to go outside for shopping, necessities, health reasons, and one form of exercise a day, or work if it was considered 'essential' such as firefighters, police, or electricity provision. Belgian government took strong measures on March 12, and ordered the closure of schools and cafes, along with the cancellation of all public gatherings. Strict strategies issued on March 17, ordered the closure of non-essential shops, prohibited non-essential travel, and banned all gatherings. Fig. 5 shows the implemented lockdown dates for different countries.

Even though major lockdown restrictions were uplifted from most of the countries after august, as the number of cases decreased, but still some countries continued to stay under lockdown or restricted movements with varying degrees. Also, reportedly, a new variant of the novel coronavirus has been detected in the UK (Wise, 2020), South Africa

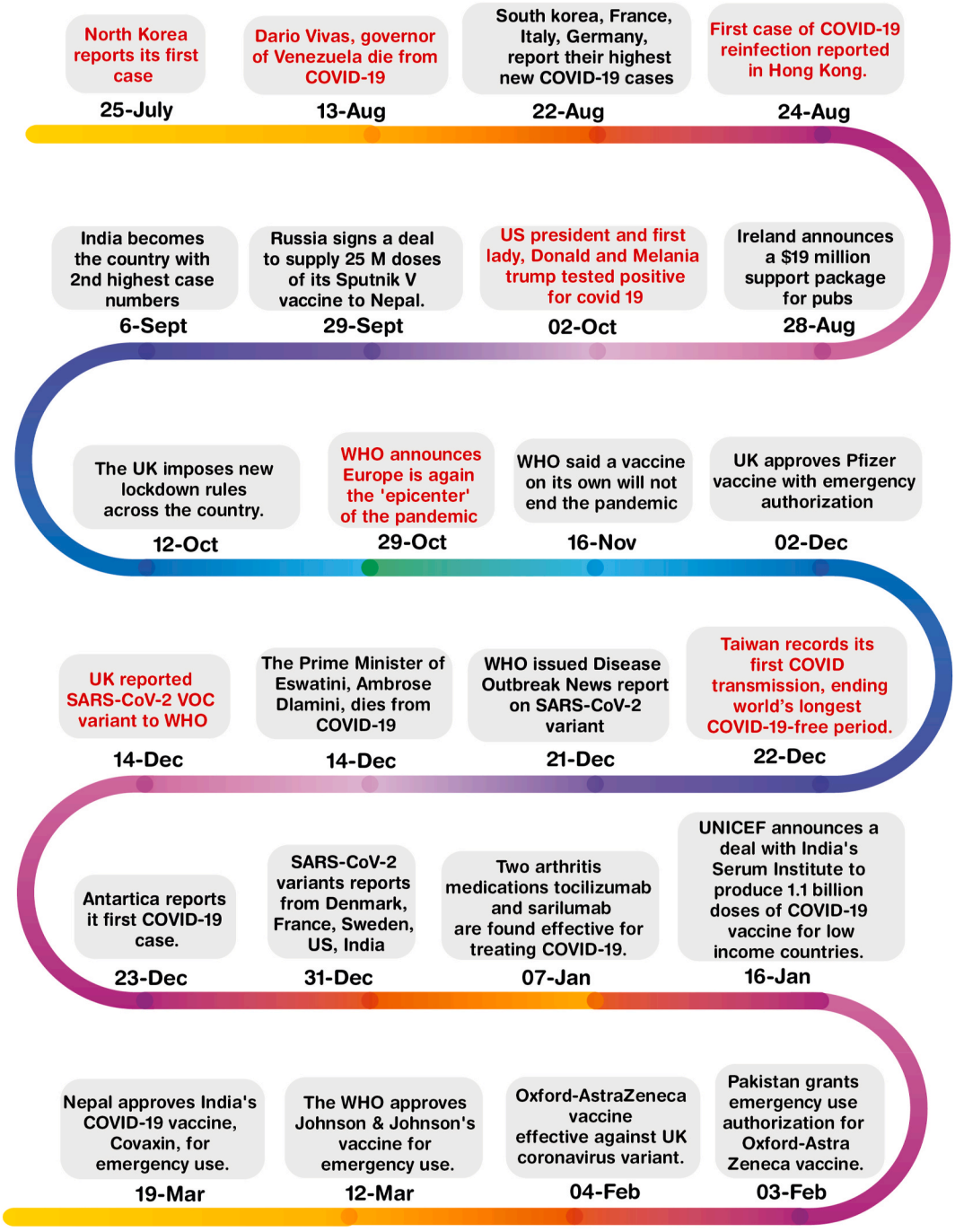

Fig. 4. Chronological major event for COVID-19 globally (July 2020–March 2021)).

(BBC, 2020a), Denmark and the Netherlands resulting a sharp increase in number of infections in these countries (News, 2020). Thus, these countries toughened their restrictions in order to control the spread of the new variant. The UK implemented local lockdown measures under tier system, with restrictions such as banning inter-household mixing and curfew in various sectors. These lockdown restrictions are expected to be implemented until end of February. Other countries like Australia, Austria, and Denmark also employed similar lockdown restrictions, keeping all shopping centres and arcades closed with only essential shops kept open. Germany, Greece, Ireland, Israel, Italy and Mexico continued with their partial-lockdown restrictions, after facing their second wave. The new rules mandate only gatherings of up to five people inside and 10 people outside. Further, the Netherlands, Poland, Portugal and Switzerland extended their lockdown for two weeks more till end of January or even till February. Schools, shops, restaurants and all entertainment zones continued to remain closed. The lockdown in the USA remained controversial situation since the start. More than 50 US states have reopened while high alert zones are still at a pause. India have been the among the most infected country due to its huge population, but unfortunately it started uplifting its lockdown restrictions to preserve its largely falling economy. Public transport and shops all reopened with mandatory wearing mask rule. Economy dropped greatly, with 19 million people losing jobs, however, India faced the lowest death toll in comparison to US and Brazil. Some countries still spoke out against the localised lockdowns like Spain. South Korea was one of the few countries, who managed to control the spread at very early stage. Schools reopened and people returned to their normal life with lifting of restrictions. However, wearing masks and taking

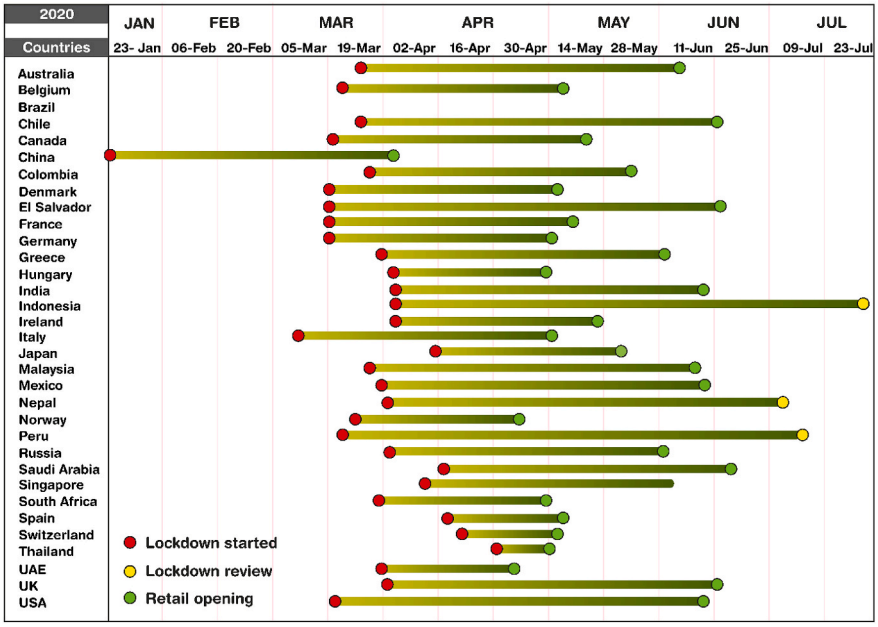

Fig. 5. Lockdown time globally for different countries for COVID-19 pandemic.

precautions still persist. Iran however faced a third wave of outbreak, nevertheless lockdown was lifted, and schools reopened. Countries like Hungary and Lithuania, reopened schools, open-air restaurants but kept their borders closed. Singapore, Dubai, Thailand, began phased reopening with reopening schools and a combination of in-person and virtual learning and work, encouraging people to work from home, reopening stores, bars, restaurants with limited capacity. Russia on the other hand eased restrictions, opened borders, and reportedly became the first country to approve the coronavirus vaccine. Among the other countries, Saudi Arabia reopened mosque and eased restrictions, Colombia surprisingly reopened tourism even with still-rising cases. The situation in different parts of the world looks different and is expected to change regularly until there is a permanent solution to this COVID-19 pandemic.

Previous studies with various viral diseases focusing on screening communities and scrutinizing sewage for traces of a pathogen have provided an indication of whether or not the pathogen is existent in the population along with its corresponding transmission pattern (Larsen and Wigginton, 2020). Apart from respiratory diseases, Diarrhoea is also reported as a significant symptom in COVID-19 cases, which was also quite prominent during the outbreak of SARS (Xiao et al., 2020). Thus, various researchers across the world employed different approaches aiming towards surveillance and detection of wastewater data to track down its relationship with coronavirus and the number of COVID-19 cases (Chen et al., 2020b). “Wastewater”, or “sewage,” includes water from household/building use (i.e., toilets, showers, sinks) that can contain human faecal waste, as well as water from non-household sources (e.g., rainwater and industrial use.) which can be tested for RNA from SARS-CoV-2, the virus that causes COVID-19. Medema et al. used four qRT-PCR assays to test sewage samples of cities and airport area during the outbreak of COVID-19 in Netherlands. A distinct direct and highly sensitive correlation was observed with increase in RNA virus in sewage with increasing COVID-19 cases (Medema et al., 2020). Even in Spain, faecal shedding of SARS-CoV-2 RNA from COVID-19 patients were reported, where Randazzo et al. investigated the occurrence of the virus in wastewater treatments plants in major municipalities using aluminium hydroxide adsorption-precipitation concentration method and real-time RT-PCR, revealing detection of virus in wastewater in early stages of the spread of COVID-19 (Randazzo et al., 2020). Peccia. et al. demonstrated the concentrations of SARS-CoV-2 RNA in primary sewage sludge obtained from COVID-19 cases in hospital during the primary outbreak in the New Haven, Connecticut. They reported a high-resolution dataset generated from sewage sludge along with statistical analysis to infer the lead-time their data may provide over epidemiological indicators. These studies strengthen the evidence that wastewater monitoring could be a powerful tool in tracking the spread of COVID-19 (Peccia et al., 2020). The Centres for Disease Control and Prevention (CDC), US Department of Health and Human Services (HHS), and agencies throughout the federal government, are developing a National Wastewater Surveillance System (NWSS) in the state, tribal and local areas in response to the COVID-19 pandemic. The data generated by NWSS will help public health action and a better understanding of the extent of COVID-19 infections in communities (NWSS, Times, 2020). Therefore, quantitative SARS-CoV-2 measurements in untreated sewage can provide information on changes in total COVID-19 infection in the community, depending on the frequency of testing, sewage surveillance can be a leading indicator of changes in COVID-19 in a community and its detection in sewage serves as a COVID-19 indicator that is independent of healthcare-seeking behaviours and access to clinical testing.

3.3. *Vaccine and treatment*

Most common symptoms of COVD-19 cases include cough, dyspnoea fatigue, fever, sputum production, muscle ache, gastrointestinal issues, sore throat, headache, rhinorrhoea, sneezing, nasal congestion (Xu et al., 2020b). According to research, the immunity of COVID-19 patients declines at a higher rate within a month after recovering from it (Chen et al., 2020a). A first longitudinal study using 90 patients and healthcare workers at Guy’s and St Thomas’ NHS foundation trust found levels of antibodies that can destroy the virus peaked about three weeks after the onset of symptoms then swiftly declined (Seow et al., 2020).

Table 1 shows explicitly different levels or stages of vaccine development including preclinical test, safety tests, animal trials and human trials. As of July 2020, 155 vaccines were being developing, and 23 vaccines were under human trial (Table 2). A rapid success in the field of development of vaccine was seen and as of January 2021, there are around 64 vaccines in clinical trials on humans. Among these 3 vaccines have been approved for full use, 7 vaccines are in their early or limited use stage, 20 vaccines are in large scale efficacy tests (Phase 3), 20 of them are in expanded safety trials (Phase 2) and 43 of them are testing

Table 1
Stages of vaccine development and testing (T. N. Times, 2020).

Step 1	Preclinical Test	A vaccine to animals such as mice or monkeys to see if it produces an immune response.
Step 2	Phase I Safety Trials	vaccine is given to a small number of people to test safety and dosage as well as to confirm that it stimulates the immune system
Step 3	PHASE II Expanded Trials	Vaccine is given to hundreds of people including children and adults to see if it acts differently in them. Further, this trial checks the vaccine's safety and ability to stimulate the immune system.
Step 4	PHASE III Efficacy Trials	Vaccine is given to thousands of people and wait to see how many become infected, compared with volunteers who received a placebo. These trials can determine if the vaccine protects against the coronavirus
Step 5	Approval	Regulators in each country review the trial results and decide whether to approve the vaccine or not. During a pandemic, a vaccine may receive emergency use authorization before getting formal approval.

their safety and dosage criteria (Phase 1) and 85 preclinical vaccines are under active investigation in animals. Table 3 shows a list of vaccines that have reached approval and trials in humans, along with a selection of promising vaccines being tested for their final approvals. By the end of February 2021, 256 COVID-19 vaccines have been developed, 182 under pre-clinical trials and 74 in clinical trials (Li et al., 2021). Fig. 6 shows currently active different vaccines in different countries.

3.4. Climate dependency on COVID-19 transmission

The coronavirus has some impending features such as mutation and recombination while spreading, thereby causes severe health issues to patients of old age and those with an existing health condition.

Influenza prototype diseases wreck humankind under low daily temperature and with humidity up to 70% (Park et al., 2020). Initially, investigations explicated COVID-19 transmission decreased with an increase in temperature (Tobías and Molina, 2020). Another study that involved 429 cities suggested that temperature may have a strong relation to COVID-19 infection and transmission, which collected data for only 16 days (Jan 20 ~ Feb 4) (Wang et al., 2020d). Using these climatic correlations with COVID-19 cases data (Jan 20 to Feb 29: 2299 COVID-19 death counts) in Wuhan, temperature and humidity proved to have an impact on mortality, and increased temperature showed a slight decline in the rate of death. A positive association with COVID-19 daily death counts during the diurnal temperature range ($r = 0.44$) and, a negative association for relative humidity ($r = -0.32$) was observed (Ma et al., 2020). Additionally, investigation of daily COVID-19 cases association with daily average temperature and relative humidity in 30

Table 2
Vaccine under various phases: I/II, II and III (as of July 2020).

Phase	Name	Developer	Type	Design, Product Description	Location	Start date
Phase III	Moderna mRNA-1273	Moderna/NIAID	RNA	Double-blind, mRNA-1273, encodes for a form of the spike (S) protein on the virus	USA	27/07/2020
Phase III	Sinovac vaccine	Ege University	Inactivated	Double-blind, Inactivated (inactivated + alum); CoronaVac (formerly PiCoVacc)	Brazil	01/07/2020
Phase II/III	Oxford AZD1222/ ChAdOx1-S	Immunomic Therapeutics/EpiVax/ PharmaJet	Non-replicating viral vector	Single-blind, Non-replicating viral vector; AZD 1222 (formerly ChAdOx1)	UK	28/05/2020
Phase II	AZLB protein subunit vaccine		Protein subunit	Double-blind	China	12/07/2020
Phase II	Cansino Ad5-nCoV		Non-replicating viral vector	Double-blind	China	12/04/2020
Phase II	Moderna mRNA-1273	Symvivo	RNA	Observer-blind, doseconfirmation, RNA; LNPencapsulated mRNA (mRNA 1273)	USA	29/05/2020
Phase I/II	Aivita AV-COVID-19		Other	Double-blind, dose-finding	USA	01/07/2020
Phase I/II	Altimmune T-COVID		Non-replicating viral vector	TBC	TBC	01/06/2020
Phase I/II	Bharat Covaxin		Inactivated	Double-blind	India	13/07/2020
Phase I/II	BIBP/Sinopharm BBIBP-CorV	BioNet Asia	Inactivated	Double-blind, dose-finding, Inactivated	China	28/04/2020
Phase I/II	BioNTech BNT162	Takis/Applied DNA Sciences/Evvivax	RNA	3 LNP-mRNAs; BNT162	USA	29/04/2020
Phase I/II	BioNTech BNT162		RNA	Open-label, dose-finding	Germany	23/04/2020
Phase I/II	CAMS vaccine	Chula Vaccine Research Center	Inactivated	Double-blind, dose-finding, Inactivated	China	15/05/2020
Phase I/II	Cansino Ad5-nCoV	Mediphage Bioceuticals/University of Waterloo	Non-replicating viral vector	Double-blind, dose-finding, Non-replicating viral vector; Adenovirus Type 5 vector (Ad5-nCoV)	Canada	01/08/2020
Phase I/II	Genexine GX-19	Genexine Consortium (GenNBio, International Vaccine Institute, (KAIST), (POSTECH)/Binex	DNA	Double-blind	South Korea	17/06/2020
Phase I/II	Inovio INO-4800		DNA	Open-label (A), double-blind (B), dose-finding	South Korea	22/06/2020
Phase I/II	Sinovac vaccine		Inactivated	Double-blind, dose-finding	China	16/04/2020
Phase I/II	Sinovac vaccine		Inactivated	Double-blind, dose-finding	China	20/05/2020
Phase I/II	WIBP vaccine	Entos Pharmaceuticals/Cytiva	Inactivated	Double-blind, dose-finding, Inactivated	China	11/04/2020
Phase I/II	Zydus Cadila DNA vaccine		DNA	Double-blind	India	13/07/2020

Table 3
Vaccine under various phases: II/III, and III (as of January 2021).

Phase	Name	Developer	Type	Design, Product Description	Efficacy	Country	Status
Phase 2/3	Comirnaty	Pfizer/ BioNTech	mRNA	Muscle Injection/Freezer storage (−70C), 2 doses, 3 weeks apart	95%	USA	Approved in several countries, emergenecy in USA, elsewhere
Phase 3	mRNA-1273	Moderna	mRNA	Muscle Injection/30 days with refrigeration, 6 months at −20C, 2 doses, 4 weeks apart	94.50%	USA	Approved in canada, emergency use in U.S., E. U., Israel
Phase 3	Sputnik V	Gamaleya	Ad5 and AD26	Muscle injection, Freezer storage. Developing an alternative formulation that can be refrigerated, 2 doses, 3 weeks apart	91.40%	Russia	Early use in Russia, elsewhere
Phase 2/3	AZD1222	Oxford/ AstraZeneca	ChAdOx1	Muscle injection, Stable in refrigerator for at least 6 months, 2 doses, 4 weeks apart	62%–90% (depending on the dosage)	UK/ Sweden	Emergency use in Britain, India, other countries.
Phase 3	Convidecia	CanSinoBIO	Ad5	Muscle injection, refrigerated, single dose	Unknown	China	Limited use in China
Phase 3	EpiVacCorona	BEKTOP	Protein	Muscle injection, Stable in refrigerator for upto 2 years, 2 doses, 3 weeks apart	Unknown	Russia	Early use in Russia
Phase 3	BBIBP-CorV	SINOPHARM	Inactivated	Muscle injection, 2 doses, 3 weeks apart	79.34%	China	Approved in China, elsewhere
Phase 3	CoronaVac	Sinovac	Inactivated	Muscle injection, 2 doses, Refrigerated, 2 weeks apart	78%	China	Limited use in China
Phase 3	Covaxin	Bharat BIOTECH	Inactivated	Atleast a week at room temperature, 2 doses, 4 weeks apart	unknown	india	Emergency use in India
Phase 3	CVnCoV	CUREVAC	Inactivated	Muscle injection, Stable at 3 months at 2–8C, 2 doses, 4 weeks apart	unknown	USA	Under Trial
Phase 2/3	AG0302-COVID1	AnGes	Inactivated	Skin injection, over a year at room temperature, 2 doses, 2 weeks apart	unknown	japan	Under Trial
Phase 3	ZyCoV-D	Zydus Cadila	Inactivated	Skin injection, stable at room temperature for three months, 3 doses, 4 weeks apart	unknown	India	Under Trial
Phase 3	Ad26.COV2.S	Johnson-Johnson	Ad26	Muscle injection, Upto 2 years at -4C, and upto 3 months refrigerated at 2–8C, 1 dose	unknown	USA/ Israel	Under Trial
Phase 3	NVX-CoV2373	NOVAVAX	inactivated	Muscle injection, Stable in refrigerator, 2 doses, 3 weeks apart	unknown	USA	under Trial
Phase 3	ZF2001	Anhui Zhifei Longcom	inactivated	Muscle injection, 3 doses, 4 weeks apart	unknown	China	under Trial
Phase 3	CoVLP	Medicago	inactivated	Muscle injection, Stable in refrigerator, 2 doses, 3 weeks apart	unknown	Canada	under Trial

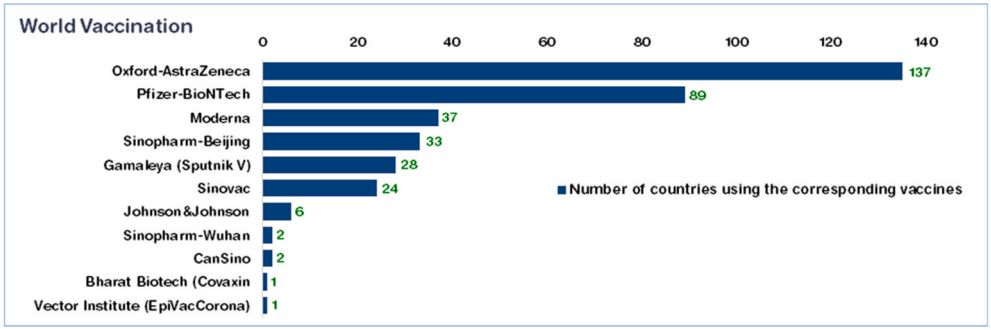

Fig. 6. Presently acting COVID-19 vaccines in different countries.

Chinese provinces (Hubei: Dec 1 ~ Feb 11 for; other districts: Jan 20 ~ Feb 11) showed both temperature and humidity had a negative association with COVID-19 cases, though inconsistent results throughout mainland China were observed (Qi et al., 2020). Results from capital cities of 30 provinces in China (Jan 20 ~ Mar 2) showed that after controlling a population, migration meteorological factors played an independent role in the COVID-19 transmission, which is plausible if local weather has a low temperature, humidity, and mild diurnal temperature range (Liu et al., 2020b). Data from five Brazilian (Brasilia, Manaus and Fortaleza, Rio de Janeiro, São Paulo) cities showed that higher mean temperatures and average relative humidity favoured the COVID-19 transmission (Auler et al., 2020). Since Feb 29, (national onset) to Mar 31, Mexican capital, and, other 31 states showed temperature associated negatively with the local confirmed COVID-19 positive cases (Méndez-Arriaga, 2020). Statistical analysis involved investigation from Jakarta (Tosepu et al., 2020), Indonesia, and California (Bashir et al., 2020), the USA reported that temperature has a moderate impact on COVID-19 transmission. Data were analyzed from 12 cities of Turkey and observed that the crowd has a positive relationship with several cases, wind speed has an inflectional impact, and the temperature has a negative relation with COVID-19 cases (Şahin, 2020). Additionally, it is reported that places with similar COVID-19 transmission had the same temperature and humidity (Sajadi et al., 2020). Data from 185 countries/region regarding COVID-19 cases (Center for Systems Science and Engineering at Johns Hopkins University; more than 3,750,000 confirmed COVID-19 cases) between Jan 21 ~ May 6, showed 60.0% of confirmed COVID-19 cases happened in places where the ambient temperature ranged from 5 °C to 15 °C (Huang et al., 2020). Oslo climate, maximum and minimum temperature were positively, and precipitation was negatively associated with COVID-19 (Menebo, 2020).

In German federal states, COVID-19 mortality negatively correlates

with local air humidity (Biktasheva, 2020). Impact of temperature and humidity on COVID-19 cases, were investigated in 166 countries (excluding China) till March 27, which showed negative relation to new daily cases and deaths (Wu et al., 2020) which also supported by another work (Sobral et al., 2020). For the USA, vulnerable absolute humidity range for COVID-19 spread came into existence (Gupta et al., 2020). The air quality index has a strong effect on COVID-19, while the temperature range varies from 10 to 20 °C (Xu et al., 2020a). Investigation in Iran showed that low solar radiation, humidity, and wind speed promote the spread of COVID-19. Nevertheless, high population density escalates the rate in higher-order, since populated cities such as Alborz, Gilian, Mazandaran, Qom, and Tehran had higher number of infection (Ahmadi et al., 2020). In Japan, a positive correlation of mean temperature and cumulative COVID-19 cases and no evidence on infectivity and temperature was noticeable (Ujiie et al., 2020). (Xie and Zhu, 2020) investigated 122 Cities in China, where the temperature has a positive linear relationship with the number of COVID-19 cases with no evidence to support that COVID-19 cases counts could decline due to warm weather. However, Yao et al., 2020 reported that temperature and UV radiation had no strong association with COVID-19 cases in Chinese Cities (Yao et al., 2020). Hubei, Hunan, and Anhui province had a positive relationship between temperature and COVID-19 while, Shandong and Zhejiang provinces had a negative relation (Shahzad et al., 2020). Collected data of daily confirmed cases from the capital and 27 states in Brazil also confirmed that COVID-19 cases do not decline due to temperature above 25.8 °C (Prata et al., 2020). Additionally, inconsistent results between temperature and COVID-19 in the provinces of Spain were observed (Briz-Redón and Serrano-Aroca, 2020). It is not entirely prominent that daily temperature and humidity possess an impact on this COVID-19 transmission or reduction. According to WHO, temperature and humidity may have some relation to COVID-19, especially their survival capacity outside the human body, but population density and human contact play a critical role in the spread of COVID-19 (WHO, 2020). Hence, non-meteorological factors such as population density should get attention to obtain more reliable results. In another study based in Iran showed that temperature has a high and population density has a low sensitivity to COVID-19 cases (Jahangiri et al., 2020). The efficiency of the data collection is also a crucial task, which could be the ground for not having a suitable correlation. Authors and data providers in the (Gov.UK, NHS) betokened that there is a lag of data entry. In addition, an infected virus whose majority of nature is unknown will be a critical task to predict.

Some authors suspected that lowering air pollution can be an influential factor to abate COVID-19 cases. As COVID-19 is primarily respiratory in nature, hence the contribution from air pollution for this disease susceptibility or outcome is a great interest among the researchers (Contini and Costabile, 2020). suggested that air pollution might have been a contributing factor to the high number of COVID-19 fatalities in Italy. In another work (Dutheil et al., 2020), showed that the COVID-19 death rate decreased due to low air pollution in China (3158 in China and 4607 worldwide reported deaths). However, this data also showed that the COVID-19 transmission rate at an early stage in the first week of March 2020 and during the lockdown in China from Jan and Feb, improved the air quality (Dutheil et al., 2020). Italy showed a clear correlation between air pollution and COVID-19 spread (Fattorini and Regoli, 2020). In northern Italy, Lombardy and Emilia Romagna, the most polluted regions in Europe, experienced the highest COVID-19 cases. The author claimed that a potential positive correlation between COVID-19 cases and pollution was present in that region (Conticini et al., 2020). COVID-19 cases and air pollution indicators from Jan 1 ~ Apr 30 showed that surface levels of air pollution and dry air intensified the fast diffusion effects in Milan (Zoran et al., 2020). Further, London revealed a strong correlation between air pollutants (PM 2.5 and NO_2) indicator and COVID-19 cases (Sasidharan et al., 2020). The high presence of NO_2 was associated with COVID-19 mortality in Italy and Spain (Ogen, 2020). Hazardous waste sites are also sources of air pollution. Recently a "double-hit hypothesis" was proposed. Due to chronic exposure to PM 2.5, alveolar ACE-2 receptor overexpression, which might increase viral load in patients exposed to pollutants, in turn, depleting ACE-2 receptors and impairing host defences. High atmospheric NO_2 may provide a second hit causing a severe form of SARS-CoV-2 in ACE-2 exhausting lungs resulting in a worse outcome (Frontera et al., 2020).

In general, prolonged exposure to air pollution creates acute respiratory disease, inflammation, and asthma attack, which may lead to death, distress syndrome, and eventually causes death. However, for COVID-19 cases, no direct link was found with the air pollution that can work as a cofactor.

4. Findings

In this section finding from the different publication has been reviewed. To restrict the transmission of COVID-19, lockdown measure, and social distancing was adopted. Starting from March and April, extended up to May, many countries underwent lockdown; shut their industry, transport, and other non-essential sectors (Haleem et al., 2020). Back in 2015, United Nation defined 17 sustainable development goal, (SDG) which developed, and developing both countries will try to attain by making new strategies and working together to have a peaceful and sustainable world. These seventeen SDGs include no poverty (SDG1), zero hunger (SDG2), good health and well-being (SDG3), quality education (SDG4), gender equality (SDG5), clean water and sanitation (SDG), affordable and clean energy (SDG7), decent work and economic growth (SDG8), industry innovation and infrastructure (SDG9), reduced inequalities (SDG10), sustainable cities (SDG11), responsible consumption and production (SDG12), climate action (SDG13), life below water (SDG14), life on land (SDG15), peace justice and strong institution (SDG16), partnerships for the goals (SDG17). It is widely discussed that progress towards these 17 SDGs was mixed before the pandemic (Huan et al., 2021). In the world, still, 673 million have no toilet, 736 million people suffer from poverty, 785 million people have no basic drinking water, 821 million people are undernourished, 840 million people have electricity. At least 28 poor countries will not attain the SDGs 1–4, 6 and 7 by 2030 (Moyer and Hedden, 2020). After the pandemic achieving this target is projected to be slower (Lancet and Health, 2020). Keeping in mind these goals, this work tried to focus on the key five sector, which got immense negative affect during this COVID-19 and specially during lockdown and broadly represents these 17 SDGs. These fives sectors are social/human life, environment, economy, energy, transport. For social impact, we tried to focus on factor, which can shades lights on SDG1-6 while for environment impact our goal was to bring alignment with SDG 6, 7, 13, 15. Impact on economic has relation with SDG 8–10; while for Energy SDG 7, 11–13 are crucial. For transport SDG 6,7,13 and 15 all, of these together had an impact on SDG 16 and 17. It is evident that most of the sectors are connected to each other (as shown in Fig. 7) and thus the impact of this pandemic is so drastic. The following section will discuss areas, which got adversely impacted due to COVID-19 or precisely lockdown and now suffering from social distancing.

4.1. Impact on social/human life

Nonetheless, throughout history, pandemics have wrought a considerable number of social changes such as from the black plague in the middle ages to the Spanish Flu in the early 20th century, and now similar effects are happening due to COVID-19 pandemic. COVID-19 created a variety of changes in daily human life. To subdue the transmission, most of the countries started lockdown strategy and social distancing (Mitjà et al., 2020). During the lockdown, people were encouraged to stay at home and only go out if it is inevitably essential, e.g., buying food, and thus advised to use masks and maintain social distance, to reduce the droplet transmission (Lau et al., 2020b). These

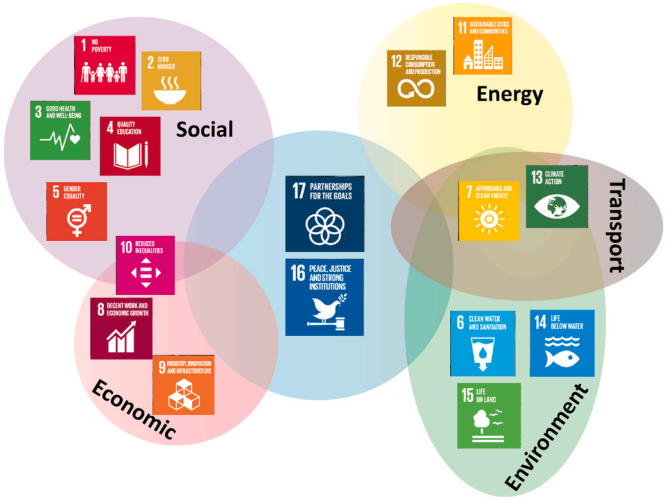

Fig. 7. Five key sector, Social, Environment, Economy, Energy and Transport in terms of 17 sustainable development goal.

rules are similarly applicable to any respiratory disease. Because of this social distancing, Olympic and para Olympic games were suspended (BBC, 2020b). However, coronavirus made an immensely positive impact on society, to get in touch frequently with distant friends and family to share experiences and stories and to know their health and wellbeing. Staying at home gave them ample amount of time and opportunity to nurture their old hobbies, interest, and exploring more creative stuff. People kept themselves busy with making or watching different online videos (Sheth, 2020). Though people spent more time at home with a partner, because of stress arising from pandemic and risk of job loss, sexual function did not improve. Collected data from 89 women in Rome showed that high stress and pandemic death in Italy increased their intercourse interval (Schiavi et al., 2020).

Unfortunately, COVID-19 has affected all levels of the education system, pre-school to tertiary education. Over 100 countries initiated the cessation of schools. UNESCO estimates 990 million learners to have been affected by the closure of educational institutions, as shown in Fig. 8 (UNESCO, 2020). Children and adolescents faced immense negative psychological impact because of the fear of infection, boredom, lack of personal space at home, stress, lack of in-person contact, family financial issue. For adolescents, life quality improvement, independence

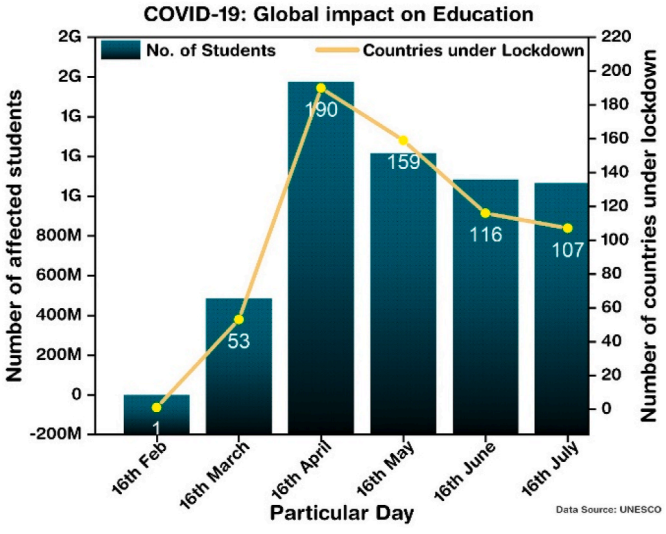

Fig. 8. Number of affected students from education due to global lockdown (UNESCO, 2020).

achieved through socialization, was absent during the lockdown period. Mean post-traumatic stress scores were four times lower in non-lockdown children than in those under lockdown (Wang et al., 2020b). Home-schooling and widespread use of remote teaching via online learning modules and television were brought into use, to tackle this issue. However, these modes of education are accessible to an economically built country with the availability of internet and computers. Countries with not-so-upgraded systems suffered a lot. These young pupils, being deprived of the right to education during the lockdown, suffered mental trauma leading to emotional breakdown and suicides (Lathabhavan and Griffiths, 2020). It might appear to be a rare issue but not at all an ignorable area. The online education system started, still can't replace the real-world classroom education (Schwarz et al., 2020).

Changes in medical treatment facilities, like oral and telephonic Medicare, were also adopted to avoid COVID-19 transmission (Machado et al., 2020). In addition, exclusive emergency dental procedures conducted to protect the medical personnel and the patients and to reduce as much as possible the consumption of personal protective equipment. It is expected that because of the unavailability of reproductive and sexual health service for women, 2.7 million extra unsafe abortions was being carried out (Wenham et al., 2020).

Fear of no food and household material haunted people and reflected in their purchasing style. Additionally, the scarcity effect and stockpiling as unnecessary buying habits in every country, during the lockdown periods, were visible. Toilet paper and cleaning pieces of stuff were on the prime list. People stood in a long queue before entering the shop, which was later restricted to limit the number of customers and handle them simultaneously. In the United Kingdom, new purchase limits, online, and home delivery services, and priority delivery slots for vulnerable or elderly customers started (e.g., Waitrose and Ocado shops) (Pantano et al., 2020). However, ignorance created huge chaos to tackle this transmission. Negligence in the use of masks and maintaining social distancing occurred in every country. Understandably, maintaining social distance in a populated country like India is hard, but, in the USA, people were not eager enough at the beginning to keep them at a safe level. Thus, a mixed reaction among people from different countries, with excessive food storage but not abiding rules, was observed. In contrast, the Kingdom of Saudi Arabia (KSA) implemented strict measures for social distancing where it was hard for them due to their social and religious norms, level of urbanization, and religious mass gatherings annually (Yezli and Khan, 2020).

Further, the negative impact of COVID-19 on the economy, daily life, and social activity, created psychological difficulties (Cao et al., 2020). Previously for the SARS outbreak, due to quarantine, high rates of depression and anxiety among people were visible. This pandemic also created psychological issues including depression, frustration and stress while survey was conducted with 1182 individual in New Delhi, India which included different age groups and genders (Chaturvedi et al., 2021). In London 70,000 adults data between 23rd March and 9th August, showed in the early stage of lockdown depression and anxiety was present, which reduced later, may be because of the adaption with circumstances (Fancourt et al., 2021). Similar outcome was also found in Germany (Bendau et al., 2021). Using 500 adult samples from nationwide, the USA community showed the positive impact of COVID-19 on daily life associated with health anxiety, financial worry, and social support, and a negative association with loneliness, due to self-isolation and no social life was prominent (Tull et al., 2020). In the Greek population, insomnia was prevalent for women and people living in an urban area. Financial pressure, changes in social life, and the daily routine increased health issues during a virus outbreak (Voitsidis et al., 2020). Depression, anxiety, and PTSD symptoms were prominent among the USA young adults, age between 18 and 30 years, with high levels of COVID-19-specific worry and loneliness (898 participants from April 13, 2020, to May 19, 2020) (Liu et al., 2020a). Based on different published reports, due to economic hardship, isolation, quarantine suicide rate

increased during this time. In some cases, unavailability of food and alcohol was also a reason for suicide. Six different couples committed suicide in Bangladesh, India, and the USA for various reasons such as public harassment, fear from COVID-19, and financial constraint (Griffiths and Mamun, 2020). Suicide for financial distress was higher in economically hard countries (Rajkumar, 2020). Increasing levels of domestic violence, which includes physical, emotional, and sexual abuse increased (Roesch et al., 2020) in Brazil (40%–50%), and in Spain, Cyprus, UK, and Singapore helpline received 20%, 30%, 25%, 33% higher call respectively because of the domestic violence (Bradbury-Jones and Isham, 2020). Domestic violence tripled during February 2020 compared to February 2019 in Hubei, an increase of 30% in France, and 25% in Argentina were observed since they initiated a lockdown in March 17 and March 20 respectively (Boserup et al., 2020). Lockdown adversely affected the life of refugee in Uganda because of the insecurity in income while gender-based and sexual violence and anxiety increased (Bukuluki et al., 2020).

During this COVID-19 pandemic, technology played a key role (Oztemel and Gursev, 2020). Worldometer' renders a real-time update on the genuine number of people known to have COVID-19 worldwide, including diurnal new cases, distribution by countries, and austerity of the disease in each country (recovered, critical condition or death). What's app was employed in Singapore to inform people about the updated COVID-19 details (Wang and Tang, 2020). COVID-19 Intelligent Diagnosis and Treatment Assistant Program (nCapp)" based on the Internet of Things, contributed to the long-term follow-up of patients diagnosed with COVID-19. The ultimate goal is to facilitate different levels of COVID-19 investigation and medication among different doctors from various hospitals to upgrade to the national and international level through the nCapp system (Bai et al., 2020). In India, Arogya Setu was launched to develop a connection between the potential healthcare assistance and the people of India (Singh et al., 2020). A mobile application named Close Contact was launched for chinses civilians to track the corona-positive person (Wang et al., 2020a). The use of video conferencing technologies such as Zoom, Microsoft Teams during the pandemic skyrocketed, as they have morphed from an obscure brand name to a household verb. However, fatigue from excessive use of web conferences also became another cause of illness (Kirk and Rifkin, 2020). Excessive use of digital media and video games during the lockdown and home confinement decreased sleep quality (Cellini et al., 2020).

In the event of natural disasters, pandemics, riots, terrorist attacks, criminal activity, home theft rate decreased, thereby leading to a decline in the crime rate, worldwide (Hodgkinson and Andresen, 2020). However, some commercial burglary increased as most of the markets and shops were closed for a prolonged period without any workers or owners around the shop (Mohler et al., 2020). Some habits after this pandemic such as using masks, remote working, less traveling, increased security checking of health in the airport to test the presence of virus, will be remarkably altered (Sheth, 2020).

Out of the 17 SDGs, preventing the deaths of new-borns and under-fives, and sending all under five children into primary schools were the two SDGs (SDG 3–4), which were close to being achieved before the COVID-19 pandemic (Fisher, 2020). However, it is evident that COVID-19 has changed the scenario again. Increase of domestic violence during this pandemic proved again that how essentials are the gender equality and women's empowerment (SDG 5 and SDG 10). Existing inequalities in socio-economic and health sector has now enhanced the issues in higher order. COVID-19 impact on the most vulnerable and poor people is now most staggering as action on SDGs were not taken seriously since 2015.

4.2. Impact on the environment

Global warming and preventing the rise of global temperature is one of the global challenges. Presently, 90% of the CO_2 emission occurs due to human activity such as burning fossil fuels, while 10% comes from deforestation (Jackson et al., 2018). Air pollution, which is a complex mixture of particulate matter (PM) (2.5,10), NO_2, SO_2, ozone (O_3), has an adverse impact not only on the environment but also on human health (Yang, 2020). Combustion of fossil fuels and road transportation (motor exhaust; brake, wear and road erosion; resuspension due to wheel-generated turbulence) emits nitrogen dioxide (NO_2), which is appalling for human health and, long-term exposure can even increase the mortality rate. Presence of particulate matter (PM, 2.5 to 10-μm in diameter), in the ambient and engendering from biomass and fireworks burning has an adverse effect on human health, causing asthma and COPD (Liu et al., 2016).

Probably the environment is the only sector that got an immensely positive impact form this COVID-19 scenario. International energy agency reported that global coal use was 8% lower in the first quarter in 2020. Due to the Locked down, transport, industry, and all non-essential sectors were closed, which reduced emission significantly. NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) published recent data (Fig. 9) declaring that compared to last year, NO_2 emission reduced by 30% (Dutheil et al., 2020). The decline in PM2.5 was significant in the US, UAE, Italy, and Spain, in the month of March, due to cumulative lockdown (Chauhan and Singh, 2020). Noticeably, in China, the overall air quality improved as NO_2 reduced by 22.8 $\mu g/m^3$, PM 2.5 decreased by 1.4 $\mu g/m^3$ particularly in Wuhan (Zambrano-Monserrate et al., 2020) and by 18.9 $\mu g/m^3$ in 367 other cities (Lal et al., 2020). However, some cities also witnessed the air quality index over 100. These reductions accounted for lowering the particle loadings (Wang et al., 2020f). Air quality showed improvement near the Yangtze River Delta (YRD) region, which is one of the economic city-clusters in Eastern China. However, the percentage of PM 2.5 attributed to residences and long-range transport (Li et al., 2020). Additionally, 44 cities of northern China marked 69.5% reduction in human mobility improving the air quality as SO_2, PM2.5, PM10, NO_2, and CO decreased by 6.76%, 5.93%, 13.66%, 24.67%, and 4.58%, respectively (Bao and Zhang, 2020). In 2017, the energy sector in Italy (industry and transport) contributed 80% of the total country GHG emissions. COVID-19 related lockdown caused an overall 20% reduction of GHG emission, lower than emissions of March and April in 2015–2019 (Rugani and Caro, 2020). In Milan, Italy, partial lockdown restricted the people movement, and total lockdown terminated industry and transport activities. Reduction of PM10, PM2.5, BC, benzene, CO, and NOx level was observed because of a decrease in road transport (Collivignarelli et al., 2020). In Barcelona, PM10 reduced by 31% (Tobías et al., 2020) and NO_2 by 50% (Baldasano, 2020). Initially, Madrid and Barcelona contributed 55% and 56% of NO_2 emission from traffic. However, due to the COVID-19 scenario-based lockdown, since March, Barcelona and Madrid (Spain), emitted 50% and 62% less NO_2 respectively (Baldasano, 2020). In the continental USA, PM2.5 reduced during the lockdown, especially in urban counties and wherever non-essential businesses were closed (Berman and Ebisu, 2020). During the lockdown period (March 19th to April 14th, 2020), reduction in PM2.5, NO_2, and CO concentration by 21%, by 35%, CO by 49%, was noticed in Almaty, Kazakhstan (Kerimray et al., 2020). Sao Paolo Brazil also encountered a reduction in CO and NO_2 emission by 64.8%, and 77.3% (Nakada and Urban, 2020). Further, PM10, NO_2, and SO_2 emissions decreased by more than half during the COVID-19 lockdown period in Salé City, Morocco (Otmani et al., 2020). India, every year battles more than 350,000 new cases of childhood asthma and 16000 premature death attributed to air pollution, mostly NO_2 and PM (2.5–10 μm) generated from fossil fuels and transportation sector (CREA, 2020). Additionally, lockdown resulted in the suspension of transportation, and industries, the primary sources of air pollution. The first phase-locked down showed betterment of air quality with a reduction of NO_2. Delhi, the capital of India, reported air quality index to change from 900 to below 20 because of the absence of 11 million registered cars from the road, with an alarming reduction in PM2.5 in Delhi (Sharma et al.,

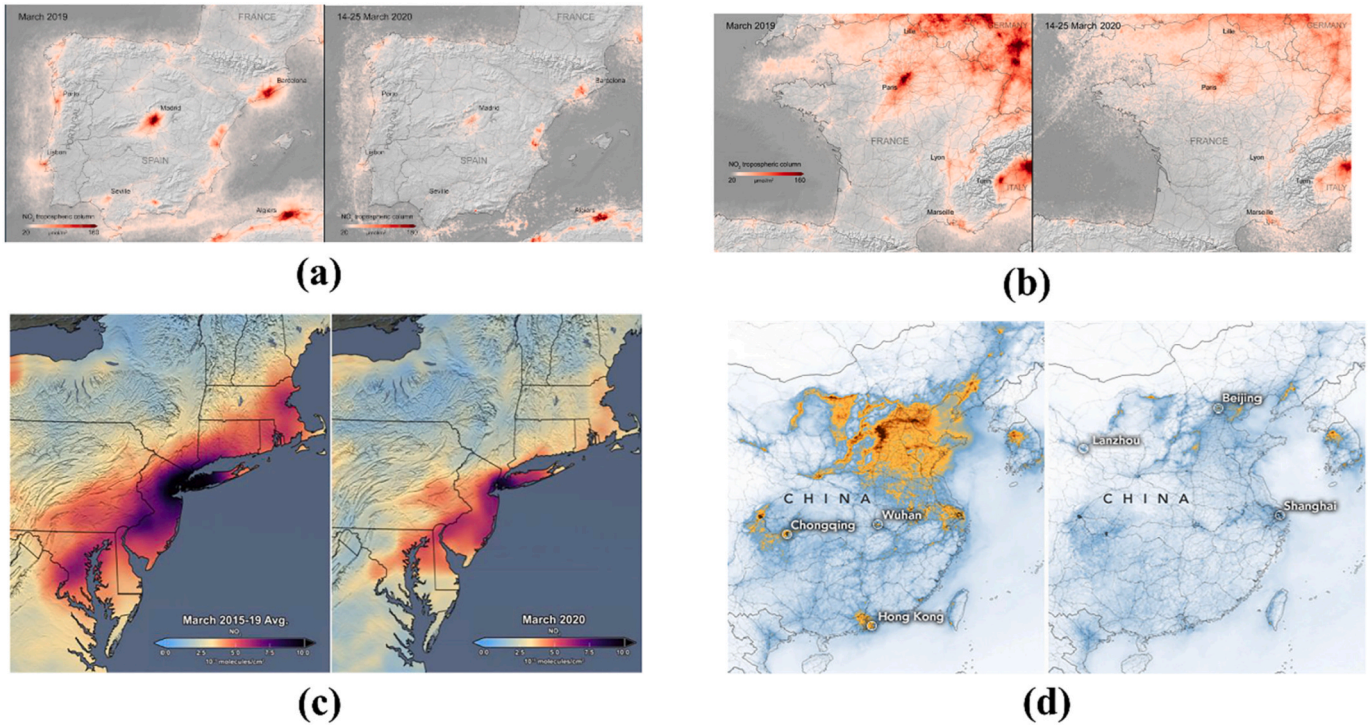

Fig. 9. NO_2 emissions in (a) Spain, (b) France, (c) USA, (d) China before and after lockdown (ESA, 2020)

2020). In Malaysia, open, burning motor vehicles and industrial emissions are primary sources of PM2.5, which reduced up to 24% due to Movement Control Order from the Malaysian Government (Abdullah et al., 2020a). Studies supported that quarantine and lockdown reduced the PM2.5 for Dhaka (14%), Kampala (35%), Delhi (40%), Bogotá (57%), and Kuwait City (42%). Maximum reduction in the capitals of America, Asia, and Africa was recognized (Rodríguez-Urrego and Rodríguez-Urrego, 2020). PM2.5 concentration reduction was only possible from automobiles or industry, and not from any residential sectors. A report from Ontario, Canada, showed that residential sector emits 56% of PM2.5 emissions. Hence, during the lockdown, 28% of PM2.5 resulted from outdoor cooking using barbeques. However, NO_2 and NO_X both were lowered because of the reduction of automobiles (Adams, 2020). In amidst of COVID-19 lockdown situation, even though the major air pollutants like PM2.5, PM10, NO_2, SO_2 reduced largely, Ozone (O_3) appeared to increase in various parts of the world: Milan (Collivignarelli et al., 2020), China (Wang et al., 2020f), Rio de Janeiro, Brazil (Siciliano et al., 2020), Barcelona (Tobías et al., 2020), mostly produced from household VOCs in lockdown. An investigation reflected that four European cities (Nice, Rome, Turin, Valencia) and Wuhan in China showed a drastic increase in ozone ~17% and 36%, respectively. Further, the reduction of PM2.5 and PM10 led to less scattering of solar radiation which, eventually increased the solar radiation, favouring O_3 formation (Sicard et al., 2020).

Another significant factor to be influenced is noise pollution, which reduced due to a decline in road transport. Barcelona indicated a 50% decrease in sound pressure (Baldasano, 2020), whereas, Dwarka river basin of Eastern India marked a drop in noise level from 85 dB to <65 dB (Mandal and Pal, 2020). Another global concern being water pollution also revealed remarkable improvement in water quality during lockdown days. The lagoon of Venice, being affected by the regional geomorphological evolution, anthropogenic stressors, and global change stress from human activities, marked a decline in water traffic due to mobility restrictions during the lockdown (Braga et al., 2020). India witnessed prosperity in water quality: Vembanad lake, longest freshwater lake in Kerala, experienced a 15.9% reduction in suspended PM concentration (Yunus et al., 2020). Groundwater in the proximity of the Tuticorin industrial city noticed a drop in the amount of NO_3, As, Fe, Se, Pb, total coliforms, and faecal coliforms (Selvam et al., 2020). National River of India, Ganga (declared in 2018), with over 29 cities, 97 towns and thousands of villages along the banks marked a sudden decrease in the quantity of dissolved oxygen (DO), biological oxygen demand (BOD) and nitrate (NO_3-), securing the quality of water nearly at drinkable level (Dutta et al., 2020). Another harmful measure taken to prevent COVID-19 transmission is disinfecting urban public areas by spraying corrosive chlorine-releasing agents, quaternary ammonium cation with the help of trucks, drones, and mini-tankers, destroying the wildlife and human settlement in these areas. Both the physical and mental health of humans is immensely hampered due to the death of wild animals, causing a massive biodiversity massacre (Nabi et al., 2020). Previously, heavy traffic and daylight human activities caused several species to adopt a nocturnal lifestyle. However, current mobility restrictions limited human intervention in wildlife, resulting in free animal wandering even during the daytime. Nevertheless, the negative impact of COVID-19 on wildlife remains elusive, as the feeding of animals depends on human activities, tourism. A prolonged pandemic may endanger such animals due to the scarcity of sufficient, nutritious, and safe food.

Compared to 2019, global CO_2 emissions for 2020 were estimated to be between 4 and 7%, which was achieved by limiting mobility, and sacrificing societal cost (Fisher, 2020). Thus, this development in the environment is temporary; the scenario will alter after the COVID-19 scenario. Developed and developing both will employ fossil fuel sources to secure productivity (Geography, 2020). To keep global temperature rise below 2 °C and 1.5 °C, need reduction of 3% and 8% a year respectively (Gillingham et al., 2020). To achieve the required target, imposing tax on pollution and emitting other environment pollutant gasses will be good practice (Yoshino et al., 2021).

4.3. Impact on economy

Due to COVID-19, every analysis showed that 2020 experienced a negative or reduced growth of the economy. Moody Investor Services estimated 0.5% contraction, an organisation for Economic Co-operation

and Development predicted a 1.5% reduction (assessment as on March 3, 2020) and the Institute of International Finance expected a 1.6% reduction. First quarter of 2020 in China faced 6.8% national economic output contraction which was its worst performance in last two decades (Liu, 2021). The United Nations Conference on Trade and Development estimated US$2 trillion shortfalls in global income (Srivastava, 2020), while the USA predicted at least three years of recovery time to cope up with the COVID-19 dip. Areas like commercial aerospace, travel, and insurance might see a more delayed restoration. EU GDP anticipated declination by 7.5% as the IMF states that the global economy will shrivel by 3% by the end of this year (BBC, 2020c). In the second quarter of 2020 global GDP declined by over 4.9% though, it was better than 2007–08 global financial crisis. These factors negatively affect the job market. More than 300 million people lost jobs due to COVID-19 in the second quarter of 2020, higher than the recession faced in 2008–2009 (Kenny, 2020). To cope up with this scenario, some companies already adopted sacking steps. Uber disclosed its plan to lay off 3700 drivers (Heater, 2020), while in the UK, over 600,000 people lost their job between March and July. British Airways, BP, Rolls Royce, restaurants and builders have cut jobs (BBC, 2020d). Even though India did not release official job loss data but Centre for Monitoring the Indian Economy data widely accepted that unemployment increased by 14.2% since March to April (BBC, 2020e). America also marked more than 2.9 million employment as of May 14, 2020, bearing a two-month total of 36 million, and with 20 million jobs lost in April, and the rate of unemployment rose to 14.7%

The sectors, which got immensely affected by COVID-19, includes travel & tourism, aviation, automobile. Tourism sector experienced drastic declination as more than 50 million jobs were at risk, as declared by the World Travel and Tourism Council. On 7 May, the UN World Tourism Organisation predicted a decline of 80% from the earnings of international tourism as compared to last year ($1.7 ton) along with 120 million job layoffs. Tourism contributes ~15% of Spain's and some 13% of Italy's GDP (The Guardian, 2020).

The next sector to be affected by COVID-19 is the automobile industry. June accounted for more than 6000 automotive job layoffs jobs in the UK. These layoffs affect thousands of jobs affecting an industry, employing around 800,000 people in the UK (Guardian, 2020). Various automobile companies experienced various drawbacks during this pandemic: Toyota Motor minimized its global production capacity by 2% for the month of August along with a temporary halt of production at Bidadi, Karnataka, India, Nissan Motor delayed its production and aimed at 30% more production, by the end of Dec 2020, Volvo Cars experienced a revenue drop of 14.1% along with an operating loss of 989 SEK since January to June, Mercedes-Benz stopped making C-Class in Tuscaloosa, Alabama plant. However, among all this chaos, South Korea reported positive news were light vehicles sold increased by 41%. Maruti Suzuki and Hyundai India both announced enhancement of sales after the retrieval of lockdown in India (Roberts, 2020).

The aviation industry is another concerned sector during COVID-19 (Iacus et al., 2020). On March 23, the International Air Transport Association (IATA) budgeted revenue loss from globally passenger airlines ~ $252 billion and contributed ~ $200 billion in government assistance (Forbes, 2020). Previously this sector faced bankruptcy due to oil refusal, airline deregulation, terrorist attacks (9/11 attack) and, SARS (Took three years to overcome the losses) (Sobieralski, 2020). International, low-cost, and regional airlines suffered job layoffs (Sobieralski, 2020). UK airports squandered £10,000 per minute between March and June (Independent, 2020). Since June, 40% of the aircraft has returned to the line and, total seat capacity increased by 32% compared to the previous month but remained 35% below the level (IATA, 2020).

Direct impact on agriculture due to COVID-19 was less affected as compared to other sectors. The agricultural sector saw a price drop of 20% attributed to demand crash from restaurants and hotels during the COVID-19 outbreak (T. E. Times, 2020). Labour – intensive agricultural production systems got affected due to social distance and lockdown measures (OECD, 2020). Real time data collection from ship tracking before and after lock down showed disruption was not that much bad as it was expected and countries, which had strong trade link with China suffered lot (Verschuur et al., 2021).

During COVID-19 pandemic (March ~ April), facemasks and N95 respirators became a worldwide healthcare necessity causing a shortage of supply in various countries along with rising the prices exorbitantly. Consecutively, industries have changed their production process based on high demand. Non-renewable and biodegradable petroleum and polymer-based materials like polypropylene, polystyrene, polycarbonate, polyethylene, and polyesters were used for the production of environment-friendly masks to fight COVID-19 and pollution (Das et al., 2020). Production line of various companies altered due to change of demand and for corporate social responsibility: Ford automotive industry (vehicles to modified respiratory and ventilator), Tesla (Electrical vehicles to ventilators), Airbus (aerospace to ventilators), Dyson Tech (Vacuum cleaners to hand dryers), Ventilators Ineos (Oil, gas, plastics Chemicals and other products to Hand sanitizer and other healthcare products), Gucci (Luxury clothing to Masks), and Zara (Apparel to Surgical masks). In the economy, consumers play a significant role. Panic buying of household items (e.g., toilet paper, groceries) at the starting of this pandemic increased and, suppliers were not ready to meet the demands. Hence, the supply-demand chain disrupted, and soon restriction on the maximum purchase was enforced. Globalization might suffer due to current trends (He and Harris, 2020).

Governments prepared emergency plans, and compensation packages to support their economies. The UK offered £330 billion as an emergency loan to help those in financial difficulty, the People Bank of China and the Bank of Japan granted $240 billion and $43 billion for maintaining bank movement, respectively (Nicola et al., 2020) Germany offered unlimited loans to protect companies from collapsing. Small and large businesses were provided with loans to protect their employees, which affected the tax system. In Denmark, 75% of wage bills were covered by the government, which helped companies to struggle against the drop in the economy and, employees were entitled to take five days' leave from work (Forum, 2020). Social distances created problems, particularly in the industries, where contactless working is difficult. Remote working facilities like digital seminar conferences, work from home concept gained importance due to lockdown measures, which remained a challenge in populated cities: India (Population: 1.38 billion), China (Population: 1.43 billion), Singapore (Population density: 8358/km^2) and Hong Kong (Population density: 6754/km^2). By October 2020, US$12.7 trillion was committed by G20 countries to recover the economic down from COVID-19. However, only US$3.7 trillion was directed to environment and carbon emissions sector (Griffiths et al., 2021).

It is evident that trade losses during lockdown was higher and it is recommended that shorter but strict rules could minimize the overall losses. Lifting up the restriction with go slow approach is only valid if further lockdowns are avoided (Guan et al., 2020). However the economic down will force to slow down to attaint he SDG goal. Previously because of the recession, global investors were less interested to invest in SDG, which implies that the achievements of the SDGs in the post Covid-19 is fully dependent on the government support (Shulla et al., 2021). To promote investment towards SDGs, investment institution should look for the optimal portfolio allocation. Ellen MacArthur Foundation also batted the circular economy as the key to creating resilient supply chains after the COVID-19 pandemic. Government must fund long-term green recovery policies as well as short-term emergency packages.

4.4. Impact on energy

Energy is essential commodity for poverty reduction and economic growth. Energy security for a nation is important to be interdependent in international scenario (Le and Nguyen, 2019). Nation must supply

adequate energy in affordable and reliable price to the people. Energy security is the most popular term in 20th century because of the need to decarbonise the energy sector, associated gas supplies issues in Europe and increase in demand in Asia. From 1960s this term is well known and because of the oil crisis in 1970 it became most popular term (Cherp and Jewell, 2014). To ensure the energy security global energy trade is most common fashion nowadays however it fully depends on any countries own strategic decision (Sutrisno et al., 2021). Understanding the necessity and importance of it, UN has made clear that affordable and clean energy should be one of SDG.

Even though the energy sector has a strong correlation with the environment and economy, it remained the most ignored area by the researchers, who only investigated the economic, social, and environmental impact during the pandemic (Henry et al., 2020). In the current world of modernization and urbanization, uninterrupted energy and electrical power supply was a great boom to society, contributing to continuous work from home facilities and balancing the consumption demand, which was otherwise reduced by the industrial sectors (Mastropietro et al., 2020). Energy consumption and demand pattern were different in different countries based on lockdown strictness, adopted measures, and industry closures (Bahmanyar et al., 2020). The reduction of global primary energy demand from 5% to 52% between mid –March and the end of April 2020, shrunk the global economy 4.4% in the same year (Griffiths et al., 2021). Previously, electricity demand from the residential sector was dominant only during Sundays, which now became a daily scenario (Abu-rayash and Dincer, 2020). In New York City, overall industrial and commercial energy consumption decreased ~7% while domestic household consumption increased ~23% in March and ~10% in April 2020. In the UK, 30% and in the USA, 20% increment of electricity consumption was experienced during the middle of the day (9 a.m.–5 p.m.) in lock down period (Rouleau and Gosselin, 2021). Building energy consumption reduction now in highest priority globally by employing advanced building envelop (Ghosh et al., 2015) but this pandemic clearly showed the essence to take this matter seriously (Nundy et al., 2021). Energy insecurity and inability to pay the extra utility bills previously created tremendous issues among low to middle income family (Graff and Carley, 2020). Thus, it was expected that similar condition will rise during pandemic (Memmott et al., 2021). However, in reality it was not the case. Various measures were taken to reduce excessive energy bill (space heating and cooling load increased) in residential and abate the burden from the customers during lockdown (previously consumed 40% of the total energy), as listed in Table 4 (Qarnain et al., 2020). The measures were inclined more towards discounts on electricity bills rather than advising consumers to lessen consumption.

Full lockdowns decreased daily electricity demand by at least 15% (France, India, Italy, Spain, the United Kingdom, and the US northwest), which was later recovered after the ease of confinement (April ~ May), and later by June, electricity demand, decreased >10%, except in India, where the recovery is more pronounced (Fig. 10). Thus, during the lockdown, renewable energy got attention to overcome the electricity demand. In May, renewables have strengthened their second position after natural gas. In India, coal energy and renewables managed to acquire a significantly equal position after the first lockdown, and thus, coal energy's share in the electricity mix stayed under 70%. In Germany, renewable energy penetration in the net electricity generation was above 55% in 2020 compared 47% in 2019 (Halbrügge et al., 2021). In late May, levels of electricity demand started recovering while the rising share of renewables in the mix reflected their seasonal availability. In late June, electricity demand grew with rising temperatures, where share of coal energy increased in the electricity mix while the share of wind energy decreased (IEA, 2020a). For energy industry, the change of energy demand and consumption pattern was damaging. In the USA, at least 19 energy companies bankrupted due to this change. Although the overall energy demand dropped, not only residential but medical industry consumed energy to produce medical products and personal protective equipment (Klemeš et al., 2020a). Change of the spatial and temporal distributions of energy consumption have shifted the peaks of electricity consumption. The reduced electricity demand created negative impact on the power generation from fossil fuels like coal. To maintain the grid dynamic energy generation by coal, oil and nuclear was reduced in favour of intermittent renewable sources (Werth et al., 2021). On the other hand, continuous development of vaccines can enhance energy consumption. At the beginning of the pandemic limited time was there for energy managers to deal with this pandemic and balance system for energy demand and supply (Jiang et al., 2021). More solutions should be discussed on the use of reusable masks, appealed to minimize the plastic waste, energy, and environmental footprints during and after the COVID-19 pandemic (Klemeš et al., 2020b). It was also reported that new construction for energy facilities faced challenges. Production and global delivery of solar panels wind turbines and batteries were in halt from China while India's 3000 MW RE installation faced serious slowdown from the lockdown (Zhang et al., 2021a).

In summary, it is evident that during the lockdown closure of industry sectors reduced the demand for fossil fuel energy, which in turn improved the environment. Even though the energy demand was higher in the residential areas, fossil fuel engendering did not increase. Post COVID-19, to maintain renewable energy following the energy generation mix, all governments should create a strict energy policy, where enhancing subsidies in renewable energy can be one of the solutions (Akrofi and Antwi, 2020). The IEA expected that the net renewable energy expansion capacity would be 13% in 2020 compared to 2019. However, COVID-19 slowed down this pace. Subsidy on renewable energy could improve the situation. According to IEA, spend of US$1 trillion per year between 2020 and 2024, can improve the sustainable energy goal. The International Renewable Energy Agency (IRENA) has

Table 4
Details of electricity supply during COVID-19 global lockdown period.

Argentina	Starting from 24th March 2020, no disconnection of electricity services for non-payment of bills up to three consecutive bills or alternate bills	(Buenos. Aires. Times, 2020)
Australia	At crisis time, no one would be deprived of electricity at a residential and commercial building. Financial support for the energy consumer	(Energy.gov.au, 2020)
Canada	Uninterrupted power supply until pandemic exists.	(The.Canadian. Press, 2020)
China	Price of electricity was reduced	
France	from midnight of 16 March 2020 for a period of 30 days, all utility bill was Suspended for all business establishments	SKWAWKBOX (2020)
Germany	Consumer having loss of income no need to pay electricity payments till 30 June 2020	(Germany.VISA, 2020)
India	The Indian government announced a three months moratorium for state-owned electricity distribution companies to make payments for their power purchased by them; it also reduced the payment security to 50% for future power purchases.	Mint (2020)
Indonesia	Free electricity for poor people starting from 24 April 2020	(The.Jakarta.Post, 2020)
Italy	Until 30th April all electricity bills were suspended	Williams (2020)
Japan	Japanese government requested all the electricity companies to present a bill on providing moratorium for bill electricity bill payment for 3 months.	
Malaysia	The people of Sabah Province will get a 30% discount on Electricity bill for 3 months starting from 1 April 2020.	Mail (2020)
UK	No power interruption for energy users, the energy supply is ensured with support and initiatives from the Government of the UK.	(GOV.UK, 2020)
USA	No interruption during the prevalent pandemic times	KSLA (2020)

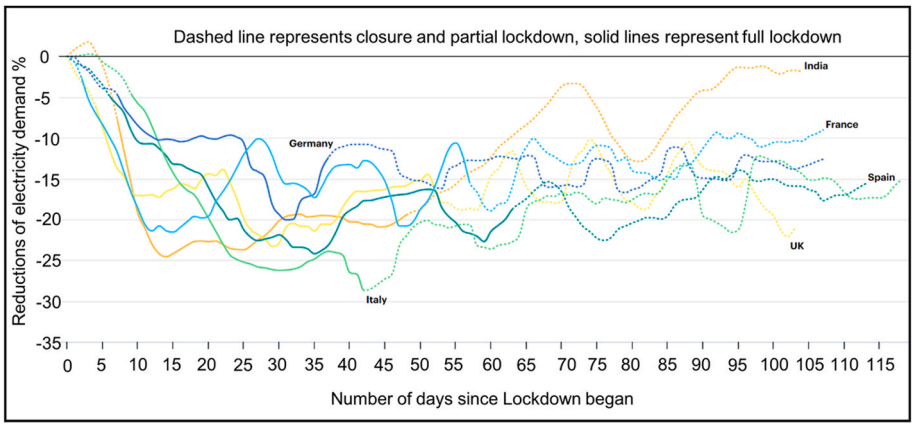

Fig. 10. Decrease in daily electricity demand during lockdown (118 days): France- Mar 14; Germany- Mar 15; India- Mar 18; Italy- Mar 4; Spain- Mar 9; UK- Mar 19 (IEA, 2020a).).

suggested between 2021 and 2023, spending US$2 trillion per year on clean energy and related infrastructure to address the global climate agenda. These steps can improve the scenario to attain UN's SDG 7, 11–13 goal. On the other hand, accurate prediction of daily energy demand must be in line to protect the national grid from future disturbances either from a pandemic or similar issues (Lu et al., 2021).

4.5. Impact on transport

Human mobility occurs due to various reason, which can include travel for shopping, work, personnel essential services, military services. The spread of infectious disease has a direct relation to human mobility (Peak et al., 2018). Thus, travel restriction is indispensable during pandemic (Yan et al., 2018). Travel restrictions are generally stricter for travel from a medium to a high-risk area. The spread of COVID-19 accelerated due to different modes of public transport (Zhao et al., 2020). Spread from one country to another one occurred through the commercial air flight (Shen et al., 2020). It was found that near the airport (25 miles) had 1.392 times higher COVID-19 cases and 1.545 times higher deaths due to COVID-19 in comparison to places that are over 50 miles away from an airport (Gaskin et al., 2021). Domestic land travel was also full of risk for the pandemic. Thus to limit the spread, transport sector was under lockdown. Different countries adopted different degrees of restrictions to tackle and abate COVID-19 spread, which affected largely on peoples' lifestyles as explained in section 3.1. On the other hand, the pandemic, lockdown and travel restriction due to COVID-19 created long lasting damaging in transport sector. Impact on transport sector for the 2003 SARS epidemic and 2008 swine flu outbreak were less compared to 2019 COVID cases (Vickerman, 2021). Transportation, a non-ignorable part of daily life, suffered mobility restrictions due to the COVID-19 lockdown measure, which in turn reduced 57% of global oil demand. Additionally, automobiles also have a strong relation to the environment, as they produce environmental pollutants, which in turn decreased during the lockdown, as discussed in section 3.2. In the lockdown regions, road transport dropped between 50% and 75% (as shown in Fig. 11) while, with global average road transport activity fell to 50% as of the 2019 level by the end of March (IEA, 2020b). Countries that didn't impose strict lockdown, also faced revenue losses, as people avoided public transport (Kanda and Kivimaa, 2020). Public transport usages in Stockholm decreased to 60%, and 75% in Nashville and Chattanooga, TN, US (Jenelius and Cebecauer, 2020). Due to official stay at home in the USA, 7.87% of human mobility was reduced. The rise of the infection rate from 0% to 0.0003% reduced the 2.31% mobility rate. By the second week of March in 2020, Switzerland experienced a travel reduction of up to 60% within the country and female travellers were less compared to male travellers (Abdullah et al., 2020b). In Germany, the use of single user car increased from 53% before lockdown to 66% during lockdown (Eisenmann et al., 2021). The use of bicycle was also increased during the lock down (Przybylowski et al., 2021). In Tokyo Japan, it was observed that travel for leisure and eating out was reduced in greater order while outing for grocery shopping and other type of shopping was increased (Parady et al., 2020). However just seeing the present COVID-19 spread, it is evident that just travel restriction is not enough for limiting a pandemic. During the

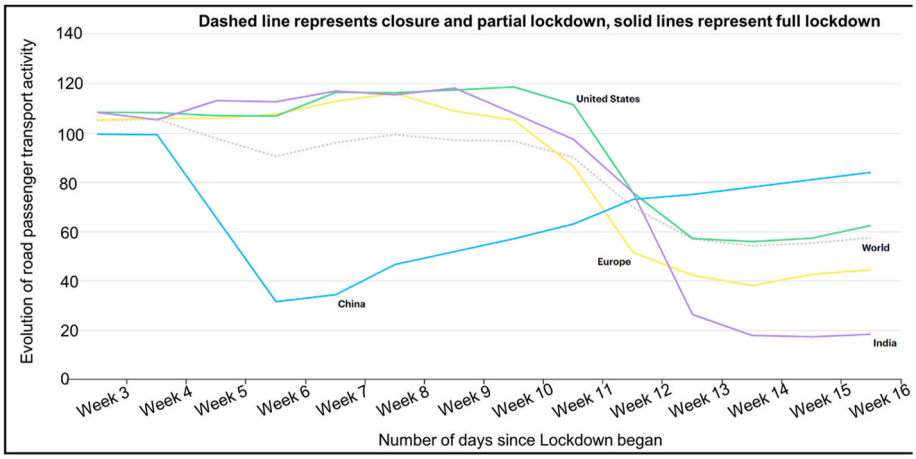

Fig. 11. Automobile usage during and post COVID-19 lockdown (image courtesy and source(IEA, 2020b):).

consideration of overall epidemic size, high- and low-risk communities should be identified with mobility restrictions to have effective results (Espinoza et al., 2020). Restrictions in the mobility of airlines also created economic downfall (Kraemer et al., 2020), as discussed in section 3.3. Probably one of the positive aspects that occurred due to the lockdown in the transport sector is less incident of accident. According to WHO, around the world, 1.35 million people are killed in a road accident and 50 million injuries, which is a huge loss in terms of material damage and economic point of view of a nation. It is also reported that traffic accident was reduced significantly during the lockdown and due to pandemic in urban (Qureshi et al., 2020), suburban (Saladié et al., 2020) and rural (Zhang et al., 2021b) areas. Human error, bad weather and visibility, road characteristics, vehicle design, are the among the main factors behind traffic accidents (Retallack and Ostendorf, 2019). However, due to less traffic (Inada et al., 2021) congestion irresponsible driving was also experienced (Meyer, 2020). To regain the economy, overall growth in the transport sector is necessary. Mobility improves the access to good employment. UN 2030 has sustainable transport is an agenda. For urban areas, sustainable public transport is crucial. Thus, positive stand, translated to a frequent yet safe use of public transport while maintaining safe distance between travellers are required as much as possible.

Thus, post-COVID-19 and lockdown, responsible transport choices will play a crucial role in daily life. Manageable work from home or necessary physical travel will be a new question in life, along with the selection of transport with the lowest environmental and social impact (Budd and Ison, 2020). Studies already showed that travellers who own car are now less likely to use public transport (Li et al., 2021). It will be critical if, after the pandemic, people just prefer the private transport over public transport. This will increase the no of car on the road, which in turn increase the traffic congestion and also if those cars are fossil fuel driven then the environment will be in danger again. In addition, both these scenarios are against the UN SDG plan. Thus, choice of transport and behaviour of public will play a crucial role. However, it is seen that travel pattern after COVID-19 is a complicated topic for travel policy-makers. A mixed outcome was observed from different countries study regarding the travel pattern of people. Studies in the city of Gdańsk, in Poland, showed that almost 75% of respondent eager to use public transport, once the epidemic is stabilized and the rest are completely lost hope regarding the safe use of public transport ever (Przybylowski et al., 2021). In the Netherlands, data from 2500 respondents showed that 80% of people limited or reduced their outdoor activities while 44% of workers are now working from home to avoid transport (Haas et al., 2020).

Cycling gained importance in different countries, as the most suitable road transport (De Vos, 2020). It is interesting that this mode of transport is not part of UN's SDG. Bogota, the capital of Colombia, changed its 100 Km bus lane to cycle lane, Berlin expanded yellow tapes marks to allow cycle movements. Mexico City aspires to quadruple its cycle lane capacity, Canadian city in Vancouver restricted vehicles inside Stanley Park (Source: World economic forum), Budapest introduced cycle lanes and lowered up to 300% of tariff for a cycle (Bucsky, 2020). In addition, in the UK, the government is supporting to use of more cycles. However, it will be a real problem for a crowded and over-populated city like London, where every 15 min, more than 325,000 people use underground (BBC, 2020f). Changing the transport policy with the inclusion of electric vehicles (EV) could be the future boom (Bhattacharjee et al., 2020) and part of UN sustainable transport goal. In 2010, 17000 EVs were on the global road while it reached to 7.2 million by 2019 (Ghosh, 2020a). Most of the countries around the globe have the plan to reach EV by 2050, which can be modified to achieve targets. Grid disturbances, which was observed in section 3.4 due to reduction of energy demand, could have create same issues if electrification is increased in transport sector (Peng et al., 2021).

After pandemic transport sector will be in the high discussion as different factors are associate with it. Staying at home and less use of transport obviously an environmentally benign solution but these could drastically damage the transport industry. On the other hand, the enhancement of the private vehicle will definitely increase the potential risk of traffic and accident. In addition, electrification of transport sector can increase the demand for energy, which still rely on the fossil fuel and negatively associated with the UN SDG target.

5. Discussion

It is clearly visible that potential danger from COVID-19 occurred because of the underestimation of previous public health crises including the 1918 Spanish Flu, SARS in 2003, Zika fever in 2005 and 2016, H1N1 influenza virus in 2009, Ebola in 2014. Human society has not learned much from the past pandemics. Undoubtedly, social/human, environment, economy, energy and transport are the major segments of society, which got immensely affected due to this COVID-19 pandemic. Responses to the impact of coronavirus was very different for different countries, for e.g. while South Korea implemented testing facility, Italy, the U.K., and the USA suffered huge losses. It is also analyzed that reduction of mortality could save 40.76 trillion USD globally (Yoo and Managi, 2020). Impact of this virus was so dreadful, that even vaccine has been developed within a year in comparison to other diseases (Mahase, 2020), where, generally it takes a long time. For example, it took about 40 years for polio vaccine, 5 years for Ebola, and an average of 15 years for most vaccines development (Wibawa, 2020). COVID-19 lockdowns decreased carbon emissions from top three greenhouse gas emitters in the world: China, the EU, and the USA. A broader range of environmental benefits were obtained from cleaner air, reduced air travel and vehicle traffic, shipping manufacturing, and other activities. It is noteworthy that no such world event in the 20th century could decreased the global environment pollutant emission significantly at such a level in comparison to COVID-19 (Perkins et al., 2020). Thus, COVID-19 pandemic inadvertently minimized emissions more than any individual action, policy, or intervention to date, also aligning with the Climate Action Sustainable Development Goal targets of holding warming below 1.5 °C above preindustrial levels (Perkins et al., 2020). However, containing people at home is against the sustainable living. Sustainable society and cities which were growing rapidly, now stopped due to COVID-19. It is evident that social distances are key to trim down the spread of the virus, thus, densely populated cities became unsuitable for sustainable living (Ghosh et al., 2020b), which led to focus us more about uncontrolled global urbanization (Liu, 2020). Human health is strongly related to the economy and if economy is not protected due to the COVID-19 scenario world will face tragic health issue (McKee and Stuckler, 2020).

One of the most challenging areas which needs to be improved is the building sector (Pinheiro and Luís, 2020). People spend 90% of their time indoors, which includes bedroom, office room, gym, movie hall, shopping mall (Ghosh and Norton, 2019). Now though they will stay inside more than ever only in their own home. Thus, building indoor environment quality assessment is in high demand. Indoor Environmental Quality (IEQ) is crucial parameters, which quantify the quality of a building's environment in terms of health and well-being of buildings occupants. IEQ is a combined factor of thermal comfort (Ghosh et al., 2018a), visual comfort (Ghosh et al., 2021), interior light (Ghosh and Norton, 2017a) and air temperature (Hemaida et al., 2020), psychosocial impact (Pollard et al., 2021). However, there is no standard is available which can assesses the occupants health. IEQ directly affects the comfort and well-being of occupants (Aggarwal et al., 2020). Compromised IEQ possess increased risk for diseases which are exacerbated by both socio-economic factors (Awada et al., 2021). During this pandemic while people are working from maintaining the IEQ becoming more critical (Wang et al., 2021). High occupant density in buildings increase the risk of virus transmission and also enhance the energy consumption. It was evaluated that an optimal distribution of occupant in a building can decrease 56% of infection rates and 32% of energy

consumption. Though further study is required to consider and validate this claim (Mokhtari and Jahangir, 2021). Thus, it is still unclear how the antivirus-built environment would look (Megahed and Ghoneim, 2020). According to WHO, COVID-19 can be transmitted by air and dangerous for closed environment (Greenhalghu et al., 2021). Therefore, dilution ventilation, correct direction of airflow, pressure differential, etc. offered by the well-maintained HVAC system could effectively mitigate the risk of COVID-19 transmission. ASHRAE even stated two statements officially opposing the advice not to run residential or commercial HVAC systems. HVAC-related institutions including the Architectural Society of China, the Chinese Association of Refrigeration, the American Society of Heating, Refrigeration, and Air Conditioning Engineers, the Federation of European of Heating, Ventilation, Air-conditioning Associations, and the Society of Heating, Air-Conditioning and Sanitary Engineering in Japan have all issued documents in response to COVID-19 (Guo et al., 2021). ASHRAE pointed out that staying away from crowded and poorly ventilated areas may help reduce infection risk. Previously, to minimize the risk of infectious diseases, interior design, architecture, cities, and infrastructure were redesigned. The pandemic has highlighted the lack of how we manage our built environment and presented certain lessons from this forced experiment, alerting the architects, planners, and policymakers to react wisely (Ghosh, 2020b) and think about how post-pandemic housing and office spaces or any indoor built environment should look like (Megahed and Ghoneim, 2020). For city, urban heat island is a critical issue (Ghosh et al., 2016a), which is caused by anthropogenic heat emission, changes in urban land use and heat emission from buildings (Ghosh et al., 2016b). It is estimated that COVID-19 restrictions resulted a 0.13 °C temperature reduction in urban areas which improved the urban heat island issue (Nakajima et al., 2021).

Strong sustainability by preserving natural resources and not exploiting them for financial benefits could be the great lessons from this pandemic. Hence, energy sector should now lean more towards renewable energy resources. Major energy consumption sectors are building, industry and transport. As building energy demand increased during lockdown and even after lockdown the work from home culture increased the energy demand, integration renewable energy technology in the building sector now should be in high demand (Krarti and Aldubyan, 2021). Integration of photovoltaics in to the building as a form of building integrated Photovoltaic (BIPV) (Reddy et al., 2020) can be considered which can generate onsite electricity and replace the traditional roofs, walls, windows (Alrashidi et al., 2020b), as well as shading devices (Mesloub and Ghosh, 2020). PV shading devices already showed potential suitability for hot and desert climate (Mesloub et al., 2020). Exploitation of solar energy can further be improved by employing solar water heating, solar thermal cooling (Khalid et al., 2021). Building wall can be improved by employing phase change material (PCM) (Roy et al., 2020a) or PCM-aerogel (Buratti et al., 2021) or PCM terracotta brick wall (Chelliah et al., 2021). PCM has latent heat storage capacity which is beneficial for colder climate and also to shift the peak of higher temperature from mid-day to afternoon time (Karthick et al., 2020). Building windows play crucial role to manage the overall energy performance of a building (Ghosh et al., 2019a). Thus, replacing the traditional window with advanced or smart window technology as per their climatic requirement can be a good option (Ghosh et al., 2019b). Energy efficient building windows are either highly insulated static transparent or solar hat control switchable smart window (Ghosh et al., 2016c). Currently smart windows are operated by either electrical, optical or thermal actuation (Ghosh and Mallick, 2018b). Electrically activated smart windows (Ghosh and Mallick, 2018a) are particularly interesting because by changing its transmission state it can tune the incoming solar radiation depends on the occupants comfort and also can trim down the overall building energy demand (Ghosh and Norton, 2018). At present electrically activated smart windows includes suspended particle device (SPD) (Ghosh and Norton, 2017b), electrochromic (EC), and polymer dispersed liquid crystal (PDLC) (Ghosh and Mallick, 2018b). For colder climate, replacing single or double glazing window with vacuum glazing will be beneficial as they have lower heat loss (Ghosh et al., 2017a). As vacuum glazing limit or reduce the conductive, convective and radiative heat flow, it has 53% higher heating load demand reduction potential over double glazing (Ghosh et al., 2016d). As vacuum glazing has similar transmission (Ghosh et al., 2017b), it is possible to make it switchable which will have controllable transmission and low heat loss capacity (Nundy and Ghosh, 2020). Employing more smart window technology to reduce building energy consumption (Ghosh et al., 2018b) and generation of energy from benign sources should get more priority (Ghosh et al., 2018c). Solar energy which is one of the most promising renewable energy sources can get more priorities and should experience the benefit from cleaner environment (Ghosh et al., 2020a). To utilize solar energy solar cells are the key technologies (Alrashidi et al., 2020a). At present solar cell technologies includes first generation crystalline silicon based, second generation thin film CdTe (Alrashidi et al., 2019), CIGS and a-Si, and third generation DSSC (Selvaraj et al., 2019), Perovskite (Bhandari et al., 2019) and carbon (Roy et al., 2020b) types. At present, first and second generations are commercially available. However because of the potential, research should be more focus on third generation (Bhandari et al., 2020). Globally because of air pollution and suspend particle in the air and deposition of them on photovoltaic (PV) technology reduces the power generation from the PV which is lower than its rated values (Ghosh, 2020c). Globally depends on the location, this deposition varies from 5% 70% (Chanchangi et al., 2020a). Cleaning those PV system is essential to keep the power generation high either by using manual (Chanchangi et al., 2020b) or anti-soiling coating (Nundy et al., 2020). Cleaner environment will allow more sunlight to incident on PV panel to generate more power (Naderipour et al., 2020).

In the future, the transport sector stands as a real question. Currently work from home (WFH) concept is sufficiently popular and also it was found that productivity has been increased significantly (Hensher, 2020). Technological firms are happy to maintain this WFH and most of the Universities have been developed online teaching. Also it is expected that people will choose such job which will allow them to work from home (Junyi Zhang et al., 2021c). Now, environmentally this is a good option as IC engine based vehicles will be less on the road and there will be possible improvement of the transport sector (Chen et al., 2021). However, this causes a serious revenue loss from transport sector and resulting in associated job losses. Airline industry faced around US$250 billion revenue losses in 2020 (Amankwah-Amoah, 2020). It is very hard for some firms to sustain financially by maintaining environmental sustainability orientation. For connectivity point of view, several unprofitable routes will be closed and remain unknown when they will open to meet the standard as in 2019. Thus, government support is now the pragmatic approach (Abate et al., 2020). On the other hand, to improve the public transport and increase the crowd, fare-free public transport policies can be introduced. This policy is not uncommon and visible in Estonia, some remote location in China and the USA (Hess, 2017). Recently after pandemic, three cities in China, Hangzhou, Ningbo, and Xiamen, implemented fare-free policies to attract passengers back to public transport (Dai et al., 2021). Sustainable transport should get more priority to maintain a cleaner environment which was achieved during pandemic lockdown period (Shokouhyar et al., 2021). Also as people will use less transport hence penetration of electric vehicles will be easier now to change the human habit and also the charging facilities will be easier now because of the less number of Car on the street (Basu and Ferreira, 2021).

In July 2020, UN recognized that digitization and virtual delivery is now essential because of the COVID-19. Though, school students are disappointed from online learning experiences due to lack of informal student engagement opportunities (Piyatamrong et al., 2021), still, undoubtedly this digital technology helped to maintain the education sector. During social isolation lockdown condition, digital space became the necessity for economic, educational, and leisure activities as well as

for social interactions. Digital inequalities were prominent between developed and developing country and also between urban and rural areas (Beaunoyer et al., 2020). The pandemic highlights the importance of distributing smaller units such as health facilities, schools, and services across more of the urban tissue and strengthen local centres. After this COVID -19, application of 6G will probably take high gear (Allam and Jones, 2021). Also, artificial intelligence and use of machine learning will be increased in research area (Chandran et al., 2021). An exit strategy from this quarantine and lockdown is essential (Peto et al., 2020).

Sustainability, which is multidimensional and complex, has the potential to bring the different sector together with help of policymakers, government, and practice and habit change of common people. This pandemic jeopardized basic health, well-being, life quality, education and social needs which should now on high demand to attain the sustainable goal. Based on the UN report, 690 million people, which accounts of 8.9% of the population of the world were hungry before pandemic and this COVID-19 created the issues more critical to solve because of the overall damage to the economy. One analysis pointed out that because of the pandemic, 4 countries from Asia, 6 countries from Oceania, 10 countries from Latin America and 15 countries from Africa can face food issues because of the import dependency and can have an impact on SDG2 food security (Udmale et al., 2020). Imposing a green tax and innovation on industry could enhance the economy. However, it should be remembered that earning money from low subsidy on fossil fuel would only be fruitful when clean affordable alternative energy will be available for everybody. Otherwise, societal inequality will still be in the society and effort to achieve the SDGs will be hampered. For developing countries, it will be difficult to create policy aligned to SDGs after COVID-19 pandemic and grow towards all 17 SDGs. Without sacrificing the other SDGs, cost effective and policy and raising and saving revenue should be implemented may require additional investment fund. Subsidy swap from fossil fuel to clean energy to invest in rural areas, subsidy on irrigation for better water supply (Barbier et al., 2020), waste water and sanitation, and employment of carbon tax could be effective (Barbier and Burgess, 2020). Because of so many issue, there is a sought that whether UN should revise their practice (Degai and Petrov, 2021). However, a difference in opinion is also there which says that may be time to consider this pandemic a positive way, which can now trigger to achieve those SDGs promptly. UN, which was created to bring the world together with peace and save from war threaten, must now also think about the threat from pandemic (Naidoo and Fisher, 2020). We must understand now that no one is safe until everyone is safe (Tikkinen et al., 2020).

6. Conclusion

In December 2019, one of the deadliest viruses in the last 100 years is reported. Because of its destructive nature, human life changed completely and made people confine themselves at home. Vaccination has just developed within a year to tackle this virus. However, in the beginning, lack of tackling methods of this COVID-19 transmission, the old methods of self-isolation, lockdown, and home confinement were employed in the play and still valid until vaccines are widely available. Because of the lockdown and total closure of the major industrial sectors, which created a dip in the economy, caused job losses, financial uncertainty, and probably a recession for the near future. Lockdown created tremendous change in the human mind and their social life. Domestic violence, self-harming was prominent which indicated that 24 h staying at home had a negative psychological impact on the human mind. Working from home and using immense technology is now more prominent. The industrial and transport sector was fully closed, which eventually improved the environment. The emission of air pollutants decreased due to the reduction of fossil fuel power generation as industry and transport sector consumption was low. It is expected that to reach the pre COVID-19 situation considerable amount of time will be taken. Particular attention should be given to building an indoor environment, as working from home is very popular. With the presence of so many different negative aspects due to COVID-19 pandemic, SDGs are expected to get a much longer time to achieve.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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