ECONOMIST IMPACT

Green vaccine procurement

How multilateral organisations can prepare for sustainability

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About this report

Green vaccine procurement: how multilateral organisations can prepare for sustainability is a report by Economist Impact, with sponsorship from Sanofi. It explores how vaccines can be sustainably procured within the health sector and particularly focuses on multilateral procurement organisations. The report reviews the current thinking, planning and sustainability goals of key players. It then goes on to explore how vaccines can play a role in the health sector's climate change mitigation and adaptation solutions.

The research started with **two literature reviews**. One addresses green health procurement, while the other covers green vaccine procurement. Following this, a **framework** was developed that outlines the main factors that should be considered in vaccine procurement and identifies **the key domains to green this supply chain**. Finally, a **snapshot analysis** was constructed that compares the vaccine greening efforts of two major multilateral organisations—the United Nations Children's Fund and the Pan American Health Organization.

Despite our literature reviews, this is an emerging field. Much of our analysis was drawn from a wide interview programme and a thematic analysis based on their findings.

For the initial scoping interviews, which helped us frame and build our initial literature review, we would like to thank the following experts for contributing their time and insights (in alphabetical order):

- **Neydi Cruz**, sustainability associate director, Health Care Without Harm and Practice Greenhealth (Mexico)
- **Shane Dunne**, associate director, sustainability, Memorial Sloan Kettering Cancer Center (US)
- **Ishika Jharia**, senior programme co-ordinator (sustainable healthcare), Centre for Chronic Disease Control (India)
- **Susan Wilburn**, senior sustainability consultant, Salud sin Daño (Healthcare Without Harm) (Switzerland)

Additional interviews and insights added depth to our research and frameworks. We would like to thank the following experts for their contributions (in alphabetical order):

- **Matendrick Adolphe**, technical officer, quality and regulation of medicines and health technologies, Pan American Health Organization (PAHO) (Haiti)
- **Corentine Berthet**, supply chain sustainability co-ordinator, Médecins Sans Frontières (MSF) (Switzerland)
- **Rachel Silverman Bonnifield**, senior fellow, Centre for Global Development (US)

- **Mau Capelli**, immunisation category manager, Médecins Sans Frontières (MSF) (The Netherlands)
- **Rob Handfield**, distinguished professor of supply chain management, director of the supply chain resource co-operative, adjunct professor with the supply chain management research group, Manchester Business School, North Carolina State University (US)
- **Ahmed Abdi Ismail**, national co-ordinator, Africa Centres for Disease Control and Prevention (CDC) (Ethiopia)
- **Mark Jit**, professor of vaccine epidemiology, London School of Hygiene and Tropical Medicine (UK)
- **Esper George Kallas**, director, Butantan Institute (Brazil)
- **Melchior Kuo**, manager, innovation and vaccine policy, International Federation of Pharmaceutical Manufacturers and Associations (IFPMA) (Switzerland)
- **Bruce Y Lee**, professor of health policy and management, City University of New York (CUNY) (US)
- **Yang Liu**, assistant professor, London School of Hygiene and Tropical Medicine (UK)
- **Anne Marie Mbengue Seye**, associate DG, Afrivac; CSO representative, GAVI PPC (Senegal)
- **Leila Gharagozloo Pakkala**, director of UNICEF supply division, United Nations Children's Fund (UNICEF) (Denmark)
- **Adar Poonawalla**, CEO, Serum Institute of India (India)
- **Daniel Rodriguez**, director, procurement and supply management, Pan American Health Organization (PAHO) (US)
- **Isabel Rodriguez**, supplier sustainability assessment lead, Médecins Sans Frontières (MSF) (Belgium)
- **Ana Júlia Dias Santiago**, climate and environment policy officer, British Embassy in Brazil (FCDO) (Brazil)
- **João Saravia,** head of global field procurement, Médecins Sans Frontières (MSF) (Brazil)
- **Luciana Vasconcellos**, procurement professional, formerly with Pan American Health Organization (PAHO) (Brazil)

Economist Impact bears sole responsibility for the content of this report. The findings and views expressed here do not necessarily reflect the views of the sponsor or the experts who kindly gave their time to advise us. We would also like to thank Professor Mark Jit for his insightful comments on the development of our frameworks (Table 1: Greening the vaccine supply chain; and Table 3: Economist Impact framework on key components of vaccine procurement).

The research was led by Elizabeth Sukkar. Sarah Repucci and Amanda Stucke were the programme directors. The research team consisted of Roshni Saleem Chagan, Deni Portl, Alyse Sayed, Anne Dorothée Slovic and Elizabeth Sukkar. This report was written by contributing writer Rebecca Lipman and edited by Elizabeth Sukkar.

Foreword

The planet's and people's health are intrinsically linked; as the environment degrades, human health will be directly and indirectly impacted through the increased prevalence and severity of existing and emerging diseases.

This global threat requires action from all key stakeholders.

This collective work needs to continually reflect on what further actions can be taken: from providing robust evidence to creating momentum and amplifying awareness of this critical conversation to **embedding environmental factors at every point in the strategic decision-making journey**.

Urgent attention and action through collaborative, multisectoral approaches on a global, regional and national level are needed, from all key stakeholders.

We welcome this report, which provides a global view on green vaccine procurement, the readiness of multilateral procurement organisations and the way forward. It is a first step towards better understanding the current state of sustainable vaccine procurement as well as exploring developments in this area.

The global and regional procurement bodies have undoubtfully a critical role to play with their purchasing power to shape the market towards more sustainable vaccine procurement.

More environmental/climate criteria need to be part of the tendering process to accelerate and transform procurement practices, by defining incentives for vaccine manufacturers to accelerate the development of innovative solutions that support a better mitigation of, and adaptation to, climate change impact.

Lamia Badarous-Zerroug
Global vaccines public affairs head Endemic, global institutions and associations
Sanofi, Vaccines

Executive summary

"Vaccines are among the most powerful inventions in history, making once-feared diseases preventable," declared Dr Tedros Adhanom Ghebreyesus, the director-general of the World Health Organization (WHO), in April 2024.[1] The latest figures reveal that vaccines have saved 154 million lives over the past 50 years.[2]

At the same time, sustainability has risen dramatically on the sociopolitical agenda to become an undercurrent to all global development.

This report acknowledges the vital public health role of vaccines while considering their intersection with sustainability. Based on desk research, framework building and expert insights, it addresses what is being done to make vaccine development, procurement and delivery more sustainable.

Global and regional vaccine procurers, known as multilateral procurement organisations, such as the United Nations Children's Fund (UNICEF) and the Pan American Health Organization (PAHO), are asking what they can do to incentivise and shape sustainable vaccine procurement. With just these two organisations procuring 3.4 billion and 400 million vaccines each year, respectively, their activities can influence the wider vaccine industry.[3,4]

How vaccines can be sustainably developed, procured and delivered is also being explored by manufacturers.

Key findings from the research include:

Quality healthcare requires vaccines, but the vaccine lifecycle contributes to greenhouse gas (GHG) emissions and waste. In most countries, the carbon footprint of the healthcare sector, of which vaccines are a part of, is only exceeded by the energy, transport and construction sectors. The vaccine lifecycle can be broken down into four domains: production and development, transport and distribution, delivery and healthcare systems, and waste and ancillary products. Numerous sustainability and GHG challenges exist in each. Given that reducing vaccine production is not an option due to the public benefits, multilateral organisations, producers, suppliers and other stakeholders are looking closely at the industry for opportunities to improve sustainability.

As the concept of green vaccine procurement develops, the quality, efficacy, availability, affordability and health security of vaccines remain paramount.

Although environmental considerations are increasingly recognised as important in vaccine decision-making, any improvements to their sustainability require careful consideration so as not to compromise these priorities.

Multilateral procurement organisations, such as UNICEF and PAHO, hold great power for encouraging industry-wide sustainability changes. Considering their reach, these organisations could influence other vaccine buyers to adopt more sustainable public procurement practices. They could also prompt vaccine manufacturers to change how they produce GHGs and report emissions. On this point, Luciana Vasconcellos, a procurement professional formerly with PAHO, states that "if multilateral organisations start to put sustainability criteria in their procurement processes, it acts as a major incentive directing their attention towards crucial sustainable practices."

Multilateral organisations UNICEF and PAHO are adding sustainability to their vaccine procurement strategies and value statements—which is a promising first step. While these actions demonstrate progress for the vaccine industry, sustainability procurement remains an early concept. There are no well-defined criteria by which to act and implementation by manufacturers is still voluntary. The two agencies are on par in developing their sustainability goals for greener vaccines. UNICEF is focusing on GHG emissions, energy and water consumption, wastewater, hazardous waste, biodiversity, and packaging. Meanwhile, PAHO has already set targets to reduce GHGs in the supply chain. It is also looking at promoting air to sea transport, reducing packaging and using green shipping lanes.

Incentives can help businesses along the entire supply chain adopt sustainable practices. In this heavily regulated industry, change can be risky and costly. Incentives such as legal instruments or environmental weightings in contracts by multilateral organisations are particularly helpful to promote sustainability.

Innovations around greener vaccine solutions are on the rise, but vaccine producers are at varied stages of their sustainability journey. Actors along the supply chain are exploring innovative methods to reduce their GHGs and waste, but they vary in their sustainability maturity. Promising solutions include improved vaccine design (such as thermostable vaccines), minimal packaging, renewable energy in production, and less carbon-intensive modes of vaccine transport and delivery.

Vaccines play a vital role in mitigating climate change and adapting to its impacts. Effective vaccines can prevent carbon emissions, as treating infectious diseases can be carbon-intensive. As climate change results in diseases sometimes developing in new geographical areas, vaccines are crucial in controlling the effects on public health and on healthcare systems' emissions.

Vaccines and climate change

There is an inherent tension in vaccines' contribution to public health. They reduce the need for carbon-intensive healthcare systems and prevent climate-sensitive diseases, yet their manufacture contributes to GHG emissions, which is driving climate change.

The interplay between vaccines and climate change

Billions of vaccines are administered annually.[5,6,7] Each one is the product of a long supply chain, which brings raw materials to manufacturers that produce, package, store and transport the doses under carefully controlled conditions. Every step in that process generates GHGs and waste streams.[8]

"The vaccination process itself significantly contributes to carbon emissions, from manufacturing to delivery, including the journey from production sites to individuals receiving the vaccine," says Mark Jit, who is the professor of vaccine epidemiology at the London School of Hygiene and Tropical Medicine. "Transporting it to the country, through the cold chain to clinics, and finally to vaccination points for administration, represents the environmental downside of vaccines. Finding ways to minimise this would be a clear benefit."

"The vaccination process itself significantly contributes to carbon emissions, from manufacturing to delivery, including the journey from production sites to individuals receiving the vaccine."

Mark Jit, professor of vaccine epidemiology at the London School of Hygiene and Tropical Medicine

These are some of the primary reasons why there has been increasing concern about the environmental sustainability of vaccines and reducing their footprint. More than 98% of UNICEF's total emissions come from its supply chain, of which vaccines are the biggest driver.[9] Any sustainable measures taken across just this one supply chain could have a notable global impact.

At the same time, vaccines are a key tool to reduce GHG emissions in healthcare systems, which are contributing to climate change.

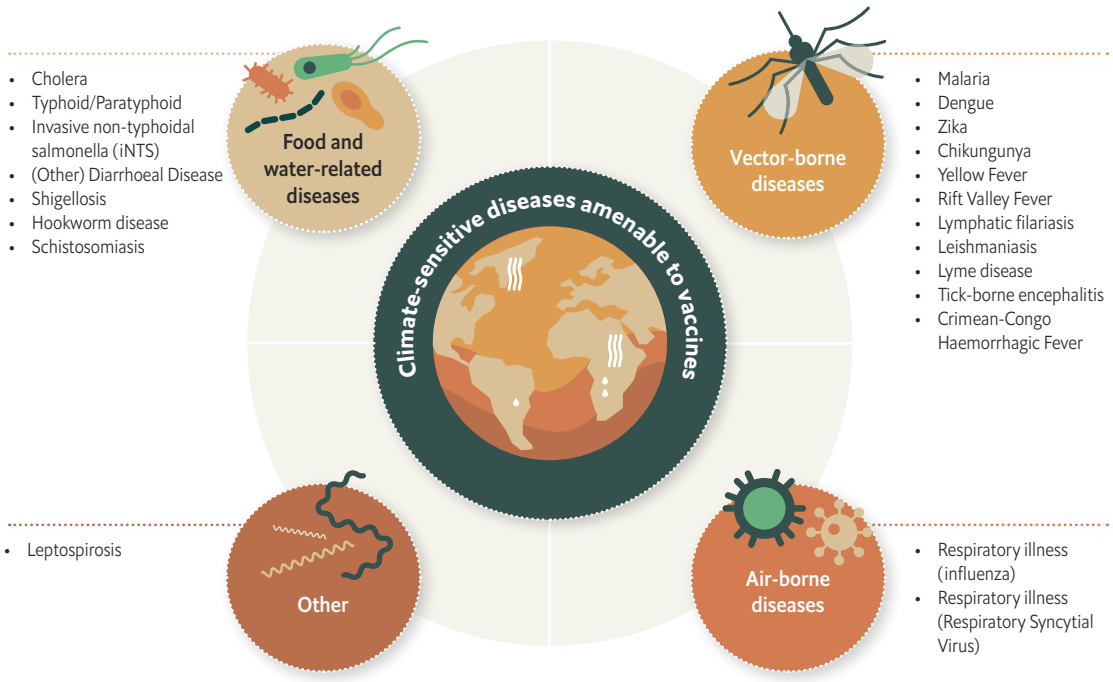
The healthcare sector accounts for around 4.6% of global GHG emissions,[10] driven by energy consumption, transport, and product manufacture, use and disposal.[11] Around 17% of the healthcare sector's GHGs come directly from facilities and owned vehicles (known as Scope 1); 12% are indirect emissions from purchased energy

sources (Scope 2); and 71%, the bulk of emissions, come indirectly from the healthcare supply chain (Scope 3). This final category includes the production, transport, and disposal of goods and services, such as medicines and other chemicals, food, medical devices and hospital equipment.[12] Healthcare is the largest service sector in terms of its carbon footprint, on par with that of the food industry.[13] In most countries, its footprint is only exceeded by the energy, transport and construction sectors.[14] Data are emerging on the carbon footprint of vaccines. One study, which assessed some covid-19 vaccines, found that their transport emissions were 19 times higher than the emissions generated by ultra-deep freeze technologies and other processes.[15] However, vaccines also reduce demand for health services and lower costs.[16]

Vaccines also address diseases that are sensitive to climate change. Global warming is altering temperature and weather patterns, allowing diseases typically contained to one region to spread to new areas or increase in incidence.[17,18] (**See Figure 1**) For example, yellow fever and chikungunya are increasingly significant concerns alongside zika and dengue. And with rising temperatures, diseases like malaria are also seeing a higher volume of cases.[19] "This shifts the geographic areas at risk, altering the service delivery areas for vaccines and often expanding them," explains Bruce Y Lee, professor of Health Policy and Management at City University of New York (CUNY).

As Esper Kallas, director of the Butantan Institute—a producer of vaccines and immunobiological products—in Brazil, says, "these developments underscore the urgent need to combat global warming, while simultaneously ensuring wider availability of vaccines to address tropical diseases."

Figure 1: Climate-sensitive diseases amenable to vaccines*



*Please note that this list is not exhaustive.
Source: Kim, C L, Agampodi, S, Marks, et al. Mitigating the effects of climate change on human health with vaccines and vaccinations. Frontiers in Public Health, 11. 2023. Available from: https://doi.org/10.3389/fpubh.2023.1252910.
For details, please see Appendix 1.

Green vaccine procurement, explained

The WHO views sustainable procurement in a broad manner, looking at three pillars—environment, social and economic (ESE).[20] "Sustainable Procurement practices integrate requirements, specifications and criteria that are compatible and in favour of the protection of the environment, of social progress and in support of economic development, namely by seeking resource efficiency, improving the quality of products and services and ultimately optimising costs," it says.

Experts we spoke with have more details to add to the sustainability procurement definition. For example, Susan Wilburn, senior sustainability consultant at Healthcare Without Harm, a non-governmental organisation that works to reduce the environmental footprint of the healthcare sector, argues that the definition of green procurement "needs to include sustainability components such as GHG emissions, chemicals and toxicity of products, human rights, labour rights and environmental issues."

João Saravia, head of global field procurement at Médecins Sans Frontières (MSF), describes green vaccine procurement as focusing on "the triple bottom line": 1) it addresses environmental issues related to raw materials and distribution; 2) it considers social aspects, such as the communities and labour involved in extraction and ensuring workers are fairly treated; and 3) it evaluates the economic impact to enhance vaccine accessibility and affordability while creating a sustainable business model.

The nuances in experts' perspectives reflect the nascent stage of development of the concept of green vaccine procurement. Ahmed Abdi Ismail, national co-ordinator for the Africa Centres for Disease Control and Prevention (CDC), explains: "The concept of vaccine procurement, which includes green procurement, has emerged relatively recently in the grand scheme of things. This has especially grown over the years, particularly during the covid-19 era." Moreover, he adds, "some of the most experienced supply chain experts lack sufficient understanding of green procurement, highlighting a significant gap in knowledge."

Corentine Berthet, supply chain sustainability co-ordinator at MSF, is nevertheless optimistic: "Green vaccine procurement is still very new. But incorporating the environmental aspect into the process is inevitable; there's no turning back."

Thus far, the concept is slow to take hold and green leadership in this area is only starting

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to be reviewed by academia.[21] Only a few healthcare organisations are taking proactive steps in this area, including the UK's National Health Service (NHS), which is focusing its attention on sustainability programmes and enforcing sustainability requirements among its suppliers.[22]

Greening the vaccine supply chain

Although vaccines have a critical and positive impact on public health outcomes, they have negative externalities that can add up. The vaccine lifecycle creates a hefty amount of GHG emissions, packaging and waste.

To better understand how vaccine procurement could be 'greened', we must first understand the problem areas. Based on analysis by Economist Impact, the vaccine supply chain can be viewed on a chronological basis that comprises four domains (**Table 1; see also chapter on decarbonisation solutions for the vaccine supply**). Each domain cuts across Scope 1, 2 and 3 GHG emissions and is ripe for sustainability measures and solutions.

Scope 1, 2 and 3 emissions[23]

Scope 1: direct emissions from the supplier's own resources

Scope 2: indirect emissions from the generation of purchased energy from suppliers

Scope 3: indirect emissions from the supplier's supply chain, which ranges from the goods it purchases to the disposal of the products it sells.[24]

Domain 1: production and development

Vaccines are composed of many parts that are sourced from around the globe. Their production and processing can require large amounts of energy, which experts say is rarely sourced from renewables. However, some manufacturers have committed to 100% renewable electricity by 2030.[25] Moreover, about 65% of UNICEF's vaccine and biological suppliers' GHG emissions come from their raw materials suppliers—such as agricultural products, mineral extraction and water.[26] Experts interviewed for this report also noted hazardous discharge from production facilities as another area of concern, which can affect the health of both the public and employees.[27]

Domain 2: transport and distribution

The emissions and costs associated with transporting vaccines can be especially high given that they are often highly time-sensitive and require precise temperature control (which is known as the cold chain).[28] If vaccines get too hot or cold, the active ingredients can degrade, reducing their effectiveness[29] and potency.[30] Air freight, a common mode of transport in certain parts of the supply chain, addresses time concerns[31,32] but is far more carbon-intensive than sea and road freight.[33]

Vaccines must be delivered to all parts of a country, including urban and rural areas, and consideration must be given to the ease, effectiveness and sustainable nature of these routes to maintain the cold chain.

Table 1: Greening the vaccine supply chain

All scope emissions are present across the value chain 1 2 3	 **Production and development**	 **Transportation and distribution**	 **Delivery by healthcare systems**	 **Waste and ancillary products**
Stage	This process involves **research, manufacturing and testing to meet safety, efficacy and quaity standards**, encompassing antigen identification, preclinical and clinical trials, as well as **scaling up production and packaging** for distribution.	Transportation of vaccines, including the **maintenance of the cold chain, is crucial to ensure their potency and effectiveness** during transit to different locations.	This process entails ensuring the **arrival of the vaccines at vaccination sites and ensuring proper storage and handling**.	Vaccines and ancillary products, including syringes, swabs, personal protective equipment (gown, eye protection, gloves, face mask) and packaging materials can be **disposed of in various ways, such as burial or incineration.**
Stakeholders	Vaccine manufacturers and ancillary suppliers	Logistics firms, wholesalers & procurement bodies	Local/national governments and multilaterals	Local/national governments and waste companies
Solutions	Local or regional vaccine production Supporting vaccine research, development and production* Energy efficiency/renewable energy Minimise packaging volume Manufacturing innovation Digital labelling and information Thermostable vaccines	Sustainable shipping containers Switch from air to sea freight Use of renewable energy	Minimising ancillary waste around vaccination Energy efficiency/renewable energy (refrigeration) Improved cold chain storage due to thermostable vaccines More accurate forecasting	Energy efficiency/renewable energy Reusable tertiary packaging
	Sustainable procurement policy which sets science-based climate targets (skills and capability building of procurers) and considers appropriate incentives			
	Strong regulatory framework			
	Recycling/circular economy			
	Thermostable delivery to reduce vaccine waste			

* Innovations include injectors/devices (which reduce the need for needles and syringes), combination vaccines, nasal spray, patches, microarray patches (MAP), heat-stable and controlled temperature chain qualified vaccines, and barcodes on primary packaging.
Source: Economist Impact analysis.

The type of transport used depends on the actors involved and the particular segment of the journey in the procurement process. For example, air transport is typically used from the vaccine manufacturer to the procurement body, though it could include sea travel. Road is generally used from the procurement body's central depot to processing storage points in a country, then to healthcare providers, and finally from healthcare workers to people, including those in hard to reach locations. The latter may include the use of motorcycles, animals such as donkeys or travel by foot to remote villages.[34,35,36]

Domain 3: delivery and healthcare systems

It is challenging to ensure responsible on-site storage and last-mile delivery for vaccines from hospitals and clinics, particularly in rural communities. Ultra-cold storage is sometimes necessary—certain covid-19 vaccines require storage at -80°C, far beyond the capabilities of a common refrigerator and necessitating more energy investment.[37,38,39,40] Many facilities also have a limited number of coolers and refrigerators, which can cause bottlenecks in the safe delivery of vaccines to final recipients. Vaccines that are not stored properly must be disposed of,[41] leading to waste and contributing to unnecessary GHG emissions. In addition to the green vaccine framework that appears in Table 1, a wider view would account for the GHGs caused by patients travelling to healthcare centres to receive vaccines.[42]

Domain 4: waste and ancillary products

Waste management is a weakness in low- and middle-income countries because of limited resources to establish sophisticated processes, including proper disposal methods for remaining vaccine products.[43] Proper disposal methods vary based on the item being disposed of. Waste from vaccination centres should be separated into categories such as packaging and vials, general waste such as alcohol swabs, and personal protective equipment (PPE) and used syringes, among others.[44] Packaging and vials should be returned for reuse or recycling, or shredded if this is not an option. For general waste, disposal in a normal manner is most effective and efficient; there is no need for double-bagging. PPE and syringes should be treated as infectious waste and disinfected using steam-based methods.[45]

Consequently, many healthcare facilities resort to less effective methods such as incinerating leftover products or even dumping.[46,47] Improper waste management leads to environmental degradation, which poses risks to health workers, recipients of vaccinations, and the wider public as well as wildlife and agriculture.[48,49] For instance, the impact of biomedical and plastic waste from covid-19 vaccination on the environment has been studied,[50] including microfibre waste, which can contribute to environmental degradation.[51] Microfibres (small synthetic fibres shed from materials) are released into the water, air and soil, where they can be ingested by wildlife. These materials can enter and contaminate the human food chain, potentially causing chronic health problems.[52]

The "waste" domain also captures secondary waste streams from the healthcare systems that deliver vaccines. This includes ancillary products such as PPE, swabs and syringes. Ultimately, a circular approach to vaccine waste management needs to be considered and planned, including the collection, separation, treatment, recycling, and disposal of waste.[53,54] The WHO advocates for a health waste management hierarchy. It says the most preferable approach, if possible locally, is to avoid producing waste as much as possible and reducing any amounts entering the waste stream.[55] Any waste that cannot be recovered must then be dealt with using the least preferable options, such as treatment or land disposal, to reduce its environmental effects, it adds.

How multilateral organisations are approaching green vaccine procurement

Vaccine procurement involves a range of stakeholders, including vaccine producers and major multilateral procurement organisations such as UNICEF and PAHO.

All stakeholders need to be involved if procurement is to be "greened", with incentives built into the system to drive change. End users and procurers are responsible for transforming the demand side, and vaccine producers (suppliers, manufacturers and intermediaries) are responsible for following the path to developing sustainable alternatives.

Multilateral organisations as key drivers

UNICEF and PAHO play a particularly crucial role in fostering industry partnerships, driving innovation, and setting industry direction and standards.

Their reach is enormous. UNICEF oversees operations in over 190 countries and provides vaccinations for nearly half of the global child population annually.[56,57] Vaccines are by far the biggest commodity group that UNICEF procures—2.3 billion doses of paediatric vaccines in 2021 alone. In all, five product categories (vaccines, nutrition, long-lasting insecticide treated nets, international freight, and cash and voucher assistance) drive 90% of UNICEF's total emissions, of which vaccines make up the majority (71%).[58]

PAHO specialises in population health for 41 countries in the Americas. In 2022 it was the second-largest spender among UN agencies on vaccine procurement,[59] purchasing more than 400 million vaccines, syringes and other supplies.[60]

Because they are at the forefront of vaccine access, if these multilaterals give importance to sustainability criteria, they generate a sense of accountability and urgency among those who are working with them. In addition, their behaviour will likely influence other multilateral organisations to create and align their own sustainability criteria. In the words of Ms Vasconcellos, "when buyers mandate sustainability as criteria, adherence becomes imperative."

This point is echoed by Mr Saravia. "If major purchasers start to consider green requirements, producers will need to adhere to these standards," he says.

"If major purchasers start to consider green requirements, producers will need to adhere to these standards."

João Saravia, head of global field procurement, Médecins Sans Frontières

The multilateral green vaccine snapshot analysis

To understand the readiness of UNICEF and PAHO to embrace green vaccine procurement, we created a framework in May 2024 based on 15 indicators: 13 qualitative and two quantitative. The snapshot provides a comparative analysis of the progress that both multilateral organisations have made on integrating sustainability into their vaccine procurement processes (see Appendix 2 for the full snapshot analysis).

Our headline takeaway is that both have signalled their intentions to significantly reduce their Scope 1, 2, and 3 emissions, with an emphasis on Scope 3, in their vaccine procurement and distribution processes. Both have also recently referred to sustainable vaccine procurement as a key strategic area moving forward. (**See Table 2**)

Table 2: Snapshot analysis of green vaccine procurement by UNICEF and PAHO (with publicly available information)

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
	Score	Score
Indicator 1: does it have a sustainability agenda/ plan for general procurement?	Yes	Yes
Indicator 2: is mandatory GHG reporting required annually under the general sustainability plan or its equivalent?	No	No
Indicator 3: does it have a sustainability agenda/ plan directly for vaccine procurement? (Year)	Yes, 2023	Yes, 2024
Indicator 4: what type of environmental criteria does it include specifically for vaccines?	Partially, environmental (GHG emissions, energy consumption, water consumption, wastewater, hazardous waste, biodiversity, and packaging)	Yes (encourage supplier sustainability action; promote shift from air to sea transport; better/reduce packaging; green shipping lanes; low emission transport)
Indicator 5: has it consulted vaccine suppliers about future green vaccine procurement?	Yes	No information
Indicator 6: does it have numeric targets for vaccine suppliers in terms of climate mitigation factors? (For example, a specific environmental numeric weighting that producers meet) *Eg, from April 2027 all NHS suppliers in the UK will be required to publicly report targets and emissions and publish a carbon reduction plan for global emissions aligned to the NHS net zero target for Scope 1, 2 and 3 emissions.* Source: https://www.england.nhs.uk/greenernhs/get-involved/suppliers	No	No

Continued on next page

Table 2: Snapshot analysis of green vaccine procurement by UNICEF and PAHO (with publicly available information) (cont.)

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
	Score	Score
Indicator 7: does it have a vision/plan/target that new vaccine development considers climate-sensitive diseases?	No	No
Indicator 8: does it procure vaccines that are associated with climate-sensitive diseases? This includes water-related diseases such as cholera and other enteropathogens, helminthic infections and leptospirosis; vector-borne diseases like dengue, chikungunya, and malaria; airborne diseases like influenza and respiratory syncytial virus infection. Scoring: yes, 5 or more; partially, less than 5; no=nil bought. *Note: we relied on the academics Kim et al (2023) to decide what vaccines are related to climate-sensitive diseases.*	Yes	Yes
Indicator 9: does it consider the principle of fair competition by encouraging local supply production, including that of vaccines?	Yes	Yes
Indicator 10: does it include (or plan to include) direct and explicit incentives for vaccine manufacturers to undertake green vaccine procurement for climate change adaptation or mitigation? To score "yes", it should consider any of the following: a) incentivising vaccines with fewer GHG emissions per dose; b) encouraging the use of fewer vaccine doses or combination vaccines; c) minimised packaging volume; d) energy efficiency; e) science-based climate targets; f) use sea freight over air transport; and g) incentivising vaccines that directly address climate-related outbreaks.	No information	No information

Source: Economist Impact analysis (based on information and analysis completed in May 2024). This snapshot was presented to UNICEF officials and a former PAHO official for their review, with responses received in May 2024. For the full methodology and analysis, see Appendix No 2.

UNICEF

While UNICEF has a general sustainability plan that covers procurement[61] **(Indicator 1)**, it was not until 2023 that it introduced a vaccine-specific procurement plan[62] **(Indicator 3)**. This approach involves applying an ESE focus across the entire vaccine supply chain.[63] These ESE elements include GHG emissions, energy consumption, water consumption and wastewater, among others **(Indicator 4)**.

UNICEF is currently developing a comprehensive sustainable procurement strategy for the future. According to Leila Gharagozloo Pakkala, director of the UNICEF supply division, the organisation aims to publish this later in 2024. "It will guide future tenders and embed sustainability as a key priority," she says.

However, some areas remain under development. For example, their 2023 *Annual Supply Report* mentions that they are still identifying indicators to help strengthen the ESE aspects of procured immunisation supplies, including emission reductions.[64]

"Green procurement is a critical factor in tender strategies," says Ms Pakkala. She explains that "all procurement teams, including our vaccine teams, must follow the procedure, which guides teams through our three pillars of sustainability—ESE—as they apply to the product or service being procured."

Ms Pakkala adds that "given the complex manufacturing requirements of biologics, UNICEF is working closely with manufacturing and regulatory experts to identify opportunities to reduce the environmental impact of vaccine production without compromising accessibility."

UNICEF has officially consulted vaccine suppliers on sustainability **(Indicator 5)**. UNICEF's *Vaccine Industry Consultation* (2023) explains that any company doing business is required to follow the UN Supplier Code of Conduct, which makes environmental considerations.[65] UNICEF says it has faced challenges determining its GHG emission baseline by the limited availability of emission factors in the public domain, particularly for vaccines.[66] It stresses the need for supplier engagement and collaboration to

increase transparency on the availability and accuracy of these data, otherwise its baseline may "remain indicative for certain commodities and eventually undermine decarbonization efforts".[67]

Separately, UNICEF is a member of a decarbonisation alliance, the Sustainability Markets Initiative Health Systems Taskforce. This involves some pharmaceutical companies and aims for a transition to net zero, sustainable healthcare.[68]

A PowerPoint published by UNICEF in 2023 for the vaccine consultation industry[69] states that there will be increased engagement with suppliers on ESE in the short term. In the medium to long term, the engagement with suppliers on ESE criteria would include expanded annual reporting and bilateral meetings with ESE focal points (see Appendix 2). However, at the moment UNICEF does not have numeric targets for vaccine suppliers around climate mitigation factors (for example, a specific environmental numeric weighting that producers meet) **(Indicator 6)**.

For more information on local supply production **(Indicator 9)**, please refer to Case Study: Africa CDC's mission for a local solution.

In summary, UNICEF has already begun informing the vaccine sector that there will be a future need for "reporting key program indicators around sustainable procurement, including GHG metrics."[70]

PAHO

PAHO has a general sustainability procurement plan that covers all UN processes.[71] **(Indicator 1).** In 2024 it introduced a vaccine-specific procurement plan for the Revolving Fund **(Indicator 3)**.[72] The plan considers five specifications, including encouraging supplier sustainability action, promoting a shift to lower emission transport options, reducing packaging and promoting sustainable material, leveraging low-emission transport solutions, and enhancing shipping consolidation in the supply chain **(Indicator 4)**.

According to information in the public domain, PAHO has not officially consulted vaccine suppliers on sustainability **(Indicator 5).** As Ms Vasconcellos has stated in an interview, "PAHO has engaged in discussions with manufacturers to incorporate sustainability requirements, including minimising the material used in packaging and promoting sustainable and reusable packaging. Efforts are in progress to incorporate sustainable criteria into forthcoming procurements beginning this year."

In this line, PAHO aims to halve "the GHG emission intensity factor from the transport and distribution of procured goods by PAHO Revolving and Strategic Fund from a 2022 baseline by 2030".[73] It also stated that it would encourage suppliers to report against targets annually.[74] The director of procurement for PAHO, Daniel Rodriguez, explained that the organisation is adopting five strategies to achieve its goal. These, according to Mr Rodriguez, "range from achieving the commitment of our key suppliers to reducing emissions, using, whenever possible, lower emission modes of transport in our supply chains, optimising packaging for transportation, leveraging more regional manufacturing sources, looking for opportunities to consolidate shipments, and adapting emerging technologies for more efficient transportation with lower environmental impact."

PAHO also set up a Green Working Group, which will propose actions to lower the organisation's carbon footprint and foster environmental sustainability in its activities, including in procuring and delivering goods and

services through its Regional Revolving Funds,[75] showcasing its efforts for more sustainable practices.

However, PAHO does not currently have numeric targets for vaccine suppliers around climate mitigation factors (for example, a specific environmental numeric weighting that producers meet) **(Indicator 6).** For information on the multilaterals' stance on local manufacturing **(Indicator 9)**, see chapter on opportunities to decarbonise the vaccine supply chain.

In summary, PAHO has a five-point strategy to make the vaccine supply chain more sustainable, although there is no public information on whether it has consulted with vaccine suppliers about these strategies.

Integrating sustainability into vaccine procurement

In the vaccine procurement hierarchy of needs, safety, quality and effectiveness, affordability, availability and role in health security are paramount. Experts overwhelmingly agree that **sustainability cannot come at the expense of any of the aforementioned**.

Through analysis and expert insight, Economist Impact has created the framework below, which outlines the key components that should be considered during vaccine procurement. The pillars in red are considered critical while "sustainability" is indicated in green to show it is an emerging concept.

Table 3: Economist Impact framework on key components of vaccine procurement

	Pillars	
Vaccine procurement	Health security	**Outbreaks, epidemics and pandemics, including climate-sensitive diseases**
		Routine vaccines
	Acceptability	**Public acceptability** (multiple doses required, halal vaccines, real and perceived adverse reactions)
	Affordability	**Value for money** (for deaths averted/DALYs)
		Price of vaccines/cost-effectiveness
	Availability	**Timeliness**
		Delivery and logistics
		Awareness/health equity (eg. using the covid vaccine in younger/healthy people in high income countries over vulnerable groups in the global south)
	Regulatory	**Safety and quality**
		Efficacy
		Monitoring and evaluation (for overall population risks, benefits, and costs)
	Sustainability	**Environmental** (eg, GHG)
		Economic (eg, diversification of suppliers and manufacturing sites, as well as enough demand)
		Social (eg, labour/slavery)

Source: Economist Impact analysis

"Quality is non-negotiable [...]. All other things being equal, there should be no trade-off between environmental choices and health outcomes."

Leila Gharagozloo Pakkala, director of UNICEF supply division, United Nations Children's Fund (UNICEF)

"Quality is non-negotiable," Ms Pakkala of UNICEF declares. "A sustainable transition is needed without sacrificing the strict quality standards along with expanded access to these life-saving interventions. All other things being equal, there should be no trade-off between environmental choices and health outcomes."

Others in the global south seemed aligned. "People are losing their lives to infectious diseases, some of which could be easily prevented with vaccines that are already on the market. So even while multilaterals prioritise green production platforms, their main focus remains on providing access to life-saving prevention products," echoes Dr Kallas.

The cost of change

Affordability is one of the pillars of procurement for good reason: multilaterals, specifically those that cater to low- and middle-income countries, are seeking to optimise their reach at the lowest possible price.[76] The higher the price point, the fewer people it can afford to vaccinate.

"I think price is still the dominant factor for a lot of vaccines, efficacy is probably second and sustainability is probably down the list if you use a weighting element in vaccine procurement," argues Professor Rob Handfield, distinguished professor of supply chain management at North Carolina State University.

Not all sustainable approaches are more expensive than the alternatives. For instance, the cost of a vaccine that has been developed to be more thermostable may be higher than a standard thermolabile vaccine, but this could mean reduced costs in the long run. The vaccine would not require an extensive cold chain for distribution, making it more sustainable. In addition, this could help to reduce waste from poorly stored vaccines (that need refrigeration) and improve access, given its suitability for distribution at mobile health clinics or other outreach activities.[76,78,79,80,81]

Yet, most experts agree that, in most cases, sustainability will require additional expenses. And the consequences of a price shift—a green premium—are grounds for hearty debate.

Some experts we interviewed argue that governments and multilaterals need to consider the likelihood of higher prices for the green aspect in vaccine procurement. Ms Vasconcellos is among them: "There are undoubtedly costs associated with establishing green criteria in production. However, as global demand for sustainability practices grows, suppliers, government authorities, and multilateral

organisations should discuss the implications of these costs and collaborate to explore ways to reduce them, making operations more cost-effective, and establish a cost-benefit relationship to all parties involved."

Education and collaboration are necessary to understand the importance and reasons behind the higher costs, she adds. "By reaching long-term agreements with countries, it is possible to lower long-term costs and benefit all parties involved. Additionally, sustainability should become a procurement requirement, ensuring that only suppliers with a sustainable mindset are considered during the procurement process."

Other experts we interviewed are staunchly against the idea of any green premium. "Green procurement is seen as a luxury primarily affordable to wealthier countries," explains Rachel Silverman Bonnifield, senior fellow at the Centre for Global Development. "Low and middle-income countries are extremely cost-conscious. They may even decide against adopting new vaccines due to high cost. Given this, the idea of green procurement, or anything involving additional barriers and costs, is unlikely to be politically palatable. They are still focused on providing basic services to their populations."

As sustainable vaccine procurement is a new space, time will tell how industry and procurers approach such issues.

Incentives to change

A common fear among stakeholders, according to our interviewed experts, is that sustainability will come at a cost that would negatively impact their business.

Melchior Kuo is the manager of the innovation and vaccine policy division of the International Federation of Pharmaceutical Manufacturers and Associations (IFPMA), made up of R&D pharmaceutical companies. He engages with the UN and WHO on behalf of the IFPMA. "Companies are making significant investments to implement sustainability criteria, whilst ensuring vaccines are as competitive as possible in procurement agreements."[82] He adds that there are very low margins for vaccines in developing countries.

How can stakeholders be convinced to make potentially costly sustainability changes? Experts shared that few things would spur change as effectively as a company's bottom line. As a result, some suggested that the greatest drivers of sustainability are coming (or could come) in the form of incentives.

Multilaterals are planning to ask companies about sustainability in their procurement processes. Our snapshot analysis does not suggest that there are any hard criteria (**Indicators 6 and 10, Table 2**). However, other health procurement bodies are specifying hard criteria. For instance, the Norwegian Hospital Procurement Trust has introduced environmental weightings of 30% in the procurement of certain pharmaceutical products.[83] The NHS has stated that all procurements must include a minimum 10% net zero and social weighting from 2022. And by April 2027 all suppliers will need to publicly report targets and emissions and publish a carbon reduction plan for global emissions aligned to the NHS net zero target for all Scope emissions.[84] "Money talks, so if these stipulations are included to enforce green aspects of production, it will be helpful," says Professor Lee.

Professor Handfield adds that multilaterals could incentivise companies to take risks or absorb the costs associated with sustainability by providing assurance that it would help them win contracts. "If a certain weighting is given to green criteria in vaccine procurement, then that weighting will provide the emphasis of the buyer," he says.

Rewards also incentivise. For example, Professor Handfield believes vaccine producers may be motivated to adopt the green agenda if they could gain preferential market access to certain regions that the WHO or multilateral procurer bodies are supporting.

"If a certain weighting is given to green criteria in vaccine procurement, then that weighting will provide the emphasis of the buyer."

Rob Handfield, distinguished professor of supply chain management at North Carolina State University

Government incentives are also needed, according to several interviewed experts. Ana Júlia Dias Santiago, climate and environment policy officer at the British Embassy in Brazil (FCDO), is among those advocating for more frameworks and policies from governments, especially for offsetting the costliness of emission reductions. She says that incentives such as regulated carbon markets and higher payments for companies that adopt green practices are "crucial" for promoting sustainability.

UNICEF has suggested some possible approaches to accelerate progress on sustainability, such as better education for suppliers on GHG reporting, collaborations to source green power and recognition programmes. However, the organisation also notes that any incentives-based approach needs to be aligned to its public procurement policies.[85]

In summary, incentives could be brought in for manufacturers. However, there is no consensus on what type of sustainability incentive or weighting should be applied in vaccine procurement and whether this will be more important than keeping costs down. Another question is whether sustainability will trump other key components of vaccine procurement noted in **Table 3**. Some public health procurement bodies have stated the weightings they apply to pharmaceutical purchases; multilateral procurement bodies such as UNICEF and PAHO could use these as an indication of the levels they could apply to incentivise manufacturers.

Regulators' review

Experts have mixed views on regulators' involvement in sustainability. Increased regulation could increase costs and de-incentivise sustainability, and regulators' rigid protocol, some argue, should be focused on efficacy, safety and quality.

The role of medicine regulators in driving sustainability is still being drawn out. "You will get different responses from companies," Mr Kuo reflects. "Some companies may say regulators should not look at this as it is not part of their remit, but others are looking for regulators to take a greater role."

Vaccine manufacturers are mindful that there is a great deal of regulation and documentation involved when making their processes more sustainable. When even minor tweaks are made, new marketing authorisation needs to be submitted.[86,87,88] This is costly work, and often requires a long time to achieve, explains Ms Pakkala of UNICEF. "However, manufacturers can engage in other activities that do not require regulatory input. For instance, they can reduce their Scope 1 and Scope 2 emissions by adopting clean technologies within their production facilities; and influence emission reduction efforts further up the input value chain," she adds.

Mr Kuo of the IFPMA adds to this: "It is important that [drug] regulators consider the marketing authorisation changes that are necessary to make a product more environmentally sustainable. A streamlined approach by regulators that links up with the environmental policymakers can help manufacturers make amendments to marketing authorisations as efficiently as possible."

The regulatory costs associated with these approvals can create an uneven playing field for suppliers, with those in richer countries facing higher regulatory costs, warns Professor Handfield. "I do not think the regulatory compliance around sustainability in places like India, China, Brazil is on par with the EU or North America. Vaccine suppliers in emerging economies are very much based on high volume, low cost, types of vaccines."

Regulators cannot compromise on vaccine safety but could be flexible on new approvals to boost sustainability. Regulators may review marketing authorisation changes made for sustainability reasons in a less burdensome manner. The sustainability journey of producers and suppliers differ, and part of this is likely due to the imposing costs of change, particularly when that requires new regulatory approvals.

Opportunities to decarbonise the vaccine supply chain

Stakeholders along the vaccine supply chain know that the writing is on the wall around sustainability. Not only is the global public raising its voice and driving a change in attitudes,[89] but some governments and national procurers, such as the NHS, are also already moving in that direction by mandating sustainability criteria in procurement contracts.[90] Companies are also increasingly driven by the need for ESG reporting.[91]

But in such early days of green vaccine procurement, there are no well-defined criteria or metrics to evaluate it. "While sustainability considerations are gaining prominence, there's a need for formal criteria and quantification of the environmental impact of vaccines to make informed decisions," says Professor Jit.

Vaccine producers are on different routes to achieving sustainability goals. For example, some large vaccine producers have established goals to reduce GHG emissions by 2030 or aim for 100% reliance on imported and generated renewable electricity.[92] Meanwhile, others recognise the importance of managing GHG emissions but have not yet set specific targets.[93]

And while vaccine producers consider decarbonisation solutions, similar ideas are also being expressed by multilateral organisations (see **Indicator 10 in Table 2; and Table 1**) and vaccine academics. Organisations are taking it upon themselves to become more sustainable, addressing various environmental issues associated with vaccine production in their own ways.[94,95]

As Mr Kuo says, the R&D pharmaceutical companies that make up the IFPMA membership take different approaches. "Some firms are big on biodiversity, while others are big on CO_2 emissions and packaging. It is not homogenous."

Efficient vaccine development and production

Manufacturers are looking at innovations in vaccine development as an effective way to reduce their environmental footprint—in particular, GHG emissions and waste. For example, combination vaccines and heat-stable vaccines[96] may not require cold chain storage. Combination vaccines occupy less refrigerated storage capacity and require less syringes than standalone vaccines, minimising logistical challenges and reducing waste.[97] These types of vaccines also reduce the number of visits to the clinic,[98] a critical factor when factoring in potential disparities in logistical supply chains[99] among standalone vaccines, which could mean fluctuations in the health centre's vaccine stock.[100]

Professor Handfield is particularly keen on these developments. "Combination vaccines reduce the number of trips to the clinic or pharmacy, so this helps people in remote areas where they may need to travel 100 miles to get a vaccine. And the co-benefit is that it reduces the carbon footprint of travelling to the vaccination site."

Vaccination schedules can also be optimised, such as changing from two doses to just one, if clinically effective. Other changes to vaccine characteristics, such as vial size and dosage, have significant downstream effects on carbon emissions.[101] "These characteristics impact how many vaccines need to be produced in each production run, which in turn affects production costs, the production process, and ultimately the delivery process. All these factors contribute to carbon emissions," explains Professor Lee.

"Of course," Professor Lee adds, "if you open a ten-dose vial and only use two doses, you must discard the remaining eight, leading to waste. Therefore, it's not always best to maximise the number of doses per vial. By understanding these trade-offs, we can develop more optimal solutions tailored to different countries and settings."

Other innovations include design changes, which could result in smaller devices that lead to more efficient transport. Examples include single-dose, ready-to-use oral vaccines such as blow-fill-seal technology and microarray patches, which offer dermal delivery of vaccines that are currently delivered via conventional injections.[102,103]

Renewable energy

Reducing or greening the energy demand for vaccine production is another area ripe for innovation.[104,105,106]

Some vaccine producers are considering alternative energy sources such as wind power instead of traditional power for their manufacturing facilities.[107] By adopting these measures, they aim to generate cleaner and more affordable energy, ultimately reducing the cost of vaccine products and making them more accessible.

Some companies are engaging in power purchase agreements for green energy. This strategy has been used by several multinational companies, including those operating in the US, Canada and China.[108,109,110] Mr Kuo explains that "for companies with smaller energy requirements, building manufacturing facilities near each other can help to pool the purchase of green energy. This works well in emerging economies, where it is more difficult to source green energy."

One vaccine producer told us they are embarking on a new project with a local energy supplier to diversify energy sources to "enhance flexibility and resilience in various scenarios we may encounter."

Some vaccine producers are exploring the use of installing solar panels across their facilities, but one industry expert told us the surface area available isn't sufficient to meet even 10% of their energy needs.[111]

Transport

As focus shifts to reducing the carbon footprint, many vaccine suppliers and producers are looking at transport, much of which requires carbon-intensive cold-chain practices.[112,113,114,115] This applies to the inbound side of raw materials but also to the outbound side on distribution.

Ms Pakkala says UNICEF and its partners are working on solutions that may reduce the environmental footprint of international air freight, including using sea freight and more diversified manufacturing and regionally sourced vaccines (especially from Africa).

As for last-mile delivery, according to one expert who preferred to be anonymous, early experiments with large electric or battery-operated freight trucks have shown they are not economically viable. But smaller electric-powered vehicles should be explored to help reduce the carbon footprint around vaccine distribution, both on inbound and outbound shipments.

Local manufacturing

Economist Impact's "snapshot analysis" of UNICEF and PAHO showed that they are encouraging local supply production as part of their sustainability efforts (see **Indicator 9, Table 2**). Both are supporters of the principle of fair competition by encouraging local supply chain production, including vaccines. UNICEF, for example, procures supplies (including vaccines) from various developing countries to support their local supply production.[116,117,118] And PAHO is an active supporter of the local production capacities of the region. It makes a point to source its supplies, including vaccines, locally to reduce the dependence on imports.[119]

The full benefit of local vaccine manufacturing still needs to be fully assessed in terms of its net GHG emissions as opposed to large singular manufacturing sites (see Case study: Africa CDC's mission for a local solution). A plurality of vaccine producers also helps maintain competition, reduce potential vaccine shortages and improve the bargaining power of procurers.[120]

Some academics see potential innovation in vaccine manufacturing. Professor Handfield suggests that mobile vaccine manufacturing units should be considered for local production.[121] These units can also ramp up production capacity during pandemics.[122]

"It is a type of disposable vaccine production unit that these countries could use, where it is shipped to these countries and it is quite innovative. Some pharmaceutical companies are developing these mobile factories, which are called 'single-use networks' to allow production of these vaccines domestically. Some mega producers are exploring this idea. However, local sites still need the availability of the raw materials and chemicals."

CASE STUDY

Africa CDC's mission for a local solution

The Africa Centres for Disease Control and Prevention (Africa CDC) is actively thinking about African vaccine manufacturing. Formed under the supervision of Africa CDC, The Partnership for African Vaccine Manufacturing has set a lofty goal: develop, produce and provide 60% of the continent's necessary vaccine doses by 2040.[123]

Leading the charge to produce the roughly 1.5 billion vaccine doses[124] are African Union member states, Africa CDC, the Clinton Health Access Initiative and PATH (an international health organisation that was formerly known as the Program for Appropriate Technology in Health).[125]

The benefits are clear: local vaccination production can help reduce transport-related emissions and improve local economic development. And, crucially, countries with local manufacturing capacity are better positioned to ensure a stable vaccine supply, especially during emergencies or times of limited global supply—as highlighted by the covid-19 pandemic.

While Africa CDC's drive for local manufacturing could reduce the general risk of vaccine shortages and competition concerns,[126] it has also placed a stake in vaccine procurement. In partnership with the African Export-Import Bank (Afreximbank), UNICEF and the World Bank,[127] it formed the African Vaccine Acquisition Trust, which procured 762 million covid-19 vaccine doses by April 2022.[128]

"The push to bolster local vaccine manufacturing in numerous African countries lacking substantial production capacity has been motivated by health security concerns, particularly highlighted during the covid-19 pandemic," says Professor Jit. "Countries without local manufacturing capabilities experienced significant challenges in accessing vaccine supplies." He adds that local manufacturing could streamline the process of administering vaccines, making it easier to get them to people.

But some experts warn that it is not all positive. Among them is Melchior Kuo, manager of innovation and vaccine policy at the International Federation of Pharmaceutical Manufacturers and Associations. "We are all for local manufacturing but there has to be a market for those vaccines," he says. "We have found that vaccines produced locally can be more expensive compared with those produced on a huge scale."

"It is questionable whether local manufacturing has lower CO2 emissions because you still have to get ingredients (such as vials, syringes, bioreactor bags) from different places all over the world to make these vaccines, while the alternative is sending them to a few places."

While local production could lower vaccine carbon footprints, this depends on African governments' commitment to supporting the procurement of African-made vaccines. However, this seems to be unclear, as they are likely to be more expensive than alternative options.[129]

Packaging, plastics and bioplastics

Like many other modern products, the vaccine lifecycle heavily relies on plastics. Replacing those plastics and optimising vaccine packaging is increasingly on stakeholders' radars.[130,131]

Mr Kuo observes that producers are currently largely looking to make changes that reduce their GHG or CO2 emissions; fewer are looking at their plastic production. This may soon change: "Lots of packaging regulation is emerging such as microplastics and PFAS [per- and polyfluorinated substances] and this will encourage pharma companies to think more about this," he says.

Some producers are working to reduce or eliminate the amount of plastic waste, as well as supporting more sustainable alternatives such as recycling.[132]

For others, bioplastics hold some promise. "These are also known as green plastics as they are biodegradable plastics that are manufactured using plants not petrochemicals. This is still an emerging field, but we are seeing growth in this area," says Professor Handfield. However, bioplastics are not always the solution, as they can take many years to break down and then become microplastics and enter the environment.[133]

Analytics

Analytics are also emerging as a tool for producers to make vaccines more sustainable. They can be used to better track the journey or lifecycle of a vaccine to understand where the bottlenecks are and when a vaccine goes outside its assigned temperature range (when vaccines aren't thermostable, they become unusable).[134,135,136]

Using analytics, such as real time and continuous temperature data, can reduce waste and improve efficiency in the vaccine supply chain.[137] As one example, analytics were used to ensure covid-19 vaccines stayed thermostable in Kenya in 2021.[138] "This is a very promising area, with lots of potential," says Professor Handfield.

Policy takeaways

There is no easy path to sustainable vaccine procurement, but experts are unanimous that it is essential as a way to alleviate the hazards of climate change and for its preventive health benefits. Our analysis captures the nuance, challenges and opportunities associated with green vaccine procurement. Some of the key takeaways from our research include:

Multilateral organisations must work quickly and jointly with the vaccine sector if the vaccine supply chain is to be transformed to become more sustainable. This will take time and careful relationship management. "The value chains are complex," says Ms Pakkala, "but as we start to take on each step in the chain, working with our suppliers hand in hand with other partners, we are building towards the transformation over time to reduce emissions from vaccine supply."

It is necessary to build collective awareness and incentives in the tendering process so that no part of the problem goes unaddressed. Awareness is still growing across the vaccine supply chain. Many actors in the vaccine lifecycle (ie, production, transport, storage and waste) can further act to reduce GHG emissions and waste. Tools like analytics in transport, for example, should be encouraged to help increase efficiency and reduce waste.

Multilateral organisations need to define the criteria and path towards sustainability and decarbonisation directly with suppliers. While many suppliers are already looking into becoming more sustainable, driven in part by legal and social pressures, it falls to multilaterals to set clear(er) criteria and

requirements. Our snapshot analysis of the multilaterals shows that in-depth sustainability plans will surface in the immediate future. Any formal criteria will have a major impact due to their purchasing power, reach and influence. They will need to ensure that they do not create barriers that may disadvantage vaccine producers on early stage sustainability pathways, and that they leverage their prominent position to drive positive change.

Further decarbonisation innovations are needed along the supply chain. Several promising developments are emerging along the four domains of the vaccine lifecycle that could help reduce GHGs and waste. Many ideas are being tested and adopted, such as improved vaccine design, renewable energy partnerships, improved packaging and greener transport options. The vaccine sector should share best practices and ideas with partners to encourage the wider uptake of effective solutions.

The vaccine sector needs to build up the momentum it has produced with its first sustainability steps. According to Ms Pakkala, although multilateral organisations are highly motivated, alongside the global health sector, it "is still learning what it means to drive sustainable vaccine supply chains."

Multilateral organisations need to build consensus across the vaccine sector (including with vaccine manufacturers) on green vaccine procurement, an emerging concept. Stakeholders, including multilateral organisations and vaccine producers, should carefully consider the most efficient sustainability wins, without compromising vaccine quality, health security, access, effectiveness and affordability. Integrating sustainability criteria into vaccine procurement will likely be subject to much debate in the years to come.

Multilateral organisations need to approach the sustainable price premium problem carefully. Maintaining cost-effectiveness within the vaccine supply chain ensures there are enough resources to produce the greatest number of doses for global health. Although sustainability often comes at a cost, it will need careful consideration by suppliers and purchasers so that it does not diminish vaccine reach to populations.

Incentives from multilaterals could help suppliers push back bottom-line concerns. Multilaterals need to carefully consider how they can incentivise vaccine manufacturers through the tendering process to innovate in order to mitigate and adapt to climate change. Including incentives and environmental weightings in procurement contracts and tendering could have widespread impacts. Vaccine producers may also be incentivised to the green agenda, in terms of climate change adaptation and/or mitigation terms, if multilateral partners could grant them preferential market access to certain regions.

Vaccine development for climate-sensitive disease should be a priority as part of climate adaptation. Changing habitats could increase the likelihood of infectious disease pathogens jumping to humans, requiring production shifts in climate-sensitive disease vaccines. "There's a significant back and forth between climate change and vaccine production. Addressing these interconnected issues requires a comprehensive approach to adapt to the evolving landscape," says Professor Lee.

Multilateral organisations need to evaluate the role that vaccines play in adaptation to climate-sensitive and endemic diseases. These organisations are already purchasing vaccines that are associated with climate sensitive diseases, but they may need to further consider how these emerging diseases influence their purchasing compared with endemic diseases. Vaccine producers may also want to shift their R&D focus towards emerging climate-sensitive diseases. This will require close collaboration among all stakeholders, including procurers, vaccine producers, healthcare systems and the national governments and local people, as they are on the receiving end of vaccines. There may be a need to create R&D incentives as well.

Vaccines should also be seen as an effective adaptation tool to prevent the use of carbon intensive healthcare systems that generate emissions. In addition to playing a role in adaptation to climate-sensitive and endemic diseases, vaccines can help mitigate GHG emissions by preventing disease, thereby reducing the use of carbon-intensive healthcare systems.

The vaccine sector needs to fully explore the benefits of local vaccine production. International organisations can provide support and bring expertise to developing countries looking to develop their own vaccines. "By doing this, countries can take ownership of activities, co-ordinate effectively, and work with the support of international stakeholders," says Matendrick Adolphe, technical officer of quality and regulation of medicines and health technologies at PAHO.

Countries should be supported in local vaccine production, as it could reduce GHG emissions and waste from transport and storage. It could also help regions become more reactive to local vaccine supply needs, shortages and economic development. Africa CDC, for example, is very keen on working in partnership to develop vaccine manufacturing capacity within the continent. But it will take some years to fully understand what local vaccine production means for net GHG emissions.

Appendix: notes on our methodology

Appendix 1

Climate change-associated major infectious diseases and corresponding vaccine development status

Disease	Pathogen	Vector	Non-human reservoir of relevance	Global burden/ incidence	Regions with major burden	Examples of observations and projections under climate change	Vaccine candidates and status of development
Food- and Water-Related							
Cholera	*Vibrio cholerae*	n/a	/	1.3–4.0 million	Africa, Asia	Increased environmental suitability Influenced by climatic factors (e.g., temperature, humidity, precipitation) Outbreaks following extreme weather events	Several nationally licensed, not WHO-prequalified vaccines available Several preclinical and clinical candidates
Typhoid/ Paratyphoid	*S. typhi* *S. paratyphi*	n/a	/	5.9–14.1 million 2.3–6.1 million	Africa, the Americas, South-East Asia, Western Pacific	Influenced by climatic factors Outbreaks following extreme weather events	Several preclinical and clinical candidates
Invasive non-typhoidal salmonella (iNTS)	*S. typhimurium* *S. Enteridis*	n/a	/	0.4–0.7 million	Sub-Saharan Africa	Influenced by climatic factors	Several candidates at preclinical or early clinical development stage
(Other) Diarrhoeal Disease	Enterotoxic *E. coli*	n/a	/	~ 145–323 million	Africa, Asia	Influenced by climatic factors	Several preclinical and clinical candidates
	Rotavirus	n/a	/	~ 258 million (children under the age of 5)	Asia, South America	Influenced by climatic factors	Several preclinical and clinical candidates
Shigellosis	*Shigella*	n/a	/	~ 176–369 million	Africa, Asia, South America	Influenced by climatic factors	Several preclinical and clinical candidates S. Flexneriza-S. sonnei Bivalent Conjugate Vaccine in Phase 3

Climate change-associated major infectious diseases and corresponding vaccine development status (cont.)

Disease	Pathogen	Vector	Non-human reservoir of relevance	Global burden/ incidence	Regions with major burden	Examples of observations and projections under climate change	Vaccine candidates and status of development
Hookworm disease	*Necator americanus* *Ancylostoma duodenale*	n/a	/	n/a, ~ 230 million prevalence	Africa, South America, Asia	Influenced by climatic factors Shift in species distribution	Na-GST-1/Na-APR-1 in Phase 1 clinical studies
Schistosomiasis	*Schistosoma*	n/a	Snail	n/a, ~ 142 million prevalence	Africa	Influenced by climatic factors Shift in expansion to cooler areas	Several candidates in preclinical/ clinical stages Sh28GST/Bilhvax in Phase 3
Vector-borne							
Malaria	*Plasmodium* parasite	*Anopheles* mosquito	/	186–290 million	Africa	Northward expansion and lengthened transmission season Regional decreases in endemic areas	R21/Matrix-M in Phase 3 trials
Dengue	*Flavivirus*	*A. aegypti*, *A. albopticus*	/	37–101 million	Asia, Americas	Higher suitability in Sub-Sahara Africa compared to Malaria Increased suitability for Europe	5 in clinical development TV-003 and TAK-003 in Phase 3
Zika	*Flavivirus*	*A. aegypti*, *A. albopticus*	/	0.2–0.3 million	Africa, Americas, Asia	Lengthened transmissions season Increased risk of transmission globally	Several in preclinical/Phase 1 VRC-ZKADNA090-00-VP only Phase 2 candidate
Chikungunya	*Alphavirus*	*A. aegypti*, *A. albopticus*	/	0.69 million	Africa, Asia, Americas	Geographic expansion to Central Europe, China, Central America Declining suitability in other areas	Several in preclinical, Phase 1/2 Valneva VLA1553 completed Phase 3, regulatory ongoing
Yellow Fever	*Flavivirus*	*A. aegypti*, *A. albopticus*	Non-human primates	0.04–0.24 million	Africa, Central and South America	Heterogenous changes for transmission across African region Varying results of modeling studies for future burden	Several second-generation candidates in preclinical 2 candidates in Phase 1

Climate change-associated major infectious diseases and corresponding vaccine development status (cont.)

Disease	Pathogen	Vector	Non-human reservoir of relevance	Global burden/ incidence	Regions with major burden	Examples of observations and projections under climate change	Vaccine candidates and status of development
Rift Valley Fever	*Bunyaviridiae*	*Aedes*, *Culex*	Livestock (Cattle, sheep, goats)	n/a	Sub-Saharan Africa	Influenced by climatic factors Geographic expansion	Licensed vaccine for livestock No licensed vaccine for humans, ChAdOx1 candidate in Phase 1
Lymphatic filariasis	*Wuchereria bancrofti* *Brugia malayi* *B. timor*	*Ae. aegypti*, *C. quinquefasciatus*	/	~ 51 million	Asia, Africa, Western Pacific, South America	Geographic expansion with shifting patterns of distribution	Preclinical candidates
Leishmaniasis	*Leishmania*	*Phlebotominae*	Rodents, dog	0.7–1 million	Africa, Asia, Mediterranean, South America	Influenced by climatic factors Geographic expansion	Several preclinical and clinical candidates
Lyme disease	*Borrelia spirochete*	*Ixodes* ticks	Mouse, small mammals, birds	0.53 million	North America, Europe, Asia	Geographic expansion, esp. northwards and to higher altitudes	VLA15 in Phase 3 LYMERix licensed 1998 (FDA) but withdrawn from market
Tick-borne encephalitis	*Flavivirus*	*Ixodes* ticks	Small rodents	0.01 million	Europe, Asia	Geographic expansion Shift to higher altitudes	FSME-Immun, Encepur, TBE-Moscow, EnceVir (nationally licensed)
Crimean-Congo Hemorrhagic Fever	*Bunyaviridiae*	*Hyalomma* ticks	Wild and domestic animals	n/a	Africa, Balkans, Middle East, Asia	Geographic expansion to Europe Reduced suitability in North Africa and Southern Iberia	Preclinical candidates Vaccine in Bulgaria since 1974 (safety/ efficacy concerns)
Air-borne							
Respiratory illness	Seasonal Influenza Virus	n/a	Aquatic birds, pigs	3–5 million	Global	Influenced by climatic factors Reduced suitability due to warming climate Increased risk of epidemics/ pandemics due to higher weather variability and novel viral pathogens	Yearly adaptations required due to antigenic drift Development of next-generation influenza vaccines ongoing

Climate change-associated major infectious diseases and corresponding vaccine development status (cont.)

Disease	Pathogen	Vector	Non-human reservoir of relevance	Global burden/ incidence	Regions with major burden	Examples of observations and projections under climate change	Vaccine candidates and status of development
Respiratory illness	Respiratory Syncytial Virus	n/a	n/a	33 million (under 60 months)	Global	Influenced by climatic factors	First RSV vaccine for infants up to 6 months and over 60 years available since 2023, approved by the FDA and recommended by the EMA Several preclinical and clinical candidates
Other							
Leptospirosis	*Leptospira*		Rodents	0.43–1.75 million	South and South-East Asia, Americas, sub-Saharan Africa	Outbreaks following extreme weather events	Vaccine available for pets Vaccines licensed in France, China, Japan, Cuba Recombinant vaccine in preclinical development

Data sourced from the World Health Organization and US Centers for Disease Control and Prevention.

Source: Kim, C. L., Agampodi, S., Marks, F., Kim, J. H., & Excler, L. (2023). Mitigating the effects of climate change on human health with vaccines and vaccinations. Frontiers in Public Health, 11. https://doi.org/10.3389/fpubh.2023.1252910.

Appendix 2

Snapshot analysis of green vaccine procurement by UNICEF and PAHO (with publicly available information up to May 2024)

Methodology: This snapshot analysis seeks to examine the green vaccine procurement policy of major multilateral procurers of vaccines. A total of 15 indicators (13 qualitative indicators and 2 quantitative indicators) were analysed. The indicators were scored according to criteria set by the EI research team after extensive review of the literature and interviews with key stakeholders. Each indicator (except for the background indicators, which are included for context) were scored as follows:

- **"Yes"** (green) the policy exists;
- **"Partially"** (yellow); there are partial elements of the policy in existence;
- **"No"** (red) there is no policy in existence or no decision has been made to meet our criteria;
- **"No information"** (grey) the EI found no information.

This scoring makes it easier to compare the multilaterals. For each indicator, a full justification and relevant references have been provided.

The information contained in this snapshot was shared with the multilaterals, however only UNICEF responded and provided feedback (response received on **17 May 2024**). A former PAHO employee (Luciana Vasconcellos) provided us with comments on the snapshot (on **12 May 2024**). We incorporated any feedback we received, integrating the information as appropriate.

All information gathered was available in the public domain at the time of research (April 2024), and some indicators were based on personal communication with the multilateral organisation.

Limitations: This type of snapshot has limitations and should be only used as a tool for improving understanding about multilateral organisations' readiness for green vaccine procurement. It is NOT intended to be predictive of eventual policy, as there are other factors at play such as vaccine equity, safety, accessibility, affordability and quality. Furthermore, the indicators included in the snapshot may not necessarily capture all the relevant indicators.

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
Indicator 1: Does it have a sustainability agenda/plan for general procurement?	**Yes** The most recent plan is from September 2018 which provides information on its approach to sustainable procurement, leading it to have a bigger impact in achieving the Sustainable Development Goals. The framework intends to "leverage its strategic procurement to address broad critical issues to advance, and attain, sustainable development by 2030." **Source:** https://www.unicef.org/supply/sites/unicef.org.supply/files/2019-06/sustainable-procurement-information-note.pdf	**Yes** The 2022 Annual Statistics report on UN Procurement (ASR) "provides an overview of the procurement of the United Nations (UN) system in support of its operations, projects and programmes." In this report, there is a presentation of the analysis of key trends in UN procurement which include statistics. The report also "contains information on collaboration within the UN system and organisations' efforts to integrate sustainability considerations into their procurement processes, in the context of the UN's continued focus on sustainable development." The document cited refers to the efforts made by PAHO, UNOPS and UNICEF. **Source:** https://www.ungm.org/Shared/KnowledgeCenter/Pages/asr_report
Indicator 2: Is there mandatory GHG reporting required annually under the general sustainability plan or equivalent?	**No** UNICEF's Sustainability and Climate Change Action Plan 2023 -2030, published in 2023, establishes that UNICEF is "accelerating its efforts to reduce its environmental footprint – including setting a goal of reducing internal GHG emissions from operations by 45 per cent by 2030". In this same plan, one of their commitments is to deploy an "innovative environmental management software tool to collect, analyse and measure UNICEF's carbon footprint, water use, energy consumption, and waste generation across all our country offices". However, they do not seem to be reporting GHG emissions annually yet. **Source:** https://www.unicef.org/media/148816/file/UNICEF%20SCAP%202023-2030.pdf (p.11 and 12)	**No** PAHO aims to reduce the GHG emission intensity factor from the transport and distribution of procured goods by PAHO's Regional Revolving Funds by 50% from a 2022 baseline. Additionally, they have seemingly established a Carbon Emission Reduction project, which provides "a comprehensive roadmap for emissions reduction across the organisation, inclusive of Scope 3, Category 4 emissions from upstream international transportation." [1] PAHO has also stated that they will encourage suppliers to report against targets annually [2]. Lastly, the organisation has established PAHO's Green Working Group which "will propose actions to lower carbon footprint and foster environmental sustainability within [their] activities, including the procurement and delivery of goods and services through The Pan American Health Organization's Regional Revolving Funds." [3] The latter information was published in March 2024, and they state that more information will be shared in the coming weeks. **Sources:** [1] https://www.linkedin.com/posts/procurement-and-supply-management-department-pro-_pahos-commitment-to-carbon-emission-reduction-activity-7168393916734545920-Cfib/ [2] https://www.paho.org/en/doing-business-paho/sustainable-procurement [3] https://www.linkedin.com/feed/update/urn:li:activity:7171231223086874625/

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
Indicator 3. Does it have a sustainability agenda/ plan directly for vaccine procurement? (Year)	**Yes, 2023** There is a powerpoint published in 2023 by UNICEF for the Vaccine Industry Consultation. This document covers UNICEF's sustainable procurement vision and strategy and how it can be related to vaccine procurement. The document establishes vaccine security as a "starting point" as it is the "fundamental principle of UNICEF vaccine procurement. Sustainability will be a key strategic area moving forward." UNICEF told EI (May 2024): In 2024, UNICEF plans to update its policy to industry. **Source:** https://www.unicef.org/supply/media/20806/file/UNICEF-Sustainable-Procurement-Vaccines-2023.pdf	**Yes, 2024** PAHO has a sustainable procurement plan for the Revolving Fund (vaccines). The multilateral considers that the environmental, social and economic (ESE) specifications are "compatible and in favour of the protection of the environment, of social progress and in support of economic development, namely by seeking resource efficiency, improving the quality of products and services and ultimately optimising costs". PAHO's aim is to "reduce by 50% the GHG emission intensity factor from the transportation and distribution of procured goods by PAHO Revolving and Strategic Fund from a 2022 baseline by 2030". [1] Furthermore, PAHO's document on key updates from September 2023 briefly mentions sustainability as a priority for procurement, but it does not provide any further detail on this, nor does it have a specific sustainability strategy document itself for vaccine procurement. Additionally, it refers to UNICEF, PAHO, and UNOPS efforts. While not directly referencing a sustainable procurement strategy for vaccine procurement, the documents talk about general procurement and sustainability and under this, they list health which lists vaccines specifically. [2] **Sources:** [1] https://www.paho.org/en/doing-business-paho/sustainable-procurement [2] https://www.ungm.org/Shared/KnowledgeCenter/Pages/asr_report
Indicator 4. What type of environmental criteria does it include specifically for vaccines?	**Partially, environmental (GHG emissions, energy consumption, water consumption, wastewater, hazardous waste, biodiversity, and packaging.)** UNICEF has a sustainable procurement strategy which confirms that there will be focus on ESE (environmental, social and economic) elements, which are still under development. The ESE elements are: GHG emissions, energy consumption, water consumption, wastewater, access to vaccines, health and safety, equal opportunities, employment opportunities, hazardous waste, biodiversity, and packaging. [1] This score is "Partially", as areas are still under development as stated by the 2023 Annual Supply report: " UNICEF is identifying indicators to help strengthen the ESE aspects of the immunisation supplies procured, including emissions reductions". It should be noted that this same document mentions that UNICEF reduced transports volume and waste by implementing new, smaller-sized syringes. [2]	**Yes (encourage supplier sustainability action; promote shift from air to sea transport; better/ reduce packaging; green shipping lanes; low emission transport)** PAHO's procurement plan for the Revolving and Strategic funds considers the following 5 points: 1. Encourage supplier sustainability action, which includes a sustainable policy and strategy, supplier emission reduction targets and annual reporting against targets. 2. Promote shift to lower emission transport options, which includes innovative low-emission transport of temperature and non-temperature controlled products. 3. Reduce packaging and promote the use of sustainable material. This includes reducing packaging, promote sustainable packaging and advocating digital solutions for product instructions. 4. Enhancing shipping consolidation in PAHO's supply chain, which includes using Green Shipping Corridors. 5. Leverage low-emission transport solutions, which includes the usage of sustainable air (SAF) and maritime fuels. [1]

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
Indicator 4. What type of environmental criteria does it include specifically for vaccines? *(cont.)*	**Sources:** [1] https://www.unicef.org/supply/media/20806/file/UNICEF-Sustainable-Procurement-Vaccines-2023.pdf [2] https://www.unicef.org/supply/media/21506/file	While the 2022 Annual Statistics report outlines sustainability criteria (environmental, social, and economic) as requirements in its definition of sustainability criteria, this document does not have a distinct nor explicit mention of sustainability criteria as it relates to vaccines. There is also no official document from PAHO that expresses their engagement with sustainability criteria. [2] **Sources:** [1] https://www.paho.org/en/doing-business-paho/sustainable-procurement [2] https://www.ungm.org/Shared/KnowledgeCenter/Pages/asr_report
Indicator 5. Has it consulted vaccine suppliers about a future green vaccine procurement?	**Yes** The cited reference establishes next steps and what they mean for UNICEF vaccine suppliers. This document establishes that in the short run, there will be increased engagement with suppliers on ESE (environmental, social, and economic sustainability). It also mentions that in the mid-long term, there will be a further expansion of engagement with suppliers on economic, social and environmental criteria which includes an expansion of annual reporting and bilateral meetings with ESE focal points. **Source:** https://www.unicef.org/supply/media/20806/file/UNICEF-Sustainable-Procurement-Vaccines-2023.pdf	**No information** Nothing that is found in the public domain.
Indicator 6. Does it have numeric targets for vaccine suppliers (in terms of climate mitigation factors)(for example, a specific environmental numeric weighting that producers meet)? *Eg. From April 2027, all National Health Service (NHS) suppliers in the UK, will be required to publicly report targets, emissions and publish a Carbon Reduction Plan for global emissions aligned to the NHS net zero target, for all of their Scope 1, 2 and 3 emissions.* Source: https://www.england.nhs.uk/greenernhs/get-involved/suppliers/	**No** There is no public information on quantitative targets for vaccine suppliers. However, based on UNICEF's powerpoint on the Vaccine Industry Consultation (2023), short-term and long-term plans have been made but no numbers have been specified regarding targets. UNICEF told EI (May 2024): "UNICEF has communicated to suppliers the future need for reporting key program indicators around sustainable procurement, including GHG metrics. UNICEF has noted to industry that sustainable procurement of vaccines includes improved environmental, social and economic sustainability." **Source:** https://www.unicef.org/supply/media/20806/file/UNICEF-Sustainable-Procurement-Vaccines-2023.pdf	**No** There is no public information on targets for vaccine suppliers.

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
Indicator 7. Does it have a vision/plan/target that new vaccine development considers climate-sensitive diseases?	**No** There is no public information on a vision/plan/target that vaccine development considers climate-sensitive diseases UNICEF told EI (May 2024): "As UNICEF is not an R&D institution or funder, UNICEF engages with partners focused on upstream strategies and aligns tender strategies accordingly to signal to industry the potential market for climate-sensitive diseases. UNICEF also develops procurement toolkits for such diseases, inclusive of diagnostics, therapeutics, LLINs [long-lasting insecticidal nets], ORS [oral rehydration salts], vaccines, etc." UNICEF told EI (May 2024): "Access to (new) vaccines is one of the key thematic areas prioritised for sustainable procurement, this includes vaccines against climate-sensitive diseases; this means UNICEF is part of the ecosystem to advance novel vaccines against climate sensitive vaccines, including Gavi/Alliance board membership, (e.g. VIS [Vaccine Investment Strategy]) engagement with CEPI [Coalition for Epidemic Preparedness Innovations] to steer the (innovation) agenda and subsequently set-up for procurement of these vaccines. We are actively working with CEPI and as part of the vaccine investment strategy for the GAVI Alliance to look at those diseases which are likely to shift their burden as a consequence of climate change; further we are exploring modalities for systems support (micro-array patches that do not require injection devices or cold chain) as well as solarisation of health facilities to support more sustainable energy provision."	**No** There is no public information on a vision/plan/target that vaccine development considers climate-sensitive diseases
Indicator 8. Does it procure vaccines that are associated with climate-sensitive diseases? [water-related diseases such as cholera and other enteropathogens, helminthic infections and leptospirosis; vector-borne diseases like dengue, chikungunya, and malaria; airborne diseases like influenza and respiratory syncytial virus infection] Scoring: Yes, 5 or more; Partially, Less than 5; No=nil bought *Note: We relied on the academics Kim et al (2023) to decide what vaccines are related to climate-sensitive diseases*	**Yes** UNICEF procured vaccines for 8 climate-sensitive diseases in 2022. The vaccines and diseases include Rota (Rotavirus Vaccine), TCV (Typhoid Conjugate Vaccine), Cholera, Yellow fever, Covid-19, Malaria, Influenza, and Rabies. **Source:** https://www.unicef.org/supply/media/17871/file/UNICEF-Vaccine-Markets-Prioritizing-and-Scaling-Up-Towards-Equitable-Access.pdf (p.18)	**Yes** PAHO will procure vaccines for the following 5 climate-sensitive diseases in 2024: Cholera, Rotavirus, Typhoid, Yellow Fever, Seasonal Influenza. **Source:** https://www.paho.org/en/documents/vaccine-prices-2024

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
Indicator 9. Does it consider the principle of fair competition by encouraging local supply production, including vaccines?	**Yes** UNICEF has a roadmap for local production in Africa. The roadmap is established through three phases: 1. The First Wave which accelerates the localised production of Oral Rehydration Salts (ORS)/Zinc, syringes and Large Volume Parenterals (LVPs). 2. Second Wave which expands to include long-lasting insecticidal nets (LLINs), malaria rapid diagnostic tests, oxygen concentrators and chlorine water treatment solutions. 3. The Third Wave which focuses on enabling local production of vaccines, amoxicillin dispersible tablets, multiple micronutrient supplements and cold chain equipment. [1] Furthermore, UNICEF has procured supplies (multiple purchased goods, including vaccines) from various developing countries, fostering local supply production. Within these supplies, vaccines are classified as the top commodity group [1]. In 2022, UNICEF procured supplies from these countries: India (amount procured: $589.2 million), Yemen ($251.3 million), Indonesia ($138.4 million), Pakistan ($132.2 million), Lebanon ($114.3 million), Kenya ($94.7 million), and Afghanistan ($82.2 million), among many others [2]. **Sources:** [1] https://www.unicef.org/supply/media/21506/file [2] https://www.unicef.org/supply/media/19791/file (p.13) [3] https://www.unicef.org/media/148816/file/UNICEF%20SCAP%202023-2030.pdf (p.12).	**Yes** After the COVID-19 pandemic, PAHO was motivated to address its high dependence on imports of health technologies (including vaccines) from outside the region and how this made global supply vulnerable. Because of this, PAHO has "renewed efforts" to improve local production capacities in the region and has launched a collaborative platform (the Speal Program, Innovation, and regional Production Platform), to "convene public and private stakeholders to facilitate the expansion of vaccine and other health technology research, development, and manufacturing in the Region." **Source:** https://www.paho.org/en/special-program-innovation-and-regional-production-platform-rp

Yes Partially No No information

Green vaccine procurement policy	UNICEF	PAHO
Indicator 10. Does it include (or plan to include) direct and explicit incentives for vaccine manufacturers to undertake green vaccine procurement for climate change adaptation or mitigation? For a score of "Yes", it should consider any or all of the following: a) incentivising vaccines with fewer GHG emissions per dose; b) encouraging the use of fewer vaccine doses or combination vaccines; c) minimised packaging volume; d) energy efficiency; e) science-based climate targets; f) use sea freight over air transport; g) incentivising vaccines that directly address climate-related outbreaks	**No information** According to an interview conducted for this project by Economist Impact, it was stated that "UNICEF and its partners are working to improve the enabling environment and procurement incentives for manufacturers, distributors, and country recipients to ensure vaccine products do not contribute to further climate and environmental degradation, especially in emergency situations." While there are no direct mentions of what these incentives are, there are efforts internally within UNICEF to work towards incentivising. While there are no direct mentions of what these incentives are, UNICEF told EI (May 2024) that "incentives will be incorporated into future tender strategies and requirements". Furthermore, UNICEF told EI (May 2024): "UNICEF has provisions on its tender process to make awards (=incentives) based on the characteristics of the vaccines that meet best the objectives of the tender; these may include product presentation, doses per vial, administration schedule, thermostability/shelf-life, packed volume. It is anticipated that such evaluation criteria and tender objectives may further expand over time. Furthermore, UNICEF together with Gavi has established roadmaps for vaccine markets that include elements to steer towards more optimal/efficient vaccine use and innovations, including move towards combination vaccines. On top of vaccine specific roadmaps this includes the vaccine innovation strategy focused on innovative vaccine presentations such as improved thermostability, controlled temperature chain compliant vaccines, micro-array patches for vaccine delivery as well as implementation of barcodes. Where feasible UNICEF includes elements of supplier diversifications and local manufacturing. Finally, UNICEF engages with partners on roadmaps, priority settings and strategies that address climate related outbreaks, including WHO [R&D] Blueprint, CEPI and expansion of the vaccine stockpiles (latest add under ICG [International Coordinating Group on Vaccine Provision] control is Ebola vaccine stockpile)."	**No information**

Background Indicators	UNICEF	PAHO
Background Indicator 1. How many vaccines does the multilateral procure p.a (or comparable data)	**3.4 billion vaccine doses per year (2022)** UNICEF distributed 3.429 billion vaccine doses to 108 countries, of which 2.451 billion doses were allocated to fulfil national vaccination objectives and address outbreaks. In total, UNICEF acquired vaccines intended to cover 45 percent of children under the age of 5 worldwide. In 2022, the vaccines procured amounted to $3.736 billion. **Source:** https://www.unicef.org/supply/media/19791/file (p.10)	**400 million vaccine doses per year (2022)** In 2022, PAHO purchased "more than 400 million vaccines, syringes and other supplies for immunisation and advised dozens of countries on various issues related to vaccination in South America, the Caribbean, Central America and North America". **Source:** https://www.paho.org/en/revolving-fund-access-vaccines-engine-equity
Background Indicator 2. Top 10 vaccines procured by volume	**OPV, COVID-19, PCV, BCG, DTP/Hep B, MR, Measles, Yellow fever, TD, Rota (2022)** In 2022, UNICEF procured various types of vaccines. In terms of the number of doses, OPV accounted for the largest quantity (almost 800 million doses). Other procured vaccines were PCV (over 150 million), BCG (around 160 million), DTP (over 4 million), MR and Measles (over 250 million), Yellow Fever (93.5 million), TD (over 130 million), Rotavirus (over 40 million), Covid (around 400 million, excluding donations). In 2023, it is noted that they bought IPV (187 million). It is also worth noting that 16 middle income countries are procuring the HPV vaccine through UNICEF, while other countries have procured through Gavi. **Source:** https://www.unicef.org/supply/vaccine-industry-consultation-vic-2023 (VIC market updates) and https://www.unicef.org/supply/media/18986/file/VIC-MarketUpdate-Poster-HPV-2023.pdf	**Influenza, Pentavalent, Pneumococo, Rotavirus and HPV(2022)** In 2022, PAHO procured various types of vaccines. In terms of the number of doses, Influenza accounted for 31 million, Pentavalent for 13.2 million doses, Pneumococcal for 9.1 million doses, Rotavirus for 6.6 million doses, and HPV for 2.6 million doses. **Source:** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10128882
Background Indicator 3. GHG Emissions	**There is information on targets and progress they have made in addressing GHG emissions.** UNICEF's Supply Annual Report 2023 states that "UNICEF made strides in syringe optimization, reducing transport volume and waste by implementing new, smaller sized syringes that lead to less transportation and waste. In this sense, "UNICEF anticipates a 50 percent reduction in shipment emissions by the end of 2025 compared to 2021". [1] Furthermore, UNICEF has set their goal of reducing GHG emissions within their operations by 45% by 2030, using their 2010 baseline. [2, pg. 11]. Also, as of Nov. 2023, UNICEF has reduced internal GHG emissions by 33% since 2010 by sourcing 32% of its energy from renewable sources to offset all unavoidable emissions from its operations. Unavoidable emissions include staff travel. [2, pg. 12] **Sources:** [1] https://www.unicef.org/supply/media/21506/file [2] https://www.unicef.org/media/148816/file/UNICEF%20SCAP%202023-2030.pdf (pages 11 and 12)	**On average, Scope 3 emissions contribute to 75% of the organisational GHG emissions** According to the reference, there are three scopes of emissions; Scope 1 (direct emissions) which includes any energy PAHO burns from sources it owns or controls. Scope 2 (indirect emissions) includes any energy that PAHO buys. Scope 3 (indirect supply chain emissions) includes any emissions from: production of purchased goods, capital goods, fuel and energy, upstream transport, waste, business travel, employee commuting, upstream leased assets, downstream transport, processing of sold products, use of sold products, end of life sold products, downstream leased assets, franchises, and investments. **Source:** https://www.unicef.org/supply/media/18881/file/UNICEF-VIC2023-Session09-RegionalProcurementupdate-PAHO-2023.pdf (p.18)

Background Indicators	UNICEF	PAHO
Background Indicator 4. Who are its largest country and other recipients of vaccines? (eg GAVI)	**100 nations (global)/ GAVI** According to the reference, "UNICEF has a key role in procurement of vaccines and immunisation supplies on behalf of around 100 countries annually, supplying over 2 billion doses of vaccines and reaching approximately 45 percent of the world's children in support of routine immunisation programs, preventive campaigns, outbreak and emergency response activities." According to the second reference, UNICEF is the main partner of GAVI and they have together delivered vaccines to "760 million children with life-saving vaccines over the last 20 years, preventing more than 13 million deaths." **Sources:** [1] https://www.unicef.org/supply/vaccine-industry-consultation-vic-2023 [2] https://www.unicef.org/supply/covax-ensuring-global-equitable-access-covid-19-vaccines#:~:text=As%20the%20largest%20single%20vaccine,behalf%20of%20nearly%20100%20countries	**41 nations (Latam and Caribbean)** According to the reference, "Through the Revolving Fund, 41 countries have access to safe and quality vaccines that are 75% cheaper than if they were to purchase them on their own. In a region that pioneered the elimination of diseases such as smallpox, polio and measles, the Fund plays a role that goes far beyond the purchase of vaccines." **Source:** https://www.paho.org/en/revolving-fund-access-vaccines-engine-equity
Background Indicator 5. Does the organisation undertake pooled vaccine procurement?	**Yes** The UNICEF supply division website (cited reference) has a post that discusses the effectiveness of UNICEF's pooled procurement approach at delivering vaccines affordably and on time. UNICEF's pooled procurement approach involves a process where UNICEF forecasts and combines vaccine demand from the countries it supports to get better commercial terms from manufacturers than the countries could on their own. It gives suppliers a long-term sense of the doses required, allows for large-scale production of vaccines, and helps UNICEF to get competitive prices by asking manufacturers to submit proposals for supply." These are the five reasons the post says it is effective: 1. Uninterrupted supply of life-saving vaccines 2. Driving down the price of vaccines 3. Building healthy markets 4. Partnerships are key to progress 5. Success stories of pooled procurement "In 2001, only one manufacturer produced the vaccine, meaning there were insufficient doses to protect every child that needed it. Although there were two suppliers by 2007, the price per dose was still high at US$3.50. Through funding from Gavi, the Vaccine Alliance, and UNICEF's efforts to consolidate the demand on behalf of low-income countries, it helped to create opportunities for manufacturers to enter the market. Today, thanks to ongoing efforts to build a healthy vaccine market, four manufacturers supply the pentavalent vaccine to UNICEF, with the lowest price at US$0.78 cent per dose – a nearly 80 percent decrease in price since 2007. In 2022, UNICEF delivered pentavalent vaccines to 76 countries." **Source:** https://www.unicef.org/supply/stories/transforming-global-access-vaccines	**Yes** Paho's Regional Revolving funds is a regional technical cooperation mechanism for pooled procurement of essential medicines and strategic health supplies, according to the cited reference. The Fund is considered to be a "central component of Paho's strategy to move towards Universal Health" and is meant to "strengthen the strategic supply management systems, providing technical cooperation to plan demand, promote rational use of medicine, and prevent stock-outs in the region of the Americas." **Source:** https://www.paho.org/en/strategic-fund

Appendix 3

Literature review methods

This research programme was initially informed by conducting two literature reviews. The first focused on the concept of green health procurement as a whole to understand what factors facilitate or hinder the implementation of green procurement in healthcare systems. The second review focused on understanding the extent to which green procurement and sustainable practices are considered in vaccine development and procurement and how prepared multilateral organisations are to incorporate the sustainable aspects into their procurement processes. For the first review on the present state of global green procurement in healthcare, a search was conducted on Web of Science, Scopus, ScienceDirect, Trip Medical Database, and Google Scholar using a combination of thesaurus and free-text terms to capture all relevant green procurement reviews focused on stakeholders of interest, green purchasing among procurement organisations and programmatic documents in relation to green procurement. Exclusion criteria for the search were any studies conducted before 2013, non-English studies, and studies that were only conference papers. The initial search returned 6,575 references. After accounting for duplicates and removing them, 5,902 references remained. After a thorough assessment through our inclusion/exclusion criteria, 419 eligible references remained. Specialty and grey databases were searched using Google and Google Scholar. This search was limited to documents from 2015 onwards. For the second review specific to sustainable practices in vaccine development, the search excluded studies with a lack of relevance such as non-green procurement topics, procurement in a non-health sector, and studies before 2013. Methods were identical for our second literature review on understanding the extent to which green procurement and sustainable practices are considered in vaccine development and procurement. Exclusion criteria for this were any studies conducted before 2013, non-English studies, and studies that were only conference papers.

Endnotes

1. Global immunization efforts have saved at least 154 million lives over the past 50 years. WHO. 2024. Available from: https://www.who.int/news/item/24-04-2024-global-immunization-efforts-have-saved-at-least-154-million-lives-over-the-past-50-years
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