

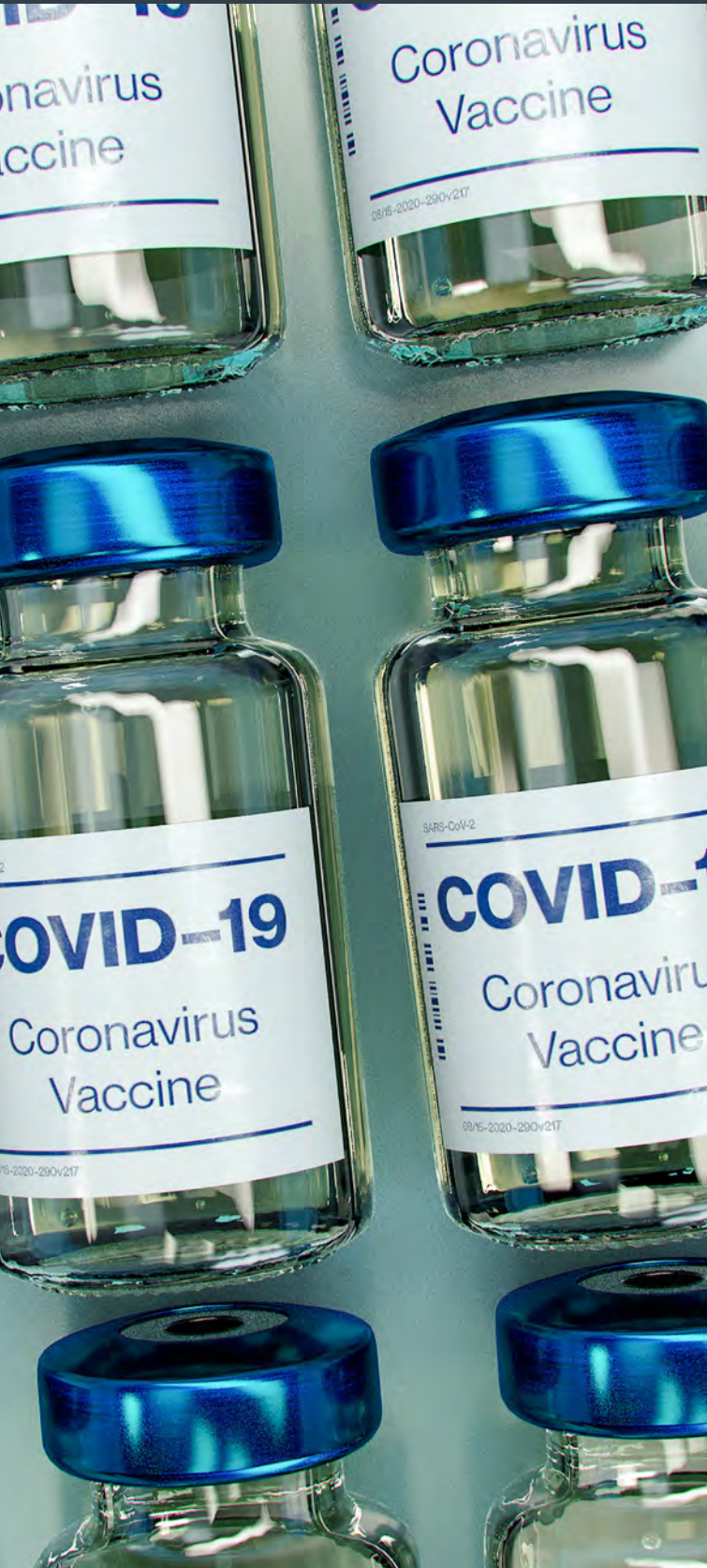
CO₂ supply feasibility assessment

Final report - Africa, Latin America and Pacific Islands

Presented to *The Bill and Melinda Gates Foundation* by *Project Last Mile* on the 11 January 2021



Project
Last Mile



Contents

Introduction and purpose of this report
page 1

Background
page 1

Summary of findings
page 1

Sources of data
page 2

Project approach
page 2

Assessment methodology
page 4

Assumptions
page 4

Assessment outputs
page 5

Outcomes
page 17

Financial analysis
page 18

Risk analysis
page 24

Appendices

1. COVAX Delivery Model calculation sheet
2. Summary of assessment outputs
3. Road transportation cost calculation
4. Dry ice operating expenses calculation

Introduction and purpose of this report

This report summarizes insights and opportunities from the feasibility assessment of liquid CO₂ supply within the Coca-Cola system to support storage and distribution of a COVID-19 vaccine that is sensitive to temperature variation and therefore requires ultra-cold chain distribution.

Background

Project Last Mile (PLM) is an innovative public-private partnership launched in 2010 between The Coca-Cola Company, The Coca-Cola Foundation, United States Agency for International Development (USAID), President's Emergency Plan for AIDS Relief (PEPFAR), The Global Fund and Bill & Melinda Gates Foundation to draw private sector lessons from across the Coca-Cola value chain to benefit health systems strengthening in Africa.

Given the need for ultra-cold chain (UCC) for an initial leading COVID-19 vaccine candidate, PLM was invited to conduct an analysis on the availability of liquid CO₂ (LCO₂) in the Coca-Cola value chain in 47 countries in Africa to assist in meeting potential dry ice needs to support ultra-cold chain vaccine distribution. This was then expanded to include COVAX countries in Latin America and the Pacific Islands.

PLM completed a rapid assessment examining the feasibility of procuring LCO₂ in 70 countries from Coca-Cola partners and suppliers across the three regions. This final report represents the culmination of this assessment. The aspiration is that this assessment will contribute significant insights to determining the operational feasibility of maintaining ultra-cold temperatures to distribute a new COVID-19 vaccine. It can also help inform where the COVID-19 vaccine may not be feasible or will require another CO₂ procurement approach.

Summary of Findings

The report below will provide in-depth analysis and assumptions leading to the high-level insights provided here:

- 1. There is abundant LCO₂ capacity to support the UCC requirements for the COVID-19 vaccination program** for up to 1% of the total country population across each of the 70 countries.
- 2. There is immediate available capacity to produce dry ice in 23 countries , covering 61% of the target population for vaccination in those countries.** There is sufficient dry ice capacity in 21 of those countries in Africa and Latin America to supply the remaining 29 countries in those two regions immediately if air transport is used to move the excess capacity between countries. For the Pacific Islands there is sufficient dry ice capacity in New Zealand to supply the remaining eight countries. Estimated cost for immediate supply across all 70 countries is \$15.8m for 1% of the total country population or \$1.12 per person vaccinated using two doses over 21 days.
- 3. Where air transport is unviable or undesirable for countries that have insufficient local dry ice supply, a combination of installing local dry ice capacity and truck transportation where possible can be implemented** at a cost of \$17.5m for 1% of the total country population or \$1.24 per person vaccinated using two doses over 21 days. Of that \$17.5m, investment in dry ice plant installation is \$5.3m. This will require sequencing for these countries, with potential delays of supply of between 12 to 30 weeks, dependent on whether additional LCO₂ storage is required for the new dry ice plant installations. Estimated cost for sequenced supply across all 47 countries is up to \$13.3m with up to \$2.8m of that cost being investment in dry ice plant installation to supply to meet demand for vaccination of 1% of the total country population.

¹ Countries include: Angola, Cote D'Ivoire, Egypt, Ghana, Kenya, Madagascar, Morocco, Mozambique, Nigeria, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Bolivia, El Salvador, Honduras, Trinidad and Tobago, Costa Rica, Guatemala, Papua New Guinea and Vanuatu.



Sources of data

In completing this assessment, the following data sources were consulted.

TCCS bottlers	Coca-Cola Beverages Africa, Heineken, Equatorial Coca-Cola Bottling Company, BGI Castel Group, DAL Group Sudan, National Bottling Company Nigeria, Coca-Cola Amatil, Embol SA, Grenada Bottling Company, Anheuser-Busch InBev, Banks DIH, Brasserie De La Couronne, Fomento Económico Mexicano SA, Du Boulay Bottling Company, Caribbean Bottling Company.
Research groups	Centre for Tropical Medicines and Health, Nuffield Department of Medicine, The Demographic and Health Surveys Program, Oxford Business Group, Worldometer.com.
LCO₂ / dry ice suppliers	TOL Gases Ltd Tanzania, Air Liquide, Dry Ice International South Africa, Modern Distillers Ltd Uganda, MOGÁS S.A. Mozambique, Sugar Corporation Of Uganda Ltd, Carbacid CO2 Ltd Kenya, G-Global Gas And Chemicals Ethiopia, Glace Polaire Morocco, SOACI SN Cote D'Ivoire, Air Products South Africa, Cyrotech Algeria, DIFCO2 Egypt, Linde Gas Algeria, Novagas Ltd Nigeria, Acail Angola, Linde BOC Gases Nigeria, Afrox-Linde South Africa, Carbogas SA, Linde (Praxair Legacy), Massy Gas Products (Trinidad), INFRA G.I. de Costa Rica SA, Carbox Costa Rica SA, Carbox Guatemala, Carbox Nicaragua, GAZ Industriels Associes SA, BOC Papua New Guinea, Vanuatu Brewing.
Air freight	DHL Cote D'Ivoire, Safe Air Kenya.
Dry ice plant	ASCO Carbon Dioxide Ltd, Switzerland.

Project approach

Understand dry ice and LCO₂ demand

To understand LCO₂ and dry ice demand, PLM used the COVAX Delivery Modeling work, commissioned by BMGF to model basic projections for vaccine distribution, to map expected demand for dry ice and LCO₂ in each country.

The model predicts the quantity of dry ice required by territory based on the proportion of the population to be vaccinated and the number of locations where they are to be vaccinated. It takes in to account distances to transport the vaccine to administration areas and the time required for vaccination teams to get to those areas. The volume of dry ice is then determined according to the doses of vaccines to be administered on each visit and the number of UCC transport boxes required. The approach described below assumes a baseline knowledge of the COVAX Delivery Modeling work. If needed, additional explanation can be provided.

The model was left unchanged, with only population size, geographical area and the number of health facilities by country input in to the model as these were the variables required to calculate dry ice demand by country. The model is shown in Appendix 1.

With the analysis of dry ice demand done by country using the COVAX Delivery Modeling work, there was a slight variance in the aggregated demand by country versus that done by administrative area within a country. This is due to the model rounding up the quantities of transportation boxes required, thus at a country level this leads to a slightly reduced volume of dry ice calculated.

With the model determining the total dry ice required by country, PLM factored in additional wastage of 8% from manufacturing and then storing the dry ice based on the experience of the dry ice suppliers consulted to give total dry ice production required by day for the period of vaccination over 30 days.

For countries where dry ice needs to be transported across borders, an additional 12% was added to account for losses due to sublimation during transport.

Using the ratio of 3kg of LCO₂ to manufacture 1kg of dry ice, the total LCO₂ required was then calculated by country.



Establish current dry ice and LCO₂ supply capacity

PLM leveraged the expertise and contacts of PLM within TCCS in Africa, Latin America and the Pacific Islands to identify potential sources of dry ice and LCO₂.

Current LCO₂ supply chain infrastructure within Coca-Cola bottling plants, local suppliers to Coca-Cola bottling plants and sources from outside the regions where LCO₂ is imported were then contacted to determine production and storage capacities. For this, 15 bottlers and 35 LCO₂ and dry ice suppliers were consulted. Supply of food-quality LCO₂ that meets TCCS quality standards was evaluated. This quality of LCO₂ has less moisture and impurities. It thus reduces the rate of sublimation of the dry ice, whilst the dry ice machine is able to perform more effectively and efficiently. In addition, lower quality LCO₂ may result in higher amounts of humidity, sulphur and bromide in the dry ice, which may have a detrimental impact when exposed to the vaccines during transportation.

The assessment confirmed that dry ice is not used by TCCS. As such, local LCO₂ suppliers and their customers producing dry ice were then assessed to understand the local dry ice manufacturing and handling capacity available.

The quantities of dry ice and LCO₂ available by country were then mapped against the demand determined by the COVAX Delivery Model and shortfalls in capacity were identified.

Establish requirements for dry ice supply

Where dry ice and LCO₂ supply capacity is insufficient for the projected demand determined by the COVAX Delivery Model, PLM evaluated each country to understand whether dry ice could be transported across borders from countries where spare dry ice capacity exists.

To identify those countries where dry ice could be transported, of the following were assessed:

- The availability of dry ice transport containers to effectively and efficiently transport dry ice
- The availability of refrigerated vehicles for transportation
- The expected travel time to deliver the dry ice
- The complexity of border custom clearance processes
- The expected sublimation losses from transporting dry ice

For those countries where transportation was inappropriate, the possibility of installing new dry ice capacity in each country was evaluated. Options to install with or without additional LCO₂ storage were analyzed, with LCO₂ storage not being required where TCCS plants or their LCO₂ suppliers are willing to connect dry ice plants to existing LCO₂ storage at their plants.



Assessment methodology

Information was initially collected from TCCS. The largest bottling groups were contacted, including Coca-Cola Beverages Africa (CCBA), Equatorial Coca-Cola Bottling Company (ECCBC), Heineken Africa, BGI Castel Group (BGI), National Bottling Company (NBC) in Nigeria, Coca-Amatil, Anheuser-Busch InBev and Fomento Económico Mexicano SA (FEMSA), with data sourced on in-house LCO₂ production and storage capabilities across all 70 countries. For those COVAX countries not covered by these bottling groups, the appropriate bottler was contacted for the data needed.

In addition, the bottling groups provided details of their LCO₂ suppliers, who were then contacted to enable assessment of their supply capabilities. These suppliers consisted of 33 local LCO₂ suppliers and two suppliers exporting LCO₂ from Europe.

In order to understand the availability of dry ice, the LCO₂ suppliers provided details of dry ice suppliers that operate dry ice plants across the three regions. In addition to understanding their dry ice production and supply capacities, the dry ice suppliers were also consulted to examine the feasibility of transporting dry ice across borders to neighbouring countries where dry ice capacity was either insufficient or unavailable to meet the projected demand determined by the COVAX Delivery Model.

Assumptions

- Analysis has been done to enable availability of dry ice at a central point of distribution in each country. No analysis has been done on the storage or transportation of dry ice within each country from the central point out to administrative areas.
- 1% of population in each country will be vaccinated for the purposes of this assessment.
- Vaccinations will take place over 30 days to enable two doses to be administered 21 calendar days apart.
- Administrative areas are based on 5m population clusters in each country.
- LCO₂ capacity for dry ice production is based on food-quality LCO₂ being sourced that meets TCCS quality standards.
- 3kg of LCO₂ is required to manufacture 1kg of dry ice.
- Dry ice wastage of 8% is incurred during manufacture.
- Dry ice wastage from sublimation is estimated at 11% per day during storage after manufacture and during transportation.
- For dry ice manufacturing capacity calculations, dry ice plants manufacture for 20 hours per calendar day.
- Dry ice pellets are of 3-16mm diameter as larger diameter pellets reduce sublimation losses.
- Dry ice manufacturing plants and LCO₂ storage units cited are sourced from ASCO Carbon Dioxide Limited in Switzerland, as their equipment is recommended by the dry ice suppliers in Africa due to their reliable, problem-free operation.
- Installation lead-time for dry ice plants is 12 weeks from order placement to first day of dry ice manufacture where plant is shipped by air.
- If LCO₂ storage tanks are required to be installed, installation lead-time is 22 weeks from order placement to first day of dry ice manufacture.
- Exchange rate of 1.2200 from Euro to US\$ and 0.0018 from XOF to US\$ was used for the purpose of estimations.
- Freight cost of transporting ASCO equipment of US\$27,572 for each item of equipment to Johannesburg.
- Freight cost for dry ice plant installation in Latin America and the Pacific Islands is adjusted for distance from ASCO in Switzerland with price variance indexed versus kilometer distance to Johannesburg.
- Dry ice plant operating unit costs based on Nigeria commercial electricity costs and average operator salaries.
- For dry ice plants, two operators and two helpers are deployed per 8-hour shift, working 40 hours per week over five days, while the plants will run every day of the 30-day duration.
- No depreciation costs were allocated to dry ice plant operating costs.
- Operating cost of manufacturing dry ice in Latin America is set at Trinidad and Tobago price of \$0.65 per kg.
- Operating cost of manufacturing dry ice in the Pacific Islands is set at Papua New Guinea price of \$6.50 per kg.
- Air freight cost of \$4.34 per kilogram for dry ice.



Assessment outputs

The outputs of the assessment for each of the 70 countries is summarized in Appendix 2.

Existing LCO₂ capacity

Analysis

Existing LCO₂ supply and demand for the COVID-19 vaccination programme are summarized in Table 1.

Table 1. Total LCO₂ supply by region.

Region	LCO ₂ KG for 30 days		
	Capacity	Required	Balance
Africa	19,942,973	7,055,107	12,887,866
Latin America	2,467,693	919,207	1,548,486
Pacific Islands	113,148	104,172	8,977
Total	22,523,814	8,078,485	14,445,329

Note: Data for Comoros, Djibouti, Egypt, Gambia, Guinea and Guinea-Bissau were not sourced directly from suppliers.

Implications

Of the 70 countries evaluated, 18 countries have sufficient LCO₂ supply capacity in place locally to meet the demand for production of the dry ice required for the COVID-19 vaccination programme, whilst a further five countries can partially supply LCO₂ to the daily quantity required.

There is significant excess capacity of 481,511kg per day of LCO₂ across the three regions to meet the demand for production of the dry ice required for the COVID-19 vaccination programme in the 52 countries where there is a shortfall in LCO₂ supply.

It is possible to transport LCO₂ in large quantities regionally to countries where local LCO₂ supply is limited. Although unlikely, where supplies in the regions are insufficient, there is significant additional LCO₂ supply capacity that can be imported from outside the regions to cover any shortfall. This is common within TCCS, especially for Africa where importing LCO₂ for local operations is common for beverage manufacturing. Thus LCO₂ supply is abundant and more than sufficient across all 70 countries.



Existing dry ice capacity

Operating model

Current dry ice suppliers will use existing dry ice plants and LCO₂ supply to manufacture dry ice. The dry ice will be manufactured on a daily basis, then prepared ready for transportation to the vaccine administration areas.

Analysis

Countries where existing dry ice and LCO₂ supplies are sufficient to meet the demand are summarized in Table 2.

Table 2. Countries with sufficient existing dry ice capacity.

Country	Dry ice KG daily		
	Capacity	Required	Balance
Angola	2,300	1,090	1,210
Cote D'Ivoire	9,600	1,156	8,444
Egypt	6,000	3,435	2,565
Ghana	2,000	1,282	718
Kenya	24,963	3,607	26,393
Madagascar	4,000	1,604	2,396
Morocco	3,000	1,756	1,244
Mozambique	2,400	1,079	1,321
Nigeria	11,590	12,387	-797
Senegal	2,200	829	1,371
South Africa	83,400	2,686	80,714
Sudan	2,000	757	1,243
Tanzania	4,800	3,734	1,066
Tunisia	9,600	1,311	8,289
Uganda	5,000	2,318	2,682
Sub-total Africa	157,483	26,645	130,838



Country	Dry ice KG daily		
	Capacity	Required	Balance
Bolivia	5,589	2,258	3,331
El Salvador	855	626	229
Honduras	1,197	930	268
Trinidad and Tobago	986	73	913
Costa Rica	1,315	430	885
Guatemala	2,500	797	1,703
Sub-total Latin America	12,443	5,113	7,329
Papua New Guinea	640	438	202
Vanuatu	298	213	84
Sub-total Pacific Islands	938	651	287
Total	170,863	32,409	138,454

Implications

Of the 70 countries evaluated, 23 countries have sufficient dry ice and LCO₂ supply capacity in place. Nigeria has a dry ice capacity shortfall of 797kg per day but this can be met by increasing the dry ice plant production each day from 20 to 22 hours, resulting in an excess daily capacity of 362 kg.

There is sufficient excess dry ice capacity in place to supply other countries in Africa and Latin America where dry ice capacity is not available. For the Pacific Islands, although sufficient dry ice capacity is not in place within the COVAX countries assessed, there is sufficient excess dry ice capacity in New Zealand to supply the eight countries where local dry capacity is insufficient.

LCO₂ supply is abundant and more than sufficient across all 23 countries.



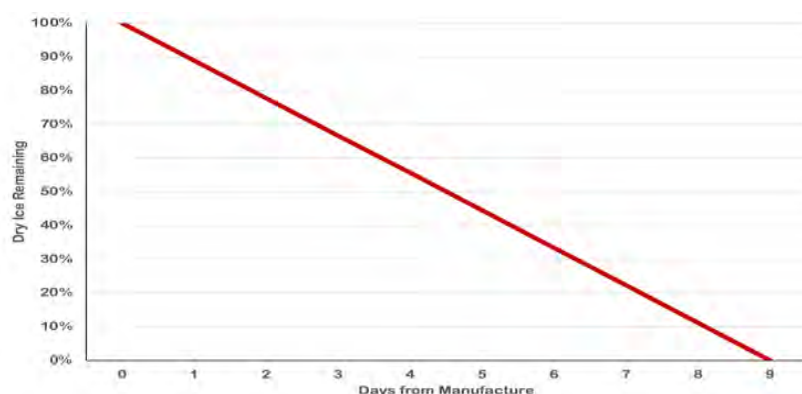
Sublimation of dry ice in containers

Analysis

When dry ice is manufactured, it is stored within lightweight polystyrene containers to be transported. When dry ice is stored in these containers, it releases CO₂ gas as it sublimates. Thus the containers must be stored properly to allow sublimated CO₂ gas to escape from the containers and the storage area to reduce the explosive risk. Hence the containers must be kept in a well-ventilated space during storage and transportation.

The expected rate of sublimation of the dry ice when transported in the containers is shown in Figure 1.

Figure 1. Sublimation rate of dry ice in transportation storage containers.



Source: Dry Ice International, South Africa.

Implications

Dry ice will sublimate moving from solid state to gas state within nine days (i.e. no usable dry ice will remain in the container at that point).

Given that transportation from the central point to the administration areas in each country is assumed to be two days in the COVAX Delivery Model, plus the rate of sublimation increases each time the containers are opened and dry ice deployed for storage of the vaccines, PLM has set the limit for transporting dry ice from the point of manufacture to the central distribution point in each country at 24 hours. For those countries where dry ice is to be transported from neighbouring countries, the quantity shipped will be adjusted by +12.5% to account for the loss of ice in transport due to sublimation.

Transport spare dry ice capacity by refrigerated truck

Operating model

Current dry ice suppliers will use existing dry ice plants and LCO₂ supply to manufacture dry ice. Where daily dry ice production capacity exceeds the local demand for dry ice in the country of manufacture, the excess dry ice capacity is transported by refrigerated truck to neighbouring countries where there is insufficient or no dry ice manufacturing capacity in place.

The maximum time for transportation of the dry ice from the point of manufacture across the border to the central vaccine administration area in the neighbouring country is 24 hours.

The dry ice is loaded in to insulated transportation boxes which are designed to minimize dry ice sublimation losses during transportation. The use of refrigerated trucks will help reduce sublimation losses. Custom clearance processes are coordinated between local governments enabling relatively frictionless movement across borders between countries. Existing pharmaceutical logistics partners with experience of efficient transporting of medical supplies across borders are to be used where available.

Analysis

Countries where existing excess dry ice can be transported by refrigerated truck to meet the demand are summarized in Table 3.



Table 3. Countries where transport by truck is possible.

Country	Dry Ice kg	
	Source	Required
Botswana	South Africa	346
Eswatini	South Africa	80
Lesotho	South Africa	79
Namibia	South Africa	213
Zimbabwe	South Africa	755
Total	South Africa	1,473
Burkina Faso	Cote D'Ivoire	1,055
Mali	Cote D'Ivoire	925
Total	Cote D'Ivoire	1,980
Burundi	Uganda	447
Rwanda	Uganda	404
Total	Uganda	851
Gambia	Senegal	77
Mauritania	Senegal	373
Total	Senegal	470
South Sudan	Kenya	996
Total	Kenya	996
Algeria	Tunisia	3,362
Total	Tunisia	3,362
Nicaragua	Costa Rica	2,435
Total	Costa Rica	2,435

Note: Required volume is not adjusted for transport.

Implications

Of the 70 countries evaluated, it is possible for seven countries with excess dry ice capacity to supply 14 neighbouring countries by transporting dry ice across border by refrigerated truck.

LCO₂ supply is abundant and more than sufficient across all seven dry ice supplying countries.



Transport spare dry ice capacity by air

Operating model

In exceptional circumstances, airfreight of dry ice with cargo planes is also an option for small quantities of dry ice required in remote, overseas locations. Although a maximum of 200 kg of dry ice can be transported in insulated dry ice containers per passenger flight, this restriction does not apply for commercial cargo flights.

The proposed operating model is similar to transport by refrigerated truck, with current dry ice suppliers using existing dry ice plants and LCO₂ supply to manufacture dry ice. Where daily dry ice production capacity exceeds the local demand for dry ice in the country of manufacture, the excess dry ice capacity is transported to neighbouring countries where there is insufficient or no dry ice manufacturing capacity in place.

Analysis

For countries where LCO₂ is imported, demand for dry ice is insufficient to commercially justify dry ice plant installation and where transport is across water then the pragmatic solution is for existing excess dry ice to be transported by air to meet the demand are summarized in Table 4.

Table 4. Countries where transport by air is necessary.

Country	Dry ice kg daily	
	Source	Required
Comoros	Kenya	41
Total	Kenya	41
Dominica	Trinidad and Tobago	36
Grenada	Trinidad and Tobago	27
Guyana	Trinidad and Tobago	230
Haiti	Trinidad and Tobago	626
St. Lucia	Trinidad and Tobago	25
St. Vincent	Trinidad and Tobago	30
Total	Trinidad and Tobago	973
Fiji	New Zealand	126
Kiribati	New Zealand	67
Marshall Islands	New Zealand	39
Micronesia	New Zealand	64
Samoa	New Zealand	13
Solomon Islands	New Zealand	215
Tonga	New Zealand	36
Tuvalu	New Zealand	11
Total	New Zealand	570

Note: Required volume is not adjusted for transport.

Countries where existing excess dry ice can be transported by air as an alternative to refrigerated truck or installing new dry ice capacity to meet the demand are summarized in Table 5.

Table 5. Countries where transport by air is a potential alternative to by refrigerated truck.

Country	Dry Ice kg	
	Source	Required
Botswana	South Africa	346
Congo	South Africa	220
DRC	South Africa	8,277
Eswatini	South Africa	80
Lesotho	South Africa	79
Namibia	South Africa	213
Zambia	South Africa	813
Zimbabwe	South Africa	755
Total	South Africa	10,783
Benin	Cote D'Ivoire	528
Burkina Faso	Cote D'Ivoire	1,055
Cameroon	Cote D'Ivoire	1,795
Central African Republic	Cote D'Ivoire	326
Guinea	Cote D'Ivoire	1,011
Guinea-Bissau	Cote D'Ivoire	34
Liberia	Cote D'Ivoire	427
Mali	Cote D'Ivoire	925
Niger	Cote D'Ivoire	1,686
Sierra Leone	Cote D'Ivoire	645
Togo	Cote D'Ivoire	192
Total	Cote D'Ivoire	8,625
Gambia	Senegal	77
Mauritania	Senegal	373
Total	Senegal	470

Note: Required volume is not adjusted for transport.

Implications

For the 70 countries analysed, 32 countries can potentially be supplied by air from excess dry ice capacity in six countries.

For Cote D'Ivoire, supplying an additional nine countries by air would lead to a daily shortfall based on 20 hours of production each day. By increasing this to 23 hours each day, dry ice capacity would exceed the demand for these additional countries.

LCO₂ supply is abundant and more than sufficient across all five countries that can supply by air.

Install new dry ice capacity

The dry ice suppliers that had excess capacity were contacted to explore the opportunity to temporarily relocate existing plants to countries where supply was insufficient. Due to the potential for damaging valuable plant machinery, the suppliers were unwilling to agree to this relocation of their plants.

In addition, the costs of moving, installing and then returning the plant outweighed those of simply installing new equipment. Thus installation of new dry ice capacity in those countries with insufficient supply was preferred.

Operating model

Where it is not feasible to transport dry ice from neighbouring countries, those countries without existing dry ice supply will require new dry ice plant installation.

Dry ice plants can be sourced from a recommended supplier. The three possible configurations of dry ice plant that can be installed are shown in Table 6.

Table 6. Dry ice plant configuration.

Specification	P15i	P28i	P75i
Dry ice capacity	150kg/hour	280kg/hour	750kg/hour
Vertical vacuum insulated LCO ₂ tank with fridge unit	20mT	28mT	
AT126 dry ice box 100kg		x2	
AT240W dry ice box on wheels 240kg		x2	

Depending on the local demand, the appropriate dry ice plant configuration is chosen to enable local supply to meet local demand.

Installation lead-time for the dry ice plant alone is estimated at 12 weeks from order, with ASCO being able to manufacture 10 dry ice plants every four weeks. If additional LCO₂ storage tanks are required, these are a further minimum 10 weeks lead-time for installation using Johannesburg as the destination for shipment.

Given the additional installation lead-time of 10 weeks for the LCO₂ storage tanks, it is preferable to install new dry ice plants and connect to existing LCO₂ storage where time is critical for the production of dry ice.

Ideally, if agreeable, installing the new dry ice plants within TCCS plants to connect to existing LCO₂ storage would save both time to begin manufacturing dry ice but also save significant additional investment in procuring the additional LCO₂ storage tanks required.

The recommended dry ice pelletizers are compact, safe and reliable whilst being simple to maintain and operate. They can be operated by a single technician per shift, with the minimum recommended qualification being a technical high school graduate with basic knowledge of electric motors, programmable logic controllers and hydraulic systems. Full training is provided by ASCO on how to operate and maintain the dry ice plant.



The technical requirements for each dry ice plant configuration are shown in Table 7.

Table 7. Dry ice plant technical requirements.

Requirements	P15i	P28i	P75i
Footprint	L 1.56m W 0.80m H 1.45m		L 2.24m W 1.10m H 3.90m
Placement in 40ft Container	Yes		No
LCO ₂ supply pressure	16 – 20 bar		
LCO ₂ pipe connection	1.0" - BSP female		1.5" - BSP female
Power supply	400 V/ 50 Hz /3 Ph + PE		
Max. power consumption	5.6 kW		19 kW
Control interface	PLC SIEMENS - S7 - 1200		

Analysis

In some countries insufficient existing dry ice capacity is in place or there is insufficient spare dry ice capacity in a neighbouring country, so they cannot be supplied by refrigerated truck to meet the demand and thus require new dry ice capacity to be installed. These countries are summarized in Table 8.



Table 8. Countries which require new dry ice capacity installed.

Country	TCCC bottler	Dry ice kg daily required	Dry ice plants required		Capacity utilised
			P15i	P28i	
Benin	Castel	528	1	0	17.6%
Cameroon	Castel	1,795	1	0	59.8%
Central African Republic	Castel	326	1	0	10.9%
Chad	Castel	793	1	0	26.4%
Congo	Heineken	220	1	0	7.3%
DRC	Heineken	8,277	0	2	73.9%
Ethiopia	CCBA	11,154	0	2	99.6%
Guinea	ECCBC	1,011	1	0	33.7%
Liberia	ECCBC	427	1	0	14.2%
Malawi	Castel	499	1	0	16.6%
Niger	Castel	1,686	1	0	56.2%
Sierra Leone	ECCBC	645	1	0	21.5%
Zambia	CCBA	813	1	0	27.1%
Sub-total Africa		28,184	11	4	50.9%
Dominica	GBC	32	1	0	1.1%
Grenada	GBC	24	1	0	0.8%
Guyana	Banks	204	1	0	6.8%
Haiti	BdIC	556	1	0	18.5%
St. Lucia	DBBC	22	1	0	0.7%
St. Vincent	GBC	27	1	0	0.9%
Sub-total Latin America		865	6	0	4.8%

Country	TCCC Bottler	Dry Ice KG Daily Required	Dry Ice Plants Required		Capacity Utilised
			P15i	P28i	
Fiji	CCA	112	1	0	3.7%
Kiribati	CCA	60	1	0	2.0%
Marshall Islands	CCA	35	1	0	1.2%
Micronesia	CCA	57	1	0	1.9%
Samoa	CCA	11	1	0	0.4%
Solomon Islands	CCA	191	1	0	6.4%
Tonga	CCA	32	1	0	1.1%
Tuvalu	CCA	10	1	0	0.3%
Sub-total Pacific Islands		507	8	0	2.1%
Total		29,545	25	4	30.3%

Countries where new dry ice capacity installed is excess to the demand in that country and where excess dry ice can be transported by refrigerated truck to meet the demand elsewhere are summarized in Table 9.



Table 9. Countries where transport by truck is possible from new dry ice capacity installed.

Country	Dry ice kg	
	Source	Required
Djibouti	Ethiopia	46
Eritrea	Ethiopia	168
Somalia	Ethiopia	591
Total	Ethiopia	805
Guinea-Bissau	Guinea	34
Total	Guinea	470
Togo	Benin	192
Total	Benin	192

Implications

Of the 70 countries evaluated, 27 countries would require new dry ice capacity to be installed. This would require 25 P15i configuration and four P28i configuration dry ice plants to enable sufficient dry ice supply capacity to meet demand.

Ethiopia would be close to maximum dry ice capacity, but this can be mitigated by increasing the dry ice plant production each day from 20 to 22 hours.

All eight countries in the Pacific Islands and five of the six in Latin America would use less than 7% of the dry ice plant capacity over the 30 days of manufacture.

If the dry ice plants are to be connected to TCCC bottler LCO₂ storage, there are potentially nine of the bottler groups that need to be consulted for agreement. However, four countries in Latin America and five countries in the Pacific Islands do not have bottling plants due to their small size, using distributor agreements for beverages, so these countries would require LCO₂ storage to be installed.

An additional three countries can use excess new dry ice capacity to supply five neighbouring countries by refrigerated truck.

LCO₂ supply is abundant and more than sufficient across all 27 countries where new dry ice capacity could be installed.

Outcomes

Immediate LCO₂ availability

There is excess LCO₂ capacity in place in 18 countries to supply all 70 countries to meet the needs of UCC distribution of the COVID-19 vaccine.

Although unlikely to be required as there is sufficient capacity on the continent, where needed additional LCO₂ capacity can be sourced from importing supply from outside the three regions.

Immediate dry ice availability by air transport

Of the 70 countries analysed, there is sufficient dry ice capacity in place to cover all countries using air transport to meet the needs of UCC distribution of the COVID-19 vaccine.

There are 23 countries with sufficient local dry ice and LCO₂ capacity to meet local demand. Within Africa and Latin America there is sufficient excess capacity to meet the demand of the remaining 38 countries without sufficient local supply, whilst for the Pacific Islands there is sufficient local dry ice and LCO₂ capacity in New Zealand to meet demand in the eight countries without local supply. There are potentially four hubs in Africa (South Africa, Kenya, Cote D'Ivoire and Tunisia) and one hub each in Latin America (Trinidad and Tobago) and the Pacific Islands (New Zealand) that have sufficient local dry ice and LCO₂ capacity to supply the remaining 38 countries by air transport.

Sequenced dry ice availability through new plants and truck transport

Alternatively, instead of transporting by air to 46 countries, it is possible for 29 ASCO dry ice plants to be installed in 27 countries, with a further 19 countries receiving dry ice by truck transport from neighbouring countries. Comoros would still be required to be supplied by air.

By installing dry ice plants, there would be a requirement to sequence the rollout of the vaccine. ASCO can manufacture 10 ice machines every four weeks, and installation takes 12 weeks. So there would be a delay in dry ice supply of between 12 to 20 weeks across up to 18 countries that require new dry ice plant installation or would be supplied by countries where new dry ice plant capacity is being installed. Where additional LCO₂ storage is required for new dry ice plant installation, these lead-times would increase by a minimum of a further 10 weeks.



Financial analysis

Immediate dry ice availability using air transport

The cost of supplying dry ice for the vaccination programme to all 70 countries where existing excess dry ice can be transported by air to meet the demand is \$15.8m. This equates to \$0.56 for each dose administered, or \$1.12 per person vaccinated. The cost by country is summarized in Table 10.

Table 10. Cost for countries for transport by air.

Country	1% of population	Total OPEX	Per vaccine	Per vaccinated
Fiji	8,964	\$22,582	\$1.26	\$2.52
Kiribati	1,194	\$12,104	\$5.07	\$10.13
Marshall Islands	592	\$7,005	\$5.92	\$11.83
Micronesia	1,150	\$11,445	\$4.97	\$9.95
Papua New Guinea	89,470	\$85,362	\$0.48	\$0.95
Samoa	1,984	\$2,257	\$0.57	\$1.14
Solomon Islands	6,869	\$38,716	\$2.82	\$5.64
Tonga	1,057	\$6,389	\$3.02	\$6.04
Tuvalu	118	\$1,949	\$8.26	\$16.53
Vanuatu	3,071	\$116,873	\$19.03	\$38.05
Sub-total Pacific Islands	114,471	\$304,680	\$1.33	\$2.66
Bolivia	116,730	\$360,577	\$1.54	\$3.09
Dominica	720	\$5,323	\$3.70	\$7.39
El Salvador	64,862	\$57,287	\$0.44	\$0.88
Grenada	1,125	\$4,004	\$1.78	\$3.56
Guyana	7,866	\$34,379	\$2.19	\$4.37
Haiti	114,025	\$93,711	\$0.41	\$0.82
Honduras	99,046	\$242,654	\$1.22	\$2.45
Nicaragua	66,246	\$698,847	\$5.27	\$10.55
St. Lucia	1,836	\$3,748	\$1.02	\$2.04
St. Vincent	1,109	\$4,517	\$2.04	\$4.07
Trinidad & Tobago	13,995	\$1,422	\$0.05	\$0.10
Costa Rica	50,941	\$25,787	\$0.25	\$0.51
Guatemala	179,156	\$62,168	\$0.17	\$0.35
Sub-total Latin America	717,657	\$1,594,423	\$1.11	\$2.22



Country	1% of population	Total OPEX	Per vaccine	Per vaccinated
Algeria	438,510	\$967,758	\$1.10	\$2.21
Angola	328,663	\$104,675	\$0.16	\$0.32
Benin	121,232	\$144,803	\$0.60	\$1.19
Botswana	23,516	\$65,505	\$1.39	\$2.79
Burkina Faso	209,033	\$289,228	\$0.69	\$1.38
Burundi	118,908	\$88,123	\$0.37	\$0.74
Cameroon	265,459	\$492,011	\$0.93	\$1.85
Central African Republic	48,298	\$89,424	\$0.93	\$1.85
Chad	164,259	\$156,415	\$0.48	\$0.95
Comoros	8,696	\$8,129	\$0.47	\$0.93
Congo	55,181	\$41,748	\$0.38	\$0.76
Cote D'Ivoire	263,783	\$131,117	\$0.25	\$0.50
Djibouti	9,880	\$9,087	\$0.46	\$0.92
DRC	895,614	\$1,568,573	\$0.88	\$1.75
Egypt	1,023,344	\$316,570	\$0.15	\$0.31
Eritrea	35,464	\$33,032	\$0.47	\$0.93
Eswatini	11,602	\$15,243	\$0.66	\$1.31
Ethiopia	1,149,636	\$2,199,185	\$0.96	\$1.91
Gambia	24,167	\$25,624	\$0.53	\$1.06
Ghana	310,729	\$202,575	\$0.33	\$0.65
Guinea	131,328	\$277,151	\$1.06	\$2.11
Guniea-Bissau	19,680	\$9,336	\$0.24	\$0.47
Kenya	537,713	\$162,323	\$0.15	\$0.30
Lesotho	21,422	\$15,024	\$0.35	\$0.70
Liberia	50,577	\$116,974	\$1.16	\$2.31
Madagascar	276,910	\$1,848,376	\$3.34	\$6.68
Malawi	191,300	\$98,338	\$0.26	\$0.51
Mali	202,508	\$253,573	\$0.63	\$1.25
Mauritania	46,497	\$124,967	\$1.34	\$2.69



Country	1% of population	Total OPEX	Per vaccine	Per vaccinated
Morocco	369,106	\$173,824	\$0.24	\$0.47
Mozambique	312,554	\$58,242	\$0.09	\$0.19
Namibia	25,409	\$40,292	\$0.79	\$1.59
Niger	242,066	\$462,117	\$0.95	\$1.91
Nigeria	2,061,396	\$1,497,919	\$0.36	\$0.73
Rwanda	129,522	\$79,579	\$0.31	\$0.61
Senegal	167,439	\$138,857	\$0.41	\$0.83
Sierra Leone	79,770	\$176,921	\$1.11	\$2.22
Somalia	158,932	\$116,583	\$0.37	\$0.73
South Africa	593,087	\$102,610	\$0.09	\$0.17
South Sudan	111,937	\$196,362	\$0.88	\$1.75
Sudan	438,493	\$40,883	\$0.05	\$0.09
Tanzania	597,342	\$334,900	\$0.28	\$0.56
Togo	82,787	\$52,578	\$0.32	\$0.64
Tunisia	118,186	\$87,776	\$0.37	\$0.74
Uganda	457,410	\$170,847	\$0.19	\$0.37
Zambia	183,840	\$154,068	\$0.42	\$0.84
Zimbabwe	145,463	\$143,082	\$0.49	\$0.98
Sub-total Africa	13,258,647	\$13,882,324	\$0.52	\$1.05
Total	14,090,775	\$15,781,428	\$0.56	\$1.12

Note: Cost is based on required volume adjusted for transport.

Sequenced dry ice availability installing Dry ice capacity

The cost of supplying dry ice for the vaccination programme to all 70 countries where a combination of installing dry ice plants and transporting excess dry ice by refrigerated truck from both existing and new capacity to meet the demand is up to \$17.6m. This equates to \$0.62 for each dose administered, or \$1.24 per person vaccinated. This is split as follows:

- If dry ice plants can be installed to existing LCO₂ storage such as TCCC bottling facilities or local LCO₂ suppliers then \$1.5m is required for new dry ice plant installation without LCO₂ storage.
- Where dry ice plants cannot be connected to existing LCO₂ storage and additional LCO₂ storage is required, this will require up to a further \$3.8m.
- \$12.3m is the total cost of manufacturing the dry ice from the new plants installed and then transporting the excess capacity to neighbouring countries where relevant.



The cost by country is summarized in Table 11.

Table 11. Cost for countries for plant installation and transport by truck.

Country	Total cost	Per vaccine	Per vaccinated	Investment
Fiji	\$208,504	\$11.63	\$23.26	\$186,729
Kiribati	\$198,401	\$83.05	\$166.10	\$186,729
Marshall Islands	\$193,483	\$163.44	\$326.89	\$186,729
Micronesia	\$197,765	\$85.97	\$171.94	\$186,729
Papua New Guinea	\$85,362	\$0.48	\$0.95	\$0
Samoa	\$188,905	\$47.60	\$95.21	\$186,729
Solomon Islands	\$224,062	\$16.31	\$32.62	\$186,729
Tonga	\$192,890	\$91.25	\$182.50	\$186,729
Tuvalu	\$188,608	\$799.73	\$1,599.46	\$186,729
Vanuatu	\$116,873	\$19.03	\$38.05	\$0
Sub-total Pacific Islands	\$1,794,853	\$7.84	\$15.68	\$1,493,832
Bolivia	\$360,577	\$1.54	\$3.09	\$0
Dominica	\$167,787	\$116.54	\$233.08	\$167,171
El Salvador	\$57,287	\$0.44	\$0.88	\$0
Grenada	\$167,634	\$74.49	\$148.98	\$167,171
Guyana	\$171,150	\$10.88	\$21.76	\$167,171
Haiti	\$178,017	\$0.78	\$1.56	\$167,171
Honduras	\$242,654	\$1.22	\$2.45	\$0
Nicaragua	\$698,847	\$5.27	\$10.55	\$0
St. Lucia	\$167,605	\$45.64	\$91.27	\$167,171
St. Vincent	\$167,694	\$75.58	\$151.16	\$167,171
Trinidad & Tobago	\$1,422	\$0.05	\$0.10	\$0
Costa Rica	\$25,787	\$0.25	\$0.51	\$0
Guatemala	\$62,168	\$0.17	\$0.35	\$0
Sub-total Latin America	\$2,468,628	\$1.72	\$3.44	\$1,003,025



Country	Total cost	Per vaccine	Per vaccinated	Investment
Algeria	438,510	\$0.55	\$1.09	\$0
Angola	\$479,681	\$0.16	\$0.32	\$0
Benin	\$104,675	\$0.90	\$1.81	\$178,140
Botswana	\$218,939	\$1.00	\$2.00	\$0
Burkina Faso	\$47,086	\$0.56	\$1.12	\$0
Burundi	\$233,244	\$0.40	\$0.80	\$0
Cameroon	\$95,247	\$0.82	\$1.63	\$178,140
Central African Republic	\$433,776	\$1.96	\$3.92	\$178,140
Chad	\$189,470	\$0.67	\$1.34	\$178,140
Comoros	\$220,216	\$0.47	\$0.93	\$0
Congo	\$8,129	\$1.75	\$3.50	\$178,140
Cote D'Ivoire	\$192,871	\$0.25	\$0.50	\$0
Djibouti	\$131,117	\$3.36	\$6.72	\$0
DRC	\$66,357	\$0.75	\$1.51	\$414,839
Egypt	\$1,348,381	\$0.15	\$0.31	\$0
Eritrea	\$316,570	\$1.51	\$3.01	\$0
Eswatini	\$106,905	\$1.30	\$2.61	\$0
Ethiopia	\$30,250	\$0.66	\$1.32	\$414,839
Gambia	\$1,519,105	\$0.77	\$1.54	\$0
Ghana	\$37,253	\$0.33	\$0.65	\$0
Guinea	\$202,575	\$1.08	\$2.15	\$178,140
Guinea-Bissau	\$282,976	\$0.70	\$1.41	\$0
Kenya	\$27,705	\$0.15	\$0.30	\$0
Lesotho	\$162,323	\$0.82	\$1.65	\$0
Liberia	\$35,250	\$2.22	\$4.45	\$178,140
Madagascar	\$225,038	\$3.34	\$6.68	\$0
Malawi	\$1,848,376	\$0.59	\$1.19	\$178,140
Mali	\$227,556	\$0.53	\$1.07	\$0
Mauritania	\$216,076	\$1.24	\$2.48	\$0



Country	Total cost	Per vaccine	Per vaccinated	Investment
Morocco	\$173,824	\$0.24	\$0.47	\$0
Mozambique	\$58,242	\$0.09	\$0.19	\$0
Namibia	\$108,670	\$2.14	\$4.28	\$0
Niger	\$354,193	\$0.73	\$1.46	\$178,140
Nigeria	\$1,497,919	\$0.36	\$0.73	\$0
Rwanda	\$76,081	\$0.29	\$0.59	\$0
Senegal	\$138,857	\$0.41	\$0.83	\$0
Sierra Leone	\$246,722	\$1.55	\$3.09	\$178,140
Somalia	\$174,237	\$0.55	\$1.10	\$0
South Africa	\$102,610	\$0.09	\$0.17	\$0
South Sudan	\$146,760	\$0.66	\$1.31	\$0
Sudan	\$40,883	\$0.05	\$0.09	\$0
Tanzania	\$334,900	\$0.28	\$0.56	\$0
Togo	\$30,538	\$0.18	\$0.37	\$0
Tunisia	\$87,776	\$0.37	\$0.74	\$0
Uganda	\$170,847	\$0.19	\$0.37	\$0
Zambia	\$255,797	\$0.70	\$1.39	\$178,140
Zimbabwe	\$125,286	\$0.43	\$0.86	\$0
Sub-total Africa	\$13,246,463	\$0.50	\$1.00	\$2,789,213
Total	\$17,509,944	\$0.62	\$1.24	\$5,286,070

Note: Cost is based on required volume adjusted for transport

It is important to note that where new dry ice capacity is installed with LCO₂ storage tanks separate from existing LCO₂ storage, transportation costs for LCO₂ to the new dry ice plant have not been included in this financial analysis.

The supporting detailed financial analysis is included in Appendices 2, 3 and 4.

Risk Analysis

Based on the assessment of a range of scenarios analyzed above, potential risks have been identified:

- 1. Delayed sourcing of ASCO dry ice plants.** ASCO has the capability to manufacture 10 dry ice plants every four weeks. Depending on existing orders and the process of prioritization, there may be significant delays in being able to source the dry ice plants from ASCO.
- 2. The lead-time of 12 weeks from order placement of the dry ice plants to installation is highly dependent on the ability of ASCO to transport the dry ice plants by air and the speed of processing through border controls.** The same applies for additional LCO₂ storage where required, which have a total lead-time of a minimum of 22 weeks from order placement, although this equipment is unlikely to be transported by air due to the weight of the equipment.
- 3. PLM has had initial discussions with both TCCC bottling groups and LCO₂ suppliers to understand the potential of building dry ice plants and connecting to existing LCO₂ storage.** Bottlers and LCO₂ suppliers have indicated that agreeing to install and connect new ice plants to existing LCO₂ storage may take time, as a full feasibility study is expected to be required prior to granting access to storage. Of the bottling groups, CCBA, ECCBC, Castel and Heineken would need to agree installation and connection of the dry ice plants, in addition to the DAL group bottler in Sudan.
- 4. In situations where a dry ice plant requires additional LCO₂ storage,** the standalone nature of the plant will require sites to be sourced with appropriate quality building structure and access to utilities.

Conclusion

Given the complexity and dynamic decision-making landscape around COVID-19 vaccine allocation and planning, it was not within this scope to make recommendations on the optimal approach. As such, PLM is pleased to share insights that can help inform decision-making for vaccine candidate allocation and planning by country. Key insights are summarized below:

- There is abundant LCO₂ capacity within Africa to support the UCC requirements for the COVID-19 vaccination programme where up to 1% of the total country population is to be vaccinated.
- 23 countries have sufficient dry ice production capability to service 1% of the total country population with COVID-19 vaccines (two doses 21 days apart). These countries include Angola, Cote D'Ivoire, Egypt, Ghana, Kenya, Madagascar, Morocco, Mozambique, Nigeria, Senegal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Bolivia, El Salvador, Honduras, Trinidad and Tobago, Costa Rica, Guatemala, Papua New Guinea and Vanuatu. The cost of procuring dry ice from existing suppliers just for these countries is \$6.3m.
- Where dry ice can be transported by air, there is sufficient dry ice capacity to meet the needs of all 70 countries immediately. With South Africa, Cote D'Ivoire, Kenya, Tunisia, Trinidad and Tobago plus New Zealand being the transport hubs with sufficient spare dry ice capacity to support the remaining countries. The cost for this option is estimated to be \$15.8m to support vaccination of up to 1% of the each of the total country populations. This equates to \$1.12 per person vaccinated (two doses 21 days apart) or \$0.56 per vaccine.
- Transport by air is expected to be necessary for 15 countries which are remote small islands where the volume of dry ice required is very low leading to low utilization of under 7% of capacity for the 30 days of manufacture. In addition, LCO₂ will have to be imported requiring new LCO₂ storage to be installed with leadtimes for shipping by boat being significantly longer than by air.
- If transport by air is deemed to be undesirable, then the alternative is to install new dry ice supply capacity in 27 countries, with the remaining countries being supplied from excess local capacity using refrigerated trucks. The cost for this option is up to \$17.5m for vaccination of up to 1% of the each of the total country populations excluding the transportation cost of LCO₂ where installation of the dry ice plant is separate from existing LCO₂ storage. This equates to \$1.24 per person vaccinated (two doses 21 days apart) or \$0.62 per vaccine.



- Movement of spare dry ice capacity with existing suppliers was considered, but their reluctance to relocate and then return valuable plant machinery was a constraint, whilst the costs exceeded that of installing new dry ice plants. Thus this option was discounted.
- Where new dry ice plant capacity is to be installed, 25 countries require a ASCO P15i to be installed. The cost for installation is estimated to be \$93,960 for the dry ice plant, including freight, but excluding LCO₂ storage. This option would require connection of the new dry ice plant to existing LCO₂ storage such as a TCCS supplier LCO₂ plant. Where this is not possible, and LCO₂ storage is required, there will be a further \$84,180 investment needed. For Ethiopia and DRC, each requires two ASCO P28i to be installed. The respective costs for the dry ice plant and LCO₂ storage are \$133,732 and \$101,260 for each P28i installed.
- Total investment required for new dry ice production equipment and installation therefore ranges from \$1.5m for the ASCO dry ice plants plus freight costs with a potential additional \$3.8m for LCO₂ storage tanks where the dry ice plants cannot be connected to existing LCO₂ storage.
- For each of the options outlined above, further detailed feasibility assessments are recommended on the transportation of dry ice by air or refrigerated truck, the capacity of ASCO to manufacture and install the new dry ice plants and whether the new dry ice plants can be connected to existing sources of LCO₂ through existing LCO₂ suppliers.

For additional questions or follow up, please reach out to Alexandra Scott, Director of Program Delivery for Project Last Mile at alex@projectlastmile.com



Appendix 1: COVAX Delivery Model calculation sheet

Country	Population	% of population to be vaccinated	Number of Health Facilities (Vaccination Points)	Size (Area) of the Admin Area (in Sq.Km)	Transport Time (in days) from Admin Store to 90th percentile remote HF (vaccination point) in Admin Area	Number of Days Vaccinator Teams can spend at Vaccination point administering vaccine	Max Number of Working Days Between Doses (6-day work week)	Assumption on % of vaccine doses wasted (Open and Closed-Vial Wastage)	Size Distribution of HFs within Administrative Area				
									% of HFs <1/5 average population	% of HFs between 1/5 and 1/2 avg. population	% of HFs between 1/2 and 2x avg. population	% of HFs between 2x and 5x avg. population	% of HFs >5x avg. population
Algeria	43,851,044	1%	7,734	2,381,740	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Angola	32,866,272	1%	1,575	1,246,700	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Benin	12,123,200	1%	819	112,760	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Botswana	2,351,627	1%	624	566,730	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Burkina Faso	20,903,273	1%	1,721	273,600	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Burundi	11,890,784	1%	665	25,680	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Cameroon	26,545,863	1%	3,061	472,710	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Central African Republic	4,829,767	1%	555	622,980	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Chad	16,425,864	1%	1,283	1,259,200	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Comoros	869,601	1%	66	1,861	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Congo	5,518,087	1%	328	341,500	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Cote D'Ivoire	26,378,274	1%	1,792	318,000	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Djibouti	988,000	1%	66	23,180	2	1	15	10%	10%	25%	50%	12.50%	2.50%
DRC	89,561,403	1%	14,586	2,267,050	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Egypt	102,334,404	1%	5,000	995,450	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Eritrea	3,546,421	1%	269	101,000	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Eswatini	1,160,164	1%	135	17,363	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Ethiopia	114,963,588	1%	19,742	1,000,000	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Gambia	2,416,668	1%	103	10,120	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Ghana	31,072,940	1%	1,960	227,540	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Guinea	13,132,795	1%	1,746	245,720	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Guinea-Bissau	1,968,001	1%	8	28,120	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Kenya	53,771,296	1%	6,146	569,140	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Lesotho	2,142,249	1%	117	30,360	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Liberia	5,057,681	1%	740	96,320	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Madagascar	27,691,018	1%	2,677	581,795	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Malawi	19,129,952	1%	648	94,280	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Mali	20,250,833	1%	1,478	1,220,190	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Mauritania	4,649,658	1%	645	1,030,700	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Morocco	36,910,560	1%	2,833	446,300	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Mozambique	31,255,435	1%	1,579	786,380	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Namibia	2,540,905	1%	369	823,290	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Niger	24,206,644	1%	2,886	1,266,700	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Nigeria	206,139,589	1%	20,807	910,770	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Rwanda	12,952,218	1%	572	24,670	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Senegal	16,743,927	1%	1,347	192,530	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Sierra Leone	7,976,983	1%	1,120	72,180	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Somalia	15,893,222	1%	879	627,340	2	1	15	10%	10%	25%	50%	12.50%	2.50%
South Africa	59,308,690	1%	4,303	1,213,090	2	1	15	10%	10%	25%	50%	12.50%	2.50%
South Sudan	11,193,725	1%	1,747	610,952	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Sudan	43,849,260	1%	272	1,765,048	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Tanzania	59,734,218	1%	6,304	885,800	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Togo	8,278,724	1%	207	54,390	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Tunisia	11,818,619	1%	2,338	155,360	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Uganda	45,741,007	1%	3,792	199,810	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Zambia	18,383,955	1%	1,263	743,390	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Zimbabwe	14,546,314	1%	1,236	390,757	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Bolivia	11,673,021	1%	4,161	1,083,300	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Dominica	71,986	1%	52	750	2	1	15	10%	10%	25%	50%	12.50%	2.50%
El Salvador	6,486,205	1%	1,103	20,720	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Grenada	112,523	1%	39	340	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Guyana	786,552	1%	377	196,850	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Haiti	11,402,528	1%	900	27,560	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Honduras	9,904,607	1%	1,635	111,890	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Nicaragua	6,624,554	1%	8,020	120,340	2	1	15	10%	10%	25%	50%	12.50%	2.50%
St. Lucia	183,627	1%	36	610	2	1	15	10%	10%	25%	50%	12.50%	2.50%
St. Vincent	110,940	1%	44	390	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Trinidad and Tobago	1,399,488	1%	114	5,130	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Costa Rica	5,094,118	1%	747	51,060	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Guatemala	17,915,568	1%	1,271	107,160	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Fiji	896,445	1%	200	18,270	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Kiribati	119,449	1%	106	810	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Marshall Islands	59,190	1%	58	180	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Micronesia	115,023	1%	101	700	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Papua New Guinea	8,947,024	1%	710	452,860	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Samoa	198,414	1%	12	2,830	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Solomon Islands	686,884	1%	352	27,990	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Tonga	105,695	1%	52	720	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Tuvalu	11,792	1%	11	230	2	1	15	10%	10%	25%	50%	12.50%	2.50%
Vanuatu	307,145	1%	400	12,190	2	1	15	10%	10%	25%	50%	12.50%	2.50%

Country	HPs in each cycle	Number of UCC Freezers Needed - for Vaccine Only	Number of Vaccinator Teams needed active per cycle in Admin Area	Number of Vehicles	Number of Dry Ice Boxes needed	Number of Kgs of Dry Ice (per Cycle of Transport)	Implied Hours of Production using dry-ice machine (per cycle)	Number of Airtels needed	Number of UCC Freezers Needed for PCM (if Airtels with PCM are being used)	Number of Dry Ice Shippers Needed	Kilograms of Dry Ice Needed for the Shippers	Reference - Kilograms of Dry Ice Needed for Transport Boxes	Total Kilograms of Dry Ice Needed	Estimated Loss / Wastage	Dry Ice Required KG	CO2 per Dry Ice Ratio	LC02 Required KG
Algeria	2,578	3	2,643	2,578	2,578	18,562	337	2,578	77	196	9,016	111,372	120,388	8.0%	130,857	3.0	392,570
Angola	525	2	598	525	539	3,881	71	525	16	148	6,808	23,286	30,094	8.0%	32,711	3.0	98,133
Benin	273	1	335	273	280	2,016	37	273	9	54	2,484	12,096	14,580	8.0%	15,848	3.0	47,543
Botswana	208	1	214	208	208	1,498	27	208	7	12	552	8,988	9,540	8.0%	10,370	3.0	31,109
Burkina Faso	574	2	689	574	574	4,133	75	574	18	94	4,324	24,798	29,122	8.0%	31,554	3.0	94,969
Burundi	222	1	416	222	228	1,642	30	222	7	54	2,484	9,852	12,336	8.0%	13,409	3.0	40,226
Cameroon	1,021	2	1,199	1,021	1,021	7,352	134	1,021	31	118	5,428	44,112	49,540	8.0%	53,848	3.0	161,543
Central African Republic	185	1	218	185	185	1,332	24	185	6	22	1,012	7,992	9,004	8.0%	9,787	3.0	29,361
Chad	428	1	524	428	428	3,082	56	428	13	74	3,404	18,492	21,896	8.0%	23,800	3.0	71,400
Comoros	22	1	27	22	22	159	3	22	1	4	184	954	1,138	8.0%	1,237	3.0	3,711
Congo	110	1	205	110	113	814	15	110	4	26	1,196	4,884	6,080	8.0%	6,609	3.0	19,826
Cote D'Ivoire	598	2	732	598	613	4,414	80	598	18	118	5,428	26,484	31,912	8.0%	34,687	3.0	104,061
Djibouti	22	1	27	22	23	166	3	22	1	6	276	996	1,272	8.0%	1,383	3.0	4,148
DR Congo	4,862	6	4,984	4,862	4,862	35,007	636	4,862	145	400	18,400	210,042	228,442	8.0%	248,307	3.0	744,920
Egypt	1,667	7	3,167	1,667	1,709	12,305	224	1,667	50	456	20,976	73,800	94,806	8.0%	103,500	3.0	309,150
Eritrea	90	1	110	90	90	648	12	90	3	16	736	3,888	4,624	8.0%	5,026	3.0	15,078
Eswatini	45	1	53	45	45	324	6	45	2	6	276	1,944	2,220	8.0%	2,413	3.0	7,239
Ethiopia	6,581	7	6,746	6,581	6,581	47,384	862	6,581	197	512	23,552	284,304	307,856	8.0%	334,626	3.0	1,003,878
Gambia	35	1	67	35	36	260	5	35	2	12	552	1,560	2,112	8.0%	2,296	3.0	6,887
Ghana	654	2	801	654	670	4,824	88	654	20	140	6,440	28,944	35,384	8.0%	38,611	3.0	115,383
Guinea	582	1	612	582	582	4,191	76	582	18	60	2,760	25,146	27,906	8.0%	30,333	3.0	90,998
Guinea-Bissau	3	1	44	22	11	80	1	6	1	10	460	480	940	8.0%	1,022	3.0	3,065
Kenya	2,049	4	2,408	2,049	2,049	14,753	268	2,049	62	240	11,040	88,518	99,558	8.0%	108,215	3.0	324,646
Lesotho	39	1	74	39	40	288	5	39	2	10	460	1,728	2,188	8.0%	2,378	3.0	7,135
Liberia	247	1	259	247	247	1,779	32	247	8	24	1,104	10,674	11,778	8.0%	12,802	3.0	38,407
Madagascar	893	2	1,071	893	893	6,430	117	893	27	124	5,704	38,580	44,284	8.0%	48,135	3.0	144,404
Malawi	216	2	454	227	227	1,635	30	216	7	86	3,956	9,810	13,766	8.0%	14,963	3.0	44,889
Mali	493	2	604	493	493	3,550	65	493	15	92	4,232	21,300	25,532	8.0%	27,752	3.0	83,257
Malta	215	1	226	215	215	1,548	28	215	7	22	1,012	9,288	10,300	8.0%	11,196	3.0	33,587
Morocco	945	3	1,157	945	945	6,804	124	945	29	166	7,676	40,824	48,460	8.0%	52,674	3.0	158,022
Mozambique	527	2	1,001	527	540	3,888	71	527	16	140	6,440	23,328	29,768	8.0%	32,557	3.0	97,670
Namibia	123	1	130	123	123	886	16	123	4	12	552	5,316	5,868	8.0%	6,378	3.0	19,135
Niger	962	2	1,131	962	962	6,927	126	962	29	108	4,968	41,562	46,530	8.0%	50,576	3.0	151,728
Nigeria	6,936	13	8,323	6,936	6,936	49,940	908	6,936	207	918	42,228	299,640	341,868	8.0%	371,596	3.0	1,114,787
Rwanda	191	1	368	191	196	1,412	26	191	6	58	2,668	8,472	11,140	8.0%	12,109	3.0	36,326
Senegal	449	2	539	449	449	3,233	59	449	14	76	3,496	19,398	22,894	8.0%	24,865	3.0	74,654
Sierra Leone	374	1	392	374	374	2,693	49	374	12	36	1,656	16,158	17,814	8.0%	19,363	3.0	58,089
Somalia	293	1	550	293	301	2,168	39	293	9	72	3,312	13,008	16,320	8.0%	17,739	3.0	53,217
South Africa	1,435	4	1,758	1,435	1,435	10,332	188	1,435	43	264	12,144	61,992	74,136	8.0%	80,583	3.0	241,748
South Sudan	583	1	612	583	583	4,198	76	583	18	50	2,300	25,188	27,488	8.0%	29,878	3.0	89,655
Sudan	91	3	1,016	508	275	1,980	36	112	4	196	9,016	11,880	20,896	8.0%	22,713	3.0	68,139
Tanzania	2,102	4	2,470	2,102	2,102	15,135	275	2,102	63	286	12,236	90,810	103,046	8.0%	112,007	3.0	336,020
Togo	69	1	211	106	82	591	11	71	3	38	1,748	3,546	5,294	8.0%	5,754	3.0	17,263
Tunisia	780	1	789	780	780	5,616	102	780	24	54	2,484	33,696	36,180	8.0%	39,326	3.0	117,978
Uganda	1,264	3	1,517	1,264	1,264	9,101	165	1,264	38	204	9,384	54,606	63,990	8.0%	69,554	3.0	208,663
Zambia	421	2	516	421	432	3,111	57	421	13	82	3,772	18,666	22,438	8.0%	24,389	3.0	73,167
Zimbabwe	412	1	495	412	412	2,967	54	412	13	86	3,036	17,802	20,838	8.0%	22,650	3.0	67,950
Bolivia	1,387	1	1,387	1,387	1,387	9,987	182	1,387	42	52	2,392	59,922	62,314	8.0%	67,733	3.0	205,198
Dominica	18	1	18	18	18	130	2	18	1	2	92	780	872	8.0%	948	3.0	2,843
El Salvador	368	1	377	368	368	2,650	48	368	11	30	1,380	15,900	17,280	8.0%	18,783	3.0	56,348
Grenada	13	1	13	13	13	94	2	13	1	2	92	564	656	8.0%	713	3.0	2,139
Guyana	126	1	126	126	126	908	17	126	4	4	184	5,448	5,632	8.0%	6,122	3.0	18,365
Haiti	300	1	360	300	300	2,160	39	300	3	52	2,392	12,960	15,352	8.0%	16,687	3.0	50,061
Honduras	545	1	559	545	545	3,924	71	545	17	46	2,116	23,544	25,660	8.0%	27,891	3.0	83,674
Nicaragua	2,674	1	2,674	2,674	2,674	19,253	350	2,674	80	30	1,380	115,518	116,898	8.0%	127,063	3.0	381,189
St. Lucia	12	1	13	12	12	87	2	12	1	2	92	522	614	8.0%	667	3.0	2,002
St. Vincent	15	1	15	15	15	108	2	15	1	2	92	648	740	8.0%	804	3.0	2,413
Trinidad and Tobago	38	1	46	38	38	274	5	38	2	8	368	1,644	2,012	8.0%	2,187	3.0	6,561
Costa Rica	249	1	262	249	249	1,793	33	249	8	24	1,104	10,758	11,862	8.0%	12,893	3.0	38,680
Guatemala	424	2	519	424	424	3,053	56	424	13	80	3,680	18,318	21,998	8.0%	23,911	3.0	71,733
Fiji	67	1	69	67	67	483	9	67	2	4	184	2,898	3,082	8.0%	3,350	3.0	10,050
Kiribati	36	1	36	36	36	260	5	36	2	2	92	1,560	1,652	8.0%	1,796	3.0	5,387
Marshall Islands	20	1	20	20	20	144	3	20	1	2	92	864	956	8.0%	1,039	3.0	3,117
Micronesia	34	1	34	34	34	245	4	34	2	2	92	1,470	1,562	8.0%	1,698	3.0	5,093
Papua New Guinea	237	1	284	237	237	1,707	31	237	8	40	1,840	10,242	12,082	8.0%	13,133	3.0	39,398
Samoa	4	1	8	4	5	36	1	4	1	2	92	216	308	8.0%	335	3.0	1,004
Solomon Islands	118	1	118	118	118	850	15	118	4	4	184	5,100	5,284	8.0%	5,743	3.0	17,230
Tonga	18	1	18	18	18	130	2	18	1	2	92	780	872	8.0%	948	3.0	2,843
Tuvalu	4	1	4	4	4	29	1	4	1	2	92	174	266	8.0%	289	3.0	867
Vanuatu	134	1	134	134	134	965	18	134	4	2	92	5,790	5,882	8.0%	6,393	3.0	19,180

Appendix 2: Summary of assessment outputs

Country	TCCC Bottler	1% Population	Required 30 Days		Existing Capacity 30 Days		Variance		Transport by Air		Unit Cost US\$		Dry Ice Installation		Unit Cost US\$		Dry Ice Installation Investment US\$
			Dry Ice KG	LCO2 KG	Dry Ice KG	LCO2	Dry Ice KG	LCO2	OPEX US\$	Per Vaccine	Per Vaccinated	Total Cost US\$	Per Vaccine	Per Vaccinated			
Fiji	Coca-Cola Amatil	8,964	3,350	10,050	0	0	(3,350)	(10,050)	\$22,582	\$1.26	\$2.52	\$208,504	\$11.63	\$23.26		\$186,729	
Kiribati	Coca-Cola Amatil	1,194	1,796	5,387	0	0	(1,796)	(5,387)	\$12,104	\$5.07	\$10.13	\$198,401	\$83.05	\$166.10		\$186,729	
Marshall Islands	Coca-Cola Amatil	592	1,039	3,117	0	0	(1,039)	(3,117)	\$7,005	\$5.92	\$11.83	\$159,483	\$163.44	\$326.89		\$186,729	
Micronesia	Coca-Cola Amatil	1,150	1,698	5,093	0	0	(1,698)	(5,093)	\$11,445	\$4.97	\$9.95	\$197,765	\$85.97	\$171.94		\$186,729	
Papua New Guinea	Coca-Cola Amatil	89,470	13,133	39,398	19,200	71,014	6,067	18,276	\$85,362	\$0.48	\$0.95	\$85,362	\$0.48	\$0.95		\$186,729	
Samoa	Coca-Cola Amatil	1,984	335	1,004	0	0	(335)	(1,004)	\$2,257	\$0.57	\$1.14	\$188,905	\$47.60	\$95.21		\$186,729	
Solomon Islands	Coca-Cola Amatil	6,869	5,743	17,230	0	35,507	(5,743)	(17,230)	\$38,716	\$2.82	\$5.64	\$224,062	\$16.31	\$32.62		\$186,729	
Tonga	Coca-Cola Amatil	1,057	948	2,843	0	0	(948)	(2,843)	\$6,389	\$3.02	\$6.04	\$192,890	\$91.25	\$182.50		\$186,729	
Tuvalu	Coca-Cola Amatil	118	289	867	0	0	(289)	(867)	\$1,949	\$8.26	\$16.53	\$188,608	\$799.73	\$1,599.46		\$186,729	
Vanuatu	Coca-Cola Amatil	3,071	6,393	19,180	8,926	6,628	2,533	(12,552)	\$16,873	\$19.03	\$38.05	\$116,873	\$19.03	\$38.05		\$186,729	
Sub-Total Pacific Islands		114,471	34,724	104,172	28,126	113,148	(6,998)	8,977	\$30,680	\$1.33	\$2.66	\$1,794,853	\$7.84	\$15.68	\$1,499,832		
Bolivia	Embol SA	116,730	67,733	203,198	167,671	641,096	99,939	437,898	\$360,577	\$1.54	\$3.09	\$360,577	\$1.54	\$3.09		\$0	
Dominica	Grenada Bottling Company	720	948	2,843	0	0	(948)	(2,843)	\$5,313	\$3.70	\$7.39	\$167,787	\$116.54	\$233.08		\$167,171	
El Salvador	Anheuser-Busch InBev	69,462	38,783	56,348	25,644	56,348	6,851	0	\$97,287	\$0.44	\$0.88	\$57,287	\$0.44	\$0.88		\$0	
Grenada	Grenada Bottling Company	1,125	713	2,139	0	0	(713)	(2,139)	\$4,004	\$1.78	\$3.56	\$167,634	\$74.49	\$148.98		\$167,171	
Guyana	Banks DH	7,866	6,122	18,365	0	0	(6,122)	(18,365)	\$34,379	\$2.19	\$4.37	\$171,150	\$10.88	\$21.76		\$167,171	
Haiti	Brasserie De La Couronne	114,025	16,687	50,061	0	0	(16,687)	(50,061)	\$93,711	\$0.41	\$0.82	\$178,017	\$0.78	\$1.56		\$167,171	
Honduras	Anheuser-Busch InBev	99,046	27,891	83,674	35,921	83,674	8,030	0	\$242,654	\$1.22	\$2.45	\$242,654	\$1.22	\$2.45		\$0	
Nicaragua	Fomento Economico Mexicano SA	66,246	127,063	381,189	54,000	177,534	(73,063)	(203,655)	\$698,847	\$5.27	\$10.55	\$698,847	\$5.27	\$10.55		\$0	
St. Lucia	Da Bouday Bottling Company	1,836	667	2,002	0	0	(667)	(2,002)	\$3,748	\$1.02	\$2.04	\$167,605	\$45.64	\$91.27		\$167,171	
St. Vincent	Grenada Bottling Company	1,109	804	2,413	0	0	(804)	(2,413)	\$4,517	\$2.04	\$4.07	\$167,694	\$75.58	\$151.16		\$167,171	
Trinidad and Tobago	Caribbean Bottling Company	13,995	2,187	6,561	29,589	226,849	27,402	220,288	\$1,422	\$0.05	\$0.10	\$1,422	\$0.05	\$0.10		\$0	
Costa Rica	Fomento Economico Mexicano SA	50,941	12,893	38,680	39,452	986,301	26,559	947,621	\$25,787	\$0.25	\$0.51	\$25,787	\$0.25	\$0.51		\$0	
Guatemala	Fomento Economico Mexicano SA	179,156	23,911	71,733	75,000	295,890	51,089	224,158	\$62,168	\$0.17	\$0.35	\$62,168	\$0.17	\$0.35		\$0	
Sub-Total Latin America		717,657	306,402	919,207	427,277	2,467,899	120,875	1,548,486	\$1,594,423	\$1.11	\$2.22	\$4,466,628	\$1.72	\$3.44	\$1,003,025		
Algeria	Equatorial Coca-Cola Bottling Company	438,510	130,857	392,570	30,000	641,096	(100,871)	248,526	\$967,758	\$1.10	\$2.21	\$476,681	\$95.55	\$191.10		\$0	
Angola	Castel Group	328,663	32,711	98,133	69,000	207,000	96,289	108,867	\$104,675	\$0.16	\$0.32	\$104,675	\$0.16	\$0.32		\$0	
Benin	Castel Group	121,232	15,848	47,543	0	0	(15,848)	(47,543)	\$144,803	\$0.60	\$1.19	\$218,939	\$0.90	\$1.81		\$178,140	
Botswana	Coca-Cola Beverages Africa	23,516	10,370	31,109	0	0	(10,370)	(31,109)	\$65,505	\$1.39	\$2.79	\$47,086	\$1.00	\$2.00		\$0	
Burkina Faso	Castel Group	209,033	31,654	94,963	0	0	(31,654)	(94,963)	\$289,228	\$0.69	\$1.38	\$233,244	\$0.56	\$1.12		\$0	
Burundi	Heineken	118,908	13,409	40,226	0	0	(13,409)	(40,226)	\$88,123	\$0.37	\$0.74	\$95,247	\$0.40	\$0.80		\$0	
Cameroon	Castel Group	265,459	53,848	161,543	0	0	(53,848)	(161,543)	\$492,011	\$0.93	\$1.85	\$433,776	\$9.82	\$19.63		\$178,140	
Central African Republic	Castel Group	48,298	9,787	29,361	0	19,726	(9,787)	(9,635)	\$89,424	\$0.93	\$1.85	\$189,470	\$1.96	\$3.92		\$178,140	
Chad	Castel Group	164,259	23,800	71,400	0	0	(23,800)	(71,400)	\$156,415	\$0.48	\$0.95	\$220,216	\$0.67	\$1.34		\$178,140	
Comoros	Coca-Cola Beverages Africa	8,696	1,237	3,711	0	0	(1,237)	(3,711)	\$8,129	\$0.47	\$0.93	\$8,129	\$0.47	\$0.93		\$0	
Congo	Heineken	55,181	6,609	19,820	0	42,411	(6,609)	(6,609)	\$41,748	\$0.58	\$1.16	\$192,871	\$1.75	\$3.50		\$178,140	
Cote D'Ivoire	Castel Group	268,783	34,687	104,061	270,000	0	235,313	(104,061)	\$121,117	\$0.25	\$0.50	\$231,117	\$0.25	\$0.50		\$0	
Djibouti	Groupe Doubeche	9,880	1,383	4,148	0	0	(1,383)	(4,148)	\$9,087	\$0.46	\$0.92	\$66,357	\$3.36	\$6.72		\$0	
DRC	Heineken	895,614	248,307	744,920	0	172,603	(248,307)	(572,317)	\$1,568,573	\$0.88	\$1.75	\$1,348,381	\$0.75	\$1.51		\$414,839	
Egypt	Bottling Investments Group	1,023,344	103,050	309,150	103,050	0	(309,150)	(309,150)	\$316,570	\$0.15	\$0.31	\$316,570	\$0.15	\$0.31		\$0	
Ertria	Red Sea Bottlers	35,464	5,026	15,078	0	0	(5,026)	(15,078)	\$33,032	\$0.47	\$0.93	\$106,905	\$1.51	\$3.01		\$0	
Eswatini	Coca-Cola Beverages Africa	11,602	2,413	7,239	0	0	(2,413)	(7,239)	\$55,243	\$0.66	\$1.31	\$30,250	\$1.30	\$2.61		\$0	
Ethiopia	Coca-Cola Beverages Africa	1,149,636	334,626	1,003,878	30,000	147,945	(304,626)	(855,933)	\$2,199,185	\$0.96	\$1.91	\$1,519,105	\$0.66	\$1.32		\$414,839	
Gambia	Equatorial Coca-Cola Bottling Company	24,167	2,296	6,887	0	0	(2,296)	(6,887)	\$25,624	\$0.53	\$1.06	\$37,253	\$0.77	\$1.54		\$0	
Ghana	Coca-Cola Beverages Africa	130,729	38,461	115,383	38,461	0	(115,383)	(38,461)	\$202,575	\$0.33	\$0.65	\$202,575	\$0.33	\$0.65		\$0	
Guinea	Equatorial Coca-Cola Bottling Company	131,328	30,333	90,998	0	0	(30,333)	(90,998)	\$277,151	\$1.06	\$2.11	\$282,976	\$1.08	\$2.15		\$178,140	
Guinea-Bissau	Equatorial Coca-Cola Bottling Company	19,880	1,022	3,065	0	0	(1,022)	(3,065)	\$9,336	\$0.24	\$0.47	\$27,705	\$0.70	\$1.41		\$0	
Kenya	Coca-Cola Beverages Africa	537,713	108,215	324,646	780,000	2,880,000	671,785	2,555,354	\$162,323	\$0.15	\$0.30	\$162,323	\$0.15	\$0.30		\$0	
Lesotho	Coca-Cola Beverages Africa	21,422	2,378	7,135	0	0	(2,378)	(7,135)	\$15,024	\$0.35	\$0.70	\$35,250	\$0.82	\$1.63		\$0	
Liberia	Equatorial Coca-Cola Bottling Company	50,577	12,802	38,407	0	0	(12,802)	(38,407)	\$116,974	\$1.16	\$2.31	\$225,038	\$2.22	\$4.45		\$178,140	
Madagascar	Castel Group	276,910	48,135	144,404	120,000	0	71,865	(144,404)	\$1,848,376	\$3.34	\$6.68	\$1,848,376	\$3.34	\$6.68		\$0	
Malawi	Castel Group	191,300	14,963	44,889	0	0	(14,963)	(44,889)	\$98,338	\$0.26	\$0.51	\$227,556	\$0.59	\$1.19		\$178,140	
Mali	Castel Group	202,508	27,752	83,257	0	0	(27,752)	(83,257)	\$253,573	\$0.63	\$1.25	\$216,076	\$0.53	\$1.07		\$0	
Mauritania	Equatorial Coca-Cola Bottling Company	46,497	11,196	33,587	0	0	(11,196)	(33,587)	\$24,967	\$1.34	\$2.69	\$115,177	\$1.24	\$2.48		\$0	
Morocco	Equatorial Coca-Cola Bottling Company	369,106	52,674	158,022	79,980	0	27,306	(158,022)	\$173,824	\$0.24	\$0.47	\$173,824	\$0.24	\$0.47		\$0	
Mozambique	Coca-Cola Beverages Africa	312,554	32,357	97,070	54,000	98,630	21,643	1,561	\$58,242	\$0.09	\$0.19	\$58,242	\$0.09	\$0.19		\$0	
Namibia	Coca-Cola Beverages Africa	25,409	6,378	19,135	0	0	(6,378)	(19,135)	\$40,292	\$0.79	\$1.59	\$108,670	\$2.14	\$4.28		\$0	
Niger	Castel Group	242,066	50,576	151,728	0	0	(50,576)	(151,728)	\$462,117	\$0.95	\$1.91	\$354,193	\$0.73	\$1.46		\$178,140	
Nigeria	Coca-Cola Hellenic Bottling Company	2,061,396	371,596	1,114,787	347,700	2,367,123	(23,896)	1,252,336	\$1,497,919	\$0.36	\$0.73	\$1,497,919	\$0.36	\$0.73		\$0	
Rwanda	Heineken	129,522	12,109	36,326	0	0	(12,109)	(36,326)	\$79,579	\$0.31	\$0.61	\$76,081	\$0.29	\$0.58		\$0	
Senegal	Castel Group	167,439	24,885	74,654	66,000	0	41,115	(74,654)	\$138,857	\$0.41	\$0.83	\$138,857	\$0.41	\$0.83		\$0	
Sierra Leone	Equatorial Coca-Cola Bottling Company	79,770	19,363	58,089	0	0	(19,363)	(58,089)	\$116,921	\$1.11	\$2.22	\$246,722	\$1.55	\$3.09		\$178,140	
Somalia	United Bottling Company	158,932	17,739	53,217	0	0	(17,739)	(53,217)	\$116,583	\$0.37	\$0.73	\$174,237	\$0.55	\$1.10		\$0	
South Africa	Coca-Cola Beverages Africa	593,087	80,583	241,748	2,502,000	9,000,000	2,421,417	8,738,252	\$102,610	\$0.09	\$0.17	\$102,610	\$0.09	\$0.17		\$0	
South Sudan	Equatorial Coca-Cola Bottling Company	111,937	23,878	89,635	0	0	(23,878)	(89,635)	\$196,362	\$0.88	\$						

Appendix 3: Road transportation cost calculation

Country	Source	Total Dry Ice Need to be transported (kg)	Daily Quantity need to be transported (kg)	Amount of Poly Containers needed	Cost for Poly Containers	Packaging Cost per Day	Distance from Supply Point (km)	Avg. Transportation Cost per km	Transport Cost per Day	Total Cost per Shipment	Total Cost per KG	Transportation Duration
Botswana	South Africa	10,370	346	18	\$10.35	\$186.30	375	\$2.05	\$768.75	\$955.05	\$2.76	4H:46M
Burkina Faso	Cote D'Ivoire	31,654	1,055	53	\$10.35	\$548.55	1,158	\$2.05	\$2,373.90	\$2,922.45	\$2.77	16H:25M
Burundi	Uganda	13,409	447	23	\$10.35	\$238.05	725	\$2.05	\$1,486.25	\$1,724.30	\$3.86	12H:40M
Djibouti	Ethiopia	1,383	46	3	\$10.35	\$31.05	870	\$2.05	\$1,783.50	\$1,814.55	\$39.36	12H:00M
Eritrea	Ethiopia	5,026	168	9	\$10.35	\$93.15	1,230	\$2.05	\$2,521.50	\$2,614.65	\$15.61	18H:35M
Eswatini	South Africa	2,413	80	5	\$10.35	\$51.75	362	\$2.05	\$742.10	\$793.85	\$9.87	4H:00M
Gambia	Senegal	2,296	77	4	\$10.35	\$41.40	310	\$2.05	\$635.50	\$676.90	\$8.84	5H:50M
Guinea-Bissau	Guinea	1,022	34	2	\$10.35	\$20.70	333	\$2.05	\$682.65	\$703.35	\$20.65	6H:00M
Lesotho	South Africa	2,378	79	4	\$10.35	\$41.40	440	\$2.05	\$902.00	\$943.40	\$11.90	5H:20M
Mali	Cote D'Ivoire	27,752	925	47	\$10.35	\$486.45	1,180	\$2.05	\$2,419.00	\$2,905.45	\$3.14	15H:00M
Mauritania	Senegal	11,196	373	19	\$10.35	\$196.65	553	\$2.05	\$1,133.65	\$1,330.30	\$3.56	8H:30M
Namibia	South Africa	6,378	213	11	\$10.35	\$113.85	1,383	\$2.05	\$2,835.15	\$2,949.00	\$13.87	14H:58M
Rwanda	Uganda	12,109	404	21	\$10.35	\$217.35	510	\$2.05	\$1,045.50	\$1,262.85	\$3.13	8H:18M
Somalia	Ethiopia	17,739	591	30	\$10.35	\$310.50	1,415	\$2.05	\$2,900.75	\$3,211.25	\$5.43	29H:00M
South Sudan	Kenya	29,878	996	50	\$10.35	\$517.50	1,140	\$2.05	\$2,337.00	\$2,854.50	\$2.87	20H:00M
Togo	Benin	5,754	192	10	\$10.35	\$103.50	150	\$2.05	\$307.50	\$411.00	\$2.14	2H:43M
Zimbabwe	South Africa	22,650	755	38	\$10.35	\$393.30	1,150	\$2.05	\$2,357.50	\$2,750.80	\$3.64	14H:20M
Algeria	Tunisia	100,857	3,362	169	\$10.35	\$1,749.15	830	\$2.05	\$1,701.50	\$3,450.65	\$1.03	10H:32M
		304,264	10,142	516		\$5,340.60			\$28,933.70	\$34,274.30		

