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Supply-Chain Cost Implications of Ultra-Low-Temperature Versus Never-Frozen COVID-19 Vaccine Formulations in Brazil

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- NF COVID-19 vaccine formulations were estimated to have substantially lower estimated supply-chain costs than ULT formulations in Brazil
- Estimates were driven by reductions in wastage. Wastage rates are not supported by strong data, so this is an important area for future research
- Formulation choice can influence budget impact beyond acquisition price through storage, distribution, and wastage
- Administration wastage is the dominant driver, suggesting that handling flexibility may translate into measurable economic value
- NF formulations may be particularly relevant where cold-chain capacity is constrained or where deployment sites have variable throughput

Background

- Formulation-specific cold-chain requirements are not commonly incorporated into vaccine economic evaluations, yet they can materially affect procurement decisions, implementation feasibility, and budget impact in public immunization programs.[1]
  - Ultra-low-temperature (ULT) storage may require specialized freezers, thermal shippers, dry ice replenishment, and additional handling controls.
  - Never-frozen (NF) formulations can use standard refrigerated cold-chain infrastructure, potentially lowering infrastructure burden, handling complexity, and wastage.

Objective

- The purpose of this study was to estimate annual supply-chain costs for ULT versus NF COVID-19 vaccines in Brazil.

Materials and Methods

- A deterministic supply-chain cost model was developed to estimate the economic impact of formulation-specific cold-chain requirements for COVID-19 vaccine deployment in Brazil (**Figure 1**)
- The model compared two vaccine formulation scenarios: an ULT formulation and an NF
- The analysis was conducted from a Brazilian public-sector health system perspective, focusing on operational costs associated with vaccine receipt, storage, distribution, and administration
- The modeled vaccination program assumed delivery of 1,000,000 doses over a 1-year time horizon
- Model inputs were drawn from public cost sources, published literature, and Brazil-relevant operational assumptions reflecting each formulation's storage and handling requirements (**Table 1**)
- Costs were estimated separately for each supply-chain component and summed to generate total annual supply-chain costs for each formulation scenario
- Incremental costs were calculated as the difference between the ULT and NF scenarios to quantify the potential economic impact of choosing a formulation with less intensive cold-chain requirements.
- Results were reported as total supply-chain costs, component-level cost drivers, and the relative cost difference between ULT and NF formulations

Figure 1. Model Diagram

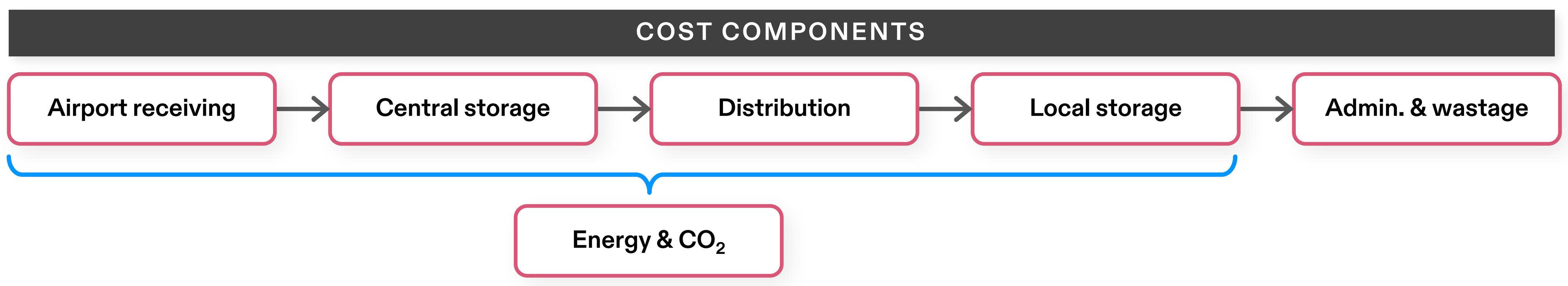


Table 1. Model Inputs and Sources

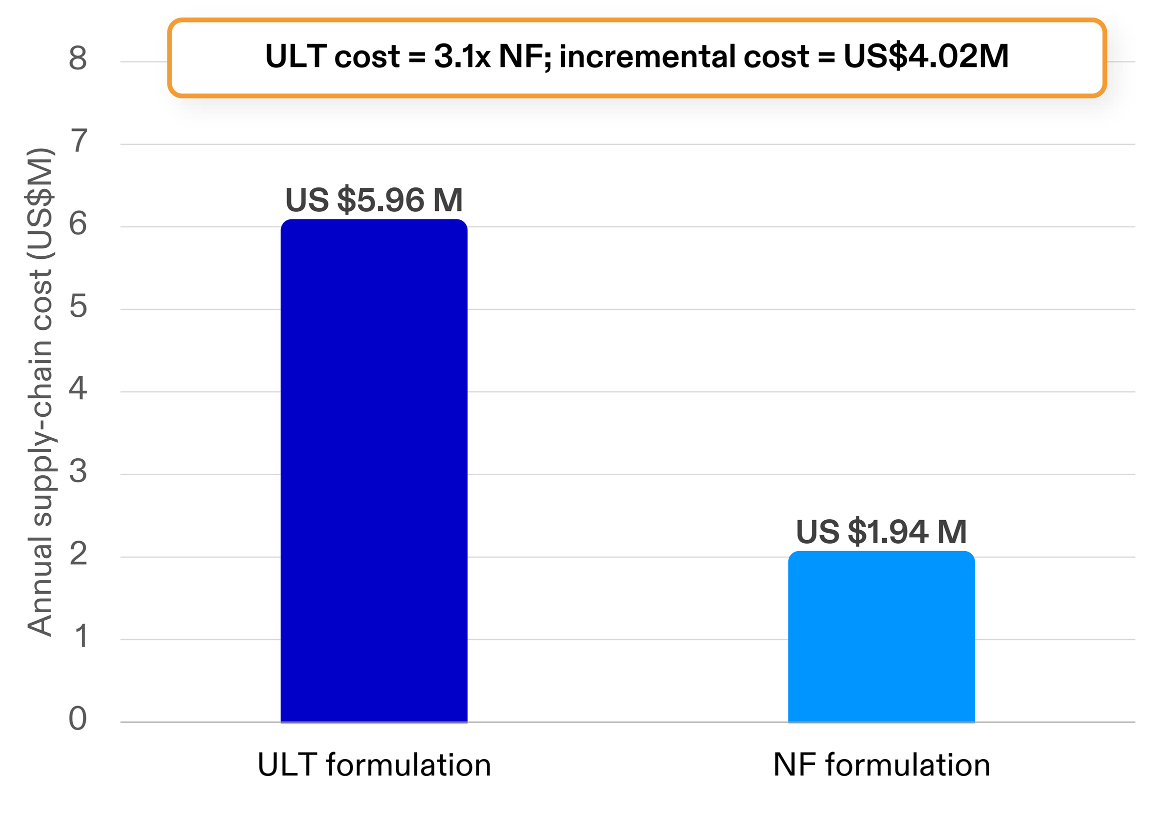
Cost Category	ULT input value	NF input value	Assumption and calculation basis	Source / note
Airport receiving	US$60,000	US$6,000	ULT includes dry ice thermal shipper intake, PPE, documentation, and dangerous-goods handling; NF assumes standard cold-chain receiving.	IATA DGR[2]
Central storage capital expenditure	10 ULT freezers; -80 C storage; US$300,000	20 WHO PQS E003 refrigerators; US$120,000	ULT assumes freezer procurement, ventilation, and maintenance requirements; NF assumes refrigerator-based central storage.	WHO ULT overview[1]; WHO PQS E003[3]; Arctiko[6]
Distribution	10 ULT thermal shippers; dry ice replenishment and DG documentation; US$344,544	PQS E004 cold boxes / reefer transport with coolant packs; US$60,000	ULT distribution includes thermal shippers plus dry ice replenishment; NF distribution assumes conventional 2-8 C cold-chain distribution.	WHO PQS E004[4]; IATA DGR[2]
Local storage	Site-level -80 C freezer capacity; US$450,000	PQS E003 refrigerators or solar direct-drive units; US$150,000	Local storage costs reflect formulation-specific equipment needed at administration sites.	WHO PQS E003[3]; UNICEF[5]
Administration-related wastage	60% wastage; ~100,000 vials lost; ~600,000 doses lost; US$4,800,000	20% wastage; ~33,333 vials lost; ~200,000 doses lost; US$1,600,000	Wastage modeled at vial level to reflect post-thaw handling constraints and operational complexity; doses lost = vials lost x 6.	Model assumption informed by handling complexity and wastage guidance[1,9,10]
Energy inputs	13 kWh/day per ULT freezer; 10 freezers; US$5,662.80 over model period	0.85 kWh/day per refrigerator; 20 refrigerators; US$740.50 over model period	Electricity tariff US$0.121/kWh; energy cost = equipment count x kWh/day x model days x tariff.	GlobalPetrolPrices Brazil[7]
Carbon inputs	Electricity plus dry ice direct CO_2; US$441.03	Electricity only; US$5.88	Grid emission factor 0.0385 tCO_2/MWh; carbon price US$25/tCO2; dry ice direct CO2 included for ULT.	MCTI/SIRENE[8]; EIGA [11]

Abbreviations: CO_2 = carbon dioxide; DG = dangerous good; DGR = Dangerous Goods Regulations; IATA = International Air Transport Association; MCTI = Ministry of Science, Technology and Innovation; NF = never frozen; PPE = personal protective equipment; PQS = Performance, Quality and Safety; SIRENE = National Emissions Registration System; tCO_2 = metric ton of carbon dioxide; ULT = ultra-low temperature; UNICEF = United Nations Children's Fund

Disclosures: JY is an employee of Pfizer and may hold stock or stock options of Pfizer. **BY** is an employee of PPD™ Evidera™ Health Economics & Market Access, Thermo Fisher Scientific. This study was sponsored by Pfizer Inc.

Results

Figure 2. Total Annual Supply Chain Costs, by Formulation



Abbreviations: NF = never frozen; ULT = ultra-low temperature.

Table 2. Total Annual Supply Chain Cost, by Component and Formulation

Cost category	ULT cost (US$)	NF cost (US$)	Difference: ULT-NF (US$)	Interpretation
Receiving (Airport)	60,000	6,000	54,000	ULT requires specialized dry ice shipper intake and documentation; NF uses standard cold-chain receiving.
Central Storage	300,000	120,000	180,000	ULT equipment and installation burden exceeds refrigerator-based NF storage.
Distribution	344,544	60,000	284,544	Dry ice replenishment and thermal shippers drive higher ULT distribution cost.
Local Storage	450,000	150,000	300,000	Site-level ULT freezers are costlier than refrigerated storage options.
Administration (Wastage)	4,800,000	1,600,000	3,200,000	Thawing limits and handling complexity increase ULT post-thaw wastage.
Energy (12 months)	5,663	740	4,922	ULT freezers require substantially more electricity than refrigerators.
CO_2 Emission Cost	441	6	435	Dry ice and higher electricity use increase the ULT carbon-cost estimate.
TOTAL	5,960,648	1,936,746	4,023,901	ULT costs are 3.1× higher; NF reduces total supply-chain costs by 68%.

Abbreviations: CO_2 = carbon dioxide; NF = nonfrozen formulation; ULT = ultralow temperature

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