WHO Global COVID-19 Vaccination Strategy: July 2021 Update

[Provisional Document for Review by SAGE]
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<th>Description</th>
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<tbody>
<tr>
<td>AU</td>
<td>African Union</td>
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<tr>
<td>BMGF</td>
<td>Bill and Melinda Gates Foundation</td>
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<tr>
<td>CEPI</td>
<td>Coalition for Epidemic Preparedness Innovations</td>
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<td>Gavi</td>
<td>Global Alliance for Vaccines and Immunisation</td>
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<tr>
<td>IMF</td>
<td>International Monetary Fund</td>
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<td>MDB</td>
<td>Multilateral Development Bank</td>
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<td>WB</td>
<td>World Bank</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<th>Country classifications</th>
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<tbody>
<tr>
<td>HICs</td>
<td>High Income Countries</td>
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<tr>
<td>UMICs</td>
<td>Upper Middle Income Countries</td>
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<tr>
<td>LMICs</td>
<td>Lower Middle Income Countries</td>
</tr>
<tr>
<td>LICs</td>
<td>Low Income Countries</td>
</tr>
<tr>
<td>AMC</td>
<td>Advanced Market Commitment: Qualifying countries can receive vaccines through COVAX with costs partially covered</td>
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<tr>
<td>AMC92</td>
<td>92 countries which qualify for AMC</td>
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<tr>
<td>SFP</td>
<td>Self-Financing Participants: Countries which get vaccines through COVAX but cover all costs themselves</td>
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<tr>
<th>Further departments and groups</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACT-A</td>
<td>The Access to COVID-19 Tools (ACT) Accelerator: Cross-organizational collaboration to accelerate development, production, and equitable access to COVID-19 tests, treatments, and vaccines</td>
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<tr>
<td>COVAX</td>
<td>Vaccine pillar of ACT-A</td>
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<tr>
<td>SAGE</td>
<td>WHO Strategic Advisory Group of Experts on Immunization</td>
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<tr>
<td>SPRP</td>
<td>Strategic Preparedness and Response Plan: WHO guidance to countries, regions etc. on action required to overcome the ongoing challenges in the response to COVID-19</td>
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<table>
<thead>
<tr>
<th>Technical language around epidemiology, health systems etc.</th>
<th>Description</th>
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<tbody>
<tr>
<td>FVP</td>
<td>Fully Vaccinated Person</td>
</tr>
<tr>
<td>HW</td>
<td>Health and Care Workers</td>
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<td>-------</td>
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<tr>
<td>IFR</td>
<td>Infection Fatality Ratio</td>
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<tr>
<td>PHSM</td>
<td>Public Health and Social Measures</td>
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<tr>
<td>PTRS</td>
<td>Probability of Technical and Regulatory Success</td>
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<tr>
<td>VOC</td>
<td>Variants of Concern</td>
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2 Executive summary

Following the WHO declaration of novel coronavirus as a public health emergency of international concern, the main global immunization partners developed a Global COVID-19 Vaccination Strategy through the Access to COVID-19 Tools Accelerator (ACT-A) Vaccines Pillar (COVAX) led by WHO. The strategy set two linked goals to protect individual and public health and minimize societal and economic impact by focusing the vaccination efforts on reduction of mortality, hospitalization and severe disease. Building on the Strategy and anticipating significant initial supply constraints of one or more effective vaccines to become available, COVAX set out to provide vaccine supply fairly and equitably. A target was set at administering two billion doses to 20% of each country’s population by the end of 2021.

Since then, COVID-19 has led to tremendous suffering across the world, both through health burden but also due to social and economic consequences of transmission control measures imposed. Nevertheless, important tools have been developed to fight the pandemic, among these, vaccines. Globally, 18 vaccines are in use, with 2.6 billion doses administered as of 21 June 2021. If used according to WHO recommendations, this number of doses would already have been sufficient to cover the initial target of 20% of the population in every country. But the world is not in fact on track to meet its ambition: while the great majority of high income countries have exceeded the 20% target, only three of the lower income have reached it.

In the meantime, there have now emerged some widely diverging coverage ambitions for 2021 – 2022. Some countries are pursuing ‘no regrets’ approaches to reducing disease and minimizing transmission by vaccinating everyone for whom vaccine use has been authorized. Others are considering how broadly to scale their programs and contemplating what they need in order to lift public health and social measures sustainably, in pursuit of their social and economic recovery. While there is some regional and global attempt for coordination, all of these efforts would benefit from some consolidation: target setting that is uncoordinated is likely to further exacerbate already unequal distribution of vaccines across countries and to reduce impact on the fight against COVID-19 and will continue to prolong the pathway to ending the pandemic and a global recovery.

In light of the above and progress in scientific understanding of COVID-19, WHO, in collaboration with its COVAX partners and with key regional and national stakeholders, is updating both its initial goals for 2021 and the WHO Global COVID-19 Vaccination Strategy, looking at a 2021-2022 timeframe. The work intends to i) inform the decisions countries, policy makers and investors are making about their vaccination goals and targets for 2022 and beyond and ii) promote an equitable approach to COVID-19 vaccination globally, including through risk mitigation strategies.

The Global COVID-19 Vaccination Strategy July 2021 Update is being submitted to the WHO Strategic Advisory Group of Experts on Immunization (SAGE) for review, input and consideration for critical appraisal when it meets on 29 June 2021. Additional analysis will be conducted, and new evidence collected on an ongoing basis so that the strategy is periodically updated as warranted by the evidence, including individual country aspirations.

The WHO Global COVID-19 Vaccination Strategy proposes a Conceptual Goal Framework, identifying possible socio-economic and health goals countries can pursue with vaccination efforts, along a continuum. The framework is not meant to be exhaustive nor to endorse any specific combination of goals and vaccination targets, but rather lay out all the possible options for individual countries and the international community as a whole. The framework is intended to help countries make more explicit the
rationale for their vaccination targets. In contrast to setting coverage targets as goal in themselves, the framework emphasizes the importance of defining explicit health and socio-economic goals and working towards equitable outcomes for all, both within and amongst countries.

The scientific understanding of SARS-CoV-2 and COVID-19 has progressed rapidly through experiences of countries and research activities across the globe supported by unprecedented real-time data-sharing and international collaboration. Nevertheless the Conceptual Goal Framework helps identify areas of substantial uncertainty. These include issues such as duration of protection, virus evolution, the potential threat posed by Variants of Concern, the full clinical impact of disease and infection, ability of vaccines to reduce transmission, and the potential impact of endemic disease circulation among low-risk cohorts to generate natural immunity, among others.

The combinations of different socio-economic and health goals in the Goal Framework result in four qualitative levels of vaccination coverage that countries can pursue. The Framework encourages the use of the WHO Prioritization Roadmap to guide choice of target of populations at each level of ambition, while proposing a simplifying age descending order and age cut-offs for analytical purposes. For each of the goals and related vaccination coverage, the Global COVID-19 Vaccination Strategy document runs scenarios analysis on health impact, resource requirements and resource availability for vaccination levels. The analysis also identifies countries’ vaccination ambitions relative to the goal framework.

The Strategy documents that many countries are setting ambitious and diverse vaccination targets driven by technical, political and economic considerations. Countries are racing upwards toward ambitious 50-70% coverage: for countries with much younger demographic distribution, mostly lower income settings, such targets imply vaccination of children and relatively important financial and system investments. The analysis of health impact shows that prioritizing vaccination of the oldest adults will achieve the greatest mortality and hospitalization reductions. While increasing the vaccination target to younger ages increases the overall number of events averted, it does so with differential efficiency across outcome measures: vaccinating those <30 years old is an efficient strategy mainly towards the goal of reducing viral transmission. This is where uncertainty begins: there are questions around ability of vaccines to reduce transmission, the need to do so relative to the unclear threat posed by Variants of Concern, the potential benefits of natural immunity, the full clinical impact of disease and infection, and gaps in evidence on the safety and performance of vaccines in children, among others.

While the biggest incremental benefit of moving to younger age strata is in lower income settings due to demographics, transmission patterns and constraints with the health system, trade-offs between ever increasing COVID-19 vaccination ambition and other health priorities is more evident. The risk is clear of impacting sustainability of immunization outcomes across many other disease of considerable burden. The risk is also clear in terms of foregone opportunities for expanding other immunization services.

These trade-offs need to be carefully weighed against the risks of lower and/or slower vaccination roll out in lower income settings in a fast-moving interconnected world. With cases on the rise, many settings could not only find themselves hit by high health costs, but also constrained by public health and social measures limiting consumption and socio-economic activity. In addition, economic losses due to reduced international trade and capital flows could be suffered. A choice, or lack of choice, to implement a limited vaccination target by low income settings will also have impact in higher income settings: both the International Chamber of Commerce and International Monetary Fund have clearly highlighted the role of an interconnected global value chain on economic gain or loss across all countries, with highest return on public investment in modern history of equitable global vaccination.
In addition to trade off-considerations, system and financial constraints can affect achievement of more ambitious country goals in LICs and LMICs, and potential booster requirements put into question sustainability of results. A ‘ramp up’ phase of vaccine implementation would require much higher throughput capabilities and this could be challenging in many settings. While financial resources would be difficult to mobilize, these are certainly not constrained: official development assistance, multilateral development loans, increased tax revenues from vaccination, are all available sources; many of these have already been committed. Nevertheless, systems, from health care workforce to cold chain to data and technologies may pose clear limits in constrained settings. To ensure all countries have similar opportunities, we need important external support for lower income settings, including technical and human resources. In addition, all countries, both lower and higher income, are likely to face challenges linked to potential need to adapt products as well as vaccine acceptance. In a last phase of the pandemic fight, tailoring efforts to reach the hard to reach will be essential.

On the vaccine supply side, this work shows a key opportunity for adequate global supply, but this will require very clear market signaling to supplier as well as collaborative behavior. We need anticipation of excess vaccine supplies, particularly in the coming months, and redistribution of surplus doses from higher to lower income settings as soon as possible, while urgently evaluate dose optimization strategies; supporting free cross-border flows of raw materials and finished vaccines; and, very importantly, early securing of manufacturing capacity scale up and diversification of vaccine productions providing increased access for developing countries, including through greater transparency.

This work highlights the following important considerations towards building consensus for an updated Global COVID-19 Vaccination Strategy:

- **The path to full global recovery advances through several goals in a step wise approach** from reducing highest risk of mortality and protecting health systems limiting most severe public health and social measures needed for crisis response to mitigating future health risks for full global recovery. The very first step in this chain represents an ‘unfinished agenda’ towards vaccination of the most vulnerable populations for which substantial investment is well under way. The second steps expands to larger share of adult population and is likely required to resume economic activity: this step is being actively pursued by many countries with important sunk investments; the analysis shows that with active market management and external technical and financial support, it could be at reach. The evidence that underpins the rationale for further steps towards larger shares of younger populations is still accruing or in early stages.

- **Vaccination targets should** be driven by an analysis of what is required to achieve certain goals and country specific targets need to account for local circumstances, including demographic and priority populations distribution. While many global goals have been expressed so far in terms of share of total population to be reached equally across all countries, this may yield an unintended vaccination strategies (such as vaccination of children) with uncertain benefits and possibly unintended use of scarce resources. This Strategy update argues for a move away from this approach.

- **Mitigating future risks is important**: uncertainties pose important risks. For instance, the potential for variants to emerge for which existing vaccines are poorly performing rendering them largely ineffective: the implication is that countries would have to reinstate control efforts already released and maintain those while reestablishing vaccine driven immunity. Another type of risk is linked to community continued acceptance of ongoing or return to public health and social measures of increased intensity as needed. While these unknowns are at play and evidence is being gathered, decisions are needed now on investments that will establish the opportunities of
the near future. For instance, **assuring global supply to potentially expand vaccination programmes in the near future is a ‘no regrets’ investment** that allows greater specification of policy and programmatic refinements of its use over time.

In light of all the above, **thee options** are proposed for the updated Global Vaccination Strategy covering the remaining of 2021 and 2022:

A. An ambitious, no-regret **‘Universal global vaccination strategy’**. This strategy would: i) **Aim to mitigate future health risks for full global recovery**, reaching the highest goal post on our conceptual goal framework; ii) **prioritise highest risk groups** where incremental benefits are largest, but encourage and support all countries to then **quickly move to vaccinate all populations**.

B. An **‘All adult global vaccination strategy with risk mitigation’**. This option would: i) **Aim to reduce disease burden and** putting countries on trajectory toward **resuming socio-economic activity**; ii) **prioritise highest risk groups** where incremental benefits are highest and encourage and support countries to reach 30+ or all adult populations. **This strategy would advocate for important investments in vaccine supply and systems to ensure readiness once scientific uncertainty is cleared**: for instance to expand immunization to all populations (including adolescent and children) should evidence become clear that this is needed; boost vaccination where evidence requires it.

C. A, **‘Older adult global vaccination strategy’ focused effort**. This option would: i) **Reduce highest risk of mortality and protecting health systems limiting most severe public health and social measures** needed for crisis response; ii) focus only on **highest risk groups of 50+** where incremental benefits are highest, and encourage all countries to await for further evidence on need/desirability of further ambitions. This options risks leaving us unprepared should the need for more ambitious vaccination targets become evident as more data and knowledge is collected on scientific uncertainties.

Notwithstanding that so much has been learned in such a short period of time, evolving evidence about the vaccines, virus evolution, community transmission, population demand, and the trajectory of the pandemic mean that any vaccination strategy must remain dynamic. Adaptive goals, which are adjusted and further specified as evidence accumulates, as the virus adapts, and vaccine performance is clarified, allow the agility the world needs to shut down this pandemic. Decisions about how best to deploy vaccines over the medium term, for their greatest and most durable impact will depend on continues updating of the world’s collective resolve.
3 Background

3.1 Initial response to the COVID-19 pandemic in 2020

During the first months of the COVID-19 pandemic, when vaccines were in the early stages of pre-clinical and clinical development, the main global immunization partners developed a Global COVID-19 Vaccination Strategy through the Access to COVID-19 Tools Accelerator (ACT-A) Vaccines Pillar (COVAX) led by WHO. The strategy set two linked goals:

1. To protect individual and public health by reducing the burden of disease related to COVID-19 and by protecting the capacity of health systems to care for COVID-19 and non-COVID-19 patients (i.e., the ‘lives’ goal)

2. To minimise societal and economic impact, thereby enabling society and the economy to function with confidence without risking the health of the community and that of its health systems (i.e., the ‘livelihoods’ goal).

In practice, a global COVID-19 vaccination programme would deliver on both goals primarily by focusing the vaccination efforts on reduction of mortality, hospitalization and severe disease, which by this point were rapidly escalating in many countries across the world. To reduce the burden on health facilities, countries of all income strata imposed significant constraints on social and economic activity through Public Health and Social Measures (PHSM). These PHSM were utilized to prevent infections, reduce the spread and minimize burden, while unprecedented worldwide efforts went into identifying and developing effective vaccines and treatment. Building on the WHO Global COVID-19 Vaccination Strategy and anticipating one or more effective vaccines in the future which would be subject to significant initial supply constraints, COVAX set out to provide vaccine supply fairly and equitably. COVAX targeted 2 billion doses, aiming to assure that 20% of each country's population could be vaccinated by the end of 2021. This level of supply was estimated to be sufficient to vaccinate both health and care workers and those at the highest risk of severe disease and death (e.g., older adults and people with co-morbidities that enhanced their risk of disease).

The WHO Strategic Advisory Group of Experts on Immunization then endorsed a recommendation for a Values Framework for the Allocation and Prioritization of COVID-19 Vaccination. The Framework laid out six principles and twelve objectives to support the achievement of the dual strategy goals, and an accompanying Roadmap for Prioritizing the Uses of COVID-19 Vaccines in the Context of Limited Supply (Prioritization Roadmap). The Roadmap guided countries towards a stepwise prioritization of target populations to achieve maximum public health impact during this initial period of constrained supply.

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1 https://www.who.int/publications/m/item/covax-the-act-accelerator-vaccines-pillar
4 Whereas the Global Strategy and the SAGE Values Framework addressed allocation of vaccine supply across countries, the SAGE Prioritization Roadmap addressed only prioritization of vaccine use within countries.
A fair allocation mechanism was also established for COVID-19 vaccines purchased through the COVAX Facility.\footnote{https://www.who.int/publications/m/item/fair-allocation-mechanism-for-covid-19-vaccines-through-the-covax-facility}

### 3.2 Current context

Over 17 months have passed since WHO declared the novel coronavirus a public health emergency of international concern on January 2020. During this period, COVID-19 health burdens have been differentially distributed across the world, although every country has suffered the social and economic consequences of the virus transmission control measures they have variously imposed.\footnote{The role of underreporting, differential health system and testing access, care seeking behavior, and demographics all need careful consideration.} In the face of these challenges, the world has witnessed i) unprecedented success in the clinical development of vaccines (together with rapid development of therapeutics and diagnostics) as a consequence of significant public investment in partnership with the private sector prior to the start of and during the pandemic; ii) accelerated vaccine production and supply through advanced purchase agreements and streamlined regulatory processes with broad regulatory reliance mechanisms; and iii) a closing of the gap between high-income and low-income countries in their initial access to vaccines compared to historical norms. At the time of writing six vaccines currently have WHO Emergency Use Listing - EUL (Pfizer-BioNTech – Comirnaty, Moderna - mRNA-1273, AstraZeneca – Vaxzevria, Janssen - Ad26.COV2-S, Beijing CNBG - BBIBP-CorV, Sinovac – CoronaVac), with numerous other vaccines nearing regulatory authorization and further upstream in the pipeline.

The scientific understanding of SARS-CoV-2 and COVID-19 has progressed rapidly through research activities across the globe supported by unprecedented real-time data-sharing and international collaboration. Nevertheless, there remains substantial uncertainty and the pandemic is still evolving. Continued high transmission in many parts of the world is leading to the emergence of variants of concern (VOC) and the cumulative death toll continues to increase, and accelerate in some areas.

Vaccine supply currently remains limited and its distribution is highly inequitable. High-income countries (HICs) are able to access much greater shares of scarce supply, thereby limiting the ability of low- and middle-income countries (LMICs) to vaccinate even their highest risk groups in 2021. Globally, 18 vaccines are in use, with \textbf{2.6 billion doses administered as of 21 June 2021}, 38% of which have been administered in one country alone, and less than 1% in LIC. \textit{If used according to WHO recommendations, this number of doses would already have been sufficient to cover the initial target of 20\% of the population in every country} and projections for the full year far exceed it. \textit{But the world is not in fact on track} to meet its ambition: while the great majority of HICs have exceeded the 20\% target, only three of the LICs and LMICs have reached it. Together they represent just 41 million of the 3.6 billion people living in these countries.\footnote{As defined by 40 doses administered per 100 population (at least 20\% theoretical coverage, assuming most vaccine types require two doses). WHO COVID-19 Dashboard using the list of economies by the World Bank.}

In the meantime, there have now emerged some widely diverging vaccine coverage ambitions for 2021 – 2022. Some countries are pursuing ‘no regrets’ approaches to reducing disease and minimising transmission by vaccinating everyone for whom vaccine use has been authorised. Others are considering...
how broadly to scale their programmes and contemplating what they need in order to sustainably lift PHSM in pursuit of their social and economic recovery.

3.3 Rationale and objectives for this work

Given the dynamics of an ongoing pandemic and the dual goals of protecting both lives and socio-economic well-being, individual countries are setting ambitious vaccination coverage targets, but these efforts are not coordinated and the resource requirements and implications are not made explicit.

This uncoordinated target-setting is likely further to exacerbate the already unequal distribution of vaccines and thus reduce the overall impact of the efforts to combat COVID-19. This will both prolong the pandemic unnecessarily and delay global recovery. Global leaders are calling for joint efforts to end the pandemic. Without a globally coordinated approach to pandemic control, however — in which vaccination is just one of a broader range of tools — the pandemic will trigger further declines in gross domestic product for countries around the world. Trillions of dollars are at stake. The burden on every country — even those with some of the highest vaccine coverage and access rates — will continue to increase. In the absence of a global, time-specified strategy, the current race towards ever more ambitious vaccination coverage targets may in fact sustain the pandemic by allowing more variants to emerge and placing unnecessary strain on health systems.

It is thus crucial for countries to take informed, evidence-based decisions in setting their vaccination targets, in which population coverage goals are based both on a clear understanding of benefits, risks, resource requirements, externalities and key uncertainties and on national as well as global ethical and equity commitments. Such an approach to vaccine strategic planning can generate more sustainable choices with greater benefit for all.

Strategy decisions need to be evidence-based while clearly ascertaining, specifying, and accounting for uncertainty, some of which will clarify during the period of the strategy. At the time of writing, key

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9 International Chamber of Commerce. The Economic Case for Global Vaccinations. 2021. [https://iccwbo.org/publication/the-economic-case-for-global-vaccinations/](https://iccwbo.org/publication/the-economic-case-for-global-vaccinations/) [accessed March 19, 2021]. The paper demonstrates the economic costs of suboptimal vaccine distribution to the international trading system at the global scale, showing that even if a particular country has access to the vaccine, it “experiences a sluggish recovery with a drag on its GDP” if its trading partners do not have such access. The economic costs borne by wealthy countries in the absence of multilateral coordination guaranteeing vaccine access and distribution range between US$ 203 billion and US$ 5 trillion, depending on the strength of trade and international production network relations.

aspects of the COVID-19 vaccine strategy are clear, especially for the most direct impact of the vaccines and the need to prioritise HW and those at highest risk. Conversely, active generation, synthesis, and deliberation on evidence is still ongoing for many issues that would influence the strategic tradeoffs. These include issues such as duration of protection, virus evolution, the potential threat posed by VOC, the full clinical impact of disease and infection, ability of vaccines to reduce transmission and the potential impact of endemic disease circulation among low-risk cohorts to generate natural immunity, among others. Individual countries and the international community as a whole need to carefully weight these uncertainties when determining the best use of resources and assessing their propensity for addressing risk. Some investments are clear, unambiguous needs while others are needed at risk while the evidence evolves over the coming months.

As fresh thinking around global targets gets underway with recent calls for action by the African Union (AU), G7, G20, International Monetary Fund (IMF), World Bank (WB), World Health Organization (WHO) and others, WHO, in collaboration with its COVAX partners and with key global, regional and national stakeholders, sees the compelling need to update both the initial goals for 2021 and the WHO Global COVID-19 Vaccination Strategy for the 2021-2022 timeframe. The present work has the following objectives:

1. Inform the decisions countries are making regarding their vaccination goals and targets for 2022 and beyond;
2. Promote an equitable approach to COVID-19 vaccination globally, as part of the broader pandemic control strategy;
3. Update global vaccination goals for 2022, based on specific changes in the global context and in light of shortage and key uncertainties;
4. Inform global policymaking and access efforts, investment decisions by financial and donor institutions, R&D groups and vaccine manufacturers as well as country planning and programmatic work.

It should be pointed out that although this work focuses on the role of vaccination, it must be considered in the broader context of reinforcing primary health care and leaving no one behind. The capacity of healthcare systems across countries is a critical factor for successfully combating this pandemic as will be made clear in the analysis.

12 https://www.g7uk.org/
13 https://www.g20.org/
18 https://www.who.int/director-general/speeches/detail/director-general-s-opening-remarks-at-the-world-health-assembley---24-may-2021
3.4 Governance and strategy development process

This WHO Global COVID-19 Vaccination Strategy July 2021 Update was undertaken by a multi-partner Task Team comprising representatives from global and regional organizations. The Task Team met weekly from April through June 2021. The Task Team built on the work of existing working groups and ongoing analytic efforts across the COVAX partnership and beyond. A broader ad hoc Strategy Working Group comprising more than 30 individuals from country, regional and global institutions across many constituencies met three times during the course of this work to provide strategic direction. Terms of reference of both the Task Team and the ad hoc Strategy Working Group are available in Annex I.

3.5 Methodological Approach

The WHO Global COVID-19 Vaccination Strategy July 2021 Update was supported by several analytic steps:

1. Development of a goal framework, identifying possible socio-economic and health goals countries can pursue with vaccination efforts, along a continuum;
2. Scenario analyses of:
   a. possible vaccination targets to achieve each goal, including modelled health impacts
   b. resource requirements for achieving each goal, including programmatic vaccine dose requirements, procurement costs and country operational costs for vaccine delivery
   c. resource availability, including available supply and financial and system constraints;
3. A goal synthesis was then conducted aiming at:
   a. identifying countries’ vaccination ambitions relative to the goal framework
   b. identifying barriers on the path towards goals
   c. calculating the incremental benefit analysis for moving between goals
   d. calibrating expectations with respect to potential global goals;
4. In light of the framework, the scenario analysis and the goal synthesis, three options for an updated global strategy were put forward.

It is important to specify that scenarios used in the analysis were designed to explore possible trajectories and the resilience of the proposed strategy to different types of uncertainty. They do not constitute forecasts by WHO or any participating partners as to the likely trajectory of the pandemic nor of any anticipated vaccine performance, regulatory or policy decisions. Neither do these scenarios represent any judgement by WHO or participating partners about their relative desirability.
4 Conceptual goal framework

The development of the conceptual goal framework (also referred to as simply “goal framework” hereafter) builds upon WHO’s broader COVID-19 Strategic Preparedness and Response Plan (SPRP) initially published in 2020 and updated in 2021. WHO’s SPRP outlines the comprehensive approach to suppress transmission, reduce exposure, prevent infection, and reduce disease and death, and identifies interconnected and systematic interventions to achieve this (see Exhibit 1). As one of the SPRP’s ten pillars, vaccination must be deployed in combination with other public health and social measures, diagnostics, therapeutics, and broader health system functions in a comprehensive response to COVID-19 that builds resilience for future disease threats. The SPRP Strategic Objectives inform and align with both the health and socioeconomic dimensions of this updated WHO Global COVID-19 Vaccine Strategy goal framework.

Exhibit 1: Public health and social measures are supported by multiple response pillars

https://www.who.int/publications/i/item/WHO-WHE-2021.02
As was the case with the 2020 COVID-19 Global Vaccination Strategy, the goal framework is anchored on
the dual ambition of (i) protecting health and (ii) protecting social and economic welfare, extending the
“lives” and “livelihoods” goals for 2021 to a continuum of goals through 2022 (see Exhibit 2). The socioeconomic dimension of the goal framework is itself a continuum which stretches from more to less stringent public health and social measures (PHSM), which in turn is assumed to lead to increasing social and economic activity (horizontal axis of Exhibit 2). In the absence of vaccination, movement along this socioeconomic dimension by relieving the PHSM interventions, is associated with an increased effective reproductive number (i.e., accelerating transmission) of the SARS-CoV2 virus. This results in increased health impacts in the form of cases, deaths and strain on the healthcare systems leading to further loss of life, health, and wellbeing.

The health dimension of the goal framework (vertical axis of Exhibit 2) is also on a continuum moving from reducing severe to less severe outcomes at population level. The sequencing of goals along the health dimension provides continuity with the 2020 strategy by prioritizing reduction of severe disease (and its associated mortality and capacity to overwhelm health systems) as a means of achieving both the “lives” and “livelihoods” goals.

The framework connects these two dimensions with the key assumption that the underlying ambition of all countries over the 2021-2022 period is to use vaccination as a tool to resume “new normal” social and economic activity to the greatest extent possible, while minimizing negative health impacts and building back better, including through stronger health systems. Because movement along the socioeconomic dimension implies greater transmission potential, higher vaccination coverage targets are required to achieve and preserve the same health goal while countries reduce PHSM.

By applying this logic, the framework provides combinations of socio-economic and health goals that countries can pursue over time, given that in the context of this pandemic, health and socio-economic goals are inextricably linked. These combinations are not exhaustive and the level of vaccination ambition for each target varies depending on country characteristics, factoring in demographics and strength of health systems, viral transmission patterns and the vaccine products being used (see the ‘Key uncertainties and other consideration’ section below). The framework is not meant to endorse any specific combination of goals and vaccination targets, but rather lay out all the possible options for individual countries and the international community as a whole. The combinations of health and socioeconomic goals result in four qualitative levels of vaccination coverage:

- **‘Low’**: the mini minimum level of vaccination needed to protect the most vulnerable, against the most severe outcomes. Existing PHSM should be maintained as vaccines are being rolled out - with different stringency levels depending on transmission intensity, capacities, context - in order for vaccination to have the greatest impact in reducing mortality.
- **‘Medium’**: an intermediate level of vaccination, delivered while an appropriate level of PHSM are maintained in order to reduce disease burden and protect the health system from being overwhelmed as the stringency of the PHSM declines, or to achieve an equivalent reduction in mortality while resuming some socioeconomic activity fully.
- **‘High’**: a higher level of vaccination needed, delivered while stringent PHSM remain in place, to reduce SARS-CoV-2 transmission once PHSM are relaxed, or to reduce disease burden and protect

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18 ‘It is well understood that there can be no lasting end to the economic crisis without an end to the health crisis. Pandemic policy is thus economic policy’ [https://blogs.imf.org/2021/05/21/a-proposal-to-end-the-covid-19-pandemic/](https://blogs.imf.org/2021/05/21/a-proposal-to-end-the-covid-19-pandemic/)
the health system from being overwhelmed when PHSM are further reduced to travel measures only.

- ‘Very high’: the highest level of vaccination feasible during 2021-2022, with the intention of reducing viral transmission, including curbing the emergence and transmission of VOC, while seeking to lift all PHSM (aside from routine testing and isolation of cases, contact tracing and quarantine of contacts).

It is of importance to stress the dynamic nature of the goal framework. The framework suggests that a given pair of health-socioeconomic goals can be achieved at a given level of vaccination. If the aspiration becomes to attain that same health goal with fewer PHSM in place, the vaccination level would need to increase (as we move from left to right). Importantly, modelling shows that reducing PHSM too early in the course of vaccination rollout reduces the public health benefit of the programme, because transmission increases before the maximum impact of vaccination is established (please refer to next section).

As countries increase their vaccination reach as envisaged above, the important guidance presented in the SAGE Prioritization Roadmap highlights the sequence of high-risk groups to be reached at different stages of vaccination ambition, as vaccine supply becomes available and in different epidemiological settings (community transmission, sporadic outbreaks or clusters of cases and no cases). In line with this conceptual framework, the Roadmap includes consideration of groups according to the principles and objectives of the SAGE Values Framework; groups are therefore prioritised for multiple reasons in the Roadmap (e.g., preserving essential societal functions, ethical principles) and not only to maximize health benefits. The Roadmap recommends that health workers at high risk of exposure and older adults be prioritized with initial vaccine supply in most settings, in line with the initial targets and rationale of the 2020 Global Vaccination Strategy and COVAX Fair Allocation Mechanism to protect health workers (and thus health care systems) and reduce mortality. Of note, for vaccine supply up to the first 50% of the population as a whole, the Roadmap does not recommend prioritising vaccination of children except those at high risk of severe disease due to specific comorbidities.

The conceptual goal framework is intended to help countries make more explicit the rationale for their vaccination coverage targets. It is also intended to facilitate dialogue across countries and with global partners about where collective action is needed and the tradeoffs involved in pursuing different goal combinations. In contrast to setting coverage targets as goals in themselves, the framework emphasizes the importance of defining explicit health and socio-economic goals which then define the coverage targets, tailored to country characteristics. This approach reinforces working towards equitable outcomes for all within and between countries. In this goals framework, vaccination is positioned as an instrument to achieve informed and equitable outcomes.
Exhibit 2: The conceptual goal framework

Exhibit 2: The socio-economic dimension (horizontal axis) begins with (i) stringent PHSM in place (such as lockdowns or other forms of stay-at-home policies, business closures, gathering and movement restrictions), moving to (ii) less stringent PHSM (e.g., masks, distancing, travel measures), to (iii) only travel measures in place at points of entry with “new normal” of restored economic and social activity within a country’s borders, and finally to (iv) lifting travel measures to return to a “new normal” both domestically and with international trade and travel. At all stages along the socioeconomic goal continuum, it is assumed that routine public health measures are in place (e.g., testing, contact tracing, quarantine). In the absence of vaccination, movement along the socioeconomic dimension by releasing PHSM is associated with increases in the effective reproductive number (i.e., accelerating transmission).

The health dimension begins from the goal of (i) reducing COVID-19 mortality and protecting health workers (many of whom face higher SARS-CoV-2 occupational exposure risk), followed by the goal of (ii) reducing COVID-19 disease burden (including long COVID) and protecting the health system (including avoiding overwhelm by COVID-19 cases and maintaining delivery of other essential services), and finally the goal of (iii) reducing transmission, thereby also maximizing the impact on severe disease and death and constraining the emergence of variants which may undermine vaccine impact.

Note that frameworks for considering the tradeoffs between protecting “lives or livelihoods” have been developed to help countries calibrate their PHSM[^19] and can be used along with the goal framework in this COVID-19 vaccination strategy to qualitatively assess impacts of combining vaccination targets with different PHSM.

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5 Applying the goal framework: Scenario analysis of vaccination targets and resource requirements by country income group

5.1 Establishing vaccination targets within the framework

For analytic ease and tractability, the scenario analyses use an age-descending prioritization order as vaccination targets within the goal framework. Age was chosen as a simplifying approach because older age represents the most consistent risk factor for severe disease and death across countries worldwide; the age-descending strategy is consistent with the SAGE Prioritization Roadmap which strongly emphasizes the importance of protecting the vulnerable first to reduce mortality, before expanding vaccination to younger or less at-risk populations. This approach accounts for different demographic structures in countries and hence promotes an epidemiologically driven and efficient use of resources to reach desired goals.

The goal framework and scenario analyses should not be interpreted as a policy recommendation by WHO or partner agencies of vaccinating adolescents and children; rather the goal framework reveals this as an implication of certain combinations of health and socioeconomic goals. Within the framework, expanding coverage down to adolescents and children is an implication of aiming for the health goal of reduced transmission, or of preserving achievement of the health goals of reducing mortality or disease burden while lifting PHSM to permit socioeconomic reopening.

Acknowledging there are not clear age cut-offs that can be assigned to different vaccination targets along the conceptual goal framework and guaranteeing specific health and socio-economic outputs, we have selected the following thresholds based on comprehensive epidemiologic analyses: for the ‘low’ vaccination target, the analysis proposes that countries vaccinate all HW\textsuperscript{20} and individuals 50 years of age and older. For the ‘medium’ vaccination target, the proposed target is vaccination of those 30 years of age and older. For the ‘high’ and ‘very high’ vaccination targets, the thresholds are proposed at 12 years old and above, and the entire population (infants and older), respectively. The rationale behind the choice of the specific age thresholds is given in Table 1. Thresholds should be interpreted as indicative along a continuum of expanding vaccination coverage from older to younger populations with some variability across different country contexts. Of note, there are currently no vaccines authorized for use below the age of 12 and specifying “entire population” in this framework does not prejudice what the evidence will conclude.

Table 1: Rationale behind choice of age thresholds

<table>
<thead>
<tr>
<th>50+ years to reduce mortality</th>
<th>• Based on consistent infection fatality ratio (IFR) and relative risk for mortality across countries showing substantial greater risk above 50 years\textsuperscript{1}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Given younger demographic structure in LICs/LMICs, and some variability in IFR across countries for 65+ due to care home outbreaks in HICs, lower</td>
</tr>
</tbody>
</table>

\textsuperscript{20} For analytical purposes, the assumption that health and care workers correspond to 3% of total population has been made throughout the document. When compared to the ILO estimates and the WHO health workforce estimates, the underlying assumption over-estimates the actual number of health and care workers.
<table>
<thead>
<tr>
<th><strong>“older adult” threshold of 50+ is more appropriate cross-country threshold</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lower “older adult” threshold of 50+ will include many adults with comorbidities, many of which are correlated with age, so accounts for this additional source of mortality risk²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>30+ years to reduce disease burden and limit health system impact</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Based on hospitalization data from several HIC settings showing higher risk and number of hospitalizations for those 30+³,⁴</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>12+ years to reduce viral transmission</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Severe disease burden (hospitalizations) lower among those &lt;30 years; but still direct benefit of vaccination to this age group to reduce symptomatic cases, “long COVID”, and multisystem inflammatory syndrome in children (MIS-C);</td>
</tr>
<tr>
<td>• 12-29 years have some of highest pre-pandemic contact rates⁵</td>
</tr>
<tr>
<td>• Evidence that adolescents’ susceptibility to and transmission of SARS-CoV-2 is similar to adults⁶,⁷</td>
</tr>
<tr>
<td>• 12+ cutoff chosen based on vaccines with current/anticipated adolescent indications based on clinical trial ages⁷</td>
</tr>
<tr>
<td>• Separates decision to vaccinate adolescents vs. younger children</td>
</tr>
</tbody>
</table>

While lifting some PHSM:

<table>
<thead>
<tr>
<th><strong>0+ years to preserve viral transmission reduction;</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lifting PHSM increases Rt; with higher Rt, it is necessary to vaccinate a larger share of the total population to achieve the same public health goal</td>
</tr>
</tbody>
</table>


5.2 Variables affecting vaccination targets and goal achievement: working assumptions for scenario analysis

There are many variables that affect the ability to reach established health and socio-economic goals under different levels of vaccination targets within the proposed goal framework. Given substantial uncertainties and heterogeneity across countries, for analytic tractability the following simplifying assumptions were made for framework development and scenario application:

- **Naturally-acquired immunity** will provide some protection beyond PHSM and immunization, thus allowing reaching of goals under lower vaccination targets. Nevertheless, the extent and duration of natural immunity remain unclear, and WHO does not currently recommend screening individuals for prior SARS-CoV-2 infection for purposes of vaccination decision making, or any changes to dosing regimens for those with prior infection. For these reasons, the framework currently does not take natural immunity into account at the risk of underestimating impact and overestimating vaccine needs.

- **Vaccine product characteristics** allow for different degrees of protection against different endpoints (e.g., infection, mild disease, severe disease) and variant strains, so that a country may need to achieve a higher vaccination target if using a vaccine with lower effectiveness to achieve a given goal. For simplification, the proposed framework assumes the efficacy/effectiveness profiles of current and near-term vaccines with WHO EUL, including against currently known VOC. See Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis for more details.

- **Indirect protection** from vaccines currently in use is still under study, although initial results from early introducing countries suggest that several available vaccines reduce infection and transmission; however, there is emerging evidence that protection against infection may be reduced by certain VOC even if protection against severe disease is preserved. For these reasons, the framework takes a primarily direct protection conservative approach. Indirect protection from vaccination is considered as a potential “buffer” against VOC, lifting PHSM, supply delays, hesitancy, and other factors that may reduce the health benefits of vaccination.

- **Country characteristics**, such as health system features, imply that a more ambitious vaccination target may be needed to not overwhelm the health system in a country with constrained resources to care for COVID-19 patients (e.g., limited intensive care units, limited access to mechanical ventilation or supplemental oxygen). Other **within-country population characteristics**, such as mixing patterns and exposure risk (e.g., dense residential settings, multigenerational homes), would imply potentially different types of programmatic delivery efforts to reach goals in different settings. It is assumed that countries would follow the SAGE Prioritization Roadmap to consider additional risk factors (e.g., sociodemographic characteristics, occupational risk, residential risk) for more context-specific prioritization in their vaccination deployment plans.

- **Public Health and Social Measures (PHSM)** are assumed to be deployed at a relatively stable intensity in the framework to achieve a given combination of health and socioeconomic goals. However, PHSM deployment should be and are quite dynamic over time, as countries may apply and lift them based on epidemiological trends, political pressure, social acceptance and risk tolerance. The framework only uses qualitative PHSM categories for the horizontal axis of the
goal framework and does not specify a detailed combination of PHSM interventions that will guarantee achievement of specific goal.

- **Variants:** VOC that are more transmissible and/or exhibit possible immune-escape properties will require higher and longer coverage of PHSM to achieve or maintain a given population immunity or protection threshold. This is addressed further in the scenarios for impact modelling (see Incremental benefit section below).

6 Scenario analysis: Health impacts of achieving vaccination targets

6.1 Methodology

A published model (Hogan et al., *Vaccine*, 2021) of SARS-CoV-2 transmission, that is linked to a framework to simulate global COVID-19 vaccine allocation and prioritization scenarios, was leveraged to estimate the deaths, hospitalizations, and infections that would be averted when vaccinating the age groups assumed for each coverage target in the goal framework:

**Table 2:** Vaccination target age thresholds and within age group coverage, for scenario analysis

<table>
<thead>
<tr>
<th>Goal framework vaccination coverage target</th>
<th>Assumed age threshold for scenario analysis</th>
<th>Within age group coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>50+ years</td>
<td>85% for 65+ years; 70% for 50-64 years</td>
</tr>
<tr>
<td>Medium</td>
<td>30+ years</td>
<td>70%</td>
</tr>
<tr>
<td>High</td>
<td>12+ years (modelled as 10+ years)</td>
<td>70%</td>
</tr>
<tr>
<td>Very high</td>
<td>0+ years</td>
<td>70%</td>
</tr>
</tbody>
</table>

*For dose requirements and costing below, 87% coverage for 0-4 years was assumed for HICs.

Within each age group **coverage levels depicted in a published** model (Hogan et al., *Vaccine*, 2021) of SARS-CoV-2 transmission, that is linked to a framework to simulate global COVID-19 vaccine allocation and prioritization scenarios, was leveraged to estimate the deaths, hospitalizations, and infections that would be averted when vaccinating the age groups assumed for each coverage target in the goal framework:

Table 2 were defined based on historical immunization program performance and vaccine acceptance considerations. Assumptions were also made about the **evolution of epidemiologic variables (Rt)**, the timing of lifting of PHSM and the **vaccination pace**, as well as **vaccine efficacy** with respect to infection, severe disease and transmission.

The analysis was performed after grouping countries into **four archetypes based on income groups**, mainly to account for the highly variable demographic structures and the systems’ constraints across
group. The detailed assumptions are given in Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis.

6.2 Results: Health impacts

Across all income groups, there are greater health impacts in absolute terms when expanding vaccination to an ever-increasing share of the population by descending age cohorts from 50+ to 30+ to 12+ to 0+. This result is due mainly to the assumption that the vaccine product used will reduce infection and transmission to some degree in addition to protecting against severe disease, but also holds to a lesser extent even when the vaccine is assumed to protect against severe disease only (see Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis).

While increasing the vaccination target to younger ages increases the overall number of events averted, it does so with differential efficiency across outcome measures. For reducing deaths and hospitalizations, achieving high vaccination coverage for those 50+ is the most efficient strategy per FVP, followed by vaccinating those 30+ (Exhibit 3). Vaccinating those 12+ and vaccinating those 0+ provides almost no incremental benefit when scaled by the number of people needed to vaccinate to avert one of these outcomes at the population level. For deaths and hospitalizations, the benefit vaccinating younger cohorts accrues mainly through indirect protection to older cohorts at higher risk of these outcomes who were not effectively protected directly because of incomplete vaccine coverage. (Exhibit 4: Age group in which deaths are averted for each vaccination coverage age targeting strategy Exhibit 4, Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis). For averted infections, however, there is increasing incremental benefit to vaccinating younger and younger age cohorts, reflecting the greater social mixing by these age groups in all country income groups and their much larger share of the population in LMICs/LICs such that the benefits of reduced infections accrue primarily to these younger cohorts (Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis).

Under the scenario assumptions modeled, the results suggest that prioritizing vaccination of the oldest adults will achieve the greatest mortality and hospitalization reductions for a given level of vaccine supply, and that vaccinating those <30 years is an efficient strategy mainly towards the goal of reducing viral transmission. Vaccinating those 30+ is an intermediate strategy towards further reducing deaths and hospitalizations for a given level of PHSM, or maintaining the reduction of mortality and hospitalizations achieved by vaccinating those 50+ years while lifting some PHSM.

It is also very important to note that COVID-19 vaccination impact modeling suggests that the population health benefits of vaccination are greater if PHSM are kept in place during the period of vaccination rollout, an assumptions that has been implemented in the scenarios (Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis).
Exhibit 3: Deaths, hospitalizations, and infections averted per 100 fully vaccinated people (FVP) by country income group
Exhibit 4: Age group in which deaths are averted for each vaccination coverage age targeting strategy
7 Scenario analysis: Resource requirements for achieving vaccination targets

7.1 Methodology: Dose requirements and costing

To quantify the doses needed and the corresponding vaccination cost (procurement and delivery), the same four vaccination targets by age and within age coverage described for the health impact modelling (see A published model (Hogan et al., Vaccine, 2021) of SARS-CoV-2 transmission, that is linked to a framework to simulate global COVID-19 vaccine allocation and prioritization scenarios, was leveraged to estimate the deaths, hospitalizations, and infections that would be averted when vaccinating the age groups assumed for each coverage target in the goal framework:

Table 2 above) were assumed. Dose requirements were estimated for a two-year period assuming a baseline of no vaccination. On top of this, uptake curves were applied to establish the minimum time to reach programmatic coverage based on system strength, human resources, financial considerations, and past experience with large campaigns (refer to Annex III: Methodological simplifications for resource requirements for detailed uptake methodology and assumptions).

Three different dose schedule scenarios were considered for each vaccination target to account for uncertainty around viral evolution and vaccine cross-protection against new variants, as well as duration of protection (Table 3), giving rise to 12 vaccination target-scenario combinations.

Table 3: Dose requirements scenarios

<table>
<thead>
<tr>
<th>Dose schedule scenario</th>
<th>Primary series</th>
<th>Booster</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘No booster scenario’</td>
<td>Two-dose course primary vaccination for HICs and UMICs and one-dose course primary vaccination for LMICs/LICs</td>
<td>No booster</td>
</tr>
<tr>
<td>‘High-risk booster scenario’</td>
<td>Two-dose course primary vaccination for all countries</td>
<td>Annual one-dose booster for those 50+ years only. Booster every two years for other populations.</td>
</tr>
<tr>
<td>‘Yearly booster scenario’</td>
<td>Two-dose course primary vaccination for all countries</td>
<td>Annual one-dose booster for all target populations</td>
</tr>
</tbody>
</table>

21 Low resource requirement scenario requested by African Union for exploratory purposes.
It is important to note that the uptake assumptions imply not all doses necessary to complete the 12 scenarios are needed over the two-year period; for the most ambitious scenarios, booster doses (primarily) are required over a longer timeframe.

A 10% wastage rate was added across all scenarios.

Of note, dose required over the two-year period of analysis were associated to 2021 and 2022 calendar years for ease of analysis and comparison with supply. This is an aggressive assumption for many of the lower income settings when most doses are likely to be purchased in the latter part of the biennium, while possibly under-estimating early vaccine consumption in higher income settings through early use of booster doses.

The programmatic dose requirements calculated above were used to calculate the required health system needs by focusing on HW surge: relating the number of doses to be administered with the estimated time to administer each dose to establish the HWF need and then comparing with the HWF density per country and the reallocation of existing HWF.

The programmatic dose requirements calculated in the previous step were finally used as a base to calculate country vaccination cost. This analysis was performed for a total of 130 countries: 38 self-financing countries and 92 Advance Market Commitment (AMC) economies COVAX for 2021 and 2022. The calculations were performed on the basis of cost-per-dose supplied, which was, in turn, broken down to three components:

- **Procurement cost**: 6.7 USD, constant across scenarios based on an analysis of estimated weighted average price currently paid across doses contracted under COVAX and non-COVAX deals as per data available to date
- **Delivery cost**: ~0.5 to ~1 USD, decreasing with increasing number of doses, thanks to economies of scale
- **HW surge cost**: ~0.75 to ~2 USD, increasing with the number of doses supplied

This work was conducted by the COVAX Global Market Assessment Working Group and the Country Readiness and Delivery Task Team for Global Delivery Costs. More details on the methodology followed to calculate programmatic dose requirements and costing can be found in Annex III.

### 7.2 Results: Dose requirements

There is a large variance in programmatic dose requirements across goals and scenarios: as expected, dose requirements increase with increasing levels of goal ambition and when boosters are assumed to be required to maintain the desired health impacts. Requirements range from 2.8 billion doses if only 50+ year populations are targeted and no boosters are required to 16.2 billion doses for universal vaccination along with an annual booster requirement for 2021 and 2022 (Exhibit 5). It is important to note that, at the time of writing 2.7 billion doses have already been administered, although primarily in high income settings with China, United States, India, Brazil, United Kingdom, Germany, France, Italy, Turkey, Mexico as the biggest consumers.
At the lowest level of ambition, i.e. targeting populations 50 years and over, high income countries, who have older demographics, and China drive most of the dose needs. As goal ambition increases and all ages are targeted, lower income settings are the biggest driver of global demand.

In the ‘no-booster scenario’, the one-dose primary vaccination course assumed for lower income settings require significantly reduces doses required by these countries across all age targets.

Exhibit 5: Dose requirements

<table>
<thead>
<tr>
<th>Goal</th>
<th>Scenario</th>
<th>HICs</th>
<th>UMICs</th>
<th>LICs &amp; LMICs</th>
<th>China</th>
<th>India</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yearly booster</td>
<td>1.2</td>
<td>0.9</td>
<td>0.8</td>
<td>1.2</td>
<td>0.7</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>No booster</td>
<td>0.8</td>
<td>0.6</td>
<td>0.3</td>
<td>0.8</td>
<td>0.2</td>
<td>1.7</td>
</tr>
<tr>
<td>50+</td>
<td>Yearly booster</td>
<td>2.0</td>
<td>1.9</td>
<td>2.1</td>
<td>2.3</td>
<td>1.6</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>No booster</td>
<td>1.3</td>
<td>1.3</td>
<td>0.7</td>
<td>1.5</td>
<td>0.5</td>
<td>3.5</td>
</tr>
<tr>
<td>30+</td>
<td>Yearly booster</td>
<td>2.5</td>
<td>2.6</td>
<td>3.3</td>
<td>3.0</td>
<td>2.3</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>No booster</td>
<td>1.7</td>
<td>1.9</td>
<td>1.3</td>
<td>2.0</td>
<td>0.9</td>
<td>4.6</td>
</tr>
<tr>
<td>12+</td>
<td>Yearly booster</td>
<td>3.1</td>
<td>3.1</td>
<td>4.3</td>
<td>3.3</td>
<td>2.7</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>No booster</td>
<td>2.0</td>
<td>2.4</td>
<td>1.8</td>
<td>2.3</td>
<td>1.1</td>
<td>6.8</td>
</tr>
<tr>
<td>0+</td>
<td>Yearly booster</td>
<td>2.8</td>
<td>3.1</td>
<td>4.3</td>
<td>3.3</td>
<td>2.7</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>No booster</td>
<td>2.0</td>
<td>2.4</td>
<td>1.8</td>
<td>2.3</td>
<td>1.1</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Some longer-term considerations are worth noting. The ‘high-risk’ booster scenarios (every 2 year boosters and annual boosters for high-risk groups) have the largest variability since booster doses are required only for a small share of the target population on an annual basis and the whole target population every 2 years. Most importantly, as of year two, in all scenarios, there is a considerable drop in dose requirements as target populations are reached. Global programmatic dose requirements reach zero in all ‘no-booster’ scenarios by year three. These longer term considerations are important for investment decisions of vaccine manufacturers (and governments), in terms of speed and scale of manufacturing capacity increase and business sustainability (Exhibit 6).
7.3 Results: Costing and programmatic requirements

Given the wide range of dose requirement scenarios, there is a similarly wide range of costs up to ~63 USD bn for LMICs/LICs alone for the most vaccination target ambition and booster scenarios in 2021 and 2022 accounting for vaccine procurement and delivery costs.\(^{23}\)

Under the assumption of a 6.7 USD per dose, Covid-19 vaccines would be among the most expensive in lower income settings portfolios\(^{24}\) and their procurement clearly a major driver of cost. Delivery costs, driven primarily by HWF surge costs, represent an essential one fourth of the total costs. Importantly, the analysis is not accounting for the opportunity cost of already existing HWF that would be leveraged and possibly diverted from their other immunization and primary health care tasks. Finally, the analysis shows that covering larger and larger shares of population as well as the need for boosters are important drivers of cost difference between scenarios.

It is important to note that some of these costs have already been covered by existing investments by countries and international community.

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\(^{22}\) Intermediate scenarios are still work-in-progress,


8 Scenario analysis: Resource availability

8.1 Methodology: Global vaccine supply

The global vaccine supply projections come from an ongoing Global Market Assessment led by COVAX partners. Estimates are based on a Monte Carlo simulation global production model leveraging publicly available sources (media monitoring) and BMGF, CEPI, Gavi and UNICEF intelligence. The model incorporates all vaccine developers with vaccines licensed or in clinical development.

Global supply estimates account for risk and uncertainty about:

- The probability of technical and regulatory success (PTRS)
- The timing of regulatory approval and production launch
- The manufacturing risk and technology transfer experience
- Availability of raw materials and manufacturing inputs, drug substance yields and manufacturing scale(s)
- Companies’ strategy regarding variants

Based on Monte Carlo simulation outputs three scenarios of low (5th percentile), base and high (95th percentile) supply have been introduced for 2021 and 2022.

In addition, some estimates have been generated on distribution of available manufacturing capacity across countries leveraging information on i) formalized bilateral, multilateral, and COVAX deals (secured doses); ii) domestic production capacity; and iii) publicly announced donations and transferred doses. Key assumptions were then made on prioritization of deals, with high income countries assumed to have their mRNA vaccine deals met first, countries of production prioritized, some export bans from key producing countries for limited amount of times, and implementation of dose-sharing policies.

More information on the supply methodology is provided in Annex IV.

8.2 Results: Global vaccine supply availability

Global vaccine supply forecasts depend on a set of parameters that are hard to accurately predict. The results and production distribution outcomes are summarized in three scenarios - Low scenario, Base scenario, High scenario - see below (Exhibit 7). The production figures encompass multiple different technology platforms. In 2021, the production scenario is divided between mRNA, Non-Replicating Viral Vector, and Inactivated Vaccines with about a 1/3, 1/3, 1/4 split in the base scenario. The 2022 scenarios reflect the potential entry of Protein Subunit Vaccines with about a 1/3 from mRNA and 1/5 to Viral Vector, Inactivated and Protein Subunit split in the base scenario. As is described below, different platforms are more or less sensitive to different drivers of uncertainty and variance. By construction the model leads to production forecasts which must therefore be taken with great caution.

Among multiple factors which have been considered, the key ones which lead to the largest variance in supply estimates across the three scenarios are:
- **The probability of technical and regulatory success (PTRS) – up to 3.9 billion doses variance over 2021-2022:**
  - The model uses a probability of success to reach licensure. However, for a given candidate yet to be registered, it will either pass or fail registration. Hence, impact of this factor is the most significant.
  - The technology platform most sensitive to this factor is the Protein Subunit platform. It combines the fact that (i) no candidate has reached licensure yet, and (ii) large volumes are being claimed from this technology platform.

- **The manufacturing risk, technology transfer experience, and scale-up curve – up to 2.3 billion doses variance over 2021-2022:**
  - The more technology transfers are being envisaged and the more limited the experience is at the receiving sites of these transfers, the wider the variance on the outcome.
  - The most sensitive technology platform to this factor is the Viral Vector platform. Indeed, the three leading companies have limited in-house capacity and rely on a very large number of technology transfer recipients to successfully reach the production volumes.

- **The availability of raw materials and manufacturing inputs, which impact both drug substance and drug product manufacturing steps – up to 1.8 billion dose variance over 2021-2022:**
  - While the magnitude of the impact of raw materials and manufacturing supplies scarcity varies across geographies, all technology platforms suffer from it.

- **The timing of regulatory approval and actual production ramp-up – up to 1.2 billion dose variance over 2021-2022.**

According to the booster/variant strategies which will finally be applied, two more factors could significantly reduce the overall production capacity:

- **The use of multivalent vaccine to protect against multiple variants at once would have immediate and substantial effect on reducing the drug substance capacity per dose.**

- **The move in certain countries from multi-dose to single-dose vials as they shift from mass to targeted booster vaccination. While this may make sense programmatically in a country context, it would have immediate and substantial effect on reducing the drug product capacity per dose:**
  - Indeed, nominal speed of filling lines are expressed in vials per minute, and only slightly vary as a function of vial size (and the number of doses it can contain)
  - Hence, the filling of single-dose vials versus multi-dose vials significantly reduces overall filling capacity when expressed in total vaccine doses

It must be noted that only the first of these two factors has only been reflected in the capacity simulation.

Very importantly, throughout the 2021-2022 period, countries’ ability to secure the supply they need for their vaccine programs is linked not only to supply availability, but also factors that drive distribution.

Exhibit 7: Production estimates in billion doses of COVID-19 vaccines per annum
8.3 Methodology: Financial and system resource availability

To identify financial resource availability, **key sources of funding** for lower income settings have been identified. The mapping is not exhaustive, but aims to identify most important drivers. Additional resources necessary for vaccine delivery beyond existing finances were also estimated. As explained above, the attention has focused on mapping available HW to quantify the needed surge. Countries’ performance on Diphtheria-tetanus-pertussis third dose (**DTP3**) vaccine delivery was finally used as a proxy for the ability of the health system to deliver ambitious vaccination targets for COVID-19 vaccine.25

8.4 Results: Financial and system resources availability

Successful delivery of a vaccination target depends both on the financial capacity of a country to support the goal (either through national resources and/or external support) and its health system’s capacity. Those aspects become increasingly important in the case of LICs/LMICs, since the aforementioned resources are, in several cases, limited.

When it comes to financial resources, various sources of funding can be considered:

- **Multilateral Development Banks (MDB):** As of writing ~USD 3 bn have been committed in MDB lending for vaccine procurement and delivery (an additional ~USD 5 bn in applications are under review) against ~USD 24 bn announced envelope.26 Given the nature of the instrument (concessional loans), attractiveness for LICs/LMICs for vaccination financing remains unclear. Trade-offs between

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25 https://immunizationdata.who.int/
COVID-19 vaccines and other health priorities will need to be considered carefully by each country given the opportunity costs for other health interventions, especially in epidemiological settings where there is a low perceived burden of disease.

- **Official Development Assistance (ODA):** Funding raised to-date for vaccines in LICs/LMICs, largely done via COVAX AMC, was mostly funded through Official Development Assistance (ODA), as well as contributions from the private sector and philanthropy. In the high-demand scenario (corresponding to vaccinating the entire population plus booster), the funding required could reach up to 70% of a yearly Official Development Assistance (ODA) 2018, concluding on the need to rely on alternative sources of financing than ODA alone under certain scenarios and conditions.

- **Dose sharing:** An important source of funding can be unlocked as countries start to share their excess supply. It is currently estimated at >1bn doses.

- **Returns on investment from vaccination:** Finally, economic returns of vaccination accrue to all countries as PHSM are progressively lifted and socio-economic activity resumes. The IMF has estimated this benefit at 9 trillion USD by 2025, with over 40% of this gain going to advanced economies. Under the premise that these levels of return can only occur in a global vaccination context, consideration for HICs sharing their returns on investment by funding part of the needs of LICs/LMICs can be envisaged.

9  Goal synthesis under different scenarios

Based on considerations of incremental benefits, dose requirements, vaccine supply availability, cost and funding sources, and system constraints, a goal-synthesis was conducted as a structured process that aims to:

1. identify countries’ current vaccination ambition relative to the framework and progress to date
2. identify barriers on the trajectory towards different goals
3. incremental benefit analysis for moving to higher ambition goals
4. calibrate expectations with respect to global goals

For the goal synthesis, countries were often clustered by income archetype as a proxy for demographic and system strength, in addition to financial resource availability.

Of note, some barriers can be measured (e.g., supply-demand balance, funding) and quantified from the analysis of the previous chapter, while others are factored in using a more qualitative approach (e.g., systems constraints). The intent of the synthesis is to provide an evidence-based view for goal-setting, to identify barriers to reach targets, and establish what is needed to overcome them.

9.1 Vaccination ambition and progress to date

9.1.1 Methodology

An overview of publicly stated country goals, their current achievement rate and some estimates of the associated supply deals are demonstrated in this section. The information about stated country goals is sourced through media coverage and does not aspire to be exhaustive. Country goals are publicly stated in different forms, primarily as share of total population. Available information was standardized into target age of populations to be covered using an age descending order. 100% within-group coverage was assumed before descending to the next youngest age range.

Information about the country bilateral deals is sourced from COVAX global market assessment. The achievement rate per country is sourced as of June 16.29

9.1.2 Results

A review of publicly communicated vaccination targets as of June 20, 202130 shows that countries are already setting ambitions that go well beyond those established in 2020 for at least 20% population coverage.

29 https://ourworldindata.org/grapher/cumulative-covid-vaccinations

30 Source: the Yellow House
Countries tend to express their COVID-19 vaccination ambitions by specifying their target for total population percentage vaccinated. Overall, countries have been setting goals beyond the original 20% target, and the majority of goals in the public domain lie between 50% and 75% of total population.

Each share of population target was translated into a corresponding age target accounting for specific country demographics. This allowed us to plot targets against the conceptual framework in terms of the lowest age range that would be implied for vaccination if the total population coverage target were to be achieved (Exhibit 8).

Exhibit 8: Publicly-stated country vaccination goals

According to the conceptual framework, and inferences drawn by applying the country specified coverage targets, countries appear to be converging towards ambitious health goals of “reducing COVID-19 disease burden” or “reducing transmission” and/or at durable lifting of PHSM and hence increasing levels of socio-economic activity.
Interestingly, applying the total population coverage targets to country specific demographics, LICs and LMICs appear to be setting some of the highest level of ambition, clustered around vaccinating their population down to those 15-25 years of age. High income countries are setting targets at a somewhat lower level of aspiration. Upper-middle-income countries display the most variance in the levels of their goals. The high variability observed among country goals (even belonging to the same income archetype) is likely the result of multiple influences including perceptions regarding supply availability, dynamics of the pandemic, countries influencing one another in terms of the goals they set, population preferences, and, most importantly, a desire to resume economic activity with lack of clarity on required vaccination targets. The purpose of the goal framework and the goal synthesis process described in this section is to offer a means for greater clarity when setting and pursuing those goals.

The majority of countries cluster within the 12+ to 30+ year age bands (pink stripe in Exhibit 8) raising the question of whether countries are considering the implications of their total population coverage targets for vaccination of adolescents and younger children for some. The current approach of setting goals as a percentage of the total population, when coupled with very different age demographics by countries, leads to several countries implicitly committing to vaccinate younger populations, when this may not necessarily be intended. To date there is a single vaccine that is authorized for use below 16 years of age (Pfizer vaccine), and a limited safety and immunogenicity experience in that age group. With transmission reduction one of the main motivations for vaccination of adolescents and younger children, the impact on mortality and serious disease is very limited in this age group, and instead confers some indirect benefit for older age groups based on modeled scenarios. On the other hand, the uncertainty of MIS-C prevalence and the long-term health consequence of COVID-19 in young people could be an argument for vaccination of the latter. It is too early for impact evidence to bear out the prediction of the modeled data.

From a timeline perspective, the majority of countries have set their goal end-date to be end of 2021, irrespective of their country archetype. Few countries have set the end-date sometime in quarter one of 2022, with the notable exception of the African Union that aspires to reach its target by end of 2022. The relatively short time frame pursued by countries is another indication of the highly-aspirational targets they have set.

Finally, an analysis of available information on supply deals shows that HICs have commitments to meet their ambition through supply deals which provide more than 5 times (on average) the supply needed to meet their goals. On average, also UMICs and LMICs have also entered into supply deals to meet their goals, based on public information, but with wide variance among countries.

An overview of current progress against projected goals shows high disparities with HICs having an average current achievement rate of 62% by the second half of 2021 and hence on a very good trajectory towards reaching their goals while LICs are much further away (second half of 2021 have an average achievement rate of 20%) as a combination of lack of supply as well as resource constrains.32

9.2 Barriers on the trajectory towards different goals

31 Interestingly, when defined as share of total population, targets show higher income countries ‘leading in the race’ towards highest ambition.
32 The Yellow House
9.2.1 Supply-demand balance

The feasibility analysis examines the supply-demand balance for 2021-2022 under the three supply scenarios – low, base, and high – which are defined in Section 8.2. By comparing programmatic dose requirements over a two-year period with supply available to countries based on deals and donations, we observe that under high supply scenario, supply could meet all demand dose requirements. Nevertheless, in the base and low supply scenarios, critical gaps remain visible in LICs and LMICs for the 0+ years and 12+ years scenarios (Exhibit 9). This is despite an assumption of 1 billion doses from HICs.

Over-procurement and trade barriers/export bans contribute to supply and demand imbalance on country group and country level. Misaligned product preferences are another factor that could lead to shortages in a complex market with multiply vaccine technologies and products available with varying level of performance and characteristics, despite supply to meet demand when looking at gross total numbers.

Of note, there is an estimated ~1.5B doses of currently unreserved manufacturing capacity in the low and ~4.5B doses in the base supply scenarios that could be further secured to address gaps, but this requires clear signaling to manufacturers for intent to purchase these doses. This can be done through transparent goal setting, accurate forecasting and early contracting to allow sufficient lead times to inform investment decisions and for the manufacturers to implement planned scale-up activities.

The feasibility analysis indicates that global production may be adequate over the course of the 2021-2022 biennium, but it will require active management of the supply and the market to ensure:

- That all worst-case-scenarios across uncertainties do not realize simultaneously, e.g., PTRS\(^{33}\) of candidates to come do not drop significantly, or increased delays and/or failure of the multiple scale-up do not materialize in parallel
- Important redistribution of doses now and in the next months as supply is still building up
- Clear market signaling for 2022 to sustain manufacturing cadence and capacity expansion
- Active portfolio management to ensure proper planning, forecasting, acceptable product characteristics, harmonized regulation, matching of product preferences
- Postponing of multivalent and monodose vaccine presentations until equitable vaccination has been reached in all countries

\(^{33}\text{PTRS: Probability of technical and regulatory success}\)
Exhibit 9: Biennial supply-demand balance by group (low supply scenario)

Exhibit 9: Several supply-constrained scenarios for the 12+ and 0+ years age targets for all country groups except for HICs. In the “no-booster” scenarios the LICs/LMICs are not constrained resulting from assumption about one-dose courses.

9.2.2 Financial and system challenges

The costing analysis has emphasized a broad range of cost for Covid-19 vaccination in lower income settings, depending on scenarios. The mapping of financial resources has pointed to key funding sources that could be leveraged to fund such costs.

While it is hard to predict, particularly at a time of economic downturn, it is likely that at lower levels of the cost spectrum (50+ years and 30+ years target population), economic returns from vaccination and Official Development Assistance could be leveraged to cover most of the costs in lower income settings making vaccination targets seem feasible from a financial perspective. COVAX has already been able to mobilize 8.6 USD bn at the time of writing and additional amounts have potentially been committed by LICs/LMICs through bilateral deals.34

Nevertheless, in cost scenarios (12+ years, 0+ years, annual boosters), the biennium costing estimate would represent about 70% of 2018 ODA, clearly a too important share. In such case, MDBs would likely need to play a key function to support financially constrained settings. The current estimate of funding availability is at “~24 USD bn35, out of which 8 USD bn have been awarded. These amounts would also need to be complemented by government revenues both in LICs and HICs leveraging very important returns on investment from vaccination.

34 Key assumption: ~50% of the deal value paid upfront
The international economic community is united in highlighting important economic returns to HICs from global vaccination through trade and capital flows channel. With the right level of political will, such returns could be leveraged to support ambitious vaccination everywhere, but this certainly represents an ambitious endeavor and should not be under-estimated. Finally, and very importantly, reduced procurement costs, particularly for lower income settings, can represent another important means to redistribute resources and enhance access.

It is key to note that the costing ranges provided do not account for investments required beyond procurement and delivery of vaccines at both country level (e.g. surveillance systems) and international level (e.g. support for technology transfer, regulatory efforts), nor for potentially needed costs to externally support mass campaigns to reach very ambitious targets in a short time frame. Highlighting these left-out costs is essential because they increase the financial requirements to reach different targets.

In addition to comparing overall cost with financial resource availability, in order to have a sense about the ability of a country to successfully achieve a vaccination goal, three indicators have been introduced that assess the relative capacity of the country systems to support a given goal-scenario pair. Countries scoring below the threshold in at least one of those three indicators, are considered to be “at-risk” of not achieving the specific goal under the given scenario.

The three indicators are:

- Indicator 1: The cost of vaccinating x% of the population is over 1% of 2021-2022 General Government Expenditure (IMF WEO April 2021 data) for countries where expected government revenue per person vaccinated is less than the cost per person vaccinated
- Indicator 2: The additional HWF for vaccinating x% of the population is larger than 10% of existing HWF in countries where the number of physicians/1000 population is lower than 0.2
- Indicator 3: Countries are not able to reach DTP3 coverage above 60% (WUENIC estimates extracted from WIIEEE, June 2021)

The methodology is detailed in Annex IV: Methodological simplifications for resource availability.

A total of 137 countries were considered and evaluated against each of the above criteria against the four goals described in a published model (Hogan et al., Vaccine, 2021) of SARS-CoV-2 transmission, that is linked to a framework to simulate global COVID-19 vaccine allocation and prioritization scenarios, was leveraged to estimate the deaths, hospitalizations, and infections that would be averted when vaccinating the age groups assumed for each coverage target in the goal framework:

Table 2, under all three dose schedule scenarios. The two extreme scenarios (targeting 50+ years - no boosters, and targeting 0+ years with annual boosters) are illustrated in Exhibit 10 below.
Exhibit 10: Identified countries with potential financial and system challenges

The analysis shown in Exhibit 10 leads to the conclusion that while systems are sufficiently strong to support lower levels of vaccination ambition, the majority of lower income countries will likely face key challenges in mobilizing system resources to reach the most ambitious targets – with HW surge as the main obstacle. Some UMICs may also face issues. The total population at risk in this latter scenario reaches ~3.6bn while 79 countries are affected, including India. Even in the favorable goal-scenario combination of vaccinating 50+ years without a booster, 16 LICS/LMICS countries with a total population of 0.5 bn persons, are at risk of not achieving the goal.
9.3 Incremental benefit analysis for moving to higher ambition goals

Previous analyses have estimated substantial macroeconomic returns from rapid, equitable access to COVID-19 vaccination across all country income groups. \textsuperscript{36,37,38,39} By contrast, \textit{delayed and inequitable vaccination rollout will prolong and depress economic recovery}, especially in emerging and developing economies and low-income countries (Exhibit 11). \textsuperscript{40}

\textbf{Exhibit 11: Pre-pandemic projections and forecast revisions to global growth}

![Diagram of pre-pandemic projections and forecast revisions to global growth]

\textit{Source: World Bank Global Economic Prospects, June 2021, Figure 1.1}

These prior analyses do not, however, consider the programmatic vaccination strategy issues of how to deploy available vaccines to unlock these economic benefits. These strategic issues include how vaccination should be prioritized within a country’s population, what levels of coverage need to be achieved within priority groups, and what vaccine characteristics (e.g., efficacy against infection, disease, and transmission) will permit achievement of different health and socioeconomic reopening goals. Such strategic considerations are important not only to optimize impact of COVID-19 vaccines within and across countries, but also to characterize the potential “lives and livelihoods” tradeoffs that countries face in responding to the COVID-19 pandemic.

Recent integrated epidemiological-economic modeling efforts have also sought to quantify some of the potential tradeoffs in different COVID-19 vaccination strategies, severity of business closures and other mitigation measures at the country level in low- and middle-income country settings (Table 4, Table 5). In Table 4 for an illustrative lower-middle-income country setting, the \textit{difference between the least and most stringent PHSM measures is associated with an estimated GDP loss} of approximately USD

\begin{itemize}
  \item \textsuperscript{36} RAND Europe. 2020. COVID-19 and the cost of vaccine nationalism. \url{https://www.rand.org/pubs/research_reports/RRA769-1.html}
  \item \textsuperscript{37} Cakmakli et al., 2021, \url{https://iccwbo.org/publication/the-economic-case-for-global-vaccinations}
  \item \textsuperscript{38} \url{https://www.who.int/publications/m/item/ending-the-covid-19-pandemic-the-need-for-a-global-approach}
\end{itemize}
142,000 per COVID-19 death averted over three months. Quadrupling the current vaccine administration rate results in an estimated reduction in deaths of 2.3 per 100,000 population over three months, assuming PHSM are kept in place. Table 4 reflects a general age-descending vaccination strategy but does not currently estimate the incremental economic impacts of the specific age thresholds in this global strategy scenario analysis.

In Table 5, the global strategy scenario analysis age thresholds are examined for an illustrative LIC setting. Table 5 suggests that a strategy relying only on PHSM to control COVID-19 will be much more costly than a carefully constructed strategy that involves both vaccination and PHSM. For example, compared to no vaccination and no PHSM, the model results indicate that vaccinating those 30+ before end-2021 would avert a similar number of deaths as would a strategy with no vaccination and maintaining PHSM restrictions in place; however, achieving this vaccination target would allow economic reopening that would avert over USD 2 bn in GDP losses. Deploying a combination of PHSM and vaccination as related approaches in an integrated pandemic control strategy is necessary to balance health and economic impacts, and as a bridge to return to normalcy. Together, these estimates suggest the importance of rapid vaccination rollout to save lives and reduce the need for economically costly PHSM to control COVID-19.

These initial estimates capture only the short-term economic impacts from supply side shocks, such as labor shortages due to COVID-19 illness and death and PHSM that interrupt business activity in different sectors; these are therefore conservative estimates of the economic benefits of vaccination over the short-term because they do not capture, among other things, demand shocks (e.g., changes in consumers’ preferences), changes in government revenue, international trade losses, and long-term GDP impacts (e.g., due to educational losses and reduced capital investment). On the demand side, as PHSM are lifted, COVID-19 vaccination may permit resumption of household consumption patterns, and thereby increase government revenues. These short-term estimates also do not capture longer term health impacts (e.g., lives saved beyond the analytic horizon, averted long COVID or other sequelae due to COVID-19), which may have economic implications. Further analytic work is needed to characterize the broader epidemiological and economic impacts of specific COVID-19 vaccination strategies in combination with PHSM within and across countries.

Table 4: Example lower-middle-income country scenario of deaths vs. GDP losses under different PHSM levels during the vaccination rollout in Q3 2021

<table>
<thead>
<tr>
<th>PHSM stringency</th>
<th>Deaths</th>
<th>GDP loss</th>
<th>Incremental GDP loss per life saved with increasing PHSM stringency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vax A: currently observed vaccine administration rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near-open economy and least stringent PHSM</td>
<td>25 783</td>
<td>$0.17B</td>
<td>-</td>
</tr>
<tr>
<td>Mid to low closures and stringency</td>
<td>12 181</td>
<td>$0.73B</td>
<td>$41,097</td>
</tr>
<tr>
<td>Mid to high closures and stringency</td>
<td>4708</td>
<td>$2.23B</td>
<td>$200,990</td>
</tr>
<tr>
<td>Strict closures and stringent PHSM</td>
<td>2526</td>
<td>$3.47B</td>
<td>$571,036</td>
</tr>
<tr>
<td>Vax B: vaccine administration rate doubled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid to high closures and stringency</td>
<td>4532</td>
<td>$2.23B</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
Vax C: vaccine administration rate quadrupled | Mid to high closures and stringency, | 4209 | $2.23B | Not applicable

a. COVID-19 deaths over three-month projection horizon
b. GDP loss compared to pre-pandemic GDP over three-month projection horizon
c. Incremental GDP loss per life saved compared to next least stringent PHSM scenario

**Table 4 Brief Methods**

- **Vaccination strategy**: the vaccination rollout proceeds from the oldest to the youngest adults, assuming coverage of 70% in each age group; the vaccine administration rate remains constant at the currently observed rate, with 14% of the total population fully vaccinated by the end of three-month projection horizon (21% and 36% in Vax B and C scenarios); vaccine infection-blocking efficacy assumed to be that of the AstraZeneca vaccine against the Delta variant.
- Economic impacts estimated through differential closures of 35 sectors of the economy using integrated SEIR and input-output model (DAEDALUS).


**Table 5: Example low-income country scenario of deaths vs. GDP losses under different vaccination and PHSM strategy combinations implemented over 2021-2022**

<table>
<thead>
<tr>
<th>Vaccination strategy</th>
<th>Vaccination target achieved by end-2021</th>
<th>Vaccination target achieved by end-2022</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deaths (over 1000 days)</td>
<td>GDP loss (over 1000 days)</td>
</tr>
<tr>
<td>No vaccination, no PHSM</td>
<td>73102</td>
<td>$12M</td>
</tr>
<tr>
<td>50+</td>
<td>42524</td>
<td>$65M</td>
</tr>
<tr>
<td>30+</td>
<td>31640</td>
<td>$152M</td>
</tr>
<tr>
<td>12+</td>
<td>588</td>
<td>$299M</td>
</tr>
<tr>
<td>0+</td>
<td>22</td>
<td>$462M</td>
</tr>
<tr>
<td>Alternative counterfactual: No vaccination, PHSM in place throughout*</td>
<td>29105</td>
<td>$2,385M</td>
</tr>
</tbody>
</table>

a. Number of COVID-19 deaths over 1000-day simulation period associated with each vaccination strategy.
b. Total GDP loss over 1000-day simulation period in current US dollars, compared to counterfactual no-pandemic GDP level.
c. Incremental GDP loss per life saved is the ratio of the difference in GDP loss to deaths averted by extending the vaccination strategy to cover the next youngest age group (i.e., comparing each row to the row immediately above it in the table). For the 50+ vaccination strategy, incremental GDP loss per life saved is calculated as the difference between GDP loss in the 50+ strategy and GDP loss in the no vaccination and no PHSM strategy, relative to the corresponding difference in deaths. For the other vaccination strategies, incremental GDP loss per life saved is calculated as the difference between GDP loss in the given strategy
(e.g., 30+) and GDP loss in the strategy in which only the previous older age group is vaccinated and PHSM are in place until this goal is reached, relative to the corresponding difference in deaths.

Table 5 Brief Methods

- **Vaccination strategy:** age descending by global strategy scenario analysis age thresholds of 50+, 30+, 12+, and 0+, with target of 85% coverage of those 65+ and 70% coverage of those<65 years; vaccination rollout is at a constant rate based on the rate required to achieve the target coverage within a specified time period (end-2021 or end-2022). Vaccine product assumed to be 70% effective at reducing the risk of infection.

- **PHSM** are lifted at the completion of vaccination of each age group. Simulation run over 1000 days, assuming $R_t=1.2$ at beginning of vaccination campaign with PHSM in place until the vaccination target is reached, with social contact patterns then increased to approximate level of $R_t=1.8$ when PHSM are lifted. The no vaccination and no PHSM scenario assumes contact patterns and susceptibility rates corresponding to $R_t=1.8$ at the beginning of the simulation. The alternative counterfactual of no vaccination with PHSM throughout assumes contact patterns and susceptibility rates corresponding to $R_t=1.2$ at the beginning of the simulation. $R_t$ may evolve over the course of the simulation.

- **Gross Domestic Product (GDP)** loss over 1000 days in US dollars calculated compared to a no-pandemic counterfactual GDP scenario.

*Source: Ferranna, Cadarette, Bloom (2021) Harvard School of Public Health*

### 9.4 Calibrate expectations

Many countries and the international community have stepped up in the global fight against the pandemic. The above analysis has underscored important opportunities for all stakeholders as well as clear challenges.

**Countries are setting ambitious and diverse vaccination targets driven by technical, political, social, and economic considerations.** An analysis of targets shows lack of clarity on how to achieve health and socio-economic goals: while countries’ targets, expressed as share of total population to vaccinate, are racing upwards toward ambitious 50-70% coverage, with different implications in terms of age of population to be covered and resource required country by country. For countries with a much younger demographic distribution, mostly lower income settings, such targets imply vaccination of children and very important financial and system investments coupled with much uncertainty on benefits of these younger age strata.

The analysis also shows some regional coordination, for instance by African and European countries, but a lack of global agreement towards a collective approach to leverage vaccines in the pandemic fight. The G7, G20, International Monetary Fund (IMF), World Bank (WB), World Health Organization (WHO) have put out proposed global targets for consideration, these are attempting to bring the pandemic substantially under control everywhere, and to avoid health and economic recoveries diverging dangerously. **There is indeed a pressing need for a more equitable approach to fighting the pandemic. Yet, these goalposts would benefit from consolidation** to ensure global policy making, global access efforts, investment decisions of financial, R&D groups and vaccine manufacturers can be coherently guided, as well as country planning and programmatic work.
With regards to desirability of the diverse range of goals as highlighted in the conceptual goal framework, the analysis shows important marginal returns, in terms of death and hospitalization averted, by vaccinating larger shares of population from a health viewpoint. Across all income groups, there are greater health impacts in absolute terms when expanding vaccination to an ever-increasing share of the population by descending age cohorts. Nevertheless, under the scenario assumptions modeled, the results suggest that prioritizing vaccination of the older adults will achieve the greatest mortality and hospitalization reductions for a given level of vaccine supply. While increasing the vaccination target to younger ages increases the overall number of events averted, it does so with differential efficiency across outcome measures: vaccinating those <30 years is an efficient strategy mainly towards the goal of reducing viral transmission. This is where uncertainty begins: there are questions around the magnitude of transmission reduction, the need to do so linked to the unclear threat posed by VOC and long COVID as well as potential positive public health implications of some endemic disease circulation.

While the biggest incremental benefit of moving to younger age strata is in lower income settings due to demographics, transmission patterns and health system constraints, trade-offs between ever increasing COVID-19 vaccination ambition and other health priorities are more evident, particularly given lower efficiency of younger age vaccination. Both systems (including human resources) and financial resources pose a clear challenge for more ambitious goals. The risk is clear of impacting sustainability of immunization outcomes across many other diseases of considerable burden such as measles, pneumonia, diarrhea, where vaccination has played an instrumental role to save lives and avoid morbidity. The risk is also clear in terms of foregone opportunities for expanding immunization services, such as reaching unserved communities or introducing new antigens, for instance human papilloma virus vaccines.

These trade-offs need to be carefully weighed against the risks of lower and/or slower vaccination roll out in lower income settings in a fast-moving interconnected world. With cases on the rise, many settings could not only find themselves hit by high health costs, but also constrained by public health and social measures limiting consumption and socio-economic activity. In addition, economic losses due to reduced international trade and capital flows could suffer. A choice, or lack of choice, to implement a limited vaccination target by low income settings will also have impact in higher income settings: both the ICC and IMF and other institutions have clearly highlighted the role of an interconnected global value chain on GDP gain or loss across all countries with highest return on public investment in modern history—capturing 40 percent of the cumulative $9 trillion in global GDP gains and roughly USD 1 trillion in additional tax revenues.41

But are all the goals on the conceptual framework even feasibly to reach?

We have seen that there is a key opportunity for adequate global supply over the 2021-2022 biennium, but this will require very clear and timely market signaling to supplier as well as collaborative behavior. To ensure all countries have access to precious vaccine supply for meeting ambitious vaccination targets, we need: 42

- Anticipate excess vaccine supplies, particularly in the coming months and redistribution of surplus doses from higher to lower income settings as soon as possible, while urgently evaluate dose stretching and dose optimization strategies to expand effective supply

42 Many of these actions have already been put forward as necessary in recent calls for action by COVAX, IMF, WB.
• Take steps to enable countries to reach desired targets by supporting free cross-border flows of raw materials and finished vaccines, while ensuring full and global recognition of WHO EUL’d products
• Send early, strong and clear signals about demand to secure manufacturing capacity scale up
• Governments and vaccine manufacturers to invest in diversifying vaccine productions and prioritize the scale up of vaccine production in the long term, providing increased access for developing countries
• Greater transparency on vaccine contracts, options and agreements as well as doses delivered and needed: in these challenging circumstances, information means access.

System and financial constraints can affect achievement of more ambitious country goals in LICs and LMICs, and potential booster requirements put into question sustainability of results. While global supply has been the initial barrier, once this barrier is lifted, political will could drive considerable progress. Yet, a ‘ramp up’ phase of vaccine implementation would require much higher throughput capabilities and this could be challenging in many settings, the analysis shows. Incremental financial needs from domestic resources may be unrealistic, and even more the need for human resource surge to implement vaccines. While financial resources would be difficult to mobilize, these are certainly not constrained: official development assistance, multilateral development banks, increased tax revenues and reduced costs, including through dose sharing, are all rich available sources.

Nevertheless, systems, from cold chain to data and technologies may pose clear limits in constrained settings. To ensure all countries have similar opportunities, we need:

i) important amounts of capital and external support for lower income settings, including technical and human resources for externally supported campaigns not costed by this work,43

ii) countries would need to put in place vaccine procurement and distribution plans and efforts to convey the life-saving importance of approved COVID-19 vaccinations.44

All countries, of all income strata, are likely to face challenges linked to potential need to adapt products as well as vaccine acceptance. In a last phase of the pandemic fight, tailoring efforts to reach the hard to reach will be essential.

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43 WHO and WTO, the World Bank Group and IMF have already urged international support for USD 50 billion of financing aimed at achieving more equitable access to vaccines and thus helping to end the pandemic everywhere.
44 As already called by COVAX, IMF and WB.
10 Building consensus towards an updated Global COVID-19 Vaccination Strategy

This paper has provided a conceptual framework to help coherently set vaccination goals and targets, driven by the health impacts underpinning relaxation of PHSM and restoring social and economic activity, while accounting for known and unknown uncertainties, resource limitations, incremental benefits and trade-offs. This work highlights the following **important considerations** towards building consensus for an updated Global COVID-19 Vaccination Strategy:

- **The path to full global recovery advances through several goals in a step wise approach** (Exhibit 12) from:
  - Step 1 - **Reducing highest risk of mortality and protecting health systems limiting most severe PHSM needed for crisis response.** This goal is associated with a ‘low’ level of vaccination target and with reaching populations at high risk, indicatively above 50 years of age.
  - Step 2 - **Minimizing mortality and severe disease while resuming socio-economic activity.** This goal is associated with a ‘mid’ level of vaccination target and, indicatively, with reaching populations above 30 years of age.
  - Step 3 – **Minimizing disease burden directly and indirectly advancing further towards full resumption of economic activity.** This goal is associated with a ‘high’ level of vaccination target and, indicatively, with reaching populations above 12 years of age.
  - Step 4 – **Mitigating future health risks for full global recovery.** This goal is associated with a ‘very high’ level of vaccination target and, indicatively, with reaching all populations.

Completing the immunization of populations most at risk must be a precondition for proceeding to more ambitious targets.
Exhibit 12: Stepwise approach along the trajectory of potential global goals

- **Vaccination targets** should be driven by an analysis of what is required to achieve certain goals and country specific targets need to **account for local circumstances**, including demographic and priority populations distribution. **While many global goals have been expressed in terms of share of total population to be reached equally across all countries, this is not consistently driven by epidemiologically relevant disease and infection goals and may yield vaccination strategies (such as vaccination of children) that are not explicitly intended, with uncertain benefits and possibly unintended use of scarce resources.** For example, a global target of vaccinating all individuals above the age of 30, implies vaccination of 40% of the world population, but can be achieved with vaccination of 22% of populations in countries with younger demographics (while requiring a 50% coverage in countries with older populations).

- **Available evidence to support desirability, feasibility, sustainability, of each goal and vaccination targets need to be carefully considered:** we have highlighted both health and economic benefits and uncertainties of moving up from vaccination of higher risk groups to larger and larger shares of younger, less at risk populations. Challenges and opportunities from a supply, financial and system perspective have been reviewed. At the time of writing, Step 1 in the chain of possible global goals represent an ‘unfinished agenda’ for which substantial investment is well under way. That Step should be completed in all countries. Step 2 is likely required to resume economic activity and it is already being pursued by many countries who have already made important investments in this direction; the analysis shows that with active market management and external support for lower income settings, this step could be in reach during 2021 to early 2022. **The evidence in several areas that underpins the rationale for Steps 3 and 4 is still accruing or in early stages.** These uncertainties include the benefits of vaccination with diminishing direct health returns measured by deaths and hospitalization, the burden and characterization of the long term health consequences of milder disease, limited clarity on the feasibility and overall impact of reducing transmission in younger age strata, the potential role for endemic disease circulation, and gaps in evidence on the safety and performance of vaccines in children.
- **Mitigating future risks**: uncertainties cited above, pose important risks. For instance, the potential for variants to emerge for which existing vaccines are poorly performing rendering them largely ineffective: the implication is that countries would have to reinstate control efforts already released and maintain those while reestablishing vaccine driven immunity. Another type of risk is linked to community continued acceptance of ongoing or return to PHSM of increased intensity as needed. While these unknowns are at play and evidence is being gathered, decisions are needed now on investments that will establish the opportunities of the near future. For instance, assuring that **global supply** to potentially complete Step 3 is secured now through at-risk investments, is a **‘no regrets’ investment** that allows greater specification of policy and programmatic refinements of its use. A growing body of evidence on the roles of young adults and adolescents across diverse social and epidemiologic settings in viral transmission, disease burden, vaccine performance and demand as well as the long-term consequences of disease and infection will allow an **adaptive approach** to the prioritization of additional population targets.

The more ambitious universal vaccination goal, step 4, has even more substantial uncertainties that will need time for the evidence to be developed, but here also investments at risk would be relatively small relative to their payoff should they be needed.

In light of the above, three options for the updated Global Vaccination Strategy covering the remaining of 2021 and 2022 (Exhibit 13) are laid out. These are as follows:

**A.** An ambitious, no-regret **‘Universal global vaccination strategy’**. This strategy would:

a. **Aim to mitigate future health risks for full global recovery**, reaching the highest goal post on our conceptual goal framework

b. **Prioritise highest risk groups** where incremental benefits are largest, but encourage and support all countries to then **quickly move through steps 1-4 and vaccinate all populations**

c. **Leverage recent ambitious calls for actions by international organisations and political will around C-19 vaccination and establish equitable opportunities**

d. **May require massive investments**, including of external technical support, to support externally drive, campaign-type approach to timely immunization in context of high scientific uncertainty

e. **Require concomitant investment in other immunization activities** (e.g. measles, polio catch up, strengthening of immunization systems) and primary care. This protects against diversion of resources away from other priorities and use of resources that may end up not being needed (for instance if safety of vaccine use in children was not demonstrated).

**B.** An **‘All adult global vaccination strategy with risk mitigation’**. This option would:

a. **Aim to reduce disease burden and putting countries on trajectory toward resuming socio-economic activity**

b. **Prioritise highest risk groups** where incremental benefits are highest, and **encourage and support countries to move swiftly across step 1 and 2 and reach 30+ or all adult populations**

c. **Leverage clear political will and already ongoing in investments, and could be feasible for majority of countries** with external support
d. **Promote efficient use of resources in face of many scientific uncertainties** on feasibility and desirability of steps 3 and 4.

e. **Call for important at risk investments in vaccine supply and systems to ensure readiness to implement future steps once scientific uncertainty is cleared:** for instance to expand immunization to all populations (including adolescent and children) should evidence become clear that this is needed; boost vaccination where evidence requires it.

C. **‘Older adult global vaccination strategy’ focused C-19 vaccination effort.** This option would:

a. **Reduce highest risk of mortality and protecting health systems limiting most sever PHSM needed for crisis response.**

b. **Focus only on highest risk groups of 50+ where incremental benefits are highest, and encourage all countries to await for further evidence on need/desirability of further ambitions**

c. **Reinforce and build on the current unfinished agenda**

d. **Ensure efficient and effective use of scarce resources** for more feasible and impactful targets

e. **Risk leaving us unprepared should the need for more ambitious vaccination targets become evident** as more data and knowledge is collected on scientific uncertainties.

Exhibit 13: The three possible options for a the updated Global COVID-19 Vaccination Strategy
Notwithstanding that so much has been learned in such a short period of time, evolving evidence about the vaccines, virus evolution, community transmission, population demand, and the trajectory of the pandemic mean that any vaccination strategy must remain dynamic. Adaptive goals, which are adjusted and further specified as evidence accumulates, as the virus adapts, and vaccine performance is clarified allows the agility the world needs to shut down this pandemic. Decisions about how best to deploy vaccines over the medium term, for their greatest and most durable impact will depend on continues updating of the world’s collective resolve.

11 Acknowledgements

This work has benefited from a number of contributing panels and working groups (in no specific order): COVAX global market assessment working group, SAGE Working Group on COVID-19 Vaccines, Imperial College London (MRC Centre for Global Infectious Disease Analysis, WHO Collaborating Centre for Infectious Disease Modelling), Harvard School of Public Health (Value of Vaccination Research Network Secretariat), Country Readiness and Delivery Task Team for Global Delivery Costs, COVAX Workstream Convenors and RSSE.
12 Annexes

12.1 Annex I: Task Team and Ad Hoc-Strategy Group Members and ToRs

12.1.1 Governance

Exhibit 14: Global COVID-19 Vaccine Strategy – Organization and Governance

12.1.2 Task Team

The work is organized in four Workstreams: epidemiology, dose requirements, costing/funding and supply, roughly corresponding to the chapters in which this document is organized (the goal framework as part of the epidemiology workstream, resource requirements including the dose requirements’ and costing analyses, resource availability tackling funding and supply issues). The Workstreams operate in parallel to do modeling, run simulations, gather data and sources and generate results necessary for the completion of the four steps.

As part of the governance structure, a Task Team, consisting of approx. 20 people and including the six Workstream leads, is convened for a short time. The Task Team oversees the process, develops areas of associated workstreams (as described above) and advances the content of the work. The Task Team convenes once per week for 2 hours sessions. Between meetings, team members are asked to review the workstreams’ outputs and conduct/coordinate analytic work.

<table>
<thead>
<tr>
<th>Objectives</th>
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<tr>
<td>Oversee overall progress of project deliverables</td>
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<td>Develop the areas of works for the workstreams</td>
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<tr>
<td>Advance the content of the strategy work with input from workstreams</td>
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<tr>
<td>Prepare materials Global C19 Vx Strategy for review by SAGE C19 Working Group</td>
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<td>Members</td>
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<th>Definition of key questions to be addressed by the 4 workstreams: Epidemiology &amp; Modeling, Demand, Supply, Resource requirements</th>
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<tr>
<td></td>
<td>Report and/or model with sets of 3 epidemiological, supply, demand and resource requirements scenarios</td>
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<td></td>
<td>High-level feasibility and benefit-resource analysis, assessing requirements for any given goal under the set of identified scenarios</td>
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<td></td>
<td>Understand and inform goals through a stakeholder engagement process</td>
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<td>WHO global strategy document critically appraised by SAGE</td>
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<tr>
<th>Modus operandi</th>
<th>Meets once per week for 2 hours</th>
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<tbody>
<tr>
<td></td>
<td>Review and preparation of materials between meetings</td>
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<tr>
<td></td>
<td>Leverage work already ongoing by task team members</td>
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An Ad-hoc Strategy Group of approx. 40 people representing respective organization is convened for a short time to inform/steer the work of the Task Team. The Ad-hoc Strategy Group provides perspectives from a wide range of stakeholders and shapes, challenges and creates new ideas around the scope and direction of the strategy work. The Ad-hoc Strategy Group convenes 3 times over the course of the study, each time for a 2-hour session.
### Table 6: Ad-hoc Strategy Group Terms of Reference

<table>
<thead>
<tr>
<th>Role</th>
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<tr>
<td>Provide perspective from a wide range of stakeholders across the globe to inform strategy work</td>
<td>FCDO</td>
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<tr>
<td>Shape, respond, react to and create new ideas around scope and direction of strategy work</td>
<td>Gavi</td>
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<tr>
<td>Help collect and share perspectives, as well building across wider set of stakeholders</td>
<td>Gavi</td>
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<tr>
<td>Provide input to the Task Team on the four streams of work</td>
<td>Gavi</td>
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<td>PAHO RF</td>
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<td>RSA &amp; The COVID-19 Lancet commission</td>
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<td>Instituto Mexicano del Seguro Social</td>
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<td>Deliverables</td>
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<td>Meets every 2-3 weeks for 2 hours for 3 meetings</td>
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12.2 Annex II: Health impact scenarios: methodology, assumptions and sensitivity analysis

12.2.1 Assumptions on epi variables, coverage and vaccine performance

Within each age group, coverage levels were set at the maximum levels assumed to be feasible based on historical immunization program performance and vaccine hesitancy, in alignment with assumptions made for dose and resource requirements. For each age group target, vaccination was applied in age-descending order in 5-year bands beginning with the oldest age group (80+ years).

Scenarios were explored for four country archetypes based on World Bank income group (high, upper-middle, lower-middle, and low), with representative parameters (age structure, social mixing patterns, demography, and health system capacity) for each setting. It was assumed that health system constraints in low- and lower-middle-income countries would mean that some individuals requiring health facility care (e.g., oxygen) for COVID-19 would be unable to obtain it, leading to higher infection fatality ratios than if such constraints were absent.

Scenarios assumed an initial epidemic wave, after which PHSM remain in place sufficient to keep Rt at a low level (1.2), resulting in 20% of the population with immunity following natural infection at the start of the vaccination period. During the period of vaccination (assumed to occur over four months), Rt is kept at 1.2. Public health and social measures were then assumed to be reduced gradually following completion of the vaccination campaign, resulting in a linear increase in Rt (to 3.5) over six months. For each vaccination target, the pace of vaccination was set such that the target group (50+, 30+, 12+, or 0+) was vaccinated over four months, with PHSM lifted after the same four-month campaign period for comparison of impacts across age group targets. Deaths, hospitalizations, and infections averted per
million total population and per 100 fully vaccinated people were estimated for the period of two years following completion of the vaccination campaign (corresponding approximately to 2021-22 and 2022-23), compared to the same period and PHSM trends in the absence of vaccination, in total and by age group in which events occurred. Results shown are for a single archetype country setting, and do not represent total events across all countries within or across income groups.

The default scenarios assumed a vaccine with 63% efficacy against infection, 80% efficacy against severe disease, and 45% against transmission. Immunity following natural infection was assumed to last one year on average. Sensitivity analyses considered variation in the proportion of the population already infected at the time of the vaccination campaign (10%, 30%), timing of the vaccination campaign relative to the epidemic peak, waning of immunity from natural infection (lifelong), impacts of VOC (reduced vaccine efficacy, higher transmissibility), vaccine characteristics (disease-blocking only), health system constraints (no constraints in low- and lower-middle-income countries), and differential infectiousness among children (50% reduced in <10 years old).

12.2.2 Sensitivity analysis

Exhibit 15: Share of population recovered from COVID-19 before vaccination campaign begins, and levels of implied PHSM to suppress transmission during the period of vaccination

![Graph showing death rates per million per day over time with different Rt values](image)

*Figure: Counterfactual trajectories, without vaccination.* The coloured lines show different levels of transmission during a period of suppression, resulting in different proportions of the population in the Recovered class when vaccination commences. In the LMIC setting (shown) this results in 10%, 20%, and 30% of the population Recovered for Rt1 equal to 1.05, 1.2, and 1.4 respectively.

Exhibit 16: Timing of window of vaccination relative to epidemic peak

![Graph showing different vaccination start dates and corresponding death rates over time](image)

*Interpretation: Earlier vaccination and longer duration of protection from natural infection reduce mortality from the subsequent epidemic peak.*
Exhibit 17: LMIC example: Deaths per million population per day and deaths averted per 100 fully vaccinated people (FVP) for default vs. VOC settings

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<tr>
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<th>Default setting</th>
<th>VOC setting</th>
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<tr>
<td><strong>Efficacy</strong></td>
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<tr>
<td>Infection</td>
<td>63%</td>
<td>40%</td>
</tr>
<tr>
<td>Severe disease</td>
<td>80%</td>
<td>60%</td>
</tr>
<tr>
<td>Transmission</td>
<td>45%</td>
<td>33%</td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td>$R_t = 3.5$</td>
<td>$R_t = 4.5$</td>
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**Interpretation:** Compared to the default, VOC that reduce efficacy or increase transmission will make vaccination less efficient (i.e., lower population health impacts per FVP) for every age target.
Exhibit 18: Deaths per million population per day and deaths averted per million population for default vs. VOC settings: by country income group

Interpretation: Across all income groups, compared to the default, fewer deaths are averted when assuming reduced efficacy or higher transmission in a VOC setting, with the fewest deaths averted when these effects are combined. A more transmissible VOC leads to more deaths in the absence of vaccination (and hence more deaths averted from vaccination) in the first year.
Exhibit 19: LMIC example: Deaths per million population per day and deaths averted per 100 Fully Vaccinated People (FVP) for default vs. 3 scenarios

(i) disease-blocking vaccine only; (ii) health systems able to surge in LICs/LMICs (no higher IFR due to health system constraints); and (iii) children <10 years 50% less infectious

Interpretation: Compared to the default, epidemic peaks occur at different times under the sensitivity analyses. Compared to the default, when averting death is the health outcome measure, a vaccine that blocks disease only is even more efficiently targeted to the oldest groups, and targeting to younger age groups is even less efficient. Compared to the default, when health system constraints are not present for LMICs/LICs, then averted deaths are lower (because overall deaths are lower due to better health care, and therefore fewer deaths could be averted). Compared to the default, results are not significantly different when children are assumed to be 50% less infectious.
Exhibit 20: LMIC example: Deaths, hospitalizations, and infections averted per million population for default vs. disease-blocking vaccine only

Interpretation: If a vaccine is disease-blocking only, then the incremental health benefits of extending vaccination to younger age targets are substantially reduced.
Exhibit 21: LMIC example: Deaths, hospitalizations, and infections averted per million population for default vs. health systems unconstrained in LICs/LMICs

Interpretation: If LICs/LMICs health systems are able to surge to manage COVID-19 cases, then there will be more hospitalizations but fewer deaths in the counterfactual without vaccination; therefore, compared to the default, there are more hospitalizations but fewer deaths averted when health system constraints are absent for each age group vaccination target.
Exhibit 22: LMIC example: Deaths, hospitalizations, and infections averted per million population for default vs. children <10 years 50% less infectious

**Interpretation:** Assuming reduced infectiousness among children does not significantly change the estimated impacts of the vaccination targets in this setting for the assumed scenario values.
Interpretation: Vaccinating younger cohorts benefits older cohorts through indirect protection (“herd effects”) by averting hospitalizations primarily among older cohorts not effectively directly protected. This effect is more pronounced in HICs and UMICs; in this scenario, LMICs/LICs are assumed to face health system constraints such that all patients needing care cannot receive it, therefore hospitalizations are lower and IFR is higher than in the absence of these constraints.
Exhibit 24: Age groups in which infections averted for each vaccination coverage age targeting strategy

Interpretation: Vaccinating younger cohorts benefits a more balanced distribution of age cohorts through indirect protection ("herd effects"), including averting infections among younger cohorts. This effect is most pronounced in LMICs/LICs due to their younger demographic structure.

12.3 Annex III: Methodological simplifications for resource requirements

To facilitate modeling of health and economic impact and forecasting dose requirements and cost of vaccination over the course of 2 years, namely 2021 and 2022, several methodological assumptions were made as reported here below.

12.3.1 Zero baseline assumption

An overarching assumption is that of zero baseline, i.e., the calculation of dose requirements has been performed as if no vaccination has taken place. The rationale for using this “clean-slate” assumption is to avoid forecasting dose requirement figures for the remaining 2021 with the risk of accumulating error in the end-of-year predictions and subsequently propagating this error to the 2022 forecasts.
12.3.2 Vaccination targets

While the proposed goal framework encourages countries to follow the WHO SAGE Roadmap For Prioritizing Uses Of COVID-19 Vaccines In The Context Of Limited Supply, to simplify modelling and forecasting efforts, age targets were associated with each of the four vaccination targets laid out in the goal framework.

The age targets have already been laid out in Error! Reference source not found. Methodologically, it is important to note the following:

- The new cohorts are vaccinated year on year as they enter the target age group for each goal
- A descending age order is applied within each goal

12.3.3 Programmatic coverage

To account for programmatic feasibility, we have looked on historical immunization program performance and hesitancy, and derived within age-group coverage assumptions, made as follows:

Table 7: Assumptions on programmatic coverage

<table>
<thead>
<tr>
<th>Priority Group</th>
<th>HIC</th>
<th>UMIC</th>
<th>LMIC</th>
<th>LIC</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>All HW</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
<td>Assumed high coverage given known delivery platform and pandemic setting</td>
</tr>
<tr>
<td>65+</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
<td>85%</td>
<td>Assumed high coverage given known delivery platform and pandemic setting</td>
</tr>
<tr>
<td>5-60</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>70%</td>
<td>Multidose coverage for the base case was selected based on OCV campaign 2-dose coverage reported by WHO GTFCC. Vaccination coverage surveys were documented following 31 campaigns. The estimated two-dose coverage ranged from 27.5 to 95%, with an average of 70%. A study about the OCV campaign in Haiti showed that dropout was higher in &gt;15 years than in 1-5 years.</td>
</tr>
<tr>
<td>0-4</td>
<td>87%</td>
<td>81%</td>
<td>77%</td>
<td>70%</td>
<td>DTP3 (WUENIC)</td>
</tr>
</tbody>
</table>

12.3.4 Uptake

**Uptake** indicates a maximum speed at which assumed programmatic coverage could be reached absent any supply constraints and major resource/programmatic obstacle. To calculate uptake curves, the following methodology is applied:

1. Every country is assigned a group based on the average of their scores across multiple variables, including health system strength, campaign experience, healthcare workforce, government health expenditure, financing constraints, and population size.
2. Uptake duration is assigned per country group.
3. For each country, actual administered rates are incorporated monthly if they show a higher pace of delivery is possible than previously anticipated.

The assumptions characterizing each country group with respect to its uptake are illustrated in *Exhibit 25: Uptake country groups*, while a world map view is illustrated in *Exhibit 26: Grouping of countries and uptake assumptions.*

Of note:

- Based on estimated completion dates of infant trials, countries are not expected to begin vaccinating below 12 years until 2022.
- The reference uptake estimates for speed of delivery to 18+ years population are applied proportionally to populations targeted in each scenario (50+ years, 30+ years, 12+ years, 0+ years) based on the relative size of the population in each country.

### Exhibit 25: Uptake country groups

<table>
<thead>
<tr>
<th>Country group</th>
<th># countries</th>
<th>% of 18+ pop vaccinated per month (average per group)</th>
<th>General Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longest duration</td>
<td>28</td>
<td>6%</td>
<td>• Campaign experience, lower healthcare access and quality (HAQ) scores, severe financing constraints, small proportion of vaccinators/pop and low CHE as % GGE</td>
</tr>
<tr>
<td>Longer duration</td>
<td>67</td>
<td>8%</td>
<td>• Campaign experience, mid-high HAQ scores</td>
</tr>
<tr>
<td>Shorter duration</td>
<td>42</td>
<td>14%</td>
<td>• Variable campaign experience, mid-low HAQ scores, and larger proportion of vaccinators/pop</td>
</tr>
<tr>
<td>Shortest duration</td>
<td>46</td>
<td>22%</td>
<td>• Minimal campaign experience, high HAQ scores, and higher CHE as % GGE</td>
</tr>
</tbody>
</table>
12.3.5 Dose requirements

To account for uncertainty around viral evolution and vaccine cross protection against new variants, as well as duration of protection, three dose requirements scenarios are used, illustrated in Error! Reference source not found., also listed below for conciseness:

- ‘No booster scenario’: two-dose course primary vaccination for HICs and UMICs and one-dose course primary vaccination for LMICs/LICs
- ‘High-risk booster scenario’: two-dose course primary vaccination + annual one-dose booster for those 50+ years only (in this scenario a one-dose booster every two years for all target populations is considered beginning in 2023 to get insights into long term projections)
- ‘Yearly booster scenario’: two-dose course primary vaccination + annual one-dose boosters for all

Of note:

- These scenarios are applied for dose requirement and cost calculations only – impact modelling assumes duration of protection and cross protection will be achieved through different doses requirements, as needed.
- Boosters kick in for each vaccinated population one year from previous vaccination (either primary vaccination of last booster). The rationale behind 2-dose courses in primary vaccination is twofold: (i) majority of current vaccines are two-dose and (ii) easier to normalize dose requirements and available supply and compare needs and availability.
- **Wastage assumed at 10%** additional to the % population target – i.e., it is not subtracted but rather added to the number of doses necessary to achieve the % population target
12.3.6 Funding and other programmatic requirements

Cost estimates for reaching 20% of the population in AMC economies were published in February 2021 (ref: Costs of delivering COVID-19 vaccine in 92 AMC countries (full report) (unicef.org)). Similar cost categories and unit cost assumptions were used in the present analysis.

The present analysis generates cost estimates for all LMICs with the exclusion of China and Russia. Cost estimates were generated for a total of 130 countries; 38 self-financing countries and 92 COVAX AMC economies.

Cost categories are summarized in Table 8. The scaling factor refers to assumptions made for generating total cost values. When ‘Country’ scaling factor is used, a total lump sum was assumed for the country according to size. For planning and coordination, USD 590,000 was assumed for countries with less than 10 million population and USD 800,000 for countries with more than 10 million population. Data sources for these assumptions are explained in the February 2020 report (Costs of delivering COVID-19 vaccine in 92 AMC countries (full report) (unicef.org)). With the ‘facility’ scaling factor, the number of health facilities in the respective country was used to generate total cost values. As an example, the costs of training health workers in new vaccine introduction was based on 23 previous cost studies. The total costs of training estimated in these studies were divided by number of facilities in the country to arrive at an average cost per facility estimate. This average cost was then used for extrapolation in the remaining countries. With the ‘dose’ scaling factor, a unit cost per vaccine dose delivered was derived from published studies and used for extrapolation to all countries.

An important data source for unit costs was the Immunization Delivery Cost Catalogue (IDCC) (http://immunizationeconomics.org/ican-idcc). This database stores resources on vaccine delivery costs in low- and middle-income countries (LMICs) from a large, systematic review of published and unpublished studies available since 2005. Data from IDCC were complemented with information from vaccination campaign budgets and Human Papilloma Virus (HPV) vaccine introduction budgets. Cold chain equipment costs were derived from the PATH Installed Base and Forecast Model. All costs were inflated to 2020 values. Fixed costs were defined as items that do not vary substantially by the number of doses delivered, such as planning and coordination. Variable costs vary with the number of vaccine doses delivered.

Unit costs vary between countries because of different salary levels and prices of goods, while the costs of tradable goods, such as cold chain equipment, are generally relatively similar across countries. Unit costs related to non-tradeable items were adjusted in the analysis as follows. Four cost categories were adjusted according to purchasing power parity (PPP): (i) training, (ii) vaccine transport, (iii) per diems and (iv) transportation for outreach. The methodology developed by Portnoy and colleagues for adjusting unit costs for PPP was used (Portnoy A, Vaughan K, Clarke-Deelder E, Suharlim C, Resch SC, Brenzel L, Menzies NA. Producing Standardized Country-Level Immunization Delivery Unit Cost Estimates. Pharmacoeconomics. 2020 Sep;38(9):995-1005). For social media listening, country-specific salaries were used to adjust the estimates. Country-specific water tariffs for costs of infection prevention and control were used.
Table 8: Costs categories included in cost estimates

<table>
<thead>
<tr>
<th>Cost category</th>
<th>Scaling factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Planning and coordination</td>
<td>Country</td>
</tr>
<tr>
<td>2 Training</td>
<td>Facility</td>
</tr>
<tr>
<td>3 Social mobilization</td>
<td>Facility and country</td>
</tr>
<tr>
<td>4 Cold chain equipment (2-8°)</td>
<td>Dose</td>
</tr>
<tr>
<td>5 Cold chain recurrent</td>
<td>Dose</td>
</tr>
<tr>
<td>6 Pharmacovigilance</td>
<td>Facility and country</td>
</tr>
<tr>
<td>7 Vaccination certificates</td>
<td>Dose</td>
</tr>
<tr>
<td>8 Protective Personal Equipment (PPE) for health care workers</td>
<td>Dose</td>
</tr>
<tr>
<td>9 Hand hygiene for health care workers and vaccine recipients</td>
<td>Facility and dose</td>
</tr>
<tr>
<td>10 Vaccine transport</td>
<td>Dose</td>
</tr>
<tr>
<td>11 Waste management</td>
<td>Dose</td>
</tr>
<tr>
<td>12 Per diem for outreach service delivery and supervision</td>
<td>Dose</td>
</tr>
<tr>
<td>13 Transportation for outreach services</td>
<td>Dose</td>
</tr>
<tr>
<td>14 Technical assistance</td>
<td>Country</td>
</tr>
</tbody>
</table>

Costs of technical assistance was estimated as follows:

- 13 countries were sampled to understand use and costs of TA consultants and staff as of June 2021 channeled through WHO and UNICEF country offices: Afghanistan, Bangladesh, Bosnia, Ethiopia, India, Kenya, Lao PDR, Malawi, Moldova, Nepal, Pakistan, Papua New Guinea, Uzbekistan.
- No activity costs were included.
- The 13 countries were sorted in seven categories from USD 1.5 to USD 0.1 million required for 6 months (India out of category).
- The seven categories were modelled with a series of combined indicators (income, Gavi status, conflict, fragile, population).
- Extrapolation using the seven cost categories to the 130 countries.
- Cost requirements for 5 semesters, with full cost for S2-2021 & S1-2022, then decreasing cost by 25% per semester.
- TA costs of expanded partners were assumed to be 33% additional on top of WHO and UNICEF.
Human resource surge costs were estimated separately from the other delivery costs. Methods were as follows:

- Number of doses administered x estimated time to administer each dose equals number of healthcare workers required
- HW densities per country: Total number of HW per country per type and yearly increase from new graduation
- Reallocation and new graduate employment percentages to calculate existing HW reallocated to COVID-19 vaccination
- Subtract existing HW from total HW required to identify gap
- Assumed that countries with UHC index <50% have no staff to reallocate -> all staff need to be surge
- Multiply both 1) reallocated and new graduate HW and 2) the HW gap by monthly salaries and duration of vaccination period to calculate economic and surge costs, respectively.

The source for the number of existing health care workers was ILO database. Parameter assumptions for HW costs are summarized in Table 9.

### Table 9: Assumptions for human resource surge cost estimates

<table>
<thead>
<tr>
<th>Description</th>
<th>Assumed value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Minutes per intervention</em></td>
<td>10 minutes</td>
</tr>
<tr>
<td><em>Working hours per day</em></td>
<td>7 hours</td>
</tr>
<tr>
<td><em>Working days per week</em></td>
<td>4.5 days</td>
</tr>
<tr>
<td><em>Team efficiency (leave, recruitment)</em></td>
<td>85% efficiency</td>
</tr>
<tr>
<td><em>Percentage of health workforce (HWF) reassigned for COVID-19 vaccination</em></td>
<td>5% of HWF</td>
</tr>
<tr>
<td><em>Percent increase of HWF through graduation each year</em></td>
<td>3% of HWF yearly</td>
</tr>
<tr>
<td><em>Percentage of new graduates employed for vaccination</em></td>
<td>30% of new graduates</td>
</tr>
<tr>
<td><em>Proportion per vaccine schedule types</em></td>
<td>100% 2-dose schedule</td>
</tr>
<tr>
<td><em>Proportion per delivery modality</em></td>
<td>88% fixed site; 12% outreach</td>
</tr>
<tr>
<td><em>Vaccinating team composition</em></td>
<td>0.2 supervisors per team (doctors only)</td>
</tr>
</tbody>
</table>
12.4 Annex IV: Methodological simplifications for resource availability

12.4.1 Supply
Global supply is estimated based on Monte Carlo simulation global production model. The model incorporates all developers with vaccines licensed or in clinical development and accounts for risk and uncertainty about:

- The probability of technical and regulatory success (PTRS)
- The timing of regulatory approval and production launch
- The manufacturing risk and technology transfer experience
- Availability of raw materials, drug product and adjuvant constraints
- Companies’ strategy regarding variants

The model is developed based on the publicly available sources (media monitoring) and BMGF, CEPI, Gavi and UNICEF intelligence. PTRS values are provided by Gavi and CEPI or estimated based on the Center for Global Development’s methodology (https://www.cgdev.org/sites/default/files/COVID-19-Vaccine-Predictions-Full.pdf)

Based on Monte Carlo simulation outputs three scenarios of low (5th percentile), base and high (95th percentile) supply have been introduced.

<table>
<thead>
<tr>
<th>Year \ Scenario</th>
<th>Low</th>
<th>Base</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>~6.5bn doses</td>
<td>~7.5bn doses</td>
<td>~9.0bn doses</td>
</tr>
<tr>
<td>Year 2</td>
<td>~9bn doses</td>
<td>~14bn doses</td>
<td>~17bn doses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of technical and regulatory success</td>
<td>• Estimated volumes from vaccines still in the development pipeline are risk-adjusted using PTRS</td>
<td>+/- 0.9B</td>
<td>+/- 3.0B</td>
</tr>
<tr>
<td>Timing of regulatory approval and production start date</td>
<td>• An estimated timing of first regulatory approval based on platform and stage is applied to candidates still in clinical trials and may differ from company claims</td>
<td>+/- 0.4B</td>
<td>+/- 0.8B</td>
</tr>
</tbody>
</table>

Multiple companies have indicated late 2021 and 2022 production scale-ups through
### Manufacturing risk/scale-up curves
- General as well as manufacturer-specific scale-up curves incorporated if data is available
- Manufacturing risks for facilities were assessed based on prior vaccine production and tech. transfer experience
- Resulting scores were used to adjust scale-up curves; companies with a large number of tech. transfers were the most affected

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some companies may begin producing at risk early—however the doses will not be released until the first approval</td>
<td>production launch at additional facilities</td>
<td>+/- 0.3B</td>
<td>+/- 2.0B With multiple new entrants in the market, manufacturing risk is high</td>
</tr>
</tbody>
</table>

### Scale, yield, capacity inputs
- Reported or estimated scale and yield data
- Reported manufacturer DP estimate
- We incorporate risk for all public inputs (amounts to at least 25% discount), except for vaccine developers deemed ‘trustworthy’ by experts

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported or estimated scale and yield data</td>
<td>+/- 0.3B</td>
<td>+/- 0.6B</td>
<td></td>
</tr>
</tbody>
</table>

### Raw materials, DP and adjuvant constraints
- Manufacturer-specific raw material, DP or adjuvant constraints were applied based on the available data

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturers specific raw material, DP or adjuvant constraints were applied based on the available data</td>
<td>+/- 0.3B</td>
<td>+/- 0.6B</td>
<td></td>
</tr>
</tbody>
</table>

### Variant strategy
- Production volumes may vary based on company variant strategy 1) booster 2) replacement 3) multivalent vaccine
- Companies that employ a multivalent booster will see a reduction in supply
- Depending on the strategy, timing of production and scale-up may also be pushed back

<table>
<thead>
<tr>
<th>Input</th>
<th>Description</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>+/- 0.2B</td>
<td></td>
<td>N/A</td>
</tr>
</tbody>
</table>

### 12.4.2 Supply/Demand balance

Distribution indicates how available manufacturing capacity is allocated to countries. To allocate 2021 and 2022 manufacturing capacity to countries the following country-level supply types are considered:
1. Formalized bilateral, multilateral, and COVAX deals
2. Domestic production capacity
3. Publicly announced donations and transferred doses

Key distribution assumptions include:

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Bilateral and multilateral deals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Only secured doses of formalized deals are taken into account</td>
<td></td>
</tr>
<tr>
<td>• HICs are assumed to have all their mRNA deals (secured doses only) met first starting H2 2021. All other deals are then fulfilled proportionally by supplier based on deal size and estimated deal start date</td>
<td></td>
</tr>
<tr>
<td>• Deal start date assumes the latest date of 1) expected delivery date from media announcements, 2) country vaccine approval date, or 3) vaccine time to licensure estimates</td>
<td></td>
</tr>
<tr>
<td>• Multilateral deal doses are allocated proportionately to member states based on population size</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>COVAX deals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• COVAX supply is distributed based on the outputs from WHO COVAX allocation rounds</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Domestic production</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Manufacturer’s domestic production capacity is allocated to the country where its headquarters is located</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Export bans</th>
</tr>
</thead>
<tbody>
<tr>
<td>• It is assumed that there will be no exports from India in H2 2021, and only 25% of total production exported from India in H1 2022</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Donations and dose donations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• All donations and transferred deals announced in the media are incorporated, in which the donated and transferred doses are subtracted from the supply of the donor</td>
<td></td>
</tr>
<tr>
<td>• In addition to all announced donations, 1 billion of dose donations in 2021-2022 from HICs to LICS/LMICSs is assumed</td>
<td></td>
</tr>
</tbody>
</table>

Note: the untapped manufacturing capacity in 2022 which has not yet been distributed, given limited 2022 deals have been announced to date, shows up as kept in the country of manufacture.

12.4.3 Resource availability

Three indicators are introduced to identify countries with potential financial & system challenges. The indicators are applied in the context of an “OR” condition, namely, if any of the three is active for a given country, then the country is shortlisted as “at-risk”.

The three indicators are:

- **Indicator 1:** The cost of vaccinating x% of the population is over 1% of 2021-2022 General Government Expenditure (IMF WEO April 2021 data) for countries where expected government revenue per person vaccinated is less than the cost per person vaccinated.

Note that the indicator considers increased vaccination costs relative to the general government expenditures, indirectly measuring the country’s financial capacity to deal with a vaccination target. Since the cost per vaccine dose depends on the dose schedule (boosters / no boosters)
and the age target, the overall vaccination cost, and, therefore, the value of the indicator, varies per goal-scenario pair.

Another interesting point is that the indicator is active only if the expected government revenue per person vaccinated is less than the cost per person vaccinated, explicitly taking into account the accrued economic benefit of vaccination. To factor this into the approach, there is need to model the public revenues generated by vaccinations. The methodology is described below:

Table 10: Modelling the public revenues generated by vaccinations

| What’s the intuition behind the model? | The COVID-19 economic crisis has been driven by declines in household consumption spending
| | Vaccination allows people to return to their normal consumption patterns + release some pent up demand (i.e., spend down savings)
| | Increased household consumption spending translates to economic growth and additional tax revenues, which may offset all or partial costs of vaccination
| How do we actually do it? | Household budget survey (HBS) data is used to estimate means and standard deviations of ‘typical’ per person household spending by 5-year age bands
| | Based on each country’s 2020 population by age, we construct a synthetic population of 1000 people who have consumption spending based on the HBS data (following a random normal distribution)
| | We assume that in 2020, consumption was reduced to basic needs (food, housing and rent) + some multiple of ‘typical’ spending so that when calibrated, in aggregate, consumption expenditure declined by some pre-determined amount
| | We allocate vaccines according to age, allowing some randomness in non-uptake (e.g. 80% of the 50+ population)
Vaccinated people return to typical consumption patterns + spending some (random normal) share of their 2020 savings

We run this 100 times to capture the uncertainty in consumption and savings behaviours, and in who actually gets vaccinated (this gives upper and lower bound estimates)

The growth in spending is converted to GDP and then to public revenues linearly using historical tax to GDP ratio

- **Indicator 2:** The extra HR for vaccinating x% of the population is larger than 10% of existing HR in countries where the number of physicians/1000 pop is lower than 0.2

The indicator considers the surge in health workforce costs with increasing dose requirements. As with Indicator 1, since the HR cost increases depends on dose requirements, the value of the indicator varies per goal-scenario pair.

The estimation of health workforce requirements is based on a WISN (Workforce Indicators of Staffing Needs) approach adapted to vaccination of COVID-19. Based on dose allocation, it computes for each country the need for health workers involved in vaccination including vaccinators, support staff and supervisors. Then, based on redeployment factor from 0% to 5%, proportional to the health workforce density in the country and the UHC service coverage index, the number of health workers is extracted from the current staff of medical doctors, nursing personnel, midwifery personnel and pharmacists from the National Health Workforce Accounts (https://apps.who.int/nhwaportal/Home/Index). Comparing the need and the available workforce redeployed, and accounting for the production capacity of the country using graduate statistics, a gap in health workers is estimated. Therefore the need of health workers is split between the domestic use of health workers and the additional health workers to employ to cover the gap. These numbers are multiplied by the duration in months and the average salaries for nursing personnel applied to supervisors and vaccinators and clerk for support staff to derive total health workforce costs, domestic costs and costs for additional health workers. All input parameters are available on request to hrhstatistics@who.int.

- **Indicator 3:** Countries are not able to reach DTP3 coverage above 60% (WUENIC estimates extracted from WIISE, June 2021)

The coverage criterion is applied uniformly to all countries and does not depend on other variables.