POLITECNICO DI TORINO Repository ISTITUZIONALE

Three pillars of sustainability in the wake of COVID-19: A systematic review and future research agenda for sustainable development

Original

Three pillars of sustainability in the wake of COVID-19: A systematic review and future research agenda for sustainable development / Ranjbari, Meisam; SHAMS ESFANDABADI, Zahra; Zanetti, Mariachiara; Domenico Scagnelli, Simone; Siebers, Peer-Olaf; Aghbashlo, Mortaza; Peng, Wanxi; Quatraro, Francesco; Tabatabaei, Meisam. - In: JOURNAL OF CLEANER PRODUCTION. - ISSN 0959-6526. - ELETTRONICO. - 297:126660(2021), pp. 1-23. [10.1016/j.jclepro.2021.126660]

Availability:

This version is available at: 11583/2969056 since: 2022-08-01T15:18:52Z

Publisher: Elsevier

Published DOI:10.1016/j.jclepro.2021.126660

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright Elsevier postprint/Author's Accepted Manuscript

© 2021. This manuscript version is made available under the CC-BY-NC-ND 4.0 license http://creativecommons.org/licenses/by-nc-nd/4.0/.The final authenticated version is available online at: http://dx.doi.org/10.1016/j.jclepro.2021.126660

(Article begins on next page)

1 Three pillars of sustainability in the wake of COVID-19: A systematic

2 review and future research agenda for sustainable development

- 3
- 4 Meisam Ranjbari^{a,**}, Zahra Shams Esfandabadi^{b,c}, Maria Chiara Zanetti^b, Simone Domenico
- 5 Scagnelli^d, Peer-Olaf Siebers^e, Mortaza Aghbashlo^f, Meisam Tabatabaei^{g,h,i,j,*}, Francesco
- 6 Quatraro^{a,k}
- 7
- ^a Department of Economics and Statistics "Cognetti de Martiis", University of Turin, Lungo Dora Siena 100 A, 10153 Torino,
 Italy
- ^b Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, Corso Duca degli Abruzzi 24,
 10129 Torino, Italy
- ^c Energy Center Lab, Politecnico di Torino, Via Paolo Borsellino 38/16, 10138 Torino, Italy
- 13 ^d School of Business and Law, Edith Cowan University, 270 Joondalup Dr, 6027 Joondalup, Australia
- ^e School of Computer Science, University of Nottingham, Jubilee Campus, NG8 1BB, Nottingham, UK
- 15 ^f Department of Mechanical Engineering of Agricultural Machinery, Faculty of Agricultural Engineering and Technology,
- 16 College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran
- ^g Institute of Tropical Aquaculture and Fisheries (AKUATROP), Universiti Malaysia Terengganu, 21030 Kuala Nerus,
 Terengganu, Malaysia
- ^h Henan Province Engineering Research Center for Forest Biomass Value-added Products, School of Forestry, Henan
 Agricultural University, Zhengzhou, 450002, China
- ⁱ Microbial Biotechnology Department, Agricultural Biotechnology Research Institute of Iran (ABRII), Agricultural Research,
 Extension, And Education Organization (AREEO), Karaj, Iran
- 23 ^j Biofuel Research Team (BRTeam), Terengganu, Malaysia
- 24 ^k BRICK, Collegio Carlo Alberto, Piazza Arbarello 8, 10123 Torino, Italy
- 25
- 26 * Corresponding author. Universiti Malaysia Terengganu, Malaysia.
- 27 ** Corresponding author. University of Turin, Italy.
- 28 *E-mail addresses*: <u>meisam_tab@yahoo.com</u>, <u>meisam.tabatabaei@umt.edu.my</u> (M. Tabatabaei), <u>meisam.ranjbari@unito.it</u> (M.
- 29 Ranjbari)
- 30
- 31
- 32
- 33
- 34

35 Abstract

The economic, social, and environmental pillars of sustainability in human lives have been 36 immensely impacted by the COVID-19 pandemic for the global economy and societies. Due to 37 the scholars' increasing interest in responding to the urgent call for action against the pandemic, 38 the literature of sustainability research considering the COVID-19 consequences is very 39 fragmented. Therefore, a comprehensive review of the COVID-19 implications for sustainability 40 practices is still lacking. This research aims to analyze the effects of COVID-19 on the triple 41 bottom line (TBL) of sustainability to support the future sustainable development agenda. To do 42 this, the following research questions are addressed by conducting a systematic literature review: 43 (i) what is the current status of research on the TBL of sustainability considering COVID-19 44 implications?, (ii) how does COVID-19 affect the TBL of sustainability?, and (iii) what are the 45 46 potential research gaps and future research avenues for sustainable development post COVID-19? The results manifest the major implications of the COVID-19 outbreak for the triple 47 48 sustainability pillars and the sustainable development agenda from the economic, social and environmental points of view. The key findings provide inclusive insights for governments, 49 50 authorities, practitioners, and policy-makers to alleviate the negative impacts of pandemic on sustainable development and catch the sustainability transition opportunities post COVID-19. 51 52 Finally, five research directions for sustainable development corresponding to the UN's SDGs post COVID-19 are provided, as follows: (1) sustainability action plan considering COVID-19 53 54 implications: refining sustainability goals and targets and developing measurement framework; (2) making the most of sustainability transition opportunities in the wake of COVID-19: focus on 55 SDG 12 and SDG 9; (3) innovative solutions for economic resilience towards sustainability post 56 COVID-19: focus on SDG 1, SDG 8, and SDG 17; (4) in-depth analysis of the COVID-19 long-57 58 term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10; and (5) expanding 59 quantitative research to harmonize the COVID-19-related sustainability research.

60 Keywords: COVID-19; Environmental sustainability; Social sustainability; Economic
61 sustainability; Sustainable development

62

63 **1. Introduction**

64 In the past two decades, sustainability concept has increasingly attracted both scholars and practitioners worldwide. Incorporating three interconnected pillars (Ranjbari et al., 2019), 65 sustainability deals with a balanced integration of social, environmental, and economic 66 performance of human lives within the society, environment, and economy to the benefit of 67 current and future generations (Geissdoerfer et al., 2017). Given the ambiguous and challenging 68 nature of sustainability for organizations, the Triple Bottom Line (TBL) concept was proposed 69 70 by Elkington (1998) to support and operationalize sustainable development implementation. TBL simultaneously employs and balances the three pillars of sustainability from a 71 microeconomic perspective (Gimenez et al., 2012). To put the sustainability essence into 72 practice, the United Nations (UN) General Assembly launched the 2030 Agenda for Sustainable 73 74 Development in September 2015 as a shared outline to address the TBL of sustainability. This Agenda introduces 17 Sustainable Development Goals (SDGs) and calls upon all governments 75 76 and private businesses to support the achievement of the specified SDGs (Van der Waal and Thijssens, 2020). 77

The novel coronavirus-caused infectious disease 2019 (COVID-19) first emerged in December 2019 in China and spread worldwide in such a way that the World Health Organization (WHO) announced it as a pandemic in March 2020 (WHO, 2020a). As of December 19, 2020, a total number of 74,299,042 confirmed cases of COVID-19, including 1,669,982 deaths in 235 countries, areas, and territories, has been recorded by the WHO (2020b). The crisis's magnitude has marked the COVID-19 pandemic as the most severe health catastrophe of this century (Chakraborty and Maity, 2020).

85 The COVID-19 crisis has imposed immense pressure on the global economy and business activities with significant adverse financial consequences, increased GDP loss by countries, and 86 87 raised poverty and hunger across the world (Iwuoha and Jude-Iwuoha, 2020). As a result, the global health crisis caused by this pandemic tremendously slows the international community's 88 progress towards sustainability (Lee et al., 2020). Barbier and Burgess (2020) argued that the 89 adverse impacts of COVID-19 could compromise our ability to achieve 12 out of the 17 UN's 90 91 SDGs within the 2030 Agenda for Sustainable Development. Moreover, Leal Filho et al. (2020) identified COVID-19 as a major threat to implementing sustainable development by reducing the 92

SDGs' priority. Hence, while significant global efforts are being put into controlling this
pandemic, sustainability in the post-COVID-19 era should not be neglected (Lambert et al.,
2020). As a matter of fact, sustainability and achieving the SDGs are even more critical now than
before (Leal Filho et al., 2020).

97 Although the COVID-19 pandemic has not been around for too long, a massive amount of 98 COVID-19-related research has been conducted due to its significant implications and 99 consequences for society, the environment, and the economy worldwide. The effect of this pandemic on different dimensions of sustainability and sustainable development has been 100 101 investigated by many sustainability scholars in a wide range of subject areas such as healthcare systems (Osingada and Porta, 2020; Sharma et al., 2020), tourism (Ioannides and Gyimóthy, 102 2020; Romagosa, 2020), food industry (Fleetwood, 2020), SDGs (Ashford et al., 2020; 103 Paramashanti, 2020), sustainable transition (Bodenheimer and Leidenberger, 2020; Pirlone and 104 105 Spadaro, 2020), education (Anholon et al., 2020; Tran et al., 2020), social media (AI-Youbi et al., 2020; La et al., 2020), strategic management (Barreiro-Gen et al., 2020; Hamilton, 2020), 106 environmental pollution (Somani et al., 2020), energy (Kanda and Kivimaa, 2020; Kuzemko et 107 108 al., 2020), climate change (Markard and Rosenbloom, 2020), and waste management (Kulkarni and Anantharama, 2020; Vanapalli et al., 2021). 109

110 Most previous research works have focused only on a specific subject area or considered just 111 one dimension of sustainability in the light of the COVID-19 outbreak. Besides, due to the health emergency caused by COVID-19 and the increasingly widespread interest of scholars to respond 112 113 to the urgent call for action in the context of sustainability within a short period, the literature in this area is very fragmented. Consequently, a comprehensive analysis of the COVID-19 114 115 implications for sustainability practices as a whole is lacking in the literature. Therefore, our research pays close attention to sustainability based on the TBL framework within the different 116 117 subject areas, which have been impacted by the COVID-19 pandemic to provide a well-clarified overview of the COVID-19 effects, challenges, and opportunities for the TBL of sustainability. 118 To the best of the authors' knowledge, no review has systematically addressed COVID-19 119 implications for integrating social, environmental, and economic pillars of sustainability research 120 121 area. Hence, putting all sustainability research in the wake of the pandemic together can help governments, authorities, practitioners, and policy-makers to find out where to concentrate their 122

efforts to alleviate the negative impacts of the pandemic in moving towards sustainability, and also supports researchers to find the gaps, define future research directions, and derive new research interests in the area.

This paper aims to provide an inclusive insight into and a comprehensive overview of the sustainability perspectives, dynamics, and practices in the wake of the COVID-19 pandemic crisis. In this regard, the pandemic's potential effects on economic, social, and environmental pillars of sustainability are analyzed by conducting a systematic literature review to address the three research questions of our study as the following.

RQ1. What is the current status of research on the TBL of sustainability considering COVID-19implications?

133 **RQ2.** How does COVID-19 affect the TBL of sustainability?

134 RQ3. What are the potential research gaps and future research avenues for sustainable135 development post-COVID-19?

The remainder of the paper is structured as follows. Section 2 explains the method adopted in this research. Section 3 presents the descriptive and thematic analysis of sustainability and COVID-19 implications and discusses the key findings. Section 4 offers the research gaps and different areas of sustainability disciplines affected by COVID-19, which need to be studied for further research post-COVID-19 in the future. Finally, section 5 summarizes the conclusions drawn from the research conducted for this paper

142 2. Methodology

To address the research questions and achieve the main aim of the paper, a systematic approach to review the literature adopted from Fink (2019) and Traxler et al. (2020) on the TBL of sustainability perspectives and practices in the context of the COVID-19 pandemic crisis is employed. The process of collecting papers was stopped on August 29, 2020, starting from December 2019. Besides, the sustainability literature before pandemic is also investigated separately in another systematic review process to have an update of the major sustainability challenges before COVID-19. This is done to provide a baseline of sustainability challenges before COVID-19 to better analyze the effects of COVID-19 on the sustainability and sustainable development roadmap and see how COVID-19 has affected the current challenges. This helps more effectively identify the relevant research gaps and directions for future research post COVID-19. The search protocol and the review's overall process applied in our research to select the eligible papers through a screening process are described in the following subsections.

155 **2.1. Database**

Being a significant landscape shock, the COVID-19 pandemic and the consequent urgent call for action against the restrictions imposed by this crisis in various disciplines, a considerable number of COVID-19-related research has been conducted even before the pandemic was announced by the WHO in March 2020. To ensure sufficient coverage of published papers and enrich the reliability of the gathered publications, Web of Science (WoS) and Scopus were utilized as research databases for record identification and collecting the published papers.

162 The WoS core collection covers all publications indexed in Science Citation Index Expanded (SCIE-EXPANDED), Social Sciences Citation Index (SSCI), Arts and Humanities Citation 163 Index (AHCI), Conference Proceedings Citation Index- Science (CPCI-S), Conference 164 Proceedings Citation Index- Social Science & Humanities (CPCI-SSH), and Emerging Sources 165 166 Citation Index (ESCI) (WoS, 2020). As a source-neutral abstract and citation database, Scopus 167 provides a wide range of scholarly literature across many disciplines, including more than 75 168 million records, 24,600 active titles with more than 23,500 peer-reviewed journals, and 5,000 publishers (Elsevier, 2020). 169

170 2.2. Keywords definition

The initial selection of research and review papers was carried out through applying a 171 172 structured keyword search. The main keyword of this paper is sustainability, and the COVID-19 173 pandemic is the context of the research. The combination of the keywords and operators were ("sustainability" OR "sustainable") AND ("COVID-19" OR "pandemic" OR "Coronavirus" OR 174 "SARS-CoV-2"), limited to the article title, keywords, and abstract in WoS and Scopus 175 databases. The "OR" operator means that the search will contain at least one of the keywords. 176 This keywords selection limited the search scope to those research conducted on sustainability 177 178 subject areas through the COVID-19 pandemic lens.

In addition, to catch the most recent challenges of sustainability and sustainable development before COVID-19, an initial query of ("sustainability" OR "sustainable development") limited to the article title AND ("challenges" OR "gaps") AND NOT ("COVID-182 19" OR "pandemic" OR "Coronavirus" OR "SARS-CoV-2") limited to the article title, 183 keywords, and abstract was considered for data collection in WoS and Scopus.

184 2.3. Screening: Inclusion and exclusion criteria

185 A two-stage delimitation process was considered to select the most relevant articles before186 and after pandemic.

For the pre-COVID-19 articles, only the most recent review articles published in peer-187 188 reviewed journals (in English language) from 2018 to 2020 were included in the analysis. 355 189 reviews from WoS and 449 reviews from Scopus were collected after the first screening stage. 190 Having removed 259 duplicated articles, a total of 545 reviews were included in the research. In the second screening stage, the content of the papers, which were filtered in the previous stage, 191 192 was checked by first, reading the title, abstract, and conclusion and second, by reading the entire document to check the relevancy of the paper. The major challenges of sustainability literature 193 194 before COVID-19 were extracted from the final sample of 38 reviews, which were found to be 195 the most relevant articles after conducting the second stage of screening.

196 For the post-COVID-19 articles, which were the main target of our research, only 197 scientific reviews and articles published in peer-reviewed journals in English language were considered in the first screening stage. The other document types, such as conference 198 proceedings, book chapters, notes, and letters, were excluded from the database to enrich the 199 study's validity and quality. Besides, due to the emergence of COVID-19 in December 2019, the 200 201 search's period was limited to studies conducted as of December 2019. A total of 755 articles 202 were excluded from 1436 items in the database during this stage. Afterward, 185 duplicated articles were eliminated, leaving 496 articles to be considered for the second screening stage. In 203 204 the second screening stage, the content of the papers was checked to see whether there was a sufficient linkage between the TBL of sustainability perspectives, practices, and dynamics and 205 the COVID-19 pandemic implications. Subsequently, 438 items were excluded, and finally, the 206

sample was composed of 49 articles for our review. Fig. 1 summarizes our search protocol andillustrates the overall process of the review.



209

211 **3. Results and Discussion**

In order to clearly report the results to address the research questions, as a fundamental step in a systematic literature review (Milanesi et al., 2020), the results are analyzed in two sections including before COVID-19 (Sections 3.1) and after COVID-19 (Section 3.2 and Section 3.3) periods. Since the main focus of our research is COVID-19 implications for sustainability and sustainable development, in-depth descriptive and thematic analyses for sustainability research post COVID-19 are presented.

218 **3.1.** An overview of the major sustainability challenges before COVID-19

219 To have a general image of the challenges of sustainability and sustainable development 220 before the COVID-19 pandemic crisis, the major challenges were extracted from the literature as shown in Fig. 2. The integration of education system as an important player of progressing 221 towards sustainability agenda within the sustainable development practices has been highlighted 222 223 as a significant multidisciplinary challenge in the social sustainability literature (Bascopé et al., 224 2019; Chen et al., 2020; Grosseck et al., 2019; Hermann and Bossle, 2020; Thürer et al., 2018). 225 The need for convergence of social movements and civil society (El Bilali, 2019a), fostering 226 cross-sectoral collaboration (El Bilali, 2019b), and behavioral change in the urban household 227 consumption pattern (Shittu, 2020) are challenging the sustainability transition. Besides, social entrepreneurship as a path for social change and a driver of sustainable development is facing 228 challenges due to the lack of a clear measurement framework for the different dimensions of 229 230 sustainability (Bansal et al., 2019). Environmental sustainability roadmap urgently needs to be adapted with the challenges of climate change as one of the biggest environmental problem that 231 human is facing with (Mauree et al., 2019). In this regard, policy-making, planning, and 232 management of forest resources with the possibility of improving carbon capture and helping 233 environment was presented by Nunes et al. (2019) as an important environmental sustainability 234 challenge. In addition, combating the impacts of urban droughts, which have been magnified by 235 236 climate change, has made serious challenges for policy-makers and city stakeholders towards environmental sustainability and SDGs achievement (Zhang et al., 2019). Public health crisis 237 238 arising from healthcare pollution is another environmental sustainability concern, which highly needs to be addressed to achieve a sustainable healthcare system (Sherman et al., 2020). 239

210



240

241

Fig. 2. Major challenges in the sustainability literature before COVID-19

Due to the complex and multi-dimensional concept of sustainability, which brings together 242 discourses from different domains, sustainable development policy-makers and practitioners face 243 the challenge of employing system thinking approach to consider sustainability dimensions as a 244 whole (Allen et al., 2018; Ramos et al., 2020). In this regard, some challenges, such as 245 environmental policy harmonization with industry 4.0 to create a sustainable Industry 4.0 (Oláh 246 et al., 2020), mobilizing financing and investments towards SDGs achievement (Barua, 2020), 247 urban metabolism of cities and their contribution towards sustainability (Cui, 2018), and 248 innovative policy intervention for transformative systems change and sustainability transition 249 (Kanger et al., 2020), have been highlighted as challenging approaches to support systems 250 thinking and sustainability literacy. 251

Innovation is an essential factor for enabling industries and organizations to grasp 252 sustainability transition opportunities and facilitating sustainable development agenda. However, 253 254 transforming sustainability innovation from initial idea or laboratory scale to production or 255 commercial scale is quite challenging in many areas. Instances include innovations and technological advancements in solar-powered wastewater treatment (Sansaniwal, 2019), smart 256 257 manufacturing technologies for bioenergy (Meng et al., 2018), innovation intermediaries to accelerate environmental sustainability transitions (Gliedt et al., 2018), reduction of biofuels 258 production costs (Nazari et al., 2020), sustainability-oriented service innovation as a new 259 260 business model for companies to create value towards sustainability (Calabrese et al., 2018), and disjoint challenges between eco-industrial parks planning and implementation phases due to the 261 lack of non-comprehensive assessment frameworks (Hong and Gasparatos, 2020). Moreover, 262 263 measuring the progress towards sustainability in different subject areas is still challenging and needs developing specific adequate indicators (Illahi and Mir, 2020; Kravchenko et al., 2019; 264 265 Kwatra et al., 2020; Merino-Saum et al., 2020; Rashed and Shah, 2020; Silva et al., 2020; Verma and Raghubanshi, 2018). To monitor the sustainability performance, indicators should be 266 267 designed or customized based on the characteristics of any industry. In particular, harmonization of the life cycle sustainability assessment methods (Costa et al., 2019; Fauzi et al., 2019; 268 269 Rodriguez et al., 2020), traceability for sustainability dimensions (Garcia-Torres et al., 2019), 270 sustainability assessment of energy production (Turkson et al., 2020), and effective and efficient 271 management of sustainability risks (Rafi-Ul-Shan et al., 2018) need more investigation.

272 **3.2.** Sustainability after COVID-19: Descriptive analysis

In the descriptive analysis, a statistical report on the TBL of sustainability perspectives and practices considering the COVID-19 crisis is presented to address the first research question (RQ1: What is the current status of research on the TBL of sustainability considering COVID-19 implications?). This report covers journal publications, distribution of the publications over time, countries which have contributed to the topic, citation ranking of the publications, and methodological approaches and research methods applied in the articles.

279 **3.2.1.** Journal publications

The distribution of journal papers within scientific journals in the WoS and Scopus is provided in Fig. 3. The 49 articles were published in 27 journals from different disciplines. As shown in Fig. 3, 55% of the papers in the sample were published in five journals only. The leading journal to address the TBL of sustainability perspectives in the context of the COVID-19 pandemic crisis is *Sustainability*, with 12 articles out of 49 items, which constitute 25% of our sample. *Science of the Total Environment, Sustainability: Science, Practice and Policy*, and *Tourism Geographies*, each with 4 articles, and *Energy Research & Social science* with 3 papers stand in the next positions, respectively.





Fig. 3. Distribution of the sample papers across journals in WoS and Scopus

290 **3.2.2.** Distribution of the publications over time

The search process identified a total of 49 articles on the TBL dimensions of sustainability, 291 taking COVID-19 effects into account, which were published from March 2020 to August 29, 292 293 2020, as shown in Fig. 4. Although the inclusion criteria in our search protocol allowed results with a publication date starting from December 2019, the content analysis showed that the first 294 295 article investigating the sustainability effects of COVID-19 in our sample was published in April 296 2020. After the announcement of COVID-19 as a pandemic by the WHO on March 11, 2020, as 297 observed in Fig. 4, the number of research conducted on the COVID-19 effects on the economic, social, and environmental sustainability in our sample has increased considerably. It is evident 298 299 that due to the significant COVID-19 implications for global health and the concerns regarding 300 sustainability for the economy, society, and the environment, academic interest to study the challenges caused by COVID-19 in the subject has rapidly increased. As the search process of 301 our research stopped on August 29, 2020, the lower number of publications in August 2020 is 302 due to the time that WoS and Scopus usually need to find the accepted articles online. Therefore, 303

some of the papers published in August 2020 may appear in WoS and Scopus databases in thenext month(s).



306



Fig. 4. Distribution of the publications over time

308 3.2.3. Contributing countries

The geographical distribution of the studied articles in our research for the top 10 309 contributing countries is presented in Fig. 5. Among the countries, the United States has the 310 highest contribution in COVID-19 research, focusing on different sustainability dimensions 311 312 through 11 research articles indexed in the WoS and Scopus. The second highest contribution comes from the United Kingdom with 8 articles, followed by Italy (5 papers) and Germany and 313 314 Sweden (each 4 papers). As shown in Fig. 5, most of the countries listed in the top contributing nations to the COVID-19-related research have been dramatically affected by COVID-19, 315 316 considering confirmed cases and death records. According to the report by the WHO (2020c), the United States is the most affected country by the COVID-19 in the world, with 7,206,769 317 318 confirmed cases and 206,558 death records, followed by India and Brazil by October 3, 2020. According to the same report, Spain is the second most infected country by COVID-19 in 319 320 Europe, with 789,932 confirmed cases and 32,086 death records, followed by France, the United Kingdom, and Italy. The statistics of our sample shows that heavily infected countries by 321 COVID-19 have intended to contribute more than the other countries in the world to the 322 sustainability research, considering COVID-19 implications and future challenges. 323







Fig. 5. Number of publications in the top contributing countries

326 **3.2.4.** Citation ranking

In order to provide a general overview of the influence of our sample papers on the 327 subsequent scientific publications, the list of 10 most cited articles are presented in Table 1. As 328 can be seen from this table, the first ranked article in terms of global citation score, which is 329 written by Galanakis (2020), refers to the food system and has been 117 times cited in other 330 scientific publications. The subject area of 3 out of the 10 listed articles is tourism industry and 331 all of them are published in the journal *Tourism Geographies*. These articles, which are authored 332 by Ioannides and Gyimóthy (2020), Romagosa (2020), and Galvani (2020), are ranked 3rd, 4th 333 and 6th in the citation ranking list, respectively, and are cited 113 times in total. Although citation 334 335 scores are not a proper measure to evaluate the quality of the articles (Nikulina et al., 2019), the presence of 3 tourism-related articles among the top 6 highly cited articles in the sample can 336 337 point to the significant effects of COVID-19 on the sustainability of tourism industry that have attracted the attention of researchers. Tourism along with other subject areas which have been 338 impacted by COVID-19 are discussed in the following sections of the paper. 339

340 *Table 1.* The most influential sample papers

Author(s) and year	Title of the paper	Citation score	Journal	Publisher
Galanakis (2020)	The Food Systems in the Era of the Coronavirus	117	Foods	MDPI
	(COVID-19) Pandemic Crisis			

La et al. (2020)	Policy Response, Social Media and Science Journalism	90	Sustainability	MDPI
	for the Sustainability of the Public Health System			
	Amid the COVID-19 Outbreak: The Vietnam Lessons			
Ioannides and	The COVID-19 crisis as an opportunity for escaping	46	Tourism Geographies	Taylor and Francis
Gyimóthy (2020)	the unsustainable global tourism path			Group
Romagosa (2020)	The COVID-19 crisis: Opportunities for sustainable	38	Tourism Geographies	Taylor and Francis
	and proximity tourism			Group
O'Connor et al.	Economic Recovery After the COVID-19 Pandemic:	35	The Journal of	Elsevier
(2020)	Resuming Elective Orthopedic Surgery and Total Joint		Arthroplasty	
	Arthroplasty			
Galvani et al.	COVID-19 is expanding global consciousness and the	29	Tourism Geographies	Taylor and Francis
(2020)	sustainability of travel and tourism			Group
Barbier and Burgess	Sustainability and development after COVID-19	22	World Development	Elsevier
(2020)				
Ryan et al. (2020)	COVID-19 Community Stabilization and Sustainability	22	Policy Analysis	Cambridge
	Framework: An Integration of the Maslow Hierarchy			University Press
	of Needs and Social Determinants of Health			
Kanda and Kivimaa	What opportunities could the COVID-19 outbreak	21	Energy Research &	Elsevier
(2020)	offer for sustainability transitions research on		Social Science	
	electricity and mobility?			
Leal Filho et al.	COVID-19 and the UN Sustainable Development	21	Sustainability	MDPI
(2020)	Goals: Threat to Solidarity or an Opportunity?			
(2020)	Goals: Threat to Solidarity or an Opportunity?	21	Sustainability	MIDE I
	· ·			

341

342 **3.2.5.** Methodological approaches and research methods

343 Due to the recentness of the COVID-19 crisis and the lack of adequate and reliable quantitative data in many subject areas of sustainability research, most of the research in our 344 sample was conducted by employing a qualitative approach. As shown in Fig. 6, 43 out of the 49 345 articles (i.e., 88% of the sample) applied a qualitative approach, while only 3 (i.e., 6% of the 346 347 sample) used a quantitative approach. Moreover, 3 articles (i.e., 6% of the sample) employed a mix of quantitative and qualitative approaches. In terms of research methods, content analysis, as 348 a qualitative research method, was the most frequently used method in our sample (applied in 39 349 research articles), followed by survey and case study applied in 4 and 3 research articles, 350 351 respectively.



352

353

Fig. 6. Methodological approaches and research methods

354 3.3. Sustainability after COVID-19: Thematic analysis

The focus of thematic analysis is on the perspective to study sustainability, the main subject areas, and three main pillars of sustainability, including environmental, social, and economic, in the wake of the COVID-19 outbreak. The proposed analysis addresses both the first and second research questions of our study (RQ1: What is the current status of research on the TBL of sustainability considering COVID-19 implications? RQ2: How does COVID-19 affect the TBL of sustainability?). Fig. 7 demonstrates the distribution of articles within different sustainability dimensions, considering the COVID-19 crisis.





363 Fig. 7. Distribution of the publications within the TBL dimensions of sustainability considering COVID-19

According to Fig. 7, integrated sustainability is the most paid attention sustainability intersection considering the effects of COVID-19 by scholars with the total number of 29 research articles. The environmental sustainability section and socio-economic sustainability intersection come next, each with 6 research articles, followed by social sustainability section and socio-environmental intersection with 5 and 3 articles, respectively. On the contrary, there is no specific research on the economic sustainability section without involving the social and/or environmental pillars and also eco-economic sustainability intersection.

For the rest of the thematic analysis section, the key themes and subject areas studied in terms of sustainability perspectives in the aftermath of the COVID-19 outbreak are presented in Section 3.3.1. Then, the main research conducted on the COVID-19 implications for each pillar of sustainability, including environmental and social (Section 3.3.2), different pairwise intersections of pillars including socio-economic and socio-environmental (Section 3.3.3), and the integration of all three economic, social, and environmental pillars of sustainability, which refers to sustainable development (Section 3.3.4), are discussed.

378 3.3.1. Subject areas of sustainability amid COVID-19

The main subject areas in the literature within the different sustainability dimensions 379 indicated in Fig. 7, considering the COVID-19 pandemic, are presented in Fig. 8. In terms of the 380 overall number of research articles regardless of the sustainability dimension, as illustrated by 381 Fig. 8, the healthcare industry with 8 research papers, the tourism industry with 6 research 382 papers, the food industry with 5 research papers, and the SDGs and sustainable transition each 383 with 4 research papers are the most frequent subject areas of sustainability research in the wake 384 of COVID-19 pandemic, respectively. Environmental pollutions, the education industry, energy, 385 waste management, and strategic management come next, equally with 4 articles. 386

387 As evident from Fig. 8, most of the studied subject areas in the literature belong to the integrated sustainability dimension in the wake of COVID-19 with 29 articles on the nine subject 388 areas. In this regard, the tourism industry is the most frequent subject area, which has been 389 390 addressed by sustainability researchers to investigate the COVID-19 implications, followed by the food industry and sustainable transition studies. On the contrary, socio-environmental 391 sustainability and social sustainability dimensions have the fewest subject areas, including 392 environmental pollution and healthcare sector, and education and healthcare industries, 393 respectively. Environmental pollutions, waste management, and the airline industry are the main 394 subject areas of environmental pillar of sustainability, while education, information system, 395 SDGs, and social media subject areas come from socio-economic sustainability intersection. 396





398

Fig. 8. Distribution of the publications in terms of subject areas of sustainability amid COVID-19

399 3.3.2. Main pillars of sustainability and COVID-19

As illustrated in Fig. 7, only 11 research articles among the 49 sample articles in our 400 research have analyzed the COVID-19 implications for each pillar of sustainability separately, 401 including 6 articles for the environmental pillar and 5 articles for the social pillar. Evidently, the 402 403 number of research articles that have studied COVID-19 impacts on just one pillar of 404 sustainability is considerably lower than those addressing all the three pillars at the same time. This may correspond with the complex and interconnected nature of the main pillars of 405 sustainability (Ranjbari et al., 2019), which causes them to affect each other within the whole 406 system. Table 2 summarizes these publications in terms of subject area (theme), research focus 407 408 and objective, the scale of the study, geographical scope, methodological approach, and key 409 results and findings.

The effects of the COVID-19 pandemic on each of the environmental and social pillars of sustainability are presented and discussed in the following sections.

412 Table 2. Summary of the research conducted separately on the main pillars of sustainability and COVID-19

	Sustainability dimension						Meth ar	odolo oproac	gical :h			
Reference	Environment	Social	Economic	- Subject area/ theme	Research focus and objective(s)	Scale of study	Geographical scope	Quantitative	Qualitative	Mixed method	Method	Findings
(Somani et al., 2020)	✓			Environment al pollution	Studying the implications of COVID-19 towards a sustainable environment	Macro	India			✓	Case study	Analyzed the COVID-19 environmental implications for air quality, water quality, noise pollution, and emission of GHGs
(Adelodun et al., 2020)	✓			Wastewater management	Studying the potential snowballing transmission of COVID-19 through wastewater in low- income countries	Macro	Low-income countries		•		Content analysis	Proposed sustainable preventive measures for the low-income countries against the potential outbreak of COVID-19 through wastawater
(Vanapalli et al., 2021)	✓			Waste management	Studying the challenges and strategies for effective plastic waste management during and after COVID-19	NA	NA		•		Content analysis	Presented the disruption caused by COVID-19 on plastic waste generation and recommended policies to combat the rise in the use and disposal of single-use plastics post-COVID-19
(Kulkarni and Ananthara ma, 2020)	✓			Municipal solid waste management	Reviewing the consequences of the COVID-19 pandemic on municipal solid waste management	Macro	selected developed and developing countries		•		Content analysis	Identified different types of waste generated during the COVID-19 outbreak that impact the existing municipal solid waste management practices
(Amankwa h-Amoah, 2020)	~			Airline industry	Examining the new challenges imposed by COVID-19 for adopting environmental sustainability policies in the global airline industry	Macro	Global		*		Content analysis	Indicated that some airlines had to sidestep environmentally-friendly commitments to pass new restrictions in the wake of COVID-19 such as "cost pressures", "survival threat and deprioritizing environmental sustainability initiatives"
(Anholon et al., 2020)		•		Education	Studying the need to insert sustainability into engineering education after the COVID-19 crisis	Macro	NA		•		Content analysis	Denoted the importance of academic staff in the field of engineering education during the COVID-19 pandemic to pay attention more to

								principles
(Christoffe l et al., 2020)	V	Healthcare	Examining the impact of the COVID-19 infection on vulnerable Brazilian children	Macro	Brazil	~	Content analysis	Highlighted the critical role of the nursing field in monitoring children and their families in vulnerable social situations to prevent COVID-19 contamination
(Sharma et al., 2020)	~	Healthcare	Analyzing the consequences of COVID-19 on the society for investments in family planning	Macro	NA	~	Content analysis	Highlighted the need for support by governments and public-private partnerships for ensuring family planning services considering the newly emerged situation by COVID-19
(Ryan et al., 2020)	~	Healthcare	Studying the effects of COVID-19 on the Maslow hierarchy of needs and social determinants of health to ensure community stabilization and sustainability	Macro	NA	*	Content analysis	Proposed a sustainability framework to ensure community stabilization considering the hierarchy of needs and social determinants of health through providing baseline requirements, regulations and recommendations, and triggers
(Iyengar, 2020)	V	Education	Studying the importance of education initiative in the post-COVID-19 recovery	Macro	NA	~	Content analysis	Proposed three policies for education systems post-COVID-19, including using technology to overcome in learning, community- driven support systems, and focus on SDG 4.7
(Freire- González and Font Vivanco, 2020)	~	Environment al pollution	Studying the environmental effects of the COVID-19 pandemic	Macro	NA	V	Content analysis	Outlined the environmental rebound effect of COVID-19, referring to increase environmental burdens rather than decrease them

sustainable development

413

414 3.3.2.1. Environmental sustainability and COVID-19

As a major dimension of sustainability, environmental sustainability deals with managing limited resources to reduce the processing resources and minimize the waste generated to protect the environment and natural resources (Roy et al., 2020). Various environmental implications of the COVID-19 outbreak have created some challenges and opportunities for environmental

sustainability from different perspectives. Freire-González and Font Vivanco (2020) outlined the 419 high risk of the environmental rebound effect of COVID-19, referring to the increase of 420 421 environmental burdens rather than their decrease. As a response to the environmental rebound 422 effect, they provided some recommendations for governments to put extra measures such as environmental taxation or limiting the use of resources, to support environmental sustainability 423 424 in the post-COVID-19 era. Moreover, as a negative consequence of the COVID-19 restrictions for the environment, Amankwah-Amoah (2020) demonstrated that some airlines had to skip their 425 426 commitment to environment-friendly and eco-friendly policies to survive and pass the economic 427 pressure caused by COVID-19. In line with previous studies, Somani et al. (2020), in a case study in the Indian context, identified the positive environmental effects of COVID-19 on the 428 ambient air quality, surface water quality, noise pollution, and greenhouse gas emission, while 429 430 the negative impacts on the biomedical waste generation and mixed effect of carbon dioxide emission. However, the environmental impacts of the pandemic resulting in the changes to the 431 432 access to clean and renewable energies, addressed in UN's SDG 7, and also wildlife below water and ecosystems and biodiversity on land, addressed by UN's SDGs 14 and 15, are other aspects 433 434 of environmental sustainability that calls for more attention.

As reported by SMART WASTE (2020), among the environmental impacts of the COVID-435 19 pandemic, municipal waste management practices seem to be faced with more serious 436 challenges. The role of local and regional authorities to adopt appropriate policies in municipal 437 waste management, considering the current implications imposed by COVID-19, is essential in 438 439 terms of managing waste generation, waste handling and separation, waste transportation, waste disposal, and landfilling. Besides, according to the research conducted by Mol and Caldas 440 (2020), COVID-19 can spread through solid waste and inadequate waste transport and disposal, 441 442 which can pose a risk to workers and environmental sustainability. Kulkarni and Anantharama (2020) proposed three policies for sustainable municipal solid waste management in the 443 aftermath of the COVID-19 outbreak, including using decentralized waste management for waste 444 445 collection and recycling, creating temporary waste storage and reduction site, and using thermal 446 treatment with an energy recovery facility as a solution for processing a large amount of waste. 447 The changes in consumption patterns caused by COVID-19, such as using personal protective 448 equipment and increased demand for plastic-packaged food, have increased the complexity of

plastic waste management (Vanapalli et al., 2021). As a solution, applying circular technologies 449 such as feedstock recycling, more investment in infrastructure, and using sealed bags to enhance 450 451 the safety of contaminated plastic wastes disposal proposed by Vanapalli et al. (2021) are 452 priorities in sustainable waste management during pandemic crisis. Another concern regarding the COVID-19 outbreak, especially in low-income countries that mainly rely on the surface and 453 454 groundwater resources for water consumption, is the potential of community spread of COVID-19 through wastewater (Adelodun et al., 2020). Decentralization of wastewater treatment 455 facilities, community-wide monitoring and testing of Coronavirus ribonucleic acid in 456 457 wastewater, improved sanitation and water quality, development and use of the point-of-use device for virus decontamination, and policy intervention were suggested by Adelodun et al. 458 (2020) as sustainable preventive measures for low-income countries against the potential 459 460 outbreak of COVID-19 through wastewater. In this regard, monitoring COVID-19, as a tracer in wastewater, in order to single out the infected areas has also been highlighted and a feasibility 461 462 assessment of a surveillance system is being conducted in Europe by the European Commission (EU, 2020). 463

464 3.3.2.2. Social sustainability and COVID-19

Social sustainability mainly deals with the supervision of social capital and human being by 465 integrating human and civil rights, health and safety issues, social responsibility, and community 466 (Cooper et al., 2018; Munny et al., 2019). The COVID-19 pandemic, as a global health 467 emergency, has highly affected social sustainability by jeopardizing the life quality, human well-468 being, healthy and safe lives. Health and human well-being and education, basic social needs to 469 470 achieve social sustainability, have been paid more attention than other social issues by sustainability researchers considering COVID-19 crisis effects. Based on a reflective study in 471 Brazil, Christoffel et al. (2020) outlined the challenges of maternal, neonatal, and child health 472 473 during COVID-19, especially for women who live in vulnerable situations, and called for public policy support and assistance. In line with SDG 3 for ensuring good health and well-being, the 474 475 role of nursing professions, in particular, pediatric nursing for monitoring children and their 476 families in vulnerable social situations is vital to prevent COVID-19 contamination by promoting prevention measures and detecting cases of COVID-19 (Christoffel et al., 2020). Therefore, it 477 478 could be inferred that the focus among the social needs should be on the health and sanitation

efforts against the COVID-19 pandemic, putting older people, children, and pregnant women in 479 vulnerable situations in priority towards social sustainability and its associated SDGs 480 481 achievement. Due to the cloistering of individuals, couples, and families caused by the COVID-482 19 pandemic, ensuring rights-based family planning services, as a fundamental human right, is essential towards social sustainability and achieving the SDGs within the 2030 Agenda for 483 484 Sustainable Development (Sharma et al., 2020). Community-based distribution, domestic investment in the health system, and collaboration with individual private health care providers 485 were proposed by Sharma et al. (2020) to support the family planning service provision during 486 the COVID-19 outbreak. Ryan et al. (2020) proposed a sustainability framework to ensure 487 community stabilization considering the hierarchy of needs and social determinants of health 488 through providing baseline requirements, regulations, and recommendations, triggers, and 489 490 implementation. The authorities and decision-makers involved in the COVID-19 crisis management need to use a well-considered sustainable framework to balance lockdown and 491 492 restrictive regulations and social needs to manage the crisis more sustainably.

SDG 4, referring to quality education as a fundamental enabler of social sustainability 493 within the 2030 Agenda for Sustainable Development, aims to provide free, equitable, and 494 quality primary and secondary education for all girls and boys worldwide by 2030 (General 495 Assemly, 2015). Before the COVID-19 pandemic crisis, according to the report by the UN 496 497 (2020a), 617 million youth worldwide lack basic mathematics and literacy skills, and more than 200 million children would be out of school. Based on this report, minimum proficiency 498 standards in reading and mathematics are not met by more than half of children all around the 499 500 world. COVID-19 lockdowns and closures have disrupted education systems worldwide by imposing some limitations and restrictions. Keeping social distancing and emerging new 501 approaches to education and learning enabled by digitalization and online learning methods amid 502 503 the COVID-19 outbreak has created new challenges to the education systems and the associated policy-makers worldwide. Therefore, more attention to sustainable development principles and 504 505 inserting sustainability concepts into the education system structure in the wake of the COVID-506 19 crisis are urgently required (Anholon et al., 2020). Iyengar (2020), in response to the COVID-19 implications for education systems, proposed three policies, including using technology to 507 overcome the learning difficulties caused by COVID-19, community-driven support systems, 508

and more investment in SDG 4, considering quality education to support sustainabledevelopment.

511 3.3.3. Sustainability pillars pairwise intersections and COVID-19

As stated in the previous section and shown in Fig. 7, due to the interconnected nature of the 512 sustainability pillars, in most of our sample articles (38 out of 49), it is mentioned that the 513 514 COVID-19 outbreak has affected two or even all three sustainability pillars. These intersections 515 represent the common area between multiple pillars, which meet the requirement of those areas simultaneously. Among the three sustainability pairwise intersections, socio-economic 516 517 sustainability with 6 research articles is the most frequently addressed intersection in the literature, followed by socio-environmental sustainability being the focus of 3 research articles 518 519 (see Fig. 7). There are no research articles focusing on the eco-economic sustainability 520 intersection. Table 3 summarizes the research conducted on the confluence of sustainability 521 pillars, which have been affected by COVID-19, providing subject area, research focus and 522 objective, the scale of the study, geographical scope, methodological approaches, and key results and findings. 523

524 COVID-19 implications for the pairwise intersections of sustainability pillars are provided 525 and discussed in the following sections.

	Su d	stainab limensio	ility on					Me	thodolog approacl	ical 1		
Reference	Environment	Social	Economic	Subject area/ theme	Research focus and objective(s)	Scale of study	Geographical scope	Quantitative	Qualitative	Mixed method	- Method	Findings
(Pan and		\checkmark	\checkmark	Information	Studying	Macro	NA		\checkmark		Content	Identified six
Zhang, 2020)				systems	opportunities						analysis	themes including
					for responsible							'expanding digital
					information							surveillance',
					systems							'tackling the
					research from							infodemic',
					fighting the							'orchestrating data
					COVID-19							ecosystems',
					pandemic to							'adapting
					tackling SDGs							information
												behaviors',

526 Table 3. Summary of the research conducted on the sustainability pillars pairwise intersections and COVID-19

										'developing the digital workplace', and 'maintaining social distancing' to conduct responsible IS research to tackling sustainable development after COVID-19
(Yu et al., 2020)	4	*		Pharmaceutical supply chain	Studying the potentials of pharmaceutical supply chains to scale up the sustainability for the COVID-19 pandemic crisis	NA	NA	*	Content analysis	Identified five urgent priority areas for pharmaceutical supply chains during COVID-19 regarding decision- making, optimal supply chain planning, game- theoretic analysis, life cycle sustainability assessment, and drug allocation strategies
(Paramashanti, 2020)		*	*	SDGs	Considering the challenges for Indonesia Zero Hunger Agenda in the context of the COVID-19 pandemic	Macro	Indonesia	~	Content analysis	The COVID-19 pandemic could reverse Indonesia's progress towards SDG2 (zero hunger) from the 17 SDGs within the 2030 Agenda for Sustainable Development
(Chiang et al., 2020)	•	•		Healthcare	Studying the safety and practicality of elastomeric respirators from COVID- 19	Micro	NA	~	Content analysis	Highlighted the advantages of elastomeric face masks as a sustainable alternative over reusing disposable N-95 masks
(Pulimeno et al., 2020)	•	~		Air quality	Studying indoor air quality at school considering restrictions imposed by	Масто	Italy	~	Content analysis	Presented recommendation in terms of indoor air quality at school after the COVID-19 crisis

COVID-19

and students'

performance

(La et al., 2020)	•	•	Social media	Studying the policy response, social media, and science journalism amid the COVID-19 crisis in Vietnam	Macro	Vietnam	*		Content analysis	Highlighted the importance of timely communication from the government and the media as a reliable source of information for society as a response to the public health crisis
(Tran et al., 2020)	*	*	Education	Studying the effects of COVID-19 on teaching and learning activities	Meso	Vietnam 🗸			Survey	Presented the COVID-19 implications for students' learning habits with different socioeconomic statuses in Vietnam, which can be used by the local government to increase the sustainability of the education system towards SDG4
(AI-Youbi et al., 2020)	*	~	Social media	Strategy developing for social media awareness in the COVID-19 pandemic crisis towards a sustainable higher education	Micro	Saudi Arabia		~	Survey	Presented a methodological approach to leverage social media focusing on official Twitter accounts in pandemic crisis for minimizing the negative impact of COVID-19 on education's sustainability

(Ashford et	\checkmark	\checkmark	SDGs	Studying	Macro	NA	\checkmark	Content	Introduced the main
al., 2020)				inequality				analysis	interventions and
				towards					strategies that
				sustainability					should be
				in the wake of					considered after the
				COVID-19					COVID-19 crisis to
									achieve SDG10
									(reduce inequality)
									towards
									sustainability

527

528 3.3.3.1. Socio-economic sustainability and COVID-19

The socio-economic impacts of the COVID-19 crisis on the global community have 529 disrupted the path towards sustainability and achieving SDGs to implement sustainable 530 development. According to the report by the UN (2020b) regarding hunger, the world is not on 531 532 track to achieve SDG 2, which aims to end hunger and ensure access by all people, especially the poor people and those who live in vulnerable situations by 2030. Based on this report, nearly 690 533 million people are hungry, which constitute 8.9% of the world population. The serious pressure 534 caused by the COVID-19 pandemic on the global economy has even worsened the situation 535 536 towards achieving SDG 2. Paramashanti (2020) outlined the COVID-19 crisis as a shock for Indonesia's progress towards SDG 2 by affecting hunger, malnutrition, and food insecurity, and 537 538 highlighted the importance of paying attention to the food and agriculture industry and social protection as well to prevent another humanitarian catastrophe, even though saving lives against 539 540 COVID-19 is in priority. Moreover, the COVID-19 crisis has led to many social and economic inequalities, such as income, health, education, and safety inequalities for people worldwide. 541 542 These emerging inequalities significantly threaten socio-economic sustainability and the 543 achievement of SDG 10 within the 2030 Agenda for Sustainable Development, which aims to 544 reduce inequality. In order to advance progress towards SDG 10 to reduce inequality, Ashford et 545 al. (2020) proposed some policies to address the inequality issues amplified by the COVID-19 pandemic consisting of transferring income and wealth without increasing the deficit, focusing 546 547 on workforce stabilization and safety, allocating government incentive and subsidies to support healthcare, food, and basic needs, and using debt suspension mechanisms for emerging and 548 549 developing economies. Tran et al. (2020) identified the important role of students' perception of the necessity of self-learning, school type, and also grade level on their learning habits during the 550 school suspension period caused by COVID-19, considering their different socioeconomic 551

statuses, through conducting a survey in Vietnam. The local governments need to reduce
inequality in education systems considering newly emerged limitations caused by COVID-19 to
make more sustainable education systems towards SDG 4, aiming to ensure quality education.

During a crisis, the policy response of governments and communications with social media and 555 556 the journalism community to control the crisis and its consequences are essential. For instance, in 557 the case of the COVID-19 crisis, the huge infodemic (i.e., the rapid and far-reaching spread of 558 both accurate and inaccurate information about an epidemic) and misinformation of COVID-19 559 news could cause panic within the society and threaten the socio-economic situation in many 560 sectors, such as downward trends in the stock markets and reduction of tourism activities. Timely 561 communications from the governments, authorities, and mainstream media, are reliable sources of information for societies to avoid confusion and insecurity for the public and influence public 562 perception and build trust. These are collectively critical in combating COVID-19 spread (La et 563 564 al., 2020). Consistent with previous research, Pan and Zhang (2020) outlined the importance of digital surveillance and data ecosystems orchestrating to help process and combine reliable data 565 and tackle the infodemic of COVID-19, which poses a serious challenge to sustainable public 566 567 health. Moreover, AI-Youbi et al. (2020) presented a framework to leverage a transparent strategy for social media awareness focusing on official Twitter accounts for minimizing the 568 negative socio-economic impacts of COVID-19 on education's sustainability and support 569 strategic decision-making in social media plan deployment to deal with the crisis. 570

571 3.3.3.2. Socio-environmental sustainability and COVID-19

572 As shown in Fig. 7, the socio-environmental sustainability intersection includes 3 research articles focusing on the healthcare industry and environmental pollution topics. The healthcare 573 574 industry is an important subject area, which can significantly affect the social and environmental dimensions of human lives towards sustainability. COVID-19 has imposed immense pressure on 575 576 the healthcare systems, not only to deal with COVID-19 confirmed cases but also for the provision of medical services and care for patients with other diseases that require 577 hospitalization. In such a situation, healthcare systems need to manage their resources and 578 capacities effectively for increasing the sustainability of medical services and the healthcare 579 580 system, on the whole, saving human lives. In this regard, Yu et al. (2020) identified five urgent priority areas for pharmaceutical supply chains during COVID-19 regarding decision-making, 581

optimal supply chain planning, game-theoretic analysis, life-cycle sustainability assessment, and 582 drug allocation strategies to help the pharmaceutical industry scale up sustainably for the 583 COVID-19 crisis. Due to the shortage of personal protective equipment against COVID-19, 584 Chiang et al. (2020) outlined the advantages of elastomeric face masks as a safer and sustainable 585 alternative over reusing disposable N-95 masks during the COVID-19 outbreak. This can lead to 586 587 enhanced socio-environmental sustainability by saving lives and reducing material and resource use and disposal because, as Chiang et al. (2020) claim, a single elastomeric respirator can 588 replace hundreds to thousands of new disposable N-95 masks, which significantly benefits the 589 590 environment and society.

591 The health and also learning efficiency of 64 million students and 4.5 million teachers across 592 Europe has been affected by the issue of indoor air quality of the school classrooms, which is still a neglected topic impacted by ventilation, temperature, and humidity rate (Pulimeno et al., 593 594 2020). Therefore, efforts to ensure a healthy microclimate in schools seem to be fundamental to achieve SDG 3, aiming to ensure good health and well-being, and SDG 4 to increase the quality 595 education towards sustainable development. Due to COVID-19 restrictions and the high need for 596 597 hygiene, the issue of indoor air quality has become more relevant. Regarding the indoor air quality issue at schools after COVID-19, Pulimeno et al. (2020) highlighted the importance of 598 installing air decontamination filters in schools, ventilating classrooms before the beginning of 599 600 the lessons during the pandemic, and installing thermostats in classrooms to monitor the temperature and humidity to avoid overheating or dry air, which decreases indoor air quality. 601

602 **3.3.4.** Integrated sustainability and COVID-19

Integrated sustainability brings together environmental, social, and economic responsibilities (Gimenez et al., 2012) to attain a proper balance between the objectives of these dimensions at different levels (Janjua et al., 2020). As shown in Fig. 7, among the 49 sample articles of our study, 29 research articles have addressed all three sustainability dimensions in the wake of the COVID-19 pandemic crisis. Table 4 presents a summary of these publications in terms of the subject area, research focus and objective, the scale of the study, geographical scope, methodological approaches, and key results and findings.

610 Table 4. Summary of the research conducted on integrated sustainability and COVID-19

	Methodological approach		ical 1							
Reference	Subject area/ theme	Research focus and objective(s)	Scale of study	Geographical scope	Quantitative	Qualitative	Mixed method	Method	Findings	
(Barbier and Burgess, 2020)	Energy	Identifying affordable progress policies towards several SDGs together considering the COVID-19 implications	Macro	Developing countries		~		Content analysis	Presented three policies to achieve several SDGs together considering the COVID-19 implication, including: - Fossil fuel subsidy swap to fund clean energy investments - Reallocating irrigation subsidies to improve water supply - Tropical carbon tax	
(Sovacool et al., 2020)	Energy	Providing insights on the COVID-19 effects on the supply, demand, and governance of energy and "future low- carbon transitions" and social justice	Macro	NA		~		Content analysis	Provided some recommendation for policy- makers in terms of energy and climate planning considering the opportunity to transform social practices	
(Rowan and Galanakis, 2020)	Agri-food industry	Unlocking challenges and opportunities presented by the COVID-19 pandemic for cross-cutting disruption in agri- food and green deal innovations	Macro	64 selected European startups and SMEs and 43 Irish disruptive technology projects		~		Case study	Highlighted trends in the innovation ecosystem and potential technology, product, and business service disruptors in the agri-food industry to support transitioning beyond COVID-19	
(Markard and Rosenbloom, 2020)	Climate change	Studying the COVID-19 effects on climate change	Macro	NA		*		Content analysis	Proposed to use the disruptive force of the COVID-19 pandemic to support the transition to "more sustainable" and "low-carbon systems"	
(Kanda and Kivimaa, 2020)	Electricity and mobility	Identifying the sustainability transitions opportunities in the electricity and mobility sectors after COVID-19	Meso	Finland and Sweden		*		Content analysis	The long-term implications of COVID-19 lead more changes towards "digitalization of work" and reducing "mobility needs" and overall "fossil- energy consumption"	

(Kuzemko et al., 2020)	Energy	Investigating the implications of COVID-19 for the politics of sustainable energy transitions	Macro	Emphasis on the OECD countries		~	Content analysis	Identified the effects of COVID-19 on sustainable and fossil sources of energy and how social and economic support can shape "energy demand, the carbon-intensity of the energy system, and the speed of transitions" in a sustainable manner
(Zhu and Krikke, 2020)	Food supply chain	Studying how to manage a sustainable perishable food supply chain considering the COVID-19 restrictions	Macro	NA	~		Mathematical modeling/ system dynamics modeling	Tested different scenarios of product shortages using a system dynamics simulation and identified four dominant loops that facilitate the generation of endogenous demand to manage a sustainable perishable food supply chain after the COVID- 19 crisis
(Galanakis, 2020)	Food Systems	Studying the COVID-19 implications for food systems	Macro	NA		*	Content analysis	Denoted the need for a sustainable food chain to reduce the frequency of relevant food and health crises in the future and avoiding "business as usual" practices
(Barcaccia et al., 2020)	Agri-food industry	Analyzing the impacts of the COVID-19 pandemic on the Italian agri- food sector	Macro	Italy		~	Content analysis	Highlighted the role of research networks for an "efficient socio-economic and territorial restart", and a faster transition to sustainability in the frame of a "circular bio- economy" management
(Wells et al., 2020)	Sustainability transition	Assessing future sustainability in the age of COVID-19 following a socio- technical transitions perspective	NA	NA		1	Content analysis	Analyzed four scenarios for a post-COVID-19 socio- economic future, including business, as usual, managed transition, chaotic transition, and managed degrowth
(Pierantoni et al., 2020)	Sustainability transition	Examining the COVID-19 opportunities for reorganizing and sustainable transition of human living environments	Micro	NA		~	Content analysis	Examined how COVID-19 has spread in the air and different urban contexts and provided some recommendations in terms of design and space for the future resilient cities and urban areas
(Pirlone and Spadaro, 2020)	Mobility	Adapting to the health emergency caused by COVID- 19 towards sustainable	Micro	Italy	~		Survey	Promoted the sustainable mobility practice for students when traveling between home and university as a solution to return to normality after

university mobility for students

COVID-19

(Obrenovic et al., 2020)	Strategic management	Studying main factors influencing enterprise operational sustainability in the wake of the COVID- 19 crisis implications	Macro	NA	*	Conceptual framework	Conceptualized enterprise effectiveness and sustainability model as an innovative response to COVID-19 for enterprises, which ensures survival during the COVID-19 crisis
(Cooper and Alderman, 2020)	Sport tourism	Studying the COVID-19 effects on the sport tourism economy	Macro	US	~	Content analysis	Analyzed the economic, socio- cultural, and environmental impacts of sport tourism and identified COVID-19 as an opportunity to make a more sustainable sports tourism economy
(Galvani et al., 2020)	Travel and tourism	Studying the impact of COVID-19 on the expanding global consciousness and the sustainability of travel and tourism	Macro	NA	~	Content analysis	Highlighted the role of COVID-19 in shifting human beliefs, desires, knowledge, and experiences towards positive directions and sustainable tourism
(Rydzewski, 2020)	Health and security	Studying the hierarchy of needs within social, economic, and environmental pillars of sustainability amid the COVID-19 crisis	Macro	UK	~	Content analysis	Denoted that in instability caused by COVID-19, social pillar dominates and pushes the environment and economy back with the environment being less important than the economy
(Goffman, 2020)	Sustainability transition	Studying the relationship between glocalization and sustainable future after COVID-19	NA	NA	~	Content analysis	Highlighted the significant role of innovation and local leadership within the context of glocalization to overcome the COVID-19 challenges and make future more sustainable
(Osingada and Porta, 2020)	Healthcare	Studying the challenges of nursing in the age of COVID-19 towards the achievement of the SDGs	Macro	NA	~	Systematic review	Highlighted the important role of nursing to contribute to micro and macro-level efforts toward achieving the SDGs in the post-COVID-19 era
(Bodenheimer and Leidenberger, 2020)	Sustainability transition	Seeking sustainability transitions opportunities in the	Macro	Western Europe	✓	Content analysis	Showed that continuing unsustainable behavior could lead to more crises during the pandemic and proposed some

wake of COVID-19

post-COVID-19 communication strategies

~ (O'Connor et Healthcare Proposing economic US Content Highlighted the need to plan Macro al., 2020) the sustainable resumption of recovery for analysis healthcare systems elective procedures putting the after the COVID-19 safety of patients and surgical pandemic staff in priority within the healthcare systems to reduce expenses and survive economically (Fleetwood, Food Studying the Macro NA Content Highlighted the impact of the 2020) industry interrelationship analysis COVID-19 implications on the between social commitment to social justice justice, food loss, and the achievement of SDGs and the SDGs during focusing on food loss the COVID-19 crisis (Barreiro-Gen Organization Studying the effects Macro Global Survey Denoted that the main et al., 2020) of COVID-19 on the sustainability priority for policy organizations is on the social organizations' sustainability pillar in the wake of the COVID-19 outbreak priorities Vulnerability Investigating ~ Demonstrated that a (Sakamoto et Macro Bangladesh Content al., 2020) Bangladesh's analysis considerable part of vulnerabilities Bangladesh's people would concerning the not be able to tolerate the COVID-19 current situation implications (Leal Filho et SDGs Studying the impact Macro NA Content Showed that strong focus on al., 2020) of the COVID-19 analysis fighting the COVID-19 pandemic on the outbreak is disrupting other achievement of the disease prevention programs SDGs (Hamilton, Strategic Studying business Meso Australia Case study Analyzed the strategic change 2020) marketing sustainability during matrix to adjust the business the COVID-19 considering restrictions pandemic in the imposed by COVID-19 on the digital marketing traditional client as an enabler industry of sustainable competitive business position (Ioannides Tourism Studying COVID-19 Macro NA ~ Content Highlighted COVID-19 and industry opportunities for the analysis opportunities for public and Gyimóthy, sustainable tourism private sectors to rethink and 2020) industry redesign towards a greener and more sustainable tourism

(Romagosa,	Tourism	Investigating the	Macro	NA	✓	Content	Highlighted the importance of
2020)	industry	COVID-19				analysis	the commitment of the
		opportunities for					companies involved in the
		sustainable and					tourism industry to the
		proximity tourism					principles of sustainable
							tourism for being able to well
							position post-COVID-19
(Higgins-	Tourism	Studying the	Macro	NA	\checkmark	Content	Analyzed different
Desbiolles,	industry	challenges of				analysis	opportunities and threats
2020)		sustainable tourism					regarding the future of tourism
		in the wake of the					post-COVID-19 and
		COVID-19 outbreak					highlighted the task of the
							members of the tourism
							academy to contribute to the
							sustainable tourism post-
							COVID-19 not as combatants
							but as scholars
(Weed, 2020)	Sport tourism	Analyzing the	Macro	NA	\checkmark	Content	The interface of sport and
		interconnections				analysis	tourism considering the
		between sport and					COVID-19 crisis were
		tourism in response					discussed under two main
		to the COVID-19					concepts of sports fixtures and
		crisis					events and activity, movement
							and travel to recommend
							policies for well-being,
							physical and mental health,
							green space, and sustainable
							travel

611

As can be seen from Table 4, a wide variety of subject areas, including tourism and travel, food and agriculture, healthcare, strategic management, and organizational policy, SDGs within the 2030 Agenda for Sustainable Development by the UN, climate change, energy and mobility, and sustainability transition opportunities caused by COVID-19, have been investigated in details in terms of the implications of the COVID-19 pandemic crisis on their path towards sustainability.

The tourism industry has been dramatically affected due to the pandemic restrictions on the traveling of people worldwide. Stay-at-home orders by official authorities and partial lockdown by many countries during the COVID-19 crisis have created different opportunities and threats regarding the future of sustainable tourism. Cooper and Alderman (2020) considered COVID-19 as an opportunity to make the sport tourism more sustainable from economic, sociocultural, and environmental points of view. Galvani et al. (2020) analyzed the COVID-19 effects on the knowledge and experience of people and their beliefs to expand the global consciousness

in terms of positive movements towards a sustainable travel and tourism industry. The 625 importance of rethinking and restructuring strategies for greener and more sustainable tourism 626 627 after COVID-19 was highlighted by Ioannides and Gyimóthy (2020) for public and private sectors involved in the tourism industry. Romagosa (2020) proposed the commitment to the 628 principles of sustainable tourism as a solution for tourism companies to survive in the uncertain 629 630 future after the COVID-19 era, and Higgins-Desbiolles (2020) identified the COVID-19 pandemic even as a "game-changer" for the tourism industry and called the tourism academy 631 members to support and contribute to the sustainable tourism after COVID-19 not as 632 competitors, but as scholars. 633

634 The outbreak of the COVID-19 pandemic has affected the stability of food industry supply chains globally. Galanakis (2020) indicated the need for the food industry to avoid a 635 "business as usual" strategy post-COVID-19 and to follow sustainable food system principles to 636 637 ensure food safety and security with less food waste. Managing the perishable food supply chain during the COVID-19 crisis has been challenging due to the short lifetime of the food products, 638 demand uncertainty, and product shortage caused by customers who possibly buy a larger 639 amount of food in the wake of the COVID-19 lockdowns and mobility restrictions (Zhu and 640 Krikke, 2020). According to the simulation model for testing different scenarios of product 641 shortages during the COVID-19 outbreak built by Zhu and Krikke (2020), applying a loosely 642 coupled policy for decision-making and stopping the information sharing that causes endogenous 643 demand are the best policies for managing a sustainable perishable food supply chain post-644 645 COVID-19. An enhanced innovation ecosystem and new sustainability multi-actor innovation hubs in the agri-food sector can support the COVID-19 recovery agenda for sustainable food 646 industry supply chains (Rowan and Galanakis, 2020). The role of research and development 647 sectors within the industries to deal with COVID-19 restrictions in an innovative sustainable 648 manner has become more critical than in the past. Barcaccia et al. (2020), in their study on the 649 Italian agri-food sector post-COVID-19, outlined the importance of investment in research 650 651 networks to accelerate the sustainability transition in the context of circular bio-economy. The 652 commitment to social justice and the SDGs principles were mentioned by Fleetwood (2020) as a response to the food loss and waste in the food industry supply chains during the COVID-19 653 654 crisis towards ending hunger for people in vulnerable situations.

As mentioned before, the COVID-19 pandemic is the most serious threat to global health 655 in 2020, which has substantially imposed pressure on the healthcare systems globally. This 656 657 pressure threatens the sustainability of healthcare systems and highlights the urgent need for plans and actions. Based on a study conducted by Osingada and Porta (2020), to achieve the 658 SDGs post-COVID-19, the responsive and proactive nursing efforts and policies in healthcare 659 660 systems at micro and macro levels need to be in line with the 2030 Agenda for Sustainable Development. Besides, the healthcare system decision-makers need to plan the sustainable 661 resumption of elective procedures, putting the safety of patients and surgical staff in priority 662 during COVID-19, to reduce expenses and survive economically (O'Connor et al., 2020). To 663 sustain the healthcare system fighting the COVID-19 pandemic, detecting the positive cases as 664 soon as possible is crucial. Moreover, the application of smartphone-based healthcare monitoring 665 666 systems could be a solution to support the sustainability of the healthcare system during the COVID-19 pandemic crisis. 667

Strategic planning and management are fundamental to control and timely prevent the 668 COVID-19 pandemic and its negative implications. Authorities and policy-makers need to 669 670 establish a well-clarified strategic plan to detect the confirmed cases, measure indicators, sustain the healthcare systems, and manage resources effectively beyond the COVID-19 crisis 671 considering economic, social, and environmental perspectives. Hamilton (2020) analyzed the 672 strategic change matrix to adjust the business considering restrictions imposed by COVID-19 on 673 the traditional clients as an enabler of sustainable competitive business position. Moreover, as an 674 attempt towards business sustainability post-COVID-19, Obrenovic et al. (2020) denoted that 675 676 companies with networked structure and distributed leadership, which effectively use internet and communication technologies and have a resilient supply chain and organizational culture, 677 can sustain their business operations during and after the COVID-19 pandemic. Due to the 678 financial burden imposed on the societies by COVID-19, strategic prioritizing activities towards 679 sustainability seems to be inevitable. As outlined in a survey conducted by Barreiro-Gen et al. 680 (2020) on the 11,657 organizations worldwide, the main sustainability priority for organizations 681 682 in the wake of COVID-19 is the social pillar rather than the economic and environmental pillars. Besides, consistent with their study, Rydzewski (2020) denoted that in the instability caused by 683 684 COVID-19, the environmental and economic pillars of sustainability are pushed back by the

social pillar based on the "hierarchy of needs", which should be considered as a guideline for
social policy-making and strategic planning after the COVID-19 instability.

687 The achievement of the 17 SDGs within the 2030 Agenda for Sustainable Development by the UN has faced serious challenges due to the COVID-19 outbreak. Among the 17 SDGs, 688 SDG 1 ("no poverty"), SDG 2 ("zero hunger"), SDG 3 ("good health and well-being"), and SDG 689 690 8 ("decent work and economic growth") seem to be the most affected in the wake of the COVID-691 19 crisis. However, SDG 1, SDG 4 ("quality education"), and SDG 8 were identified by Alibegovic et al. (2020) as the most impacted SDGs by COVID-19 in Italy. Moreover, Barbier 692 693 and Burgess (2020) outlined the notable effects of COVID-19 on the SDGs 1-8, SDG 11 694 ("sustainable cities and communities"), SDG 13 ("climate action"), SDG 16 ("peace, justice, and strong institutions"), and SDG 17 (which aims to collaborate for achievement of the other 16 695 SDGs). They proposed three policies for developing countries to achieve several SDGs together, 696 697 considering the COVID-19 implication, including fossil fuel subsidy swap to fund clean energy investments, reallocating irrigation subsidies to improve water supply, and tropical carbon tax. 698 Sakamoto et al. (2020), in a qualitative study on the most vulnerable populations to COVID-19, 699 700 including the garment workers, urban slums dwellers, social exclusion, and pre-existing health conditions in Bangladesh, demonstrated that a considerable part of Bangladesh's people would 701 702 not be able to tolerate the current situation. They highlighted the need for a tolerance capacity for 703 Bangladesh to deal with the COVID-19 implications and reconsideration of the SDGs towards implementing the 2030 Agenda for Sustainable Development post-COVID-19. From a different 704 angle of analysis, Leal Filho et al. (2020) warned about the strong focus of the healthcare 705 706 systems on fighting the COVID-19 pandemic, which is disrupting other diseases prevention 707 programs such as malaria, yellow fever, and others that imperils the achievement of the SDGs, in 708 particular SDG 3, to ensure the health and human well-being globally. Therefore, there is a need 709 to balance healthcare system capacities and priorities to allocate available resources more 710 efficiently.

3.3.4.1. Sustainability transition opportunities in the wake of COVID-19

The COVID-19 pandemic and its disruptive change over the established urban systems may offer some promising sustainability transition opportunities for the societies, which require to be supported by economic and societal actors, policy-makers, and governments. Wells et al. (2020),

through analyzing four post-COVID-19 scenarios including "business as usual", "managed 715 transition", "chaotic transition", and "managed degrowth" to assess the future sustainability, 716 717 identified COVID-19 as a meta-transition for socio-technical regimes and a catalytic event which 718 can redefine the ecological burdens of human activities. Markard and Rosenbloom (2020) proposed using the potential disruptive force of COVID-19 to reduce the carbon-intensive 719 720 industries, technologies, and practices and drive low-carbon innovation as an opportunity to support the climate change and sustainable development agenda. As discussed in the research 721 conducted by Kanda and Kivimaa (2020), expanding the digitalization of work to prevent the 722 COVID-19 outbreak and, consequently, reducing the need for mobility and fossil energy 723 consumption leads to more sustainable cities and urbanization. Besides, low-carbon transport 724 through "mobility as a service" concept enabled by electrification and biogas use was proposed 725 726 by Kanda and Kivimaa (2020) as a sustainable transition opportunity after COVID-19 in urban transport systems. Promoting sustainable mobility practice for students traveling between home 727 and university during the COVID-19 pandemic, using different incentives, was proposed by 728 Pirlone and Spadaro (Pirlone and Spadaro, 2020) to the public authorities as a solution to sustain 729 730 and return to normality after COVID-19 in Italy.

731 The COVID-19 pandemic implications deserve to be addressed as a subject of sustainable energy transition policy by energy policy-makers. Kuzemko et al. (2020) outlined the potential 732 of COVID-19, as a driver of the sustainable energy transition, to shape the sustainable energy 733 demand, the carbon-intensity of the energy system, and the sustainable transition speed 734 considering the investment in the clean-tech in the energy sector. The emerging situation caused 735 by COVID-19 as a "post-disaster window of opportunity" for developing new urban and 736 737 territorial planning towards sustainability transition was addressed by Pierantoni et al. (2020) to 738 highlight the need for rethinking and reorganizing the living environment of cities employing a 739 network of open spaces and greenery to make cities more secure and sustainable for dealing with 740 potential future health crises. Moreover, Sovacool et al. (2020) pointed to the "Christmas" effect of the COVID-19 pandemic by harnessing the social response to the pandemic in terms of energy 741 742 and climate planning and policy, including informing people how to reduce their carbon footprints, creating a capacity to deal with emergency measures, and providing support for 743 vulnerable people in term of energy and mobility. Goffman (2020) highlighted the significant 744

role of innovation and local leadership from glocalization (i.e., a combination of the words 745 "globalization" and "localization.") lens, which refers to local movements with globally 746 747 cooperative ethics, as an opportunity to overcome the COVID-19 challenges, support the sustainability transition, and make a more sustainable future. Although Bodenheimer and 748 Leidenberger (2020) addressed COVID-19 as a "window of opportunity" for sustainability 749 750 transitions in the future, they emphasized using the word "opportunity" with caution and 751 highlighted the importance of designing appropriate communication strategies to make it happen. Based on their study in the Western Europe context, crisis communication strategies should 752 753 address different target groups of the population through appropriate channels in a truthful and 754 cautious, understandable, fast, consistent, and explanatory manner to deliver the narrative 755 between unsustainable behavior and the COVID-19 crisis and support a sustainability transition 756 in the society.

4. Research gaps and directions for a sustainability research agenda after COVID-19

758 Our systematic review showed the need for an update of the sustainability research agenda after COVID-19. Based on the results of the present review, considering the challenges to 759 760 sustainability before COVID-19 and also the recently created challenges by COVID-19, research 761 gaps are identified and summarized in this section, and the research avenues to fill them are proposed. Although sustainability before COVID-19 was facing challenges such as 762 environmental concerns, the education system involvement in sustainability practices, mobilizing 763 financing and investments towards SDGs achievement, and public health crisis arising from 764 healthcare pollution, the COVID-19 pandemic has intensified those challenges. In the other 765 hand, COVID-19 restrictions have led to new challenges for different dimensions of 766 767 sustainability practices and sustainable development in the future. The research avenues 768 identified herein call for: (1) sustainability action plan considering COVID-19 implications: refining sustainability goals and targets and developing a measurement framework; (2) making 769 770 the most of sustainability transition opportunities in the wake of COVID-19: focus on SDG 12 and SDG 9; (3) innovative solutions for economic resilience towards sustainability post COVID-771 772 19: focus on SDG 1, SDG 8, and SDG 17; (4) in-depth analysis of the COVID-19 long-term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10; and (5) expanding 773 quantitative research to harmonize the COVID-19-related sustainability research. Fig. 9 774

- summarizes the sustainability research avenues corresponding to the SDGs for further research
- post COVID-19 towards sustainable development.





777 778 4.1. Sustainability action plan considering COVID-19 implications: refining sustainability
goals and targets and developing a measurement framework

Consistent with the suggestions made by Elliott et al. (2020), we believe that rethinking sustainability should take place in a more quickly manner, before the pandemic disaster is overcome and people return to their normal lives, forgetting about the possible future challenges resulting from the next pandemic. Therefore, a highly recommended research avenue for scholars is developing a modified solid action plan including COVID-19 consideration for sustainability to support governments, authorities, and practitioners of sustainable development.

787 To do this, revisiting the two following factors in the wake of COVID-19 are critical. First, a 788 well-scrutinized review of the COVID-19 effects on the 17 SDGs and their relevant targets to 789 prepare a well-defined description of the goals and targets based on the COVID-19 implication 790 for any area of study is crucial. Rethinking sustainability is necessary for the current SDGs of the 791 UN 2030 Agenda for Sustainable Development since they are not resilient enough towards the 792 shocks resulting from the pandemic (Ibn-Mohammed et al., 2021). And second, developing a measurement framework to efficiently assess the impacts of COVID-19 on the progress towards 793 794 sustainability pillars and sustainable development is highly required. Due to the recentness of 795 COVID-19, the lack of an adequate and effective measurement tool for sustainability monitoring 796 and assessment calls for conducting more research and investigations in the future.

4.2. Making the most of sustainability transition opportunities in the wake of COVID-19: focus on SDG 12 and SDG 9

799 As mentioned in previous sections, COVID-19 has provided some opportunities for sustainability transition and rethinking sustainability to create a more sustainable future in 800 801 different subject areas, such as urban transport system (Kanda and Kivimaa, 2020), and 802 sustainable energy transition (Kuzemko et al., 2020). In our opinion, there is no better time than 803 now to promote innovative sustainable consumption and production patterns within the sociotechnical regimes. In particular, the sustainability opportunities offered by COVID-19 to 804 SDG 12 (responsible consumption and production patterns), which ensure using the natural 805 environment and resources in a sustainable manner, need to be addressed for further research. In 806 807 this regard, we highly recommend carrying out empirical research on the potential of circular economy business models (Elliott et al., 2020), sharing economy platforms (Ranjbari et al., 808

2018), digitalization and digital sustainability (Pan and Zhang, 2020), and glocalization perspectives (Goffman, 2020) in increasing the resilience of the communities and mitigating the COVID-19 disruptive effects on sustainability in future. Moreover, the role of innovation and initiatives is significantly important to help sustainability policy-makers post COVID-19. Therefore, we recommend to seek new insight into fostering innovation processes and research and development units in a real world for building a resilient infrastructure and domestic technology development to support SDG 9 achievement.

4.3. Innovative solutions for economic resilience towards sustainability post COVID-19: focus on SDG 1, SDG 8, and SDG 17

COVID-19 has led the world to face the worst economic recession since the great 818 depression, as it has caused 400 million job losses in the second quarter of 2020, and the GDP 819 820 per capita is expected to decline by 4.2% in 2020 (UN, 2020c). Due to the severe economic 821 problems caused by this pandemic for societies, there is an urgent need for innovative proposals 822 to make economic resilience and support sustainable economic growth and decent work for all according to SDG 8. In this regard, contributing in the development of an economic recovery 823 824 plan is highly urgent, particularly with the focus on the following research avenues; (1) conducting evidence-based economic analysis for long-term and short-term recovery planning; 825 (2) initiatives to strengthen the local economy post COVID-19; and (3) policy intervention to 826 support small and medium enterprises. 827

828 This challenge is even more critical in developing and specially less developed countries, 829 which are more financially vulnerable. The achievement of SDG 8 and also SDG 1 (no poverty) has hardly been influenced by the COVID-19 implications. The global partnership among the 830 831 countries (SDG 17) to achieve UN's SDGs was taking place among various countries before the pandemic, and the aid to least-developed countries and Africa in 2019 experienced an increase of 832 833 2.6% and 1.3%, respectively, compared with the year 2018 (UN, 2020d). However, it is estimated that the 554 billion dollars of remittances to low- and middle-income countries in 2019 834 would decrease to 445 billion dollars in 2020, and the global foreign investment falls by up to 835 40% in 2020 due to the pandemic (UN, 2020d). Therefore, although almost all countries are 836 837 facing serious health and economic challenges in their own territories because of the pandemic, investigating practical solutions to support the partnerships specified in SDG 17 post COVID-19 838

is extremely encouraged to be the focus of future research to support less-developed anddeveloping countries move towards sustainable development.

4.4. In-depth analysis of the COVID-19 long-term effects on social sustainability: focus on SDG 4, SDG 5, and SDG 10

843 In general, social sustainability has not been paid as much attention as economic and environmental sustainability (Govindan et al., 2021; Yawar and Seuring, 2017). Besides, 844 845 according to the research conducted by Anisul Huq et al. (2014), most social sustainability 846 research has been conducted within the developed countries context rather than less-developed or 847 even developing countries. However, the social pillar was identified by Barreiro-Gen et al. (2020) as the main sustainability priority for organizations among three sustainability pillars 848 aftermath of the COVID-19 pandemic crisis. Additionally, in the instability caused by COVID-849 850 19, social pillar pushes environmental and economic pillars back based on the hierarchy of needs 851 (Rydzewski, 2020).

852 It is apparent that COVID-19, with its catastrophic implications for the global economy and business activities across the globe, has made social sustainability issues even more challenging. 853 854 Based on the results of our research, the literature lacks a comprehensive study to investigate the 855 long-term effects of COVID-19 on the social dimensions of sustainability towards sustainable 856 development specially in developing and less-developed countries. In particular, the following 857 three research gaps corresponding to SDG 4, SDG 5, and SDG 10 of the UN's SDGs need more research in the future. First, in line with SDG 4, the long-term sustainability effects of the 858 859 pandemic situation on the education system should be assessed in terms of (1) access of vulnerable children and youth to equitable education; and (2) quality of distance learning and its 860 861 future outcomes and challenges. Second, examining the potential mental distress and also the 862 psychological aspects of keeping away from many of regular social activities for children, as one 863 of the most vulnerable groups in societies, needs further research to evaluate the possible future impacts on different dimensions of social sustainability and SDG 10 achievement. And finally, 864 although gender inequalities and violence against women post COVID-19 have been highlighted 865 in some research (Gulati and Kelly, 2020; Vora et al., 2020), not many studies have addressed 866 867 the achievement of SDG 5 and its impact on other pillars of sustainability towards sustainable development. While women represent only 25% of the national parliament and 36% of the local 868

government in pandemic-related leadership roles, they are at the front lines of fighting COVID19 and represent 70% of the health and social workers during the pandemic period (UN, 2020e).
Such inequality requires extensive studies to evaluate its outcomes and the prospective effect on
the sustainability of societies.

873 4.5. Expanding quantitative research to harmonize COVID-19-related sustainability

874 research

875 As shown in Fig. 6, 88% of the research articles reviewed in our study adopted a qualitative 876 rather than a quantitative approach to provide analysis regarding the implications of COVID-19 877 for sustainability. As a result, the lack of quantitative methods in examining the COVID-19 crisis 878 and its impact on the environmental, social, and economic dimensions of human lives and 879 making projections on the future of world sustainability aftermath of COVID-19 are highly 880 visible. Employing quantitative methods to conduct more data-driven research and using real 881 data to provide an adequate and reliable assessment of the changes made to various aspects of 882 sustainability due to the pandemic is highly recommended for future research. In this regard, mathematical and statistical analysis and simulation models informed by real data can harmonize 883 884 the results of the research in this area.

885 In the other hand, referring to the WHO Director-General speech on 22 April 2020, COVID-19 will remain with us for a long time (UN, 2020f). Therefore, applying simulation models to 886 887 illustrate the consequences of various scenarios for a long period of time (Shams Esfandabadi et al., 2020) is of high importance. Examples of such simulation methods are System Dynamics and 888 889 agent-based modeling, the former based on the systems thinking approach, capturing causalities, and the latter based on the idea of modeling individuals and their interactions, to derive patterns 890 891 of behaviors. These models can simulate the future outcomes of taking different managerial 892 actions and changes over time, which supports decision making towards sustainability challenges 893 post COVID-19. Such simulation methods provide a ground for interdisciplinary analysis on the pandemic effects, to which researchers must pay more attention in future research of the 894 895 sustainability context.

896 **5.** Conclusion

897 The COVID-19 pandemic crisis, as the most serious health threat for the global community in 2020, has become the central issue of international concerns these days. A wide range of 898 businesses and industries such as healthcare systems, travel and tourism industry, food and 899 agriculture sectors, education system, energy, and mobility have been hardly hit by the 900 restrictions of this crisis worldwide. A tremendous amount of research has been conducted 901 within various subject areas to respond to the urgent call for action against the unprecedented 902 situation caused by the COVID-19 crisis for the global economy and societies during a short 903 period of time, leading to a fragmented literature. Our research has revisited and reviewed the 904 pandemic crisis implications for the sustainability of human lives, considering social, 905 environmental, and economic dimensions based on the TBL framework. A systematic approach 906 907 to review the literature adopted from Fink (2019) and Traxler et al. (2020) was employed to provide an inclusive insight into the three environmental, social, and economic pillars of 908 sustainability in the wake of COVID-19. The effects, challenges, and potential solutions based 909 on the TBL framework, for each pillar of sustainability including environmental and social, 910 911 different pairwise intersections of pillars including socio-economic and socio-environmental, and finally, the integration of all three pillars of sustainability, which refers to sustainable 912 913 development, were analyzed. As a result, an update of the current status of research on the TBL of sustainability considering the COVID-19 pandemic implications was presented through the 914 915 descriptive analysis of 49 research articles on the subject. Moreover, to highlight the COVID-19 effects on sustainability, the impacts of the pandemic outbreak on the sustainability dimensions 916 917 in different subject areas were synthesized and mapped for different intersections of the triple pillars through a thematic analysis. Consequently, some potential sustainability transition 918 919 opportunities post-COVID-19 for societies, such as low-carbon innovations to support the 920 climate change, promoting digitalization of the work, and sustainable mobility and energy transition were discussed. The results support governments, authorities, practitioners, and policy-921 922 makers to alleviate the negative impacts of the pandemic on the sustainable development and 923 catch the potential sustainability transition opportunities post COVID-19. At the end, future 924 research directions for sustainable development corresponding to the UN's SDGs considering 925 COVID-19 were proposed.

Our study had two limitations. Firstly, the present research focused on the academic literature 926 limited to WoS and Scopus as the main databases of the systematic literature review. The 927 928 research could be enriched by including approaches from grey literature, such as using 929 government reports, policy statements, and organizational deliverables. Due to the recentness of the COVID-19 crisis and the fragmented academic literature in its implications, conducting grey 930 931 literature to cover more insights on the sustainability practices is suggested to address this limitation and contribute to shape a more balanced picture of the available evidence. And 932 secondly, our analysis was conducted at the level of the TBL dimensions of sustainability 933 934 including environmental, social and economic pillars. More in-depth research on each one of these dimensions are required to investigate the cultural, operational, political, and technical 935 aspects of the sustainability in the wake of COVID-19, as well. 936

937 **References**

- Adelodun, B., Ajibade, F.O., Ibrahim, R.G., Bakare, H.O., Choi, K.S., 2020. Snowballing
 transmission of COVID-19 (SARS-CoV-2) through wastewater: Any sustainable preventive
 measures to curtail the scourge in low-income countries? Sci. Total Environ. 742, 140680.
 https://doi.org/10.1016/j.scitotenv.2020.140680
- AI-Youbi, A.O., Al-Hayani, A., Bardesi, H.J., Basheri, M., Lytras, M.D., Aljohani, N.R., 2020.
- The King Abdulaziz University (KAU) Pandemic Framework: A Methodological Approach
 to Leverage Social Media for the Sustainable Management of Higher Education in Crisis.
- 945 Sustainability 12, 4367. https://doi.org/10.3390/su12114367
- Alibegovic, M., Cavalli, L., Lizzi, G., Romani, I., Vergalli, S., 2020. COVID-19 & SDGs: Does
- 947 the current pandemic have an impact on the 17 Sustainable Development Goals? A948 qualitative analysis, FEEM BRIEF.
- 949 https://doi.org/https://www.feem.it/m/publications_pages/brief07-2020.pdf

Allen, C., Metternicht, G., Wiedmann, T., 2018. Initial progress in implementing the Sustainable

- 951 Development Goals (SDGs): a review of evidence from countries. Sustain. Sci. 13, 1453–
- 952 1467. https://doi.org/10.1007/s11625-018-0572-3
- Amankwah-Amoah, J., 2020. Stepping up and stepping out of COVID-19: New challenges for
- environmental sustainability policies in the global airline industry. J. Clean. Prod. 271,

- 955 123000. https://doi.org/10.1016/j.jclepro.2020.123000
- Anholon, R., Rampasso, I.S., Silva, D.A.L., Leal Filho, W., Quelhas, O.L.G., 2020. The COVID19 pandemic and the growing need to train engineers aligned to the sustainable
- development goals. Int. J. Sustain. High. Educ. ahead-of-p. https://doi.org/10.1108/IJSHE06-2020-0217
- Anisul Huq, F., Stevenson, M., Zorzini, M., 2014. Social sustainability in developing country
 suppliers. Int. J. Oper. Prod. Manag. 34, 610–638. https://doi.org/10.1108/IJOPM-10-2012-
- 962 0467
- Ashford, N.A., Hall, R.P., Arango-Quiroga, J., Metaxas, K.A., Showalter, A.L., 2020.
- Addressing Inequality: The First Step Beyond COVID-19 and Towards Sustainability.
 Sustainability 12, 5404. https://doi.org/10.3390/su12135404
- Bansal, S., Garg, I., Sharma, G., 2019. Social Entrepreneurship as a Path for Social Change and
 Driver of Sustainable Development: A Systematic Review and Research Agenda.
- 968 Sustainability 11, 1091. https://doi.org/10.3390/su11041091
- Barbier, E.B., Burgess, J.C., 2020. Sustainability and Development after COVID-19. World Dev.
 135, 105082. https://doi.org/10.1016/j.worlddev.2020.105082
- 971 Barcaccia, G., D'Agostino, V., Zotti, A., Cozzi, B., 2020. Impact of the SARS-CoV-2 on the
- 972 Italian Agri-Food Sector: An Analysis of the Quarter of Pandemic Lockdown and Clues for
- a Socio-Economic and Territorial Restart. Sustainability 12, 5651.
- 974 https://doi.org/10.3390/su12145651
- Barreiro-Gen, M., Lozano, R., Zafar, A., 2020. Changes in Sustainability Priorities in

Organisations due to the COVID-19 Outbreak: Averting Environmental Rebound Effects on
Society. Sustainability 12, 5031. https://doi.org/10.3390/su12125031

- Barua, S., 2020. Financing sustainable development goals: A review of challenges and mitigation
 strategies. Bus. Strateg. Dev. 3, 277–293. https://doi.org/10.1002/bsd2.94
- 980 Bascopé, M., Perasso, P., Reiss, K., 2019. Systematic Review of Education for Sustainable
- 981 Development at an Early Stage: Cornerstones and Pedagogical Approaches for Teacher
- 982 Professional Development. Sustainability 11, 719. https://doi.org/10.3390/su11030719
- 983 Bodenheimer, M., Leidenberger, J., 2020. COVID-19 as a window of opportunity for

- sustainability transitions? Narratives and communication strategies beyond the pandemic.
- 985 Sustain. Sci. Pract. Policy 16, 61–66. https://doi.org/10.1080/15487733.2020.1766318
- 986 Calabrese, A., Castaldi, C., Forte, G., Levialdi, N.G., 2018. Sustainability-oriented service
- 987 innovation: An emerging research field. J. Clean. Prod. 193, 533–548.
- 988 https://doi.org/10.1016/j.jclepro.2018.05.073
- 989 Chakraborty, I., Maity, P., 2020. COVID-19 outbreak: Migration, effects on society, global
- 990 environment and prevention. Sci. Total Environ. 728, 138882.
- 991 https://doi.org/10.1016/j.scitotenv.2020.138882
- 992 Chen, M., Jeronen, E., Wang, A., 2020. What Lies Behind Teaching and Learning Green
- 993 Chemistry to Promote Sustainability Education? A Literature Review. Int. J. Environ. Res.
- 994 Public Health 17, 7876. https://doi.org/10.3390/ijerph17217876
- Chiang, J., Hanna, A., Lebowitz, D., Ganti, L., 2020. Elastomeric respirators are safer and more
 sustainable alternatives to disposable N95 masks during the coronavirus outbreak. Int. J.
 Emerg. Med. 13, 1–5. https://doi.org/10.1186/s12245-020-00296-8
- 998 Christoffel, M.M., Gomes, A.L.M., Souza, T.V. de, Ciuffo, L.L., 2020. Children's (in)visibility
- in social vulnerability and the impact of the novel coronavirus (COVID-19). Rev. Bras.

1000 Enferm. 73, e20200302. https://doi.org/10.1590/0034-7167-2020-0302

- Cooper, J., Stamford, L., Azapagic, A., 2018. Social sustainability assessment of shale gas in the
 UK. Sustain. Prod. Consum. 14, 1–20. https://doi.org/10.1016/j.spc.2017.12.004
- 1003 Cooper, J.A., Alderman, D.H., 2020. Cancelling March Madness exposes opportunities for a
- 1004 more sustainable sports tourism economy. Tour. Geogr. 22, 525–535.
- 1005 https://doi.org/10.1080/14616688.2020.1759135
- 1006 Costa, D., Quinteiro, P., Dias, A.C., 2019. A systematic review of life cycle sustainability
- assessment: Current state, methodological challenges, and implementation issues. Sci. Total
 Environ. 686, 774–787. https://doi.org/10.1016/j.scitotenv.2019.05.435
- 1009 Cui, X., 2018. How can cities support sustainability: A bibliometric analysis of urban
- 1010 metabolism. Ecol. Indic. 93, 704–717. https://doi.org/10.1016/j.ecolind.2018.05.056
- 1011 El Bilali, H., 2019a. Research on agro-food sustainability transitions: A systematic review of
- research themes and an analysis of research gaps. J. Clean. Prod. 221, 353–364.

- 1013 https://doi.org/10.1016/j.jclepro.2019.02.232
- El Bilali, H., 2019b. Research on agro-food sustainability transitions: where are food security
 and nutrition? Food Secur. 11, 559–577. https://doi.org/10.1007/s12571-019-00922-1
- Elkington, J., 1998. Partnerships from Cannibals with forks: The triple bottom line of 21st
 century business. Environ. Qual. Manag. 8, 37–51.
- 1018 Elliott, R.J.R., Schumacher, I., Withagen, C., 2020. Suggestions for a Covid-19 Post-Pandemic
- 1019 Research Agenda in Environmental Economics. Environ. Resour. Econ. 76, 1187–1213.
 1020 https://doi.org/10.1007/s10640-020-00478-1
- 1021 Elsevier, 2020. How Scopus works: Information about Scopus product features [WWW
- Document]. URL https://www.elsevier.com/solutions/scopus/how-scopus-works (accessed
 8.23.20).
- 1024 EU, 2020. CALL NOTICE Feasibility assessment for an EU-wide Wastewater Monitoring
- 1025 System for SARS-CoV-2 Surveillance | EU Science Hub [WWW Document]. URL
- 1026 https://ec.europa.eu/jrc/en/science-update/call-notice-feasibility-assessment-eu-wide-
- 1027 wastewater-monitoring-system-sars-cov-2-surveillance (accessed 1.8.21).
- Fauzi, R.T., Lavoie, P., Sorelli, L., Heidari, M.D., Amor, B., 2019. Exploring the Current
 Challenges and Opportunities of Life Cycle Sustainability Assessment. Sustainability 11,
 636. https://doi.org/10.3390/su11030636
- Fink, A., 2019. Conducting research literature reviews: From the internet to paper, 5th ed. SAGE
 Publications Ltd.
- Fleetwood, J., 2020. Social Justice, Food Loss, and the Sustainable Development Goals in the
 Era of COVID-19. Sustainability 12, 5027. https://doi.org/10.3390/su12125027
- Freire-González, J., Font Vivanco, D., 2020. Pandemics and the Environmental Rebound Effect:
 Reflections from COVID-19. Environ. Resour. Econ. 1–4. https://doi.org/10.1007/s10640020-00448-7
- Galanakis, C.M., 2020. The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic
 Crisis. Foods 9, 523. https://doi.org/10.3390/foods9040523
- 1040 Galvani, A., Lew, A.A., Perez, M.S., Galvani, A., Lew, A.A., Sotelo, M., Covid-, P., 2020.

- 1041 COVID-19 is expanding global consciousness and the sustainability of travel and tourism.
- 1042 Tour. Geogr. 22, 567–576. https://doi.org/10.1080/14616688.2020.1760924
- Garcia-Torres, S., Albareda, L., Rey-Garcia, M., Seuring, S., 2019. Traceability for sustainability
 literature review and conceptual framework. Supply Chain Manag. An Int. J. 24, 85–106.
 https://doi.org/10.1108/SCM-04-2018-0152
- 1046 Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy A
- new sustainability paradigm? J. Clean. Prod. 143, 757–768.
- 1048 https://doi.org/10.1016/j.jclepro.2016.12.048
- General Assemly, 2015. Resolution adopted by the General Assembly on 1 September 2015,General Assebly, United Nations.
- Gimenez, C., Sierra, V., Rodon, J., 2012. Sustainable operations: Their impact on the triple
 bottom line. Int. J. Prod. Econ. 140, 149–159. https://doi.org/10.1016/j.ijpe.2012.01.035
- Gliedt, T., Hoicka, C.E., Jackson, N., 2018. Innovation intermediaries accelerating
 environmental sustainability transitions. J. Clean. Prod. 174, 1247–1261.
- 1055 https://doi.org/10.1016/j.jclepro.2017.11.054
- Goffman, E., 2020. In the wake of COVID-19, is glocalization our sustainability future? Sustain.
 Sci. Pract. Policy 16, 48–52. https://doi.org/10.1080/15487733.2020.1765678
- 1058 Govindan, K., Shaw, M., Majumdar, A., 2021. Social sustainability tensions in multi-tier supply
- chain: A systematic literature review towards conceptual framework development. J. Clean.
 Prod. 279, 123075. https://doi.org/10.1016/j.jclepro.2020.123075
- Grosseck, G., Ţîru, L.G., Bran, R.A., 2019. Education for Sustainable Development: Evolution
 and Perspectives: A Bibliometric Review of Research, 1992–2018. Sustainability 11, 6136.
 https://doi.org/10.3390/su11216136
- 1064 Gulati, G., Kelly, B.D., 2020. Domestic violence against women and the COVID-19 pandemic:
- 1065 What is the role of psychiatry? Int. J. Law Psychiatry 71, 101594.
- 1066 https://doi.org/10.1016/j.ijlp.2020.101594
- 1067 Hamilton, J., 2020. The Strategic Change Matrix and Business Sustainability across COVID-19.
- 1068 Sustainability 12, 6026. https://doi.org/10.3390/su12156026

- Hermann, R.R., Bossle, M.B., 2020. Bringing an entrepreneurial focus to sustainability
 education: A teaching framework based on content analysis. J. Clean. Prod. 246, 119038.
 https://doi.org/10.1016/j.jclepro.2019.119038
- 1072 Higgins-Desbiolles, F., 2020. The "war over tourism": challenges to sustainable tourism in the
- tourism academy after COVID-19. J. Sustain. Tour. 0, 1–19.
- 1074 https://doi.org/10.1080/09669582.2020.1803334
- 1075 Hong, H., Gasparatos, A., 2020. Eco-industrial parks in China: Key institutional aspects,
- 1076 sustainability impacts, and implementation challenges. J. Clean. Prod. 274, 122853.
- 1077 https://doi.org/10.1016/j.jclepro.2020.122853
- 1078 Ibn-Mohammed, T., Mustapha, K.B., Godsell, J., Adamu, Z., Babatunde, K.A., Akintade, D.D.,
- 1079 Acquaye, A., Fujii, H., Ndiaye, M.M., Yamoah, F.A., Koh, S.C.L., 2021. A critical analysis
- 1080 of the impacts of COVID-19 on the global economy and ecosystems and opportunities for
- 1081 circular economy strategies. Resour. Conserv. Recycl. 164, 105169.
- 1082 https://doi.org/10.1016/j.resconrec.2020.105169
- 1083 Illahi, U., Mir, M.S., 2020. Development of indices for sustainability of transportation systems:
- 1084 A review of state-of-the-art. Ecol. Indic. 118, 106760.
- 1085 https://doi.org/10.1016/j.ecolind.2020.106760
- 1086 Ioannides, D., Gyimóthy, S., 2020. The COVID-19 crisis as an opportunity for escaping the
- 1087 unsustainable global tourism path. Tour. Geogr. 22, 624–632.
- 1088 https://doi.org/10.1080/14616688.2020.1763445
- Iwuoha, J.C., Jude-Iwuoha, A.U., 2020. Covid-19: Challenge to SDG and Globalization.
 Electron. Res. J. Soc. Sci. Humanit. 2, 168–172.
- Iyengar, R., 2020. Education as the path to a sustainable recovery from COVID-19. Prospects 3–
 6. https://doi.org/10.1007/s11125-020-09488-9
- 1093 Janjua, S.Y., Sarker, P.K., Biswas, W.K., 2020. Development of triple bottom line indicators for
- life cycle sustainability assessment of residential bulidings. J. Environ. Manage. 264,
- 1095 110476. https://doi.org/10.1016/j.jenvman.2020.110476
- 1096 Kanda, W., Kivimaa, P., 2020. What opportunities could the COVID-19 outbreak offer for
- sustainability transitions research on electricity and mobility? Energy Res. Soc. Sci. 68,

- Kanger, L., Sovacool, B.K., Noorkõiv, M., 2020. Six policy intervention points for sustainability
 transitions: A conceptual framework and a systematic literature review. Res. Policy 49,
- 1101 104072. https://doi.org/10.1016/j.respol.2020.104072
- 1102 Kravchenko, M., Pigosso, D.C., McAloone, T.C., 2019. Towards the ex-ante sustainability
- screening of circular economy initiatives in manufacturing companies: Consolidation of
- leading sustainability-related performance indicators. J. Clean. Prod. 241, 118318.
- 1105 https://doi.org/10.1016/j.jclepro.2019.118318
- 1106 Kulkarni, B.N., Anantharama, V., 2020. Repercussions of COVID-19 pandemic on municipal
- solid waste management: Challenges and opportunities. Sci. Total Environ. 743, 140693.
 https://doi.org/10.1016/j.scitotenv.2020.140693
- Kuzemko, C., Bradshaw, M., Bridge, G., Goldthau, A., Jewell, J., Overland, I., Scholten, D., Van
 de Graaf, T., Westphal, K., 2020. Covid-19 and the politics of sustainable energy
 transitions. Energy Res. Soc. Sci. 68, 101685. https://doi.org/10.1016/j.erss.2020.101685
- 1112 Kwatra, S., Kumar, A., Sharma, P., 2020. A critical review of studies related to construction and
 1113 computation of Sustainable Development Indices. Ecol. Indic. 112, 106061.
- 1114 https://doi.org/10.1016/j.ecolind.2019.106061
- 1115 La, V., Pham, T., Ho, M., Nguyen, M., P. Nguyen, K.-L., Vuong, T.-T., Nguyen, H.-K.T., Tran,
- 1116 T., Khuc, Q., Ho, M.-T., Vuong, Q.-H., 2020. Policy Response, Social Media and Science
- 1117Journalism for the Sustainability of the Public Health System Amid the COVID-19

1118 Outbreak: The Vietnam Lessons. Sustainability 12, 2931.

- 1119 https://doi.org/10.3390/su12072931
- 1120 Lambert, H., Gupte, J., Fletcher, H., Hammond, L., Lowe, N., Pelling, M., Raina, N., Shahid, T.,
- 1121 Shanks, K., 2020. COVID-19 as a global challenge: towards an inclusive and sustainable
- 1122 future. Lancet Planet. Heal. 4, e312–e314. https://doi.org/10.1016/S2542-5196(20)30168-6
- 1123 Leal Filho, W., Brandli, L.L., Lange Salvia, A., Rayman-Bacchus, L., Platje, J., 2020. COVID-
- 1124 19 and the UN Sustainable Development Goals: Threat to Solidarity or an Opportunity?
- 1125 Sustainability 12, 5343. https://doi.org/10.3390/su12135343
- 1126 Lee, D., Kang, J., Kim, K., 2020. Global Collaboration Research Strategies for Sustainability in

^{1098 101666.} https://doi.org/10.1016/j.erss.2020.101666

- the Post COVID-19 Era: Analyzing Virology-Related National-Funded Projects.
- 1128 Sustainability 12, 6561. https://doi.org/10.3390/su12166561
- Markard, J., Rosenbloom, D., 2020. A tale of two crises: COVID-19 and climate. Sustain. Sci.
 Pract. Policy 16, 53–60. https://doi.org/10.1080/15487733.2020.1765679
- 1131 Mauree, D., Naboni, E., Coccolo, S., Perera, A.T.D., Nik, V.M., Scartezzini, J.-L., 2019. A
- review of assessment methods for the urban environment and its energy sustainability to
- 1133 guarantee climate adaptation of future cities. Renew. Sustain. Energy Rev. 112, 733–746.
- 1134 https://doi.org/10.1016/j.rser.2019.06.005
- 1135 Meng, Y., Yang, Y., Chung, H., Lee, P.-H., Shao, C., 2018. Enhancing Sustainability and Energy
- 1136 Efficiency in Smart Factories: A Review. Sustainability 10, 4779.
- 1137 https://doi.org/10.3390/su10124779
- 1138 Merino-Saum, A., Halla, P., Superti, V., Boesch, A., Binder, C.R., 2020. Indicators for urban
- sustainability: Key lessons from a systematic analysis of 67 measurement initiatives. Ecol.
 Indic. 119, 106879. https://doi.org/10.1016/j.ecolind.2020.106879
- 1141 Milanesi, M., Runfola, A., Guercini, S., 2020. Pharmaceutical industry riding the wave of
- sustainability: Review and opportunities for future research. J. Clean. Prod. 261, 121204.
 https://doi.org/10.1016/j.jclepro.2020.121204
- Mol, M.P.G., Caldas, S., 2020. Can the human coronavirus epidemic also spread through solid
 waste? Waste Manag. Res. 38, 485–486. https://doi.org/10.1177/0734242X20918312
- Munny, A.A., Ali, S.M., Kabir, G., Moktadir, M.A., Rahman, T., Mahtab, Z., 2019. Enablers of
 social sustainability in the supply chain: An example of footwear industry from an emerging
- 1148 economy. Sustain. Prod. Consum. 20, 230–242. https://doi.org/10.1016/j.spc.2019.07.003
- 1149 Nazari, M.T., Mazutti, J., Basso, L.G., Colla, L.M., Brandli, L., 2020. Biofuels and their
- 1150 connections with the sustainable development goals: a bibliometric and systematic review.
- 1151 Environ. Dev. Sustain. https://doi.org/10.1007/s10668-020-01110-4
- 1152 Nikulina, V., Simon, D., Ny, H., Baumann, H., 2019. Context-Adapted Urban Planning for
- 1153 Rapid Transitioning of Personal Mobility towards Sustainability: A Systematic Literature
- 1154 Review. Sustainability 11, 1007. https://doi.org/10.3390/su11041007
- 1155 Nunes, L.J.R., Meireles, C.I.R., Pinto Gomes, C.J., Almeida Ribeiro, N.M.C., 2019. Forest

- Management and Climate Change Mitigation: A Review on Carbon Cycle Flow Models for
 the Sustainability of Resources. Sustainability 11, 5276. https://doi.org/10.3390/su11195276
- 1158 O'Connor, C.M., Anoushiravani, A.A., DiCaprio, M.R., Healy, W.L., Iorio, R., 2020. Economic
- 1159 Recovery After the COVID-19 Pandemic: Resuming Elective Orthopedic Surgery and Total
 1160 Joint Arthroplasty. J. Arthroplasty 35, S32–S36. https://doi.org/10.1016/j.arth.2020.04.038
- 1161 Obrenovic, B., Du, J., Godinic, D., Tsoy, D., Khan, M.A.S., Jakhongirov, I., 2020. Sustaining
- 1162 Enterprise Operations and Productivity during the COVID-19 Pandemic: "Enterprise
- 1163 Effectiveness and Sustainability Model." Sustainability 12, 5981.
- 1164 https://doi.org/10.3390/su12155981
- Oláh, J., Aburumman, N., Popp, J., Khan, M.A., Haddad, H., Kitukutha, N., 2020. Impact of
 Industry 4.0 on Environmental Sustainability. Sustainability 12, 4674.
- 1167 https://doi.org/10.3390/su12114674
- Osingada, C.P., Porta, C.M., 2020. Nursing and Sustainable Development Goals (SDGs) in a
 COVID-19 world: The state of the science and a call for nursing to lead. Public Health
 Nurs. https://doi.org/10.1111/phn.12776
- 1171 Pan, S.L., Zhang, S., 2020. From fighting COVID-19 pandemic to tackling sustainable
- development goals: An opportunity for responsible information systems research. Int. J. Inf.
- 1173 Manage. 102196. https://doi.org/10.1016/j.ijinfomgt.2020.102196
- 1174 Paramashanti, B.A., 2020. Challenges for Indonesia Zero Hunger Agenda in the Context of
- 1175 COVID-19 Pandemic. Kesmas Natl. Public Heal. J. 15, 24–27.
- 1176 https://doi.org/10.21109/kesmas.v15i2.3934
- 1177 Pierantoni, I., Pierantozzi, M., Sargolini, M., 2020. COVID 19—A Qualitative Review for the
- 1178 Reorganization of Human Living Environments. Appl. Sci. 10, 5576.
- 1179 https://doi.org/10.3390/app10165576
- Pirlone, F., Spadaro, I., 2020. The resilient city and adapting to the health emergency. TeMAJournal L. Use, Mobil. Environ. https://doi.org/10.6092/1970-9870/6856
- 1182 Pulimeno, M., Piscitelli, P., Colazzo, S., Colao, A., Miani, A., 2020. Indoor air quality at school
- and students' performance: Recommendations of the UNESCO Chair on Health Education
- and Sustainable Development & amp; the Italian Society of Environmental Medicine

- 1185 (SIMA). Heal. Promot. Perspect. 10, 169–174. https://doi.org/10.34172/hpp.2020.29
- 1186 Rafi-Ul-Shan, P.M., Grant, D.B., Perry, P., Ahmed, S., 2018. Relationship between sustainability
 1187 and risk management in fashion supply chains. Int. J. Retail Distrib. Manag. 46, 466–486.
 1188 https://doi.org/10.1108/IJRDM-04-2017-0092
- 1189 Ramos, T.B., Caeiro, S., Disterheft, A., Mascarenhas, A., Deutz, P., Spangenberg, J.H.,
- 1190 Montaño, M., Olayide, O., Sohal, A., 2020. Rethinking sustainability: Questioning old
- 1191 perspectives and developing new ones. J. Clean. Prod. 258, 120769.
- 1192 https://doi.org/10.1016/j.jclepro.2020.120769
- 1193 Ranjbari, M., Morales-Alonso, G., Carrasco-Gallego, R., 2018. Conceptualizing the Sharing
- Economy through Presenting a Comprehensive Framework. Sustainability 10, 2336.
 https://doi.org/10.3390/su10072336
- 1196 Ranjbari, M., Morales-Alonso, G., Shams Esfandabadi, Z., Carrasco-Gallego, R., 2019.
- Sustainability and the Sharing Economy: Modelling the Interconnections. Dir. y Organ. 68,
 33–40. https://doi.org/10.37610/dyo.v0i68.549
- 1199 Rashed, A.H., Shah, A., 2020. The role of private sector in the implementation of sustainable
 1200 development goals. Environ. Dev. Sustain. https://doi.org/10.1007/s10668-020-00718-w
- 1201 Rodriguez, L.J., Peças, P., Carvalho, H., Orrego, C.E., 2020. A literature review on life cycle
- tools fostering holistic sustainability assessment: An application in biocomposite materials.
- 1203 J. Environ. Manage. 262, 110308. https://doi.org/10.1016/j.jenvman.2020.110308
- Romagosa, F., 2020. The COVID-19 crisis: Opportunities for sustainable and proximity tourism.
 Tour. Geogr. 22, 690–694. https://doi.org/10.1080/14616688.2020.1763447
- 1206 Rowan, N.J., Galanakis, C.M., 2020. Unlocking challenges and opportunities presented by
- 1207 COVID-19 pandemic for cross-cutting disruption in agri-food and green deal innovations:
- 1208 Quo Vadis? Sci. Total Environ. 748, 141362.
- 1209 https://doi.org/10.1016/j.scitotenv.2020.141362
- 1210 Roy, S., Das, M., Ali, S.M., Raihan, A.S., Paul, S.K., Kabir, G., 2020. Evaluating strategies for
- 1211 environmental sustainability in a supply chain of an emerging economy. J. Clean. Prod. 262,
- 1212 121389. https://doi.org/10.1016/j.jclepro.2020.121389
- 1213 Ryan, B.J., Coppola, D., Canyon, D. V., Brickhouse, M., Swienton, R., 2020. COVID-19

- 1214 Community Stabilization and Sustainability Framework: An Integration of the Maslow
- 1215 Hierarchy of Needs and Social Determinants of Health. Disaster Med. Public Health Prep.
- 1216 1–7. https://doi.org/10.1017/dmp.2020.109
- 1217 Rydzewski, P., 2020. Between Economy and Security . Dilemmas of Sustainable Development
 1218 in the Covid-19 Era an Example of Great Britain. Probl. Sustain. Dev. 15.
- 1219 Sakamoto, M., Begum, S., Ahmed, T., 2020. Vulnerabilities to COVID-19 in Bangladesh and a
- 1220 Reconsideration of Sustainable Development Goals. Sustainability 12, 5296.
 1221 https://doi.org/10.3390/su12135296
- 1222 Sansaniwal, S.K., 2019. Advances and challenges in solar-powered wastewater treatment
- 1223 technologies for sustainable development: a comprehensive review. Int. J. Ambient Energy
- 1224 0, 1–34. https://doi.org/10.1080/01430750.2019.1682038
- 1225 Shams Esfandabadi, Z., Ravina, M., Diana, M., Zanetti, M.C., 2020. Conceptualizing
- environmental effects of carsharing services: A system thinking approach. Sci. Total
 Environ. 745, 141169. https://doi.org/10.1016/j.scitotenv.2020.141169
- Sharma, V., De Beni, D., Sachs Robertson, A., Maurizio, F., 2020. Why the Promotion of Family
 Planning Makes More Sense Now Than Ever Before? J. Health Manag. 22, 206–214.
 https://doi.org/10.1177/0972063420935545
- 1231 Sherman, J.D., Thiel, C., MacNeill, A., Eckelman, M.J., Dubrow, R., Hopf, H., Lagasse, R.,
- 1232 Bialowitz, J., Costello, A., Forbes, M., Stancliffe, R., Anastas, P., Anderko, L., Baratz, M.,
- 1233 Barna, S., Bhatnagar, U., Burnham, J., Cai, Y., Cassels-Brown, A., Cimprich, A.F.P., Cole,
- 1234 H., Coronado-Garcia, L., Duane, B., Grisotti, G., Hartwell, A., Kumar, V., Kurth, A.,
- 1235 Leapman, M., Morris, D.S., Overcash, M., Parvatker, A.G., Pencheon, D., Pollard, A.,
- 1236 Robaire, B., Rockne, K., Sadler, B.L., Schenk, B., Sethi, T., Sussman, L.S., Thompson, J.,
- 1237 Twomey, J.M., Vermund, S.H., Vukelich, D., Wasim, N., Wilson, D., Young, S.B.,
- 1238 Zimmerman, J., Bilec, M.M., 2020. The Green Print: Advancement of Environmental
- 1239 Sustainability in Healthcare. Resour. Conserv. Recycl. 161, 104882.
- 1240 https://doi.org/10.1016/j.resconrec.2020.104882
- Shittu, O., 2020. Emerging sustainability concerns and policy implications of urban household
 consumption: A systematic literature review. J. Clean. Prod. 246, 119034.

- 1243 https://doi.org/10.1016/j.jclepro.2019.119034
- Silva, J. da, Fernandes, V., Limont, M., Rauen, W.B., 2020. Sustainable development assessment
 from a capitals perspective: Analytical structure and indicator selection criteria. J. Environ.
 Manage. 260, 110147. https://doi.org/10.1016/j.jenvman.2020.110147
- 1247 SMART WASTE, 2020. COVID-19 and municipal waste management | Interreg Europe [WWW
- 1248 Document]. URL https://www.interregeurope.eu/smartwaste/news/news-article/8127/covid-
- 1249 19-and-municipal-waste-management/ (accessed 10.1.20).
- 1250 Somani, M., Srivastava, A.N., Gummadivalli, S.K., Sharma, A., 2020. Indirect implications of
- 1251 COVID-19 towards sustainable environment: An investigation in Indian context. Bioresour.
- 1252 Technol. Reports 11, 100491. https://doi.org/10.1016/j.biteb.2020.100491
- 1253 Sovacool, B.K., Furszyfer Del Rio, D., Griffiths, S., 2020. Contextualizing the Covid-19
- 1254 pandemic for a carbon-constrained world: Insights for sustainability transitions, energy
- justice, and research methodology. Energy Res. Soc. Sci. 68, 101701.
- 1256 https://doi.org/10.1016/j.erss.2020.101701
- 1257 Thürer, M., Tomašević, I., Stevenson, M., Qu, T., Huisingh, D., 2018. A systematic review of
- the literature on integrating sustainability into engineering curricula. J. Clean. Prod. 181,

1259 608–617. https://doi.org/10.1016/j.jclepro.2017.12.130

- 1260 Tran, T., Hoang, A.-D., Nguyen, Y.-C., Nguyen, L.-C., Ta, N.-T., Pham, Q.-H., Pham, C.-X., Le,
- 1261 Q.-A., Dinh, V.-H., Nguyen, T.-T., 2020. Toward Sustainable Learning during School
- 1262 Suspension: Socioeconomic, Occupational Aspirations, and Learning Behavior of

1263 Vietnamese Students during COVID-19. Sustainability 12, 4195.

- 1264 https://doi.org/10.3390/su12104195
- 1265 Traxler, A.A., Schrack, D., Greiling, D., 2020. Sustainability Reporting and Management
- 1266 Control A Systematic Exploratory Literature Review. J. Clean. Prod. 276, 122725.
- 1267 https://doi.org/10.1016/j.jclepro.2020.122725
- 1268 Turkson, C., Acquaye, A., Liu, W., Papadopoulos, T., 2020. Sustainability assessment of energy
- 1269 production: A critical review of methods, measures and issues. J. Environ. Manage. 264,
- 1270 110464. https://doi.org/10.1016/j.jenvman.2020.110464
- 1271 UN, 2020a. Education United Nations Sustainable Development [WWW Document]. URL

- 1272 https://www.un.org/sustainabledevelopment/education/ (accessed 10.3.20).
- 1273 UN, 2020b. Goal 2: Zero Hunger United Nations Sustainable Development [WWW
- 1274 Document]. URL https://www.un.org/sustainabledevelopment/hunger/ (accessed 10.4.20).
- UN, 2020c. Goal 8 | Department of Economic and Social Affairs [WWW Document]. URL
 https://sdgs.un.org/goals/goal8 (accessed 1.6.21).
- UN, 2020d. Goal 17 | Department of Economic and Social Affairs [WWW Document]. URL
 https://sdgs.un.org/goals/goal17 (accessed 10.10.20).
- UN, 2020e. Goal 5 | Department of Economic and Social Affairs [WWW Document]. URL
 https://sdgs.un.org/goals/goal5 (accessed 10.10.20).
- 1281 UN, 2020f. WHO Director-General's opening remarks at the media briefing on COVID-19 22

April 2020 [WWW Document]. URL https://www.who.int/dg/speeches/detail/who-director general-s-opening-remarks-at-the-media-briefing-on-covid-19--22-april-2020 (accessed
 10.10.20).

- Van der Waal, J.W.H., Thijssens, T., 2020. Corporate involvement in Sustainable Development
 Goals: Exploring the territory. J. Clean. Prod. 252, 119625.
- 1287 https://doi.org/10.1016/j.jclepro.2019.119625
- 1288 Vanapalli, K.R., Sharma, H.B., Ranjan, V.P., Samal, B., Bhattacharya, J., Dubey, B.K., Goel, S.,
- 1289 2021. Challenges and strategies for effective plastic waste management during and post
- 1290 COVID-19 pandemic. Sci. Total Environ. 750, 141514.
- 1291 https://doi.org/10.1016/j.scitotenv.2020.141514
- Verma, P., Raghubanshi, A.S., 2018. Urban sustainability indicators: Challenges and
 opportunities. Ecol. Indic. 93, 282–291. https://doi.org/10.1016/j.ecolind.2018.05.007
- Vora, M., Malathesh, B.C., Das, S., Chatterjee, S.S., 2020. COVID-19 and domestic violence
 against women. Asian J. Psychiatr. 53, 102227. https://doi.org/10.1016/j.ajp.2020.102227
- Weed, M., 2020. The role of the interface of sport and tourism in the response to the COVID-19
 pandemic. J. Sport Tour. 0, 1–14. https://doi.org/10.1080/14775085.2020.1794351
- 1298 Wells, P., Abouarghoub, W., Pettit, S., Beresford, A., 2020. A socio-technical transitions
- 1299 perspective for assessing future sustainability following the COVID-19 pandemic. Sustain.

1300	Sci. Pract. Policy 16, 29-36. https://doi.org/10.1080/15487733.2020.1763002
1301	WHO, 2020a. WHO Director-General's opening remarks at the media briefing on COVID-19 -
1302	11 March 2020 [WWW Document]. URL https://www.who.int/dg/speeches/detail/who-
1303	director-general-s-opening-remarks-at-the-media-briefing-on-covid-1911-march-2020
1304	(accessed 10.7.20).
1305	WHO, 2020b. WHO Coronavirus Disease (COVID-19) Dashboard WHO Coronavirus Disease
1306	(COVID-19) Dashboard [WWW Document]. URL https://covid19.who.int/ (accessed
1307	12.20.20).
1308	WHO, 2020c. WHO Coronavirus Disease (COVID-19) Dashboard WHO Coronavirus Disease
1309	(COVID-19) Dashboard [WWW Document]. URL https://covid19.who.int/ (accessed
1310	10.4.20).
1311	WoS, 2020. Web of Science [v.5.35] - Web of Science Core Collection Basic Search [WWW
1312	Document]. URL
1313	https://apps.webofknowledge.com/WOS_GeneralSearch_input.do?product=WOS&search_
1314	$mode = GeneralSearch \& SID = D3 Khouw Kkl9zyyS3 CUU \& preferencesSaved = (accessed) \\ (accesse$
1315	8.23.20).
1316	Yawar, S.A., Seuring, S., 2017. Management of Social Issues in Supply Chains: A Literature
1317	Review Exploring Social Issues, Actions and Performance Outcomes. J. Bus. Ethics 141,
1318	621-643. https://doi.org/10.1007/s10551-015-2719-9
1319	Yu, D.E.C., Razon, L.F., Tan, R.R., 2020. Can global pharmaceutical supply chains scale up
1320	sustainably for the COVID-19 crisis? Resour. Conserv. Recycl. 159, 104868.
1321	https://doi.org/10.1016/j.resconrec.2020.104868
1322	Zhang, X., Chen, N., Sheng, H., Ip, C., Yang, L., Chen, Y., Sang, Z., Tadesse, T., Lim, T.P.Y.,
1323	Rajabifard, A., Bueti, C., Zeng, L., Wardlow, B., Wang, S., Tang, S., Xiong, Z., Li, D.,
1324	Niyogi, D., 2019. Urban drought challenge to 2030 sustainable development goals. Sci.
1325	Total Environ. 693, 133536. https://doi.org/10.1016/j.scitotenv.2019.07.342
1326	Zhu, Q., Krikke, H., 2020. Managing a Sustainable and Resilient Perishable Food Supply Chain
1327	(PFSC) after an Outbreak. Sustainability 12, 5004. https://doi.org/10.3390/su12125004
1328	