

Estimating Carbon Emissions FOR Delivering Immunization Program Globally

unicef 
for every child



Webinar for global dissemination on TechNet-21. 5 June 2023
Health, Immunization Supply Chain (ISC), Programme Group (PG)

BACKGROUND

- Global carbon dioxide emissions from fossil fuels and industry were 37.12 billion metric tons (GtCO₂) in 2021.
- UNICEF has ethical obligation towards reducing greenhouse gas (GHG) emissions for its interventions.
- Estimating baseline emissions is critical for strategic programmatic interventions towards reduction in carbon footprint of immunization and health programs.
- Climate Action and sustainable procurement is a major part of the 2022-2025 strategic plan of UNICEF
- Immunization supply chain unit, Programme Group, produced this first draft of carbon emissions for delivering the immunization program globally



Scope of work

- 194 countries
- 13 vaccines in the immunization profile
- Emissions from:
 - Production of all supplies
 - Global and in-country transportation
 - Operations – All supply chain levels
 - Electricity and use of diesel generators
 - Waste disposal (syringes vials, CCE)

Sources of information

- Data from manufactures
- WHO data on coverage, wastage and cold chain
- World Bank on electricity status
- Assumptions from other credible sources

Analysis

- Customized tool in Excel to consolidate data
- Scope 1, 2 and 3 categorization of emissions

CONSTRAINTS

- Very limited information on carbon emissions of immunization supplies
- Negligible response from vaccine and CCE suppliers on product specific emissions
- Unreliable CCE inventories from countries
- Supply chain information: international and in-country distances, routes not available

MITIGATION

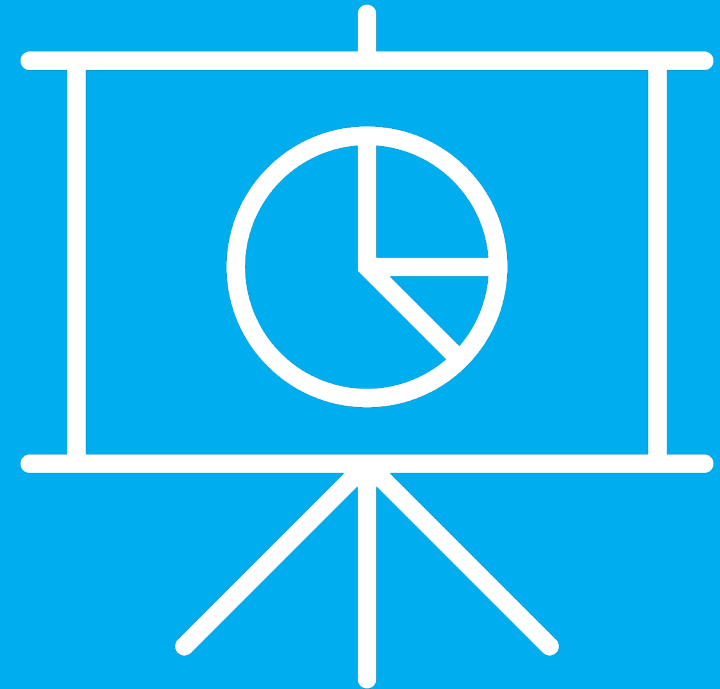
- Use of available/alternate source of information for estimating emissions of related products
- Continue to reach out suppliers for data refinement
- Estimated CCE needs at country level using 4-tier supply chain levels and attributed emissions to estimated CCE numbers, triangulated the estimation with supply division data to confirm high confidence level of estimates
- Referred to international trading standards for estimating shipment distances

KEY DATA SOURCES

- **2021 WUENIC** estimates for target population
- **2021 WHO** estimates for global coverage
- **2021 WHO** estimates for vaccine wastage
- **WHO PQS** for cold chain standards
- **DEFRA:** UK Department of Environment Food and Rural Affairs for plastic and other production emissions
- **ITC:** International Trade Center for transportation statistics

Key results

Emissions of key contributors
Sources of information and
key assumptions for
Various components



ESTIMATED TOTAL EMISSIONS FOR DELIVERING IMMUNIZATION PROGRAM GLOBALLY



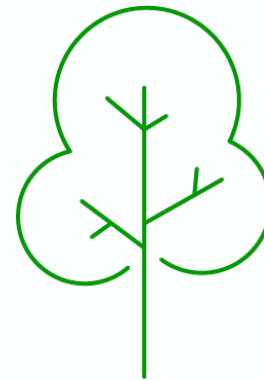
350,125 (0.00094% of global carbon emissions) Ton CO₂ equivalent estimated annual emissions from delivering immunization program



Annual emissions equivalent of **226,423** passengers flying on Dubai – New York economy class

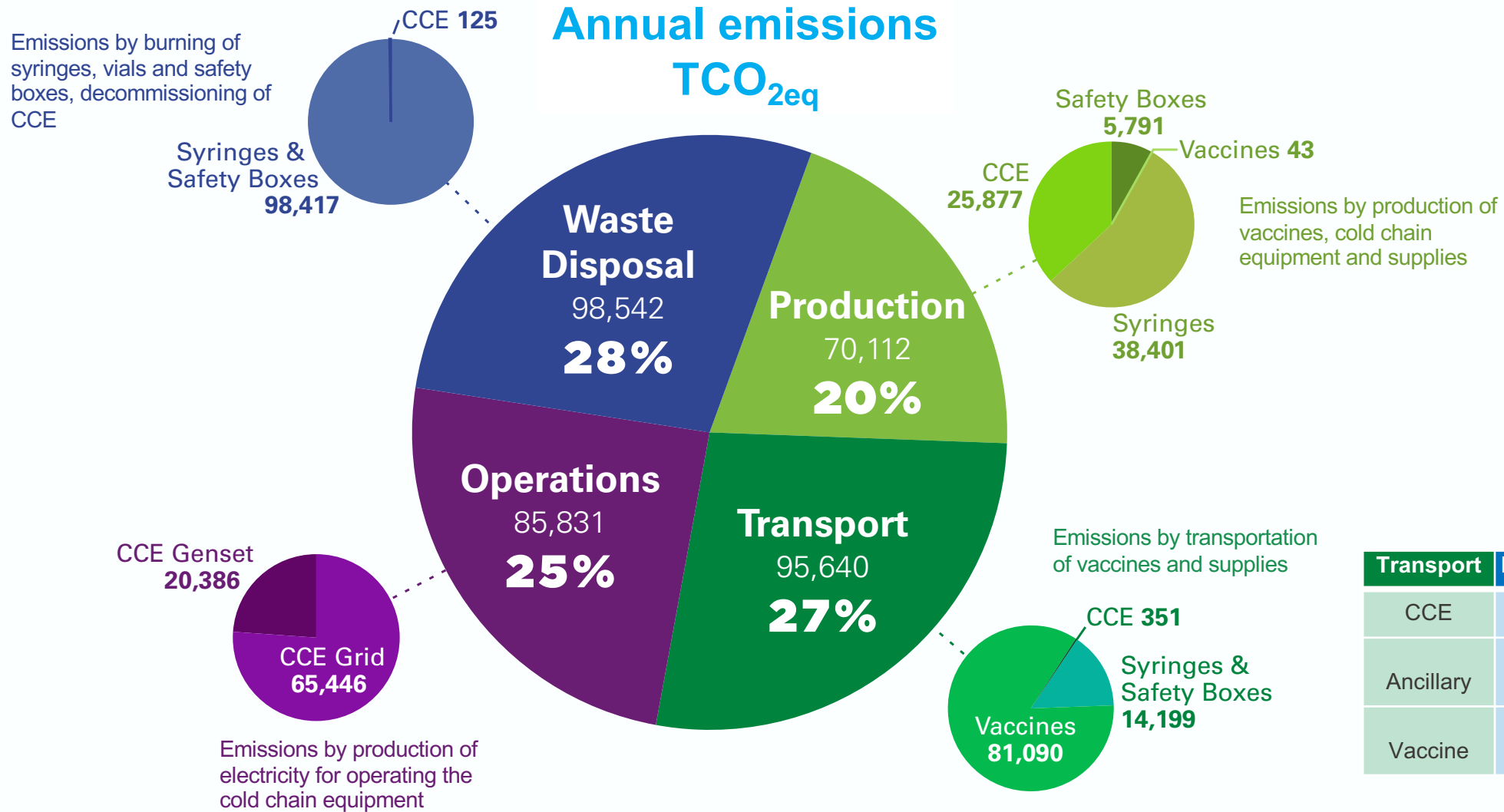


3.07 kg CO₂ equivalent per FIC
166 g CO₂ equivalent emissions per vaccine dose administered to a child



Which can be mitigated by **5,789,347** tree seedlings grown for 10 years

KEY CONTRIBUTORS OF EMISSIONS



Transport	In TCO _{2eq}	
	International	Domestic
CCE	141	211
Ancillary	5,688	8,511
Vaccine	70,282	10,808

KEY CONTRIBUTORS OF EMISSIONS CONT.

Category	Contributor	Annual emissions (Ton CO ₂)	Percentage to total emissions
Production	Vaccine	43	0.01%
	Syringes	38,401	10.97%
	Safety boxes	5,791	1.65%
	CCE	26,229	7.49%
Transportation (international shipments)	Vaccine	70,282	20.07%
	Ancillary supplies	5,688	1.62%
Transportation (in-country shipments)	Vaccine	10,808	3.09%
	Ancillary supplies	8,511	2.43%
Operations	Electricity from Grid	65,446	18.69%
	Diesel genset (backup)	20,386	5.82%
Waste disposal	Burning of waste	98,417	28.11%
	Decommissioning of CCE	125	0.04%
Total		350,125	100.00%

Production emissions

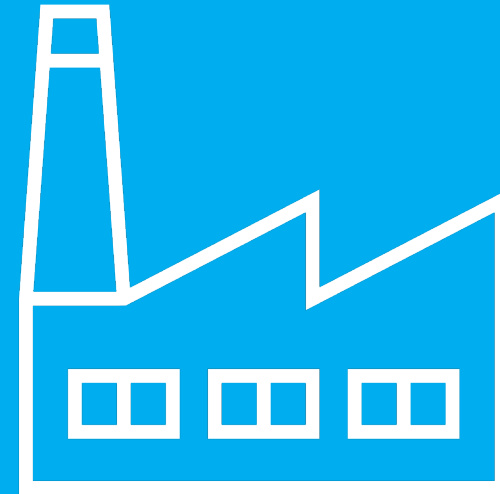
Vaccine

Ancillary supplies

Cold chain equipment

Temperature monitoring devices

Packaging for transportation



EMISSIONS BY PRODUCTION OF VACCINES

Assumptions

0.015 gram CO₂ per dose of vaccine production¹

Referred to **WHO Sizing Tool** for country specific wastage rate

Used **WHO indicative wastage rate** in lieu of countries specific data

Used **WHO recommended Doses and Volume per child for each vaccine**

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

1,216,000 Target population

1 Dose per child in FIC schedule

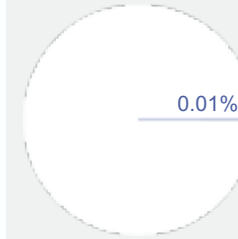
84% Coverage - 2021

80% Wastage rate

5,107,200 Estimated doses consumed

76.61 Estimated emission in kg

0.075 Emission grams / BCG immunized child



Estimated Annual emissions for production of vaccine

43 Ton CO₂ equivalent



Global

28 passengers traveling

Dubai – New York economy class flights



Can be mitigated by

711 tree seedlings

grown for 10 years



Sources:

1. Research paper reference: Kurzweil, P.; Müller, A.; Wahler, S. The Ecological Footprint of COVID-19 mRNA Vaccines: Estimating Greenhouse Gas Emissions in Germany. Int. J. Environ. Res. Public Health 2021, 18, 7425. <https://doi.org/10.3390/ijerph18147425>

EMISSIONS BY PRODUCTION OF SYRINGES

Assumptions

3.281 kg CO₂
per kg of syringes
manufactured¹

10% wastage
rate added to the
consumption by
respective vaccine
coverage

**Syringe weight &
volume reference**
WHO sizing tool

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

1,216,000 Target population

1 Dose per child in FIC schedule

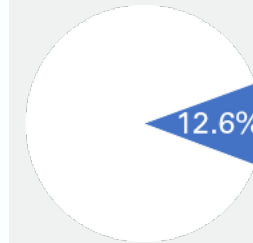
84% Coverage - 2021

10% More for diluent + wastage syringes

1,123,584 Estimated syringes consumed

22,964 Estimated CO_{2eq} emission in kg

22.48 Emission grams / BCG immunized child



Estimated annual emissions
for production of syringes

38,401 Ton CO₂ equivalent



24,831 passengers
traveling

Dubai – New York economy class flights



Can be mitigated by
634,964 tree seedlings
grown for 10 years



Sources:

1. "Syringes and Sustainability: Planet, People, Profit" paper by The Royal Liverpool and Broadgreen University Hospitals NHS Trust, 1.18 million samples, extrapolated using emission factors by Department for Environment, Food & Rural Affairs UK, (DEFRA) (3.281 T CO_{2eq} / T) (<http://www.defra.gov.uk/>)

EMISSIONS BY PRODUCTION OF SAFETY BOXES

Assumptions

3.4 kg CO₂
per kg of safety coated
corrugated sheet boxes¹

Safety box quantity
linked to syringe
consumption

110 syringes/safety
box considered for
wastage calculations

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

1,216,000 Target population

1 Dose per child in FIC schedule

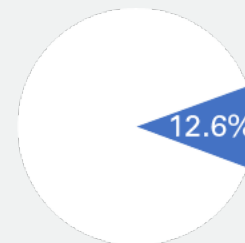
84% Coverage - 2021

1,123,584 Estimated syringes consumed*

10,214 Safety boxes used

2,799 Estimated CO_{2eq} emission in kg

2.74 Emission grams / BCG immunized child



Estimated annual emissions
for production of safety boxes

5,791 Ton CO₂ equivalent



3,745 passengers
traveling

Dubai – New York economy class flights



Can be mitigated by
95,755 tree seedlings
grown for 10 years



Sources:

1. . Sources: <https://askwonder.com/research/carbon-footprint-cardboard-boxes-single-double-wall-plastic-storage-boxes-nf5da5477>

* Including wastage

Challenges in estimating production emissions of CCE

Limited availability of global cold chain inventories

Non-availability of production data from manufacturers

Mitigating methodology used

Place holders for CCE inventory for each country created in the tool

CCE numbers estimated to fill the place holders with assumed values based on:

- Commonly used volumes of ILR, cold rooms and freezer rooms at respective supply chain levels with WHO indicative shipment frequency and storages durations
- Weighted average of most frequently used (source: supply division) CCE models for estimating embodied and operating emissions

Cold boxes, vaccine carriers, Ice-packs based on:

- Estimated shipment volumes of annual supplies of vaccines
- Most used models

TMD quantities estimated with respect to CCE numbers and vaccine shipments

EMBODIED EMISSIONS* OF MANUFACTURING CCE

Assumptions

4.36 kg CO₂ per kg of the CCE weight^{1,2}

Weighted average of CCE mass of 115 kg/fridge

Used WHO recommended Doses and Volume per child for each vaccine

Used 4-Tier Supply Chain for estimating numbers of CCE customizable to actual data by CCE model

Emissions for CCE production spread over to 10 years of life cycle

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

137,558 Liters of refrigerated vaccine storage

11+7 Cold rooms 40 and 30 m³

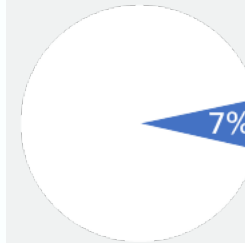
571+2055 Estimated fridges of 60 and 40 liter size

1,890 SDD nos. from UNICEF supply division

571+165 Estimated ILR (2,055-1,890 SDD)

2,626 Fridges considered for embodied emissions

59,850 Estimated embodied CO_{2eq} emission kg



Estimated annual emissions for production of CCE

26,229 Ton CO₂ equivalent



16,962 passengers traveling

Dubai – New York economy class flights



Can be mitigated by 433,699 tree seedlings grown for 10 years



* CO_{2eq} emissions associated with materials, manufacturing, and Transportation over the whole lifecycle of a product or service

Sources:

1. Used emission factors by DEFRA (<http://www.defra.gov.uk/>) for all cooling equipment (4.3633 T CO_{2eq} / T of equipment weight)
2. Used quantities and models as specified in UNICEF data excel file "CCE FROM 2015" to arrive at the weighted averages for CCE mass and daily energy consumption

EMBODIED EMISSIONS BY CATEGORY OF CCE

Category	Estimated number of CCE in the world*	Embodied annual emissions TCO _{2eq} for production	Percentage to total emission by production of CCE
Cold rooms	2,014	1,587	6.05%
Freezer rooms	893	31	0.12%
Ice lined Refrigerators (ILR)	261,363	13,149	50.13%
Freezers	6,996	237	0.90%
Solar Direct Drive (SDD) refrigerators	80,435	4,422	16.86%
Cold boxes	448,523	3,112	11.86%
Vaccine carriers	1,774,744	1,239	4.72%
Ice packs	38,184,219	1,833	6.99%
Temperature monitoring devices for fridges and cold rooms	378,193	201	0.77%
Shipment Indicators	772,264	67	0.26%
Transportation	-	351	1.34%
Total		26,229	

* Estimated based on target population, generic stock management policies as per WHO sizing tool, assumed 4 levels of supply chain in each country

TRIANGULATION OF ESTIMATED CCE NUMBERS WITH UNICEF SUPPLY DIVISION PROCUREMENT DATA

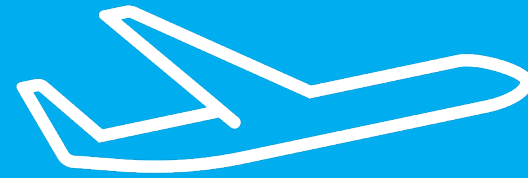
Category	Estimated number of units in the world: Analysis using assumptions (A)	Actual number of units procured through UNICEF SD since 2015 (8 years of data) (B)	Extrapolated the procured units through UNICEF to 10 years of cycle (C)	Proximity of Estimated number of CCE to extrapolated units procured through UNICEF (A)~(C)
Cold rooms	2,907	1,489	2,792	~96%
Refrigerators	341,798	172,907	324,201	~95%

- Extrapolation of procurement data done with following rationale and method
 - ✓ CCE has an active life of 10 years of before decommissioning
 - ✓ 80% of CCE in the world are procured through UNICEF, additional 20% procured through other sources

Transportation emissions

International and in-country

- Vaccine
- Ancillary supplies



EMISSIONS BY INTERNATIONAL SHIPMENT OF VACCINE

Assumptions

1.0189 & 0.57871 kg CO₂ per T-km of air and road transport¹

4,517 km average distance for air transport²

150 km average distance of road transport to and from port

0.6 lit x 24 (14.4 kg) average number of ice packs used in transport per 20 liters of cold box³

Methodology

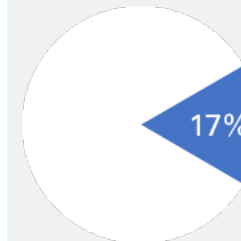
Country example: **Afghanistan**
Vaccine example: **BCG**

5,107,200 Estimated doses for transportation

10,378 Kg of total weight of shipment

Air: (10,378 kg x 4,517 km)/1000
*** 1.0189 CO₂ kg per T-km**
+ Road : (10,378 kg x 150 km)/1000
*** 0.57871 CO₂ kg per T-km**

48,664 Estimated CO_{2eq} emission in kg



Estimated annual emissions for shipment of vaccine

70,282 Ton CO₂ equivalent



45,446 passengers traveling

Dubai – New York economy class flights



Can be mitigated by 1,162,119 tree seedlings
grown for 10 years



Sources:

1. emission factors by Department for Environment, Food & Rural Affairs UK, (DEFRA) (1.0189 kg CO_{2eq} / T-km) (<http://www.defra.gov.uk/>)

2. International Trade Centre (ITC) based on UN COMTRADE and ITC statistics <https://www.trademap.org/Index.aspx>, average trade distance for pharma products = 4,517 km, transport by air freight

3. PQS E004/005 for typical RCW25 Insulated Container

EMISSIONS BY INTERNATIONAL SHIPMENT OF ANCILLARY SUPPLIES

Assumptions

Safety boxes and syringes included

0.01323 kg CO₂ per T-km of sea freight¹

4,517 km average distance for sea transport²

150 km average distance of road transport to and from port

274 grams weight per safety box

6.24 grams average weight per syringe

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

1,216,000 Target population

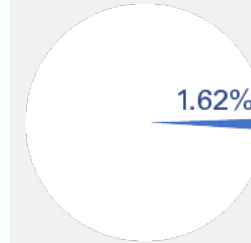
1,123,584 Estimated syringes needed for BCG

10,214 Estimated safety boxes needed

9,810 Total estimated weight for shipment in kg

Similar methodology as for air shipment of vaccine

1,275 Estimated CO_{2eq} emission in kg



Estimated annual emissions for shipment of supplies

5,688 Ton CO₂ equivalent



Global

3,678 passengers traveling

Dubai – New York economy class flights



Can be mitigated by 94,052 tree seedlings
grown for 10 years



Sources:

1. emission factors by Department for Environment, Food & Rural Affairs UK, (DEFRA) (0.013232 kg CO_{2eq} / T-km) (<http://www.defra.gov.uk/>)

2. International Trade Centre (ITC) based on UN COMTRADE and ITC statistics <https://www.trademap.org/Index.aspx>, average trade distance for pharma products = 4,517 km, transport by air freight

EMISSIONS BY IN-COUNTRY SHIPMENT OF VACCINE

Assumptions

0.57871 kg CO₂ per T-km of road transport^{1,2}

15.9 kg average weight of empty cold box³

0.6 lit x 24 (14.4 kg) average number of ice packs used in transport per 20 liters of cold box³

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

5,107,200 Estimated doses for transportation

16,874 Kg of total weight of shipment (vaccine, ice packs, cold box)

456 Average distance in km for transportation within country

Similar methodology as for air shipment of vaccine

4,452 Estimated CO_{2eq} emission in kg



Estimated annual emissions for in-country shipment of vaccine

10,808 Ton CO₂ equivalent



6,989 passengers traveling

Dubai – New York economy class flights



Can be mitigated by 178,711 tree seedlings grown for 10 years



Sources:

1. emission factors by Department for Environment, Food & Rural Affairs UK, (DEFRA) (0.57871 kg CO_{2eq} / T-km) (<http://www.defra.gov.uk/>)
2. Average transport within a country is considered as equivalent radius calculated using area of that country
3. PQS E004/005 for typical RCW25 Insulated Container

EMISSIONS BY IN-COUNTRY SHIPMENT OF ANCILLARY SUPPLIES

Assumptions

0.57871 kg CO₂ per T-km of road transport^{1,2}

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

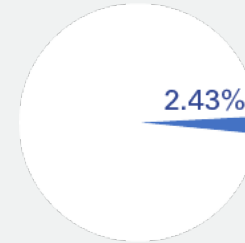
1,123,584 Estimated syringes needed for BCG

10,214 Estimated safety boxes needed

9,810 kg Total estimated weight for shipment

Similar methodology as for air shipment of vaccine

2,731 Estimated CO_{2eq} emission in kg



Estimated annual emissions for in-country shipment of supplies

8,511 Ton CO₂ equivalent



Global

5,503 passengers traveling

Dubai – New York economy class flights



Can be mitigated by 140,730 tree seedlings grown for 10 years

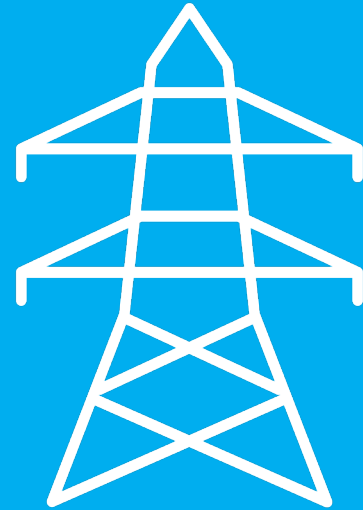


Sources:

1. emission factors by Department for Environment, Food & Rural Affairs UK, (DEFRA) (0.57871 kg CO_{2eq} / T-km) (<http://www.defra.gov.uk/>)
2. Average transport within a country is considered as equivalent radius calculated using area of that country

Operations emissions

Production of electricity from grid
and diesel generator



EMISSIONS BY OPERATIONS (ACTIVE COOLING)

Assumptions

Electricity, Diesel
CO₂ / kWh of CCE
operation per specific
operation for each country
UNFCCC, IGES, WB^{1,2,3}

For Afghanistan context
Grid electricity
emission factor of
0.41 kg CO₂/kWh

For Afghanistan context
Genset electricity
emission factor of **0.77**
kg CO₂/kWh

Weighted average of
CCE energy consumed

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

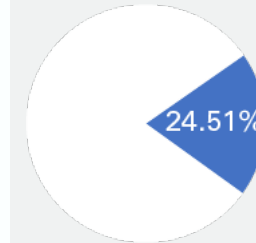
18+736 Cold rooms + ILRs considered for operation

61.7% Electricity available from grid

33,953 kg CO_{2eq} Emissions for using grid electricity

39,274 Kg CO_{2eq} Emissions for using genset
electricity

73,226 Estimated CO_{2eq} emission in kg



Estimated annual emissions
for production of electricity

85,832 Ton CO₂ equivalent



55,496 passengers
traveling

Dubai – New York economy class flights



Can be mitigated by
1,419,223 tree seedlings
grown for 10 years



Sources:

1. Used emission factors by DEFRA (<http://www.defra.gov.uk/>) for all cooling equipment (4.3633 T CO_{2eq} / T of equipment weight)
2. Used quantities and models as specified in UNICEF data excel file "CCE FROM 2015" to arrive at the weighted averages for CCE mass and daily energy consumption

Waste disposal

Burning of immunization waste
Decommissioning of CCE



EMISSIONS BY WASTE DISPOSAL OF CONSUMABLES

Assumptions

3.075 kg CO₂ per kg of syringes¹

1.631 kg CO₂ per kg safety boxes²

0.02128 kg CO₂ per kg vials¹

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

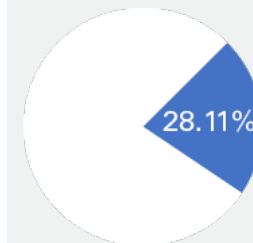
1,123,584 Estimated syringes for disposal

10,214 Estimated safety boxes

7,011 Weight of syringes in kg

2,799 Weight of safety boxes in kg

22,750 Estimated CO_{2eq} emission in kg



Estimated annual emissions on waste disposal

98,417 Ton CO₂ equivalent



63,639 passengers traveling

Dubai – New York economy class flights



Can be mitigated by 1,627,334 tree seedlings grown for 10 years



Sources:

1. Used emission factors by DEFRA (<http://www.defra.gov.uk/>) for emission factor of burning the plastic used for syringes
2. Used emission factors by DEFRA (<http://www.defra.gov.uk/>) for emission factor of burning the corrugated cardboard used for safety boxes

EMBODIED EMISSIONS BY DECOMMISSIONING OF CCE

Assumptions

21.28 kg CO₂
per kg of the CCE weight^{1,2}

Weighted average
of CCE mass of
115 kg/fridge

Used **WHO** recommended
doses and volume per
child for each vaccine

Used **4-Tier supply**
chain for estimating
numbers of **CCE**
customizable to actual
data by CCE model

Emissions for CCE
production spread over **10**
years of life cycle

Methodology

Country example: **Afghanistan**
Vaccine example: **BCG**

137,558 Liters of refrigerated vaccine storage

11+7 Cold rooms 40 and 30 m³

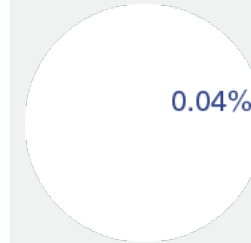
571+2055 Estimated fridges of 60 and 40 liter size

1,890 SDD nos. from UNICEF supply division

571+165 Estimated ILR (2,055-1,890 SDD)

2,626 Fridges considered for embodied emissions

286 Estimated embodied CO_{2eq} emission kg



Estimated annual emissions
for decommissioning of CCE

125 Ton CO₂ equivalent



Global

81 passengers
traveling

Dubai – New York economy class flights



Can be mitigated by
2,067 tree seedlings
grown for 10 years

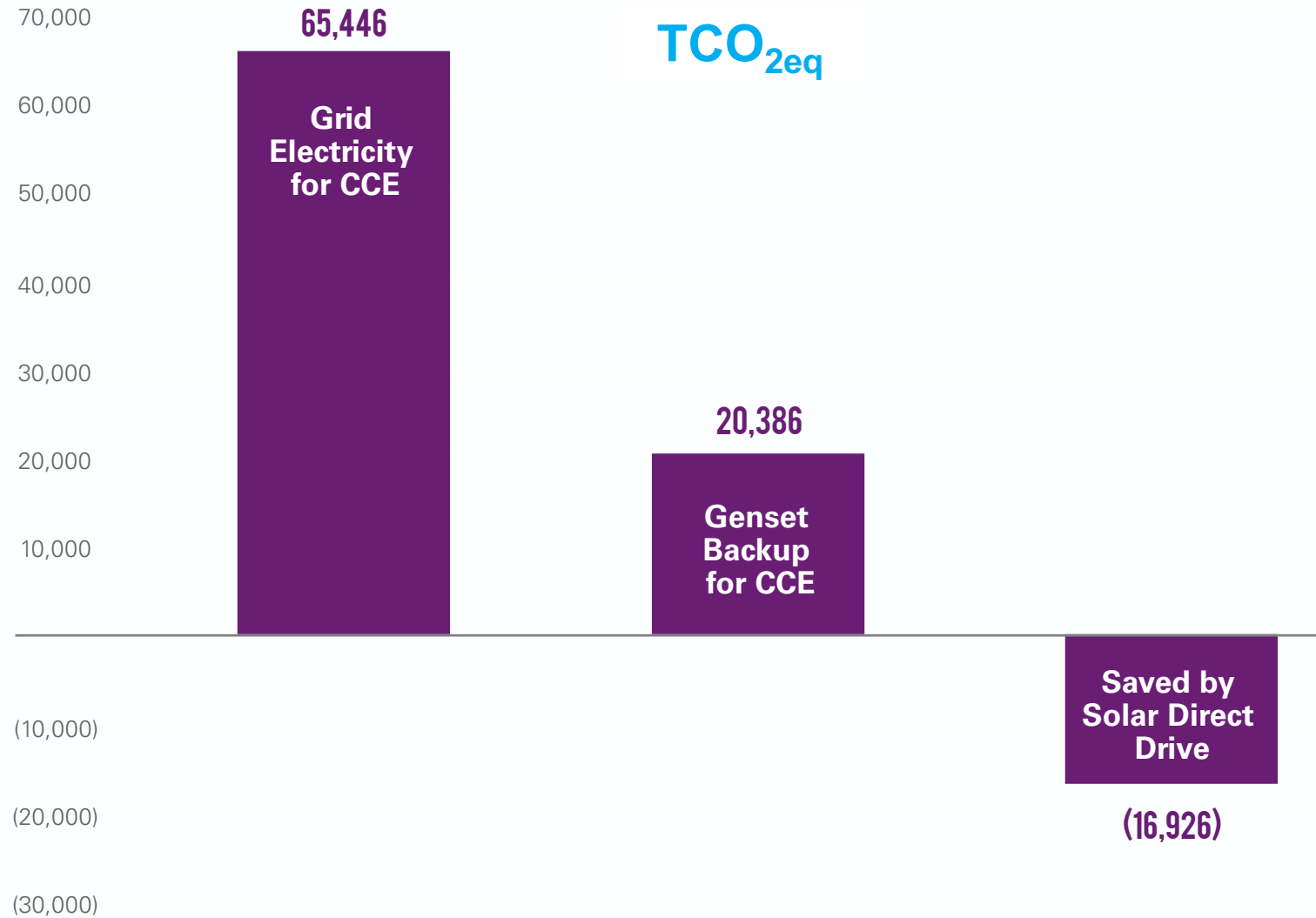


* CO_{2eq} emissions associated with materials, manufacturing, and Transportation over the whole lifecycle of a product or service

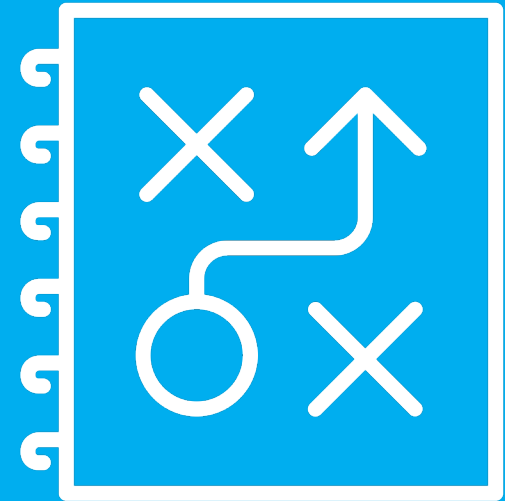
Sources:

1. Used emission factors by DEFRA (<http://www.defra.gov.uk/>) for all cooling equipment (4.3633 T CO_{2eq} / T of equipment weight)
2. Used quantities and models as specified in UNICEF data excel file "CCE FROM 2015" to arrive at the weighted averages for CCE mass and daily energy consumption

REDUCTION OF EMISSIONS BY DEPLOYED SDDs



Conclusion and recommendations



CONCLUSION

- The emissions from delivering immunization program is 0.00094% of global carbon emissions
- Burning of waste is the largest contributor (28.11%) to emissions
- CCE operation with grid and backup genset is the next significant contributor (24.51%) to emissions
- International air shipment of vaccines contributes 20.07% of emissions
- Production of syringes and safety boxes emit 12.62% of the total
- Deployment of over 80k SDD refrigerators have reduced annual emissions by 4.83%
- While the estimates are accurate given the limitation of data, further granular data might help in improving the accuracy

HIGH LEVEL RECOMMENDATIONS

“Low hanging fruits” for reduction of emissions by **70%**

Operations

Solarization / use of Renewable Energy hybrids can reduce total emissions by

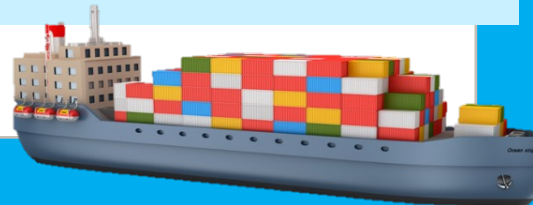
25%



Transportation

77 folds reduction in emissions for shipping vaccines by sea as compared to air, i.e. total emissions reduced by

20.5%



Disposal

Upcycling of plastics as against incineration, into useful products, reduces total emissions

25%



WAY FORWARD

Make Carbon Emission Profile of immunization program for countries available in form of a dashboard such that:

- Countries can update granular data to refine and establish baseline
- Define strategic and programmatic interventions toward reduction of carbon emission
- Program level and country level emission reduction phased targets setting
- Track country level reductions in emissions through implementation of planned interventions

Publications

- Report on carbon emissions in delivering immunization program globally
- Research paper on estimating immunization carbon emissions
- Report on emission reduction through programmatic interventions

FOR ADDITIONAL INFORMATION CONTACT

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For clarification on data sources and reference to standards

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