Engineering Response to COVID-19: A Reference List for Low- Resource Settings

A report by Engineering for Change, LLC

1 July 2020

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Engineering Response to COVID-19: An Overview

Engineering response to the novel coronavirus (COVID-19) pandemic is pivotal in devising new technologies and solutions to mitigate negative health outcomes worldwide. In low-resource settings, the availability and suitability of technology and engineered solutions are especially pressing. In this report, we categorize and identify best practices, standards, guidelines, and insights related to technology use during the COVID-19 response in low-resource settings. The document is intended to serve as a reference for technologists in current and future pandemic responses. Over 170 resources are categorized into 21 tables, which are organized under six overarching areas: (1) Standards for all medical devices, (2) Transmission mitigation, (3) Diagnostic technologies, (4) Management and treatment technologies, (5) Maintenance and optimization of existing technologies, and (6) Environmental health and safety. In the full report, each resource is categorized by name, publisher, type, audience, and purpose.

The document begins with a number of consensus standards and regulations that are fundamental for all medical devices discussed in subsequent sections. Notably, various medical device standards are being enforced via US-FDA Emergency Use Authorizations due to the emergency nature of the COVID-19 crisis.

Transmission mitigation measures include maintaining hand hygiene, social distancing norms, and use of Personal Protective Equipment (PPE), such as masks, gowns, goggles, aprons, and gloves. Local preparedness for maintaining hand hygiene involves water, sanitation, waste management, and consumables such as soap and dispensers. Institutions, such as the U.S CDC and UNHCR provide guidelines for washing hands and maintaining hygiene in healthcare settings. The WHO and UNICEF provide recommendations for local manufacturing of soap to be used in low-resource settings. There is also an increase in the number of deployed sanitizer dispensers at the entry and the exit of the buildings in use. Contraptions such as pedal powered wash basins and automatic sanitizer dispensers are developed and distributed in institutional settings, government offices, and public places that are functional after the lockdown relaxation.

Furthermore, transmission mitigation measures include social distance and contact tracing. The U.S CDC provides guidelines on maintaining social distance in a variety of public settings. Evidence of successful contact tracing programs can be found in some countries, such as South Korea, where mobile information, GPS, and credit-card transactions were used for contract tracing and supported the control of the virus across the country. Notably, there are no technological standards related to contact tracing or social distancing recommendations, with the exception of “2 arms’ length distance” recommended by the WHO. Occupational health and safety guidelines from various countries currently do not mention the use of PPE for the prevention of disease spreading, however the WHO and CDC has laid guidelines on best practices for the at-home manufacturing, wearing, and washing of masks during the pandemic. There are few standards and regulations specific to face shields, and almost no public guidelines on their use. Public health organizations continue to recommend that healthcare workers use respirators with at least a N95 or FFP2 filter grade in clinical settings with COVID-19 patients. PPEs such as goggles, aprons, and gowns are less common compared to face shields and masks in the global COVID-19 response and no guidelines regarding their use have been published nor have design and manufacturing initiatives been formed. Unlike other PPE kits and equipment, there are no community makerspace groups dedicated to glove manufacturing likely due to the complexity of glove manufacturing especially the rubber processing that is required.

Diagnostic technologies for COVID-19 are limited to viral tests and antibody tests. Most diagnostic tests use polymerase chain reaction machines (PCR). However, many studies have been conducted to enable testing even in a low-resource environment including information and communication technology (ICT) diagnostics and artificial intelligence (AI) diagnostics. Research is underway to use AI to configure lung ultrasound detecting specific patterns and diagnose the patients through image analysis. A number of self-diagnostic solutions through the mobile phone applications such as Aarogya Setu (India) and telehealth programs, are in use in resource constrained settings.

Management and treatment technologies such as oxygen therapy devices, which includes ventilators, are included in the

WHO's List of Priority Medical Devices for COVID-19 and primarily required for severely ill and critical patients. International standards and guidelines for technical specifications and enforcement policies for the adoption and fabrication of different types of oxygen therapy devices have been issued for the COVID-19 response by entities such as the WHO, AAMI, MHRA, APSF, and US-FDA. International standards are available related to oxygen concentrators, non-invasive ventilators, invasive ventilators and their related oxygen delivery devices such as masks and nasal cannula. The WHO has also issued an interim guidance of the technical specifications for invasive and non-invasive ventilators for COVID-19.

A number of multilateral and national regulatory bodies have published guidelines for managing long-term use of existing medical devices, and how to reuse disposable products including masks thus maintaining and optimizing the existing system. Guidelines provided by WHO ensure that health care workers create their own checklists to maintain their technologies. Many organizations including WHO, PAHO, and the ministries like MoHFW give guidelines and training materials to doctors, volunteers, researchers, and others associated with COVID-19 .

Waste management is one of the pivotal factors to decelerate the rapid spread of COVID-19. WHO, United States Department of Labor, CDC, and the European Commission provide guidelines and training materials to manage highly contagious waste according to the level of the waste risk. Cleaning and disinfection guidelines issued by UNICEF and USFDA instructs the workers to wear skin protection and eye protection against potential splash hazards and adequate ventilation is required.

Overview of Taxonomy

Categorization term	Definitions and taxonomy
Name and publishing unit	The full name of the resource is included and linked to the source. Below the name of the publishing organization is included.
Type of resource	Regulations & standards: all laws, rules, regulations applicable to development, manufacturing, marketing, labeling, purchase, reimbursement, pricing, and/or servicing of any products. Specifications: a set of documented design requirements to be satisfied in the design and implementation of a product or service. Guidelines: a list of suggested requirements, recommendations, strategies, or advice for a product or service with the goal to improve the overall quality of outcomes. Training materials: Coursework, instructions, or other materials used to train or educate users on a product, service, or process. Viewpoint: Expert views and insights. Community: Online groups or communities aiming to transfer resources related to technology, standards, and guidelines.
Audience	The intended audience of the resource is categorized (e.g., health care workers, manufacturers, etc.).
Purpose	A list of keywords and phrases related to the resource's goals and objectives are listed.

List of acronyms:

AACN	American Association of Critical-Care Nurses
AAMI	Association for the Advancement of Medical Instrumentation
ANSI	American National Standards Institute
AARC	American Association for Respiratory Care
ASA-APSF	American Society of Anesthesiologists and the Anesthesia Patient Safety Foundation
ASTM	American Society for Testing and Materials
BSI	British Standards Institute
CAWST	Centre for Affordable Water and Sanitation Technology (Canada)
CDC	Centers for Disease Control & Prevention
CEN	European Committee for Standardization
CHEST	American Association of Chest Physicians
EC	European Commission
EU	European Union
FCC	Federal Communications Commission
ISEA	International Safety Equipment Association
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
JAMA	The Journal of the American Medical Association
MHRA	Medicines & Healthcare products Regulatory Agency (UK)
MoHFW	Ministry of Health and Family Welfare (India)
NCDC	National Centre for Disease Control (India)
NIOSH	National Institute for Occupational Safety and Health
OECD	Organization for Economic Cooperation and Development
PAHO	Pan American Health Organization
SCCM	Society of Critical Care Medicine
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
US-FDA	U.S. Food and Drug Administration
WHO	World Health Organization
WEDC	Wisconsin Economic Development Corporation

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Standards for All Medical Devices

There are many standards and regulations for medical devices since they are directly connected to human life. ISO provides many standards for medical devices that manufacturers and designers must conform to throughout all stages of product development. ISO standards include requirements related to risk management, quality management systems, and electrical safety standards for medical devices. However, ISO does not perform certifications. In order to use a medical device in a specific geographic location, it must be certified by the appropriate regulatory body such as the US-FDA. Further, the US-FDA provides regulations on emergency use authorizations of medical devices during public health emergencies such as COVID-19. Further, US-FDA and WHO provide regulations and guidelines for managing and manufacturing medical devices. Specific to COVID-19, the WHO has published lists of resources that reference various international and American standards and technical specifications for medical devices specific to the surveillance, prevention and management of COVID-19.

Table 1. Standards applicable to all medical devices.

Name and publishing unit	Type of resource	Audience	Purpose
COVID-19 Emergency Use Authorizations for Medical Devices US-FDA	Regulations & standards	Healthcare workers	Information about emergency approval requirements of various diagnostic and therapeutic medical devices during COVID-19 emergency.
Medical electrical equipment: General requirements for basic safety and essential performance IEC 60601-1-12:2015	Regulations & standards	Healthcare workers, manufacturers	Requirements for medical equipment and medical electrical systems.
Medical devices — Quality management systems — Requirements for regulatory purposes ISO 13485:2016	Regulations & standards	Healthcare workers, manufacturers	Guide how to process for managing risks associated with medical devices.
Medical devices - application of risk management ISO 14971:2019	Regulations & standards	Manufacturers	Basic principles to manage risks associated with medical devices.
Medical devices - symbols to be used with medical device labels, labelling and information to be supplied ISO 15223:2016	Regulations & standards	Healthcare workers	Safe and proper use of medical devices.
Sterilization of health care products ISO 11137-3:2017	Regulations & standards	Healthcare workers, manufacturers	Guidance on dose measurement aspects of development, verification and routine management.
Packaging for terminally sterilized medical devices ISO 11607-1:2019	Regulations & standards	Designers, manufacturers	Specifies requirements for materials, packaging systems for terminally sterilized medical devices.
Biological evaluation of medical devices ISO 10993-1:2018	Regulations & standards	Manufacturers	International and national standards and guidelines for biological evaluation of medical devices.

21 CFR Part 820 USFDA	Regulations & standards	Designers, manufacturer	Standard for developing, marketing, manufacturing, labeling, servicing and using a medical device to ensure safety and efficacy
Decontamination and Reprocessing of Medical Devices for Health-Care Facilities WHO	Guidelines	Healthcare workers, manufacturers	Guidelines for sterilization and decontamination of medical devices
Technical Considerations of Additive Manufactured Medical Devices US-FDA	Guidelines	Industry, food, and drug administration staff	Guideline of design and manufacturing considerations and device testing considerations
Disease commodity package - Novel Coronavirus (COVID-19) WHO	Regulations & Standards, Specifications	Health care professionals	List of medical devices and associated standards and technical specifications related to surveillance, prevention and control, or case management of COVID-19.

Transmission Mitigation: Infection Prevention and Control Technologies

Hand Hygiene

Hand hygiene refers to the local preparedness in maintaining hygiene involving water, sanitation, waste management, and consumables like soap and dispensers. The institutes like CDC and UNHCR provide guidelines on how to wash hands and maintain hygiene in the healthcare settings, particularly for COVID-19 response. WHO as well as UNICEF has laid the foundation on local manufacturing of soap to be used in low-resource settings. Further, a number of case studies in low resource settings on previous pandemics can set an example for the current situation. A trend is observed in deploying sanitizer dispensers at the entry and the exit of the buildings in use. Contraptions like pedal powered wash basins and automatic sanitizer dispensers are developed and distributed. It has become a norm to see someone pouring a small amount of sanitizer in the palm of the hands when entering places like institutional settings, government offices, and public places that are functional after the lockdown relaxation. Moreover, these settings have big hoardings sharing the instructions and procedures to be followed while entering or exiting the building. Local manufacturers of soap and sanitizers are helping to combat the shortages. Research institutes like IITs in India have allowed the technicians and students from the chemical engineering or related departments to prepare hand sanitizers in bulk while following the guidelines and standards laid by the government.

Table 2. Engineering and technology related resources for Hand Hygiene.

Name and publishing unit	Type of resource	Audience	Purpose
Guide to local production: WHO-recommended Handrub Formulations WHO	Guidelines	General public	Guide to local production of soap
Water, sanitation, hygiene and waste management for COVID-19 WHO	Guidelines	Healthcare workers	Interim guidance
Guidelines on Hygiene and Healthcare WHO	Guidelines	Healthcare workers	Review of hand hygiene in health care
CDC Guidance for Healthcare providers about Hand Hygiene and COVID-19 US CDC	Guidelines	Healthcare workers	Review of hand hygiene in health care, specifically for COVID-19
UNHCR Technical WASH Guidance for COVID-19 Preparedness and Response UNHCR	Guidelines	Workers in refugee settings	Water, Sanitation and Hygiene [WASH] activities for refugee settings
UNICEF Fact Sheet: Handwashing Stations and Supplies for the COVID-19 response UNICEF	Training materials	Policy makers	Available designs for hand washing stations
UNICEF India Covid-19 Handwashing with soap (HWWS) facilities: Compendium of Indicative Layouts, Designs and Cost Estimates UNICEF	Specifications	Implementers	Handwashing Stations, design and cost estimates

Center for Disease Control (CDC) Tippy Taps Guidelines U.S CDC	Guidelines	Medical professionals	Handbook for handwashing stations
Guide to Local Production: WHO-recommended Handrub Formulations WHO	Guidelines	Local public	Hand cleaning supplies, local production
WEDC guide for local soap making WEDC	Training materials	Healthcare workers	Hand cleaning supplies, information and instruction
CAWST Soap Making Fact Sheet CAWST	Specifications	General public	Hand cleaning supplies, fact sheet
Interim Guidance Supplement on Water, Sanitation, Hygiene and Waste Management for COVID-19 (WHO) WHO	Guidelines	General public	Hand hygiene recommendations and guidance
Guidelines on Hand Hygiene and Healthcare (WHO) WHO	Guidelines	General public	Hand hygiene recommendations

Social Distancing and Related Alternatives

It is well known that social distancing reduces the spread of the COVID-19 virus, and many international organizations countries have recommended distancing 2 arms' length, or 6 feet, for their citizens. When a person coughs, sneezes or speaks, they may sprinkle a small drop of liquid in the nose or mouth containing the virus. The CDC guides people on how to properly use social distance in a variety of settings. If people are close to each other, people can inhale the drops that might include the COVID-19 virus. To understand spread, contract training is used for evaluating and managing people who have been exposed to the disease to prevent transmission. Since the start of COVID-19, solutions for contact tracing have been on the rise. Specifically, in South Korea, mobile information, GPS and credit-card transactions were used for contract tracing and supported the control of the virus across the county. Notably, there are no technological standards related to contact tracing or social distancing recommendations. Rather, the recommendations and guidelines are focused on social behavior. It describes the essential elements that should be in contact tracing, and there is a training material for what people in different locations should do. Technologies and rules for various contact tracings are also important, but non-false personal information and cooperation are also important.

Table 3. Recommendations and Guidelines for Social Distancing, Contact Tracing, and Related Alternatives.

Name and publishing unit	Type of resource	Audience	Purpose
Coronavirus disease (COVID-19) advice for the public WHO	Guidelines	General public	Social distance guidelines for general public
CDC guidelines for social distancing U.S CDC	Guidelines	General public	Social distance guidelines for general public
Considerations for quarantine of individuals in the context of	Guidelines	General public	Guidelines of social distancing for quarantine measures for individuals

containment for coronavirus disease WHO			
Surveillance strategies for COVID-19 human infection WHO	Guidelines	Health departments and ministries	Introduce overview of surveillance strategies and comprehensive national surveillance for COVID-19
Contact tracing in the context of COVID-19 WHO	Guidelines	Health departments and ministries	Suggests concepts and details on contact tracing
Digital tools for contact tracing WHO	Guidelines	Health departments and ministries	Introduce critical elements in the implementation of contact tracing digital tools
Ethical considerations to guide the use of digital proximity tracking technologies for COVID-19 contact tracing WHO	Guidelines	Health departments and ministries	Provides guidance on the ethical and appropriate use of digital proximity tracking technologies for COVID-19
CDC guidelines on contact tracing U.S CDC	Guidelines	Health departments and ministries	Suggests concepts and details on contact tracing and case investigation.
Health Departments: Interim guidance on developing a COVID-19 case investigation & contact tracing plan U.S CDC	Guidelines	Health departments and ministries	Suggests concepts and details on contact tracing and case investigation.
Case Investigation and Contact Tracing : Part of a Multipronged Approach to Fight the COVID-19 Pandemic U.S CDC	Guidelines	Health departments and ministries	Guide basic principles of case investigation and contact tracing to prevent COVID-19 transmission.
CDC training materials & guidelines for contact tracer U.S CDC	Training materials	Contact tracers, Health departments and ministries	Sample training plan including training topics to consider when designing contact tracing
CDC training materials & guidelines for case investigator U.S CDC	Training materials	Case investigators	Guidelines for those who interview COVID-19 patients and gather information on their recent close contacts.
CDC training materials & guidelines for team leader U.S CDC	Training materials	Team leader	Training materials on contact tracing to contact tracer, case investigators, team leaders.
Guidance on Contact Tracing for COVID-19 Pandemic Africa CDC	Guidelines	Health departments and ministries	Guide for contact tracing

COVID-19 Contact Tracing Protocol for African Union Staff Africa CDC	Guidelines	African Union staffs, Health departments and ministries	Instructions on the steps to follow contact tracing.
Protocol for Enhanced Severe Acute Respiratory Illness and Influenza-Like Illness Surveillance for COVID-19 in Africa Africa CDC	Guidelines	African Union staffs, Health departments and ministries	Introduce the status of the pandemic and inform Africa's response
How Korea responded to a pandemic using ICT The government of the Republic of Korea	Guidelines	Health departments and ministries	Examples of social distancing and contact tracing from Korea

Personal Protective Equipment (PPE)

This section includes resources related to PPE recommended by the WHO in their List of Priority Medical Devices for COVID-19: medical/surgical masks, respirators, face shields, protective goggles, surgical gowns/isolation gowns, aprons, and gloves. There are a wide variety of resources discussing PPE. The WHO and the CDC have published guidelines and lists of resources related to the development, distribution, and use of PPE specific to the prevention of disease such as COVID-19. Occupational health and safety guidelines from various countries currently do not mention the use of PPE for the prevention of disease spreading, however this will likely change in future iterations of these guidelines. Guidelines on the reuse of face masks and respirators have increased in count and detail since the outbreak of COVID-19, however standard practices are yet to have been formed. Although face shields are now widely adopted across healthcare settings and homemade 3D printed face shields are being widely accepted by health facilities as donations, there are few standards and regulations specific to face shields, and almost no public guidelines on their use.

Table 4. Engineering and technology related resources for all types of PPE.

Name and publishing unit	Type of resource	Audience	Purpose
21 CFR 878.4040 US-FDA	Regulations & standards	Designers and manufacturers	Requirements for surgical apparel
ASTM Standards & COVID-19 ASTM	Regulations & standards	Manufacturers, test labs, health care workers, general public	ASTM standards in the context of COVID-19 for masks, medical gowns, gloves, hand sanitizers, respirators, and thermometers.
COUNCIL DIRECTIVE 93/42/EEC of 14 June 1993 concerning medical devices EU	Regulations & standards	Policy makers	Medical devices on the European market and movement of devices within Europe.
PPE Regulation 2016/425 Category III EU	Regulations & standards	Designers and manufacturers	Requirements for the design and manufacture of personal protective equipment which is to be made available on the market.
Guidance for the Selection and Use of Personal Protective Equipment	Guidelines	Health care professionals,	Guidelines for the selection and use of PPE in healthcare settings.

(PPE) in Healthcare Settings U.S CDC		general public, lab workers	
Rational use of personal protective equipment for coronavirus disease 2019 (COVID-19) WHO	Guidelines	General public, healthcare workers	Recommendations for the use of PPE in healthcare and community settings, as well as handling the cargo.
Guidelines for the Use of Personal Protective Equipment Hong Kong Occupational Health and Safety Council	Guidelines	General public in the workforce	PPE guidelines for the prevention of workplace injuries.
Appropriate Use of Various Types of PPE All India Institute of Medical Sciences	Guidelines	Healthcare workers	India, guidelines on the appropriate use of various types of PPE in a healthcare setting.
User Guidance - Essential Technical Requirements for Personal Protective Equipment UK Government	Guidelines	Designers, manufacturers, suppliers, distributors	Process for those wanting to support the pandemic relief with products that do not meet CE guidelines or make alternative use of CE guidelines.
COVID-19 Guidance on Use of Personal Protective Equipment for Different Clinical Settings and Activities Africa CDC	Guidelines	Health care workers	Guidelines for required PPE usage for COVID-19 response in Africa.
Reuse Working Group Mass General Brigham	Community	Designers, manufacturers	Community for the reuse of supplies for COVID-19
Open Source COVID 19 Medical Supplies Facebook Group	Community	Designers, manufacturers	Open source group on Facebook with the purpose of discussing designs and manufacturing of medical supplies for the COVID-19 epidemic.

Table 5. Engineering and technology related resources for medical/surgical masks.

The shortage of medical and surgical mask supply for medical care and general public use as well as their effectiveness in reducing spread of the virus have sparked large amounts of innovation in this field. In addition to the well established standards and regulations regarding medical and surgical face masks, several international and national organizations have released guidelines on best practices for the at-home manufacturing, wearing, and washing of fabric face masks.

Name and publishing unit	Type of resource	Audience	Purpose
Medical face masks - Requirements and test methods BSI 14683:2014	Regulations & standards	Mask designers and manufacturers	Specifications for construction, design, performance requirements, and test methods for medical face masks.
Use of Cloth Face Coverings to Help Slow the Spread of COVID-19 U.S CDC	Guidelines	General public	Guidelines for the manufacturing, wearing, and washing of cloth face coverings.

Advice on the use of masks in the context of COVID-19 WHO	Guidelines	General public, health care workers	Advice on the use of masks in communities, home care, and in health care settings in areas of reported COVID-19.
ASTM F2100: Standard Specification for Performance of Materials Used in Medical Face Masks ASTM	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of medical face masks.
Surgical Masks Working Group Mass General Brigham	Community	Designers, manufacturers	Community for surgical masks for COVID-19 response.

Table 6. Engineering and technology related resources for respirators.

Unlike face masks, respirators must follow stricter regulations and cannot yet be manufactured in non-specialized facilities. Public health organizations continue to recommend that healthcare workers use respirators with at least a N95 or FFP2 filter grade in clinical settings with COVID-19 patients. However, this may soon change thanks to an increasing number of working groups around the world tasked with developing new designs and manufacturing methods for respirators. In addition, national organizations have posted guidelines on extending use of respirators in an effort to address the current global shortage. Recommendations state that the N95 mask can be reused when there is a little contact and discarded if it is contaminated with blood, respiratory or nasal secretions, or other bodily fluids from patients. N-95 respirators should also be discarded when a person has been in close contact with an infected patient. There are not currently any standards about the reuse of respirators.

Name and publishing unit	**Type of resource**	**Audience**	**Purpose**
42 CFR Part 84 NIOSH	Regulations & standards	Designers and manufacturers	Requirements for approval of respiratory protective devices
Medical face masks - Requirements and test methods BSI 14683:2014	Regulations & standards	Designers and manufacturers	Specifications for construction, design, performance requirements, and test methods for medical face masks. European standard.
NIOSH-Approved Particulate Filtering Facepiece Respirators U.S CDC	Guidelines	General public, workforce	List of NIOSH-approved particulate filtering facepiece respirators.
Decontamination and Reuse of Filtering Facepiece Respirators U.S CDC	Guidelines	Healthcare workers	Summary of research about decontamination of filtering facepiece respirators (FFRs) before reuse.
Recommended Guidance for Extended Use and Limited Reuse of N95 Filtering Facepiece Respirators in Healthcare Settings U.S CDC	Guidelines	Professionals who manage respiratory protection programs.	Guidelines for extending the use of N95 masks.
Approved Respirator Standards U.S CDC	Regulations & standards	Manufacturers, designers, distributors	Powered air purifying respirators (PAPRs), includes link to updated regulation and standards for PAPRs, links to required tests for

			certain types of PAPR
EN 149:2001+A1:2009 CEN	Regulations & standards	Manufacturers, designers, distributors	Minimum requirements for filtering half masks as respiratory protective devices to protect against particles. Laboratory and practical performance tests are included for the assessment of compliance with the requirements.

Table 7. Engineering and technology related resources for face shields.

Face shields and larger stationary shields are becoming more common in medical care and public environments. Maker communities around the world have largely focused on the local production of face shields because they can be easily manufactured with 3D printing technologies. This is likely the case because of the relative ease of manufacturing of face shields, the low number of parts, and the lack of requirements for specific material grade to be used in face shield supports. There is interestingly a lack of standards for face shield performance, evaluation, and use. Rather, this field is occupied with guidelines, most of which have only emerged within the last couple of months, and so best practices for their use are still in process.

Name and publishing unit	Type of resource	Audience	Purpose
EN 166 personal Eye Protection European Standard Eodi Wear	Regulations & standards	General public, manufacturers, designers	Technical industrial safety norm in Europe for eye protection applying to all types of individual protection of the eye. Minimum required safety certification for eyewear PPE.
Eye and Face Protection ANSI Z87.1-2020 Standard	Standards	Manufacturers, designers, producers	Prescribes the design, performance specifications, and marking of safety eye and face products.
Moving Personal Protective Equipment into the Community JAMA Network	Viewpoint	General public, researchers	Viewpoint on the effectiveness of using face shields to restrict spread of viral viruses.
COVID-19 Face Shields Program Design that matters (Innovation for Social Enterprise) and Spark Health Design	Guidelines	Manufacturer, designer	Summary of guidelines and regulations surround face shields and eye protection.
Face Shields Group Mass General Brigham	Community	Designers, manufacturers	Community for designs of face shields for the COVID-19 response.

Table 8. Engineering and technology related resources for protective goggles.

Goggles are less commonly used than face shields in the context of the COVID-19 pandemic. As such, only standards about goggle manufacturing and design are published, no guidelines regarding their use for COVID-19 have been published nor have design and manufacturing initiatives formed.

Name and publishing unit	Type of resource	Audience	Purpose
EN 166 personal Eye Protection European Standard Eodi Wear	Regulations & standards	General public, manufacturers, designers	Technical industrial safety norm in Europe for eye protection applying to all types of individual protection of the eye. Minimum required safety certification for eyewear PPE.
ANSI/ISEA Z87.1-2020 Standard ANSI	Regulations & standards	Manufacturers, designers, producers	Prescribes the design, performance specifications, and marking of safety eye and face products.
AS/NZS 1337.1 Australian Standards	Regulations & standards	Manufacturers, distributors, designers	Minimum requirements for non-prescription eye and face protectors from flying particles, splashing materials, fragments, dust, harmful gases.

Table 9. Engineering and technology related resources for surgical gowns/isolation gowns.

Surgical gowns are primarily used in medical care environments. There are several standards regarding their design and manufacturing methods. Due to their nature of being disposable, published guidelines largely focus on optimizing the use of gowns. Furthermore, community design and manufacturing groups have formed to address the large demand.

Name and publishing unit	Type of resource	Audience	Purpose
ASTM Standards & COVID-19 ASTM	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gowns
EU PPE Regulation 2016/425 EC	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gowns
EU MDD Directive 93/42/EEC EC	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gowns
Medical Gowns USFDA	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gowns
NIOSH Personal Protective Equipment (ANSI/AAMI PB70) U.S CDC	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gowns
Technical Specifications UK Government	Specifications	Manufacturer, designer, distributor, Care Providers	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gowns

Strategies for Optimizing the Supply of Isolation Gowns U.S CDC	Guidelines	Health Departments, Healthcare Workers, Clinics/Hospitals	Guidelines for the use of gowns in crisis capacity and optimizing the supply of gowns in healthcare settings
Full Body Protection Working Group Mass General Brigham	Community	Designers, manufacturers	Community for gowns and protection equipment for COVID-19 response.

Table 10. Engineering and technology related resources for aprons.

Similar to gowns, aprons are primarily used by staff in medical care facilities, but they are less commonly used in the COVID-19 pandemic likely because they offer less protection than gowns. As such, standards for apron design and manufacturing are the primary resource that exist and no guidelines or community makerspace groups specific to the COVID-19 pandemic have been formed.

Name and publishing unit	Type of resource	Audience	Purpose
EN ISO 13688 ISO	Standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of protective clothing, including aprons
EN 14126-B CEN	Standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of protective clothing, including aprons
Protective Clothing and Medical Devices A technical guide for clothing manufacturers of garments for medical use BSI	Standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of protective clothing, including aprons
ASTM Standards & COVID-19 ASTM	Standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE
Technical Specifications for Personal Protective Equipment (PPE) UK government	Guidelines	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including aprons

Table 11. Engineering and technology related resources for gloves.

Due to the versatility and diversity of glove usage among different industries, there are many standards concerning their design, manufacturing, and performance testing. There have been an increasing number of guidelines published since the start of the global pandemic concerning optimizing glove usage and selection of gloves. There are no guidelines regarding glove usage by the general public, for example, in situations like grocery stores and restaurants in regards to virus

containment. Furthermore, there are no community makerspace groups dedicated to glove manufacturing likely due to the complexity of glove manufacturing especially the rubber processing that is required.

Name and publishing unit	Type of resource	Audience	Purpose
HM Government: Technical Specifications for PPE	Specifications	Manufacturer, designer, distributor	Technical requirements for PPE including gloves, which do not have a CE mark.
Guidance for the Selection and Use of PPE in Healthcare Settings U.S CDC	Guidelines	Healthcare workers	Guidelines for selecting PPE, including gloves, for health care workers providing care
EU MDD directive 93/42/EEC Category III Emergo by UL	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of medical devices
EU PPE Regulation 2016/425 EC	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of PPE, including gloves
ANSI/ISEA 105-2016 Hand Protection Classification ISEA	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of hand protection
ASTM D6319 - 19 Standard Specification for Nitrile Examination Gloves for Medical Application ASTM	Regulations & standards	Manufacturer, designer, distributor	Classifications, performance requirements, and test methods for materials used in the construction of nitrile gloves
Strategies for Optimizing the Supply of Disposable Medical Gloves U.S CDC	Guidelines	Health Departments, Healthcare Workers, Clinics/Hospitals	Guidelines for the use of gloves in crisis capacity and optimizing the supply of gloves in healthcare settings
When to wear gloves U.S CDC	Guidelines	Healthcare workers, general public	Guidelines for the use of gloves in various health and public settings.

Diagnostic Technologies

ICT Diagnostic Technologies

Viral tests and antibody tests are two major types of diagnostic tests for COVID-19. A viral test diagnoses a current infection, and an antibody test confirms a previous infection. Both are very important diagnostic tests to identify COVID-19 cases and understand spread. Most diagnostic tests use polymerase chain reaction machines (PCR). However, many studies have been conducted to enable testing even in a low-resource environment including information and

communication technology (ICT) diagnostics and AI diagnostics. Information and communications technologies (ICT) including big data and artificial intelligence (AI) allowing the use of research resources on global online platforms can help companies develop diagnostic solutions faster and more efficiently. AI can quickly recognize and analyze big data and enable more accurate decision-making. One potential application of AI technology is lung ultrasound. Self-diagnostic through apps and telehealth programs can also diagnose COVID-19 indirectly.

Table 12. Engineering and technology related resources for ICT Diagnostic Technologies (e.g., AI diagnostics).

Name and publishing unit	Type of resource	Audience	Purpose
Guidance on Apps supporting the fight against COVID 19 pandemic in relation to data protection European Union	Guidelines	Manufacturers, designers, app developers	Features and requirements which apps for data analytics and processing should meet.
Rapid Diagnostic Tests For COVID-19 FIND	Guidelines	Manufacturers, designers	Importance role of antigen or antibody and its rapid diagnostic tests
Guidance on interpreting covid-19 test results U.S White House	Guidelines	General public	Guide interpretation and recommended action within result of viral testing and antibody testing
Testing for COVID-19: A way to lift confinement restrictions OECD	Guidelines	Manufacturers, designers	Explains the role of testing for COVID-19 while waiting for cure and vaccine.
How Korea responded to a pandemic using ICT- Flattening the curve on COVID-19 The Republic of Korea	Guidelines	Health departments and ministries	Guideline of social distancing, contact tracing, treatment using ICT in Korea
Proposal for International Standardization of the Use of Lung Ultrasound for Patients With COVID -19 Journal of Ultrasound in Medicine	Viewpoint	Manufacturers, designers	Propose standardized approach to optimize the use of lung ultrasound in patients with COVID-19.
Diagnostics Direct to Customer Working Group Mass General Brigham	Community	Designers, manufacturers	Community for diagnostics resources for COVID-19 response.
COVID-19 Telehealth Program FCC	Guidelines	General public	Guidelines of telehealth program which gives services to patent at home

Management and Treatment Technologies

Oxygen Therapy Devices

Medical oxygen has become a primary treatment for severely ill and critical COVID-19 patients. To provide this treatment, oxygen therapy devices are needed for oxygen distribution, oxygen regulation and conditioning, and oxygen delivery and patient monitoring. This section includes resources related to oxygen therapy devices recommended by the WHO in their List of Priority Medical Devices for COVID-19: oxygen concentrators for oxygen distribution; flowmeter, non-invasive and invasive ventilators for oxygen regulation and conditioning; nasal cannula, masks, tubing, nasal catheter and high-flow nasal cannula for oxygen delivery; and pulse oximeters for patient monitoring. Resources include technical specifications, guidelines, and enforcement policies for the adoption and fabrication of different types of oxygen therapy devices in the context of COVID-19; issued by entities such as the WHO, AAMI, MHRA, APSF, and the US-FDA. Resources also include international standards related to oxygen concentrators, non-invasive ventilators, invasive ventilators, and their related oxygen delivery devices such as masks and nasal cannula.

At the secondary and tertiary levels of the health system, invasive critical care ventilators and non-invasive ventilators, mainly continuous positive airway pressure (CPAP), bilevel positive airway pressure (BiPAP) and high-flow oxygen systems, have been recommended as essential equipment to treat COVID-19 patients. *Table 15 and 16* include resources on ventilator systems. WHO created an interim guidance of the technical specifications for invasive and non-invasive ventilators for COVID-19. This document includes the minimum requirements these devices must comply with and important procurement considerations such as trained personnel and infrastructure requirements for safe use. Shortages of ventilators worldwide and their high prices in conjunction with the widespread use of digital modeling and manufacturing technologies have made governments resort to locally and rapidly manufactured ventilators. In addition to the well-established standards and regulations regarding ventilators, several international and national organizations have released technical specifications and guidelines for rapidly manufactured and repurposed ventilator systems.

The need for rapidly manufactured and high-quality medical grade equipment has brought together a global community of engineers, manufacturers, physicians, regulators and others. Several online community groups focused on developing open-source ventilator designs have surfaced, global innovation challenges have been launched that aim to select low-cost ventilator designs based on previously established technical requirements, and diverse open-source emergency use ventilator projects have been started that aim to share key specifications and experimental protocols for use by the greater online maker community. Any design developed by engineers, makers, or small medical device companies must comply with medical device regulations on electrical safety, clinical efficacy, electro-magnetic compatibility, biocompatibility, risk mitigation and sterilization (refer to table 1 for more information on some of these standards). Currently, many countries do not provide guidelines on the specifications required for these devices. National health regulating authorities should distribute explicit certification requirements for the design and manufacturing of ventilators and authorities need to make sure the developers of these technologies have a clear understanding of the test protocols approved by the regulating entity.

Table 13. Engineering and technology related resources for all types of oxygen therapy devices.

Name and publishing unit	Type of resource	Audience	Purpose
Enforcement Policy for Ventilators and Accessories and Other Respiratory Devices During the COVID-19 Public Health Emergency USFDA	Regulations & standards	Manufacturers	Enforcement Policy to help expand the availability of ventilators and other respiratory devices during COVID-19.
Clinical Management of Severe Acute Respiratory Infection (SARI) when COVID-19 Disease is Suspected WHO	Guidelines	Healthcare workers	Considerations for the clinical management of COVID-19 patients.

Clinical Care for Severe Acute Respiratory Infection: Toolkit WHO	Guidelines	Healthcare workers	Toolkit for clinicians working in intensive care units in low-and-middle income countries, managing adult and paediatric patients with SARI.
Technical Specifications for Invasive and Non-Invasive Ventilators for COVID-19: Interim Guidance WHO	Specifications	Health departments and ministries, Health facility administrators, Manufacturers	Minimum requirements that invasive and non-invasive ventilators must comply with when used for COVID-19 patients.
Oxygen sources and distribution for COVID-19 treatment centres: Interim Guidance WHO	Guidelines	Health departments and ministries, Health facility administrators, Healthcare workers	Guidelines on how to quantify oxygen demand, identify oxygen sources that are available, and select appropriate surge sources to manage COVID-19 patients in low-and-middle income countries.
Oxygen Delivery Toolkit PATH	Guidelines	Decision-makers, Health departments and ministries, Healthcare workers	Provides materials to help plan, manage, communicate the value of scaling up oxygen delivery systems and access to oxygen and pulse oximetry.
Oxygen System Planning Tool UNICEF	Guidelines	Health departments and ministries, Health facility administrators	Provides guidelines on how to plan an oxygen supply system from the oxygen source to the patient delivery device, at the national, subnational or health facility level.
Guidelines for Cleaning and Disinfection of Respiratory Equipment WHO	Guidelines	Health departments and ministries, Health facility administrators	Guidelines for cleaning and disinfection of respiratory equipment.
Vocabulary and Semantics of Lung Ventilators and Related Equipment - ISO 19223:2019	Regulations & standards	Manufacturers, Healthcare workers	Standardized vocabulary applicable to lung ventilators practice.
Biocompatibility evaluation of breathing gas pathways in healthcare applications ISO 18562	Regulations & standards	Manufacturers, Health departments and ministries	Tests for emissions of volatile organic compounds, particulate matter, and leachables in condensate.
Guidance on the Selection of the Appropriate Means of Ventilation based on the Intended Patient, Use Environment, and Operator ISO/TR 21954:2018	Guidelines	Health departments and ministries, Health administrators, Manufacturers	Criteria about the intended patient, intended use environment, and intended operator across the spectrum of the types of ventilation-related equipment.

Anaesthetic and Respiratory Equipment - Compatibility with Oxygen ISO 15001	Regulations & standards	Manufacturers	Requirements for the oxygen compatibility of materials, components and devices for anaesthetic and respiratory applications.
Open Source COVID 19 Medical Supplies Facebook Group	Community	Designers, manufacturers	Open source group on Facebook with the purpose of discussing designs and manufacturing of medical supplies for the COVID-19 epidemic.

Table 14. Engineering and technology related resources for basic oxygen therapy equipment.

To treat COVID-19 patients at the primary level of the health system, Basic Oxygen Therapy equipment needs to be procured. The WHO-UNICEF technical specifications and guidance for oxygen therapy devices details product specification for a wide range of products for delivering basic oxygen therapy and provides guidance on their selection, procurement, use and maintenance. In the context of COVID-19, this equipment includes oxygen concentrators/and or oxygen gas cylinders, flowmeters, bubble humidifiers, nasal cannulas/masks/tubing and finger-tip pulse oximeters. Flowmeters are required as a separate device only when using oxygen gas cylinders as the source since oxygen-concentrators have built-in flowmeters. Pulse oximeters need to be prioritized in primary and secondary level health care facilities. During intensive or emergency care settings, these devices can provide constant monitoring of the patient's oxygen saturation levels which are necessary for healthcare workers to identify when a patient needs oxygen therapy and measure the ongoing success of the therapy.

Name and publishing unit	Type of resource	Audience	Purpose
Technical Specifications and Guidance for Oxygen Therapy Devices 2019 WHO, UNICEF	Specifications	Health departments and ministries, Health facility administrators, Manufacturers	Product specifications of products for delivering basic oxygen therapy, and guidance for their selection, procurement, use and maintenance.
Technical Specifications for Oxygen Concentrators WHO	Specifications	Health departments and ministries, Health facility administrators, Manufacturers	Product specifications of oxygen concentrators, and guidance for their selection, procurement, use and maintenance.
Pulse Oximeter COVID-19 Decision Making Tool Lifebox & ALIMA	Viewpoint	Healthcare workers	Guidance for healthcare workers in low-resource settings working with patients with respiratory compromise and suspected or confirmed COVID-19.
Pulse Oximetry Training Manual WHO	Viewpoint	Healthcare workers	Introduces how oximeters work and how to use them.
Particular Requirements for Basic Safety and Essential Performance of Oxygen Concentrator Equipment ISO 80601-2-69	Regulations & standards	Manufacturers	Requirements for the performance of an oxygen concentrator in combination with its accessories.

Table 15. Engineering and technology related resources for invasive ventilators.
This table includes resources on patient ventilators for intensive care units and patient ventilators for transport/mass-casualty care. Invasive ventilators require well-trained medical staff to perform the intubation and to manage the pressure setting controls and alarms. These devices should only be used in settings with high-pressure oxygen or air sources, controlled temperature and humidity, and well-trained technical staff to perform troubleshooting protocols, maintenance, and decontamination procedures.

Name and publishing unit	Type of resource	Audience	Purpose
Technical Specifications for Invasive and Non-Invasive Ventilators for COVID-19: Interim Guidance WHO	Specifications	Health departments and ministries, Health facility administrators, Manufacturers	Minimum requirements that invasive and non-invasive ventilators must comply with when used for COVID-19 patients.
End User Disclosures for Emergency Use Ventilators (EUVs) AAMI CR502:2020	Regulations & standards	Manufacturers	Guidance on the safe and effective emergency-use of ventilators.
Emergency Use Ventilator (EUV) Design Guidance AAMI CR501:2020	Regulations & standards	Manufacturers	Guidance on the rapid development of emergency-use of ventilators.
End User Disclosures for Emergency Use Resuscitator Systems AAMI CR504:2020	Regulations & standards	Manufacturers	Guidance on the safe and effective emergency-use of resuscitators.
Emergency Use Resuscitator Systems Design Guidance AAMI CR503:2020	Regulations & standards	Manufacturers	Guidance on the rapid development of emergency-use of resuscitators..
Rapidly Manufactured Ventilator System (RVMS) Medicines & Healthcare products Regulatory Agency (UK)	Specifications	Manufacturers	Specifications of the minimally clinically acceptable ventilator to be used in UK hospitals during COVID-19 pandemic.
Guidance on Purposing Anesthesia Machines as ICU Ventilators ASA-APSF	Guidelines	Health departments and ministries, Health facility administrators, Manufacturers	Guidance on using anesthesia ventilators safely as ICU ventilators.
Quick Reference: Setup and Monitoring Instructions - Anesthesia Machines as an ICU Ventilator ASA-APSF	Guidelines	Health departments and ministries, Health facility administrators, Manufacturers	Quick reference guide on setting up, monitoring and maintaining anesthesia ventilators as ICU ventilators.
Medtronic Open Source Ventilator Design Specifications Medtronic	Specifications	Manufacturers	Design specifications for the Puritan Bennet 560 (PB560) Medtronic ventilator.

Key Ventilation Specifications MIT	Specifications	Manufacturers	Minimum set of controllable parameters and recommended ranges to assist COVID-19 patients with mechanical ventilation.
Joint Statement on Multiple Patients per Ventilator SCCM, AARC, ASA-ASPF, AACN, and CHEST	Guidelines	Health departments and ministries, Health facility administrators, Manufacturers	Statement on the issue of placing multiple patients who have respiratory failure on a single ventilator.
Particular Requirements for Basic Safety and Essential Performance of Critical Care Ventilators ISO 80601-2-12:2020	Regulations & standards	Manufacturers	Requirements for Critical Care Ventilators intended for use in Healthcare Facilities.
Particular Requirements for Basic Safety and Essential Performance of Gas-powered Emergency Resuscitators ISO 10651-5:2006	Regulations & standards	Manufacturers	Requirements for equipment used as a controlled ventilation alternative to mouth-to-mouth resuscitation.
Particular Requirements for Emergency and Transport Resuscitators ISO 10651-3:1997	Regulations & standards	Manufacturers	Requirements for portable lung ventilators designed for use in emergency situations and transport.
Ventilators Working Group Mass General Brigham	Community	Designers, manufacturers	Community for ventilators for COVID-19 response.
Open Source Ventilator	Community	Designers, manufacturers	Community for ventilators for COVID-19 response.
OpenLung	Community	Designers, manufacturers	Community for ventilators for COVID-19 response.
Code Life Ventilator Challenge Montreal General Hospital Foundation & Research Institute of the McGill University Health Centre (MUHC)	Community	Designers, manufacturers	Community intended to design a low-cost ventilator for COVID-19 response.

Table 16. Engineering and technology related resources for non-invasive ventilators
Includes: continuous positive air pressure (CPAP); bi-level positive airway pressure (BiPAP or BPAP); high flow nasal cannula, heated humidified high-flow (HHHF) therapy or high-flow nasal oxygen (HFNO); and bag valve mask ventilation. Non-invasive ventilators avoid intubation and are easier to use than invasive ventilators once the right interface is applied. These devices require health workers to take infection control measures to reduce the risk of becoming infected with COVID-19 by the generation of aerosols. Non-invasive ventilator designs should include filters in the design to reduce the amount of aerosol released.

Name and publishing unit	Type of resource	Audience	Purpose
Technical Specifications for Invasive and Non-Invasive Ventilators for COVID-19: Interim Guidance WHO	Specifications	Health departments and ministries, Health facility administrators, Manufacturers	Minimum requirements that invasive and non-invasive ventilators must comply with when used for COVID-19 patients.
Emergency Use CPAP/BiPAP Design Guidance AAMI CR505:2020	Regulations & standards	Manufacturers	Guidance on the rapid development of emergency-use of CPAP/BiPAP machines.
End User Disclosures for CPAP/BiPAP AAMI CR506:2020	Regulations & standards	Manufacturers	Guidance on the safe and effective emergency-use of CPAP/BiPAP machines..
Rapidly Manufactured CPAP System (RMCPAPS) Medicines & Healthcare products Regulatory Agency (UK)	Specifications	Manufacturers	Specifications of the minimally clinically acceptable CPAP system to be used in UK hospitals during COVID-19 pandemic.
Sleep Apnoea Breathing Therapy - Masks and Application Accessories Sleep Apnea Breathing Therapy ISO 17510:2015	Regulations & standards	Manufacturers	Basic safety and essential performance requirement for masks and other application accessories needed when using sleep apnoea breathing therapy devices.
Particular Requirements for Basic Safety and Essential Performance of Sleep Apnoea Breathing Therapy Equipment ISO 80601-2-70:2015	Regulations & standards	Manufacturers	Requirements for sleep apnoea breathing therapy devices for patient use.
Particular Requirements for Basic Safety and Essential Performance of Respiratory Humidifying Equipment ISO 80601-2-74:2017	Regulations & standards	Manufacturers	Requirements for respiratory humidifying equipment intended for use on patients in the home healthcare environment and in healthcare facilities.

Table 17. Engineering and technology related resources for oxygen delivery devices.
Includes: nasal cannula; nasal catheter; and oxygen masks.

Name and publishing unit	Type of resource	Audience	Purpose
Anaesthetic and Respiratory - Breathing Sets and Connectors ISO 5367:2014	Regulations & standards	Manufacturers	Requirements for breathing sets and breathing tubes intended to be used with anaesthetic breathing systems, ventilator breathing systems, humidifiers and nebulizers.
Low Flow Nasal Cannulae for Oxygen Therapy ISO/DIS 23368	Regulations & standards	Manufacturers	Requirements for low flow nasal cannulae intended for use in home healthcare and in healthcare facilities.
Sleep Apnoea Breathing Therapy - Masks and Application Accessories Sleep Apnea Breathing Therapy ISO 17510:2015	Regulations & standards	Manufacturers	Basic safety and essential performance requirement for masks and other application accessories needed when using sleep apnoea breathing therapy devices.

Maintenance and Optimization of Existing Systems

Maintenance and repair of existing technologies

It is very important to manage and reuse medical devices and equipment, particularly when supply chains and resources are unstable. At the minimum, appropriate documentation and training processes are required for use of any device or equipment. A variety of multilateral and national regulatory bodies have published guidelines for managing long-term use of existing medical devices, and how to reuse disposable products including masks. The list of priority resources associated with essential services must be developed or coordinated from the existing list, and the plan should be executed with a full emergency response. Health care workers should create their own checklists according to the guidelines provided by each hospital, national organizations or WHO to maintain their technologies. Also, it is recommended to wear appropriate PPE is essential when handling equipment, including medical devices, for long-term maintenance.

Table 18. Engineering and technology related resources for Maintenance and Repair of Existing Technologies

Name and publishing unit	Type of resource	Audience	Purpose
Operational guidance for maintaining essential health services during an outbreak WHO	Guidelines	Health facility administrators	Guidelines and process for maintaining essential health services during COVID
Wearing and removing Personal Protective Equipment [part D] NCDC, India	Guidelines	Health facility administrators, general public	Guidelines of wearing and removing Personal Protective Equipment
Clinical management of severe acute respiratory infection when COVID-19 is suspected WHO	Guidelines	Health facility administrators	Clinical Management and Laboratory Diagnosis of COIVD19

Technical Capacity Building

Many organizations including WHO, Pan American Health Organization (PAHO), and ministry of health from many other countries are working to educate and provide resources to biomedical technicians working to overcome COVID-19. Training materials include various standards and guidelines to manage COVID-19. WHO provides learning resources for health care workers, decision makers and the general public about prevention to COVID-19, how to use PPE, and how to diagnose in six languages. MoHFW gives guidelines and training materials to doctors, volunteers, researchers, and others associated with COVID-19 . Further, PAHO and Engineering World Health provide training material to the general public as well as COVID-19 related workers.

Table 19. Engineering and technology related resources for Technical Capacity Building.

Name and publishing unit	Type of resource	Audience	Purpose
Severe acute respiratory infections treatment centre: practical manual to set up and manage a SARI treatment centre and a SARI screening facility in health care facilities WHO	Guidelines	Health care workers, biomedical technicians	Manual to set up and manage a severe acute respiratory infections(SARI) treatment center

Responding to COVID-19 : Real-time training for the coronavirus disease outbreak WHO	Training materials	Health care workers, biomedical technicians, general public	Learning resources for health care workers, decision makers and the general public about the occurrence of coronavirus disease (COVID-19).
Technical Documents - Coronavirus Disease (COVID-19) PAHO	Training materials	Health care workers, biomedical technicians	Technical documents for biomedical technicians, health care workers to mangange COVID-19.
Training resources for COVID-19 management MoHFW, India	Training materials	Health care workers, biomedical technicians	COVID-19 testing guidelines for technicians in India.
BMT Digital Library Engineering World Health	Training materials	Biomedical technicians	Collection of open-source books, publications, and other resources relevant to training biomedical engineering technicians (BMETs), particularly in low-income countries

Environmental Health and Safety

Waste Management

One of the important factors to prevent the rapid spread of COVID-19 is waste management. WHO, the United States Department of Labor, and the European Commission provide guidelines and training materials to properly manage highly contagious waste. These resources provide guidelines to health care workers, and the general public according to the level of the waste risk. Wastes are divided into municipal waste, medical waste, recycling, and wastewater. They suggest using administrative controls, safe work practices, and PPE including masks and gloves when managing municipal wastes and recyclings. When managing medical waste, healthcare workers should follow rules guided by CDC. And according to European commission, coronavirus is vulnerable to the same disinfection conditions as other viruses.

Table 20. Engineering and technology related resources for Waste Management.

Name and publishing unit	Type of resource	Audience	Purpose
Water, sanitation, hygiene, and waste management for the COVID-19 virus: interim guidance WHO	Guidelines	Healthcare workers	Waste management guide
Waste management work tasks associated with exposure risk levels United States Department of Labor	Guidelines	Workers	Guides how to manage waste depending on degree of exposure risk level
Waste management in the context of the coronavirus crisis European commission	Guidelines	General public, healthcare workers	Guide how to manage waste from healthcare facilities, individuals.
Guidelines for Environmental Infection Control in Health-Care Facilities CDC	Guidelines	Healthcare workers	Regulations and guidelines of managing medical wastes.
Standard precautions: Waste management WHO	Training materials	Health care workers	Teach about different kinds of waste and the process for waste management.

Cleaning and Disinfection

It is known that the COVID-19 virus survives on metal, glass and plastic for as long as nine days. Cleaning and disinfection is very important to kill the highly viable COVID-19 virus. WHO, CDC, UNICEF, and USFDA provide guidelines for cleaning and disinfection COVID-19 virus. If the surface is dirty, it must be cleaned with detergent or soap and water before disinfection. When cleaning, workers need to wear skin protection and eye protection against potential splash hazards and adequate ventilation is required. Additionally it is recommended by CDC to use a diluted household bleach solution (at least 1000 ppm sodium hypochlorite or 5% to 6% concentration) if appropriate for the surface.

Table 21. Engineering and technology related resources for Cleaning and Disinfection.

Name and publishing unit	Type of resource	Audience	Purpose
Considerations for COVID-19 management in the accommodation sector	Guidelines	Accommodation workers	Guideline for managing covid in accommodation facilities

WHO			
Cleaning and Disinfection for Community Facilities U.S CDC	Guidelines	Health care workers, Community facility workers	Guides on the cleaning and disinfection of rooms or areas occupied by those with suspected or with confirmed COVID-19
Cleaning and hygiene tips to help keep the COVID-19 virus out of your home UNICEF	Guidelines	General public	Cleaning and disinfecting guidelines of high-touch surfaces in your home from doing laundry to preparing meals
Enforcement Policy for Sterilizers, Disinfectant Devices, and Air Purifiers During the Coronavirus Disease 2019 (COVID-19) Public Health Emergency USFDA	Regulations & standards	Manufacturers	Provides the appropriate FDA regulation for each device including disinfection devices.