COST-BENEFIT ANALYSIS OF PREVENTIVE CARE SERVICES IN GHANA

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for every child

Cost-Benefit Analysis of Preventive Care Services in Ghana

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Executive summary

Introduction

Ghana's health sector is currently undergoing a shift from a focus on curative care to preventive and promotive health. While the existing package of care for Ghanaian citizens includes both health and nutrition services, it remains dominated by curative interventions, such as malaria and pneumonia treatment and baby delivery services. Preventive measures, including vaccinations, are largely subsidised by external partners.

As Gavi subsidies are phasing out before 2030, there is a need for robust evidence to guide the prioritisation of preventive health interventions. UNICEF has, therefore, commissioned Ecorys to prepare a cost-benefit analysis (CBA) of 14 preventive health and nutrition interventions in Ghana. This study provides a comprehensive assessment of the economic and health impacts of maintaining or discontinuing these interventions.

Methodology

Thise study employs an incremental, ex-ante CBA and uses a static population model that tracks the cumulative health impact of withdrawing each intervention from 2026 onwards. For each intervention, two scenarios are compared: a baseline scenario in which the intervention continues at target coverage levels, and a no-intervention scenario in which coverage drops to zero from 2026 onwards. The analysis is conducted from both the health sector and societal perspectives, quantifying direct medical costs, productivity losses, premature mortality, and years lived with disability. Key metrics include the Value of a Statistical Life Year (VSLY), which monetises the value of life year saved, and the Disability-Adjusted Life Year (DALY), which monetises the value of healthy years lost due to illness or disability, using Ghana's GDP per capita.

Interventions assessed

The interventions assessed in this study are as follows:

12. Routine immunisation with BCG vaccine
13. Routine immunisation with Pentavalent vaccine
14. Routine immunisation with Pneumococcal vaccine
15. Routine immunisation with Rotavirus vaccine
16. Routine immunisation with Malaria vaccine
17. Routine immunisation with Measles-Rubella vaccine
18. Routine immunisation with Yellow Fever vaccine
19. Routine immunisation with Meningitis A vaccine
20. Routine immunisation with HPV vaccine
21. Routine immunisation with birth dose for Hepatitis B

11a. Routine immunisation with OPV vaccine

11b. Routine immunisation with IPV vaccine as addition to the OPV vaccine

22. Child Vitamin A Supplementation
23. Micronutrient supplementation powders for children

Key findings

Discontinuing most interventions would result in substantial long-term economic and health losses, far outweighing any short-term savings of reduced vaccination efforts. The greatest losses are associated with vaccines targeting high-burden diseases, such as the Pneumococcal conjugate vaccine (PCV) (USD 5,109 million considering only mortality and 24,082 million including DALYs), malaria vaccine (USD 7,068 million and 13,439 million), pentavalent vaccine (USD 1,736 million and 3,294 million), and BCG vaccine (USD 1,046 million and 2,264 million). The discontinuation of these vaccines would, individually, result in billions of dollars in net losses over a ten-year horizon, due to increased disease incidence, mortality, and disability.

Some interventions, such as the Yellow Fever, Meningitis A, HPV, and IPV vaccines, show limited short-term economic returns. This is attributable to low disease incidence, high vaccine costs, or long latency periods before disease manifestation, as is the case with HPV-related cancers.

Scope of the study

The results of this study are strongly shaped by how infection rates are simulated after vaccination stops, and interpretation of the study's result should take that into account. Each intervention is assessed independently, without considering the negative synergistic effects of withdrawing multiple interventions at once. Moreover, herd immunity effects of vaccines are also not included, so the model likely understates the benefits of high vaccine uptake. Finally, long-term productivity losses and wider economic effects are excluded.

Conclusion

This study shows that preventive health interventions in Ghana deliver substantial economic and health benefits, generally far exceeding their short- to mid-term costs. Discontinuing these programmes would result in significant collective losses. While the analysis shows that some interventions yield higher returns on investment than others, it is important to stress that all interventions play a crucial role in preventing disease, reducing healthcare costs, and protecting public health.

Interventions with lower short-term economic returns are essential for controlling outbreaks, safeguarding vulnerable groups, and maintaining overall population immunity. In addition, there may be additional reasons to continue vaccinating or reimbursing vaccination that go beyond the scope of this study.

Glossary

Case-Fatality Rate (CFR)

The proportion of individuals diagnosed with a particular disease who die from that disease within a specified period. It is expressed as a percentage and is commonly used to indicate the severity or lethality of a disease.

Disability-Adjusted Life Year (DALY)

A measure of overall disease burden, expressed as the number of years lost due to ill-health, disability, or early death. One DALY represents one lost year of "healthy" life.

Discount rate

The discount rate is the rate used to convert future costs and benefits into their present value. In cost-benefit analysis, it reflects the principle that a dollar today is worth more than a dollar in the future due to time preference and opportunity cost of capital. Applying a discount rate allows for consistent comparison of costs and benefits that occur at different points in time.

Gross Domestic Product (GDP)

The total monetary value of all goods and services produced within a country's borders in a specific time period.

Net Present Value (NPV)

A financial metric that calculates the present value of a series of future cash flows or benefits, discounted at a specified rate. In health economics, NPV is used to compare costs and benefits over time.

Out-of-pocket (OOP)

Direct payments made by individuals to healthcare providers at the time-of-service use, without reimbursement from insurance or other third-party payers.

Relative risk (RR)

A measure used in epidemiology to compare the risk of a certain event (such as disease or death) occurring in one group with the risk in another group, or in this study's case, the risk between two scenarios.

Return on investment (ROI)

A financial metric used to evaluate the financial return of an investment by comparing its gain or loss relative to its cost.

Unit costs

The total costs per vaccine administration, which includes the vaccine costs, injection supply costs, and delivery costs.

Value of a Statistical Life Year (VSLY)

An economic measure used to assign a monetary value to one year of human life.

1 Introduction

1.1 Background and study objectives

Ghana's health sector is undertaking new initiatives aimed at shifting the focus from curative care to preventive and promotive health. This approach recognises that prevention is better than cure, as preventive care stops a problem even before it arises. In the current package of care provided to Ghanaian citizens, health care and nutrition services are included, but they currently consist predominantly of curative care services with limited preventive services. These curative services include malaria and pneumonia treatment, baby delivery services, although the costs associated with nurse-administered immunisations are not covered. Vaccines are purchased centrally by the government and distributed to health facilities at no cost to the facilities. The only preventive care measure currently included is family planning and vaccinations, currently subsidised by the GAVI-alliance, which is gradually weaned off before 2030.[1]

Consequently, there is a need for gaining a better understanding of the quantitative benefits and costs of extending the existing package of care with additional preventive care and nutrition services. To inform evidence-based decision-making, this study conducts a robust an ex-ante, incremental CBA to quantify the economic and health-related impacts of 14 selected interventions, which are:

1. Routine immunisation with BCG vaccine
2. Routine immunisation with Pentavalent vaccine
3. Routine immunisation with Pneumococcal vaccine
4. Routine immunisation with Rotavirus vaccine
5. Routine immunisation with Malaria vaccine
6. Routine immunisation with Measles-Rubella vaccine
7. Routine immunisation with Yellow Fever vaccine
8. Routine immunisation with Meningitis A vaccine
9. Routine immunisation with HPV vaccine
10. Routine immunisation with birth dose for Hepatitis B

11a. Routine immunisation with OPV vaccine

11b. Routine immunisation with IPV vaccine as addition to the OPV vaccine

11. Child Vitamin A Supplementation
12. Micronutrient supplementation powders for children

This study is part of the wider study, "Fiscal Space Analysis to Assess the Availability of Financial Resources for the Primary Level Health and Nutrition Sector in Ghana", conducted by Ecorys on behalf of UNICEF.

1.2 Methodology

This study conducts a CBA to assess each of the 14 interventions. Two scenarios are compared:

- **Baseline:** The intervention continues at the coverage level expected in 2025.

[1] Kokutse, Francis, 'In Ghana, 25 Years of Gavi-supported Immunisation Inspires National Resolve to Keep Going', Gavi, the Vaccine Alliance, <www.gavi.org/vaccineswork/ghana-25-years-gavi-supported-immunisation-inspires-national-resolve-keep-going>, accessed 5 June 2025.

- **A no vaccination scenario:** The intervention stops completely from 2026 onwards. This means that every new group of eligible people (such as newborns or adolescent girls for the HPV vaccine) will not receive the intervention.

The CBA is based on a static population model that tracks the cumulative health impact of withdrawing each intervention from 2026 onwards. The model is described in more detail in **Appendix A**. To estimate the additional cases of illness, the study team first calculated how many cases would occur if no one were protected by the intervention. The study team did this by dividing the baseline number of cases by the proportion of the population that is unprotected. The study team then subtracted the number of cases actually observed in the baseline scenario. This approach shows the effect of reducing coverage rates from the baseline level to zero.

The economic evaluation considers two perspectives:

1. **Health sector perspective**, which captures direct medical expenditures borne by Ghana's health system;
2. **Societal perspective**, which captures the wider economic implications for individuals, households and the economy at large.

1.2.1 Key elements and inputs of the CBA

Several cost and benefit elements are modelled for each of the 14 interventions.[2] These are the programme expenditures of administering vaccines, the healthcare costs that follow adjusted disease incidence (differentiated between facility costs and treatment costs), productivity losses of the caregiver, premature mortality and years lived with disability. A summary and detailed description of the methodology and these elements can be found in **Appendix A**.

Two important results of the CBA are the Value of a Statistical Life Year (VSLY) and the Disability-Adjusted Life Year (DALY). VSLY represents the monetary value assigned to one additional year of life, derived from the value of a statistical life and adjusted for remaining life expectancy. It captures both tangible and intangible benefits of reducing mortality risk, such as wellbeing and productivity. DALY, on the other hand, measures the overall disease burden by combining years of life lost due to premature death and years lived with disability. In this analysis, each DALY is monetised using Ghana's GDP per capita in purchasing power parity, reflecting the economic value of a healthy life year.

Important inputs for the estimation of the CBA include demographic projections, economic indicators, disease burden estimates, intervention coverage and efficacy, and cost parameters. Where national data of Ghana are unavailable or incomplete, estimates are supplemented with information from comparable lower-middle-income countries (LMICs). An overview of the population of Ghana of age groups zero to ten between 2018 and 2023, which underlies the population growth in this study's simulation can be found in **Appendix B**.

All monetary values are expressed in 2025 US dollars (USD); no purchasing power parity (PPP) adjustments were applied. Future costs and benefits are discounted at 3 % per annum.[3] All cost input parameters were captured in USD. When source data pre-dated 2025, USD amounts were inflated to 2025 levels using a constant 2% annual inflator. If any source reported costs in another currency,

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2 Based on: Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.
and: Robinson, Lisa A., et al., *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development*, Harvard T.H. Chan School of Public Health, Boston, May 2019.

3 Robinson, Lisa A., et al., *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development*, Harvard T.H. Chan School of Public Health, Boston, May 2019.

values were first converted to USD using the average market exchange rate for the original reference year and then inflated to 2025 at 2% per year.

1.2.2 Scope of the study

This study is a hypothetical modelling exercise aimed at estimating the costs of halting vaccine subsidies in Ghana. While in reality a portion of the population may continue to access vaccines through out-of-pocket payments, for simplicity, the study team assumes that vaccine coverage drops to zero percent when subsidies are removed.

This study has not included herd immunity effects, which are critical for highly transmissible diseases such as measles and polio. Herd immunity occurs when high vaccination coverage reduces overall transmission, indirectly protecting unvaccinated individuals. By not modelling this effect, the analysis assumes constant transmission regardless of coverage, which understates the true protective and economic benefits of maintaining high vaccine uptake.

This study evaluates each intervention independently and does not model the potential negative synergistic effects that may occur if multiple vaccines are withdrawn simultaneously. In practice, removing several vaccines at once may lead to compounding adverse outcomes. By analysing interventions in isolation, the study may have underestimated the true health and economic losses associated with broad reductions in vaccine coverage. The siloed approach does not capture the compounding risks, and therefore presents a conservative estimate of the overall impact. Future research could consider integrated modelling approaches to better reflect these synergistic effects.

While this CBA provides valuable insights into the economic and health impacts of vaccination, it is important to acknowledge that the model does not include long-term productivity losses such as reduced lifetime earnings due to chronic illness, disability, or early death, even though productivity losses are partially captured through VSLY and DALY valuations. This likely leads to an underestimation of societal costs.

The analysis also excludes the effects of illness-related school absenteeism and its long-term consequences on educational attainment and future productivity, which may undervalue the broader developmental impact of vaccine-preventable diseases. Similarly, the model does not account for macroeconomic effects on GDP, such as reduced labour force participation, increased dependency ratios, and slower economic growth, which are particularly relevant in LMICs.

Additionally, where national data for Ghana were unavailable or incomplete, estimates were supplemented with information from comparable LMICs. It should be noted that these externally sourced data were not validated through expert stakeholder consultation, which may affect the reliability of some input parameters.

1.3 Reading guide

The conclusions of the 13 cost-benefit analyses are presented in Chapter 2. This is followed by the analyses of the 14 interventions, describing the intervention, the baseline situation, the no vaccination scenario, and a summary of the cost-benefit comparison per intervention. In the appendices, the detailed methodology and supporting figures are included.

2 Conclusions

The CBA conducted for 14 preventive health interventions in Ghana provides a multifaceted view of the economic and health-related consequences associated with the hypothetical discontinuation of each intervention. The analysis spans both five-year and ten-year horizons and evaluates outcomes using two distinct valuation approaches: mortality, as measured through the VSLY, and DALYs which capture the broader burden of disease including non-fatal outcomes. The findings offer a comprehensive overview of the relative impacts of discontinuing each intervention.

The following results should be interpreted within the context of the study's objective: to assess the economic and health-related losses resulting from the discontinuation of an intervention. Therefore, observed losses are viewed as evidence that maintaining the intervention yields short to longer term economic and health-related benefits for the population of Ghana.

Economic losses and gains - mortality

When mortality is considered, the analysis reveals that the majority of interventions would result in significant economic losses if discontinued. These losses are most pronounced for interventions targeting diseases with high fatality rates and widespread incidence. After five years, the largest net losses are associated with the Pneumococcal Conjugate Vaccine (PCV), the malaria vaccine, the pentavalent vaccine, and the Bacille Calmette-Guérin (BCG) vaccine, as is illustrated in **Figure 2.1.**

By the tenth year the magnitude of these losses increases substantially, as is illustrated in **Figure 2.2**. This reflects the compounding nature of disease burden over time when preventive measures are withdrawn, particularly for interventions that protect against diseases with high transmission rates and severe outcomes.

In contrast, a small number of interventions show modest net gains when mortality is the sole metric. These include the yellow fever vaccine, the meningitis A vaccine, the human papillomavirus (HPV) vaccine, and the combined oral and inactivated polio vaccines. The net gains over ten years are small, and are largely attributable to low disease incidence, high vaccine costs, or long latency periods before disease manifestation, as is the case with HPV, and should therefore be interpreted with caution.

Economic losses and gains - DALYs

When DALYs are monetised, the economic picture shifts further, amplifying the losses associated with high-burden diseases and interventions that prevent long-term disability. The DALY-based valuation captures not only premature mortality but also years lived with disability, offering a more holistic view of the societal burden, as illustrated in **Figure 2.1 and Figure 2.2** again.

After five years, the most substantial DALY-based losses are observed for PCV, malaria, pentavalent, and BCG. These large losses emphasise the importance of interventions that prevent diseases with high morbidity, even if mortality rates are relatively lower. By the tenth year, the DALY-based losses escalate markedly. PCV, malaria, pentavalent and BCG vaccine discontinuation lead to very large economic losses in a relatively short period of time. Other interventions such as rotavirus, measles-rubella, and vitamin A supplementation also show significant DALY-based losses.

Only a few interventions show net gains if discontinued when DALYs are included. These gains are again linked to low incidence, limited disability burden, or delayed onset of disease.

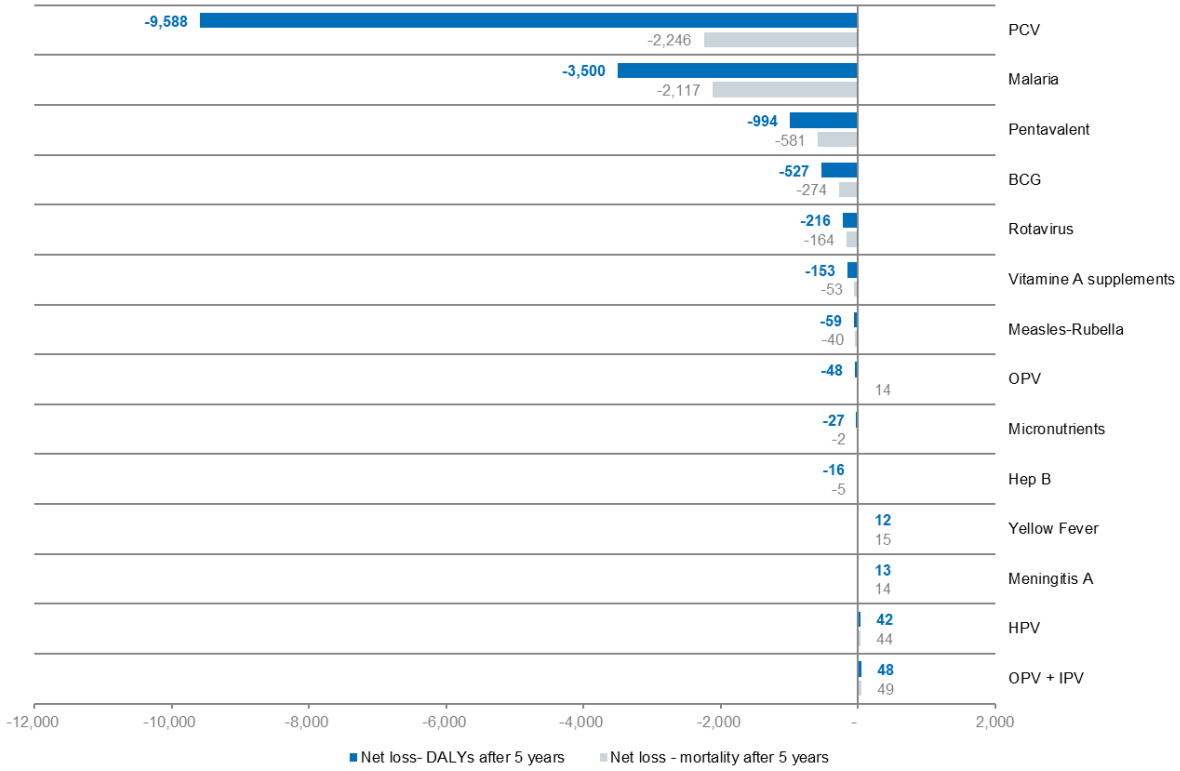
Comparative overview of interventions

The interventions that yield the highest economic returns, when both mortality and DALYs are considered, are those targeting diseases with high incidence, significant fatality rates, and substantial disability burdens. These include PCV, which protects against pneumonia and meningitis; the malaria vaccine, which addresses one of the leading causes of child mortality; the pentavalent vaccine, which covers five serious childhood diseases; and the BCG vaccine, which targets tuberculosis. These interventions consistently show the largest net losses when discontinued.

Interventions such as vitamin A supplementation and micronutrient powders also demonstrate strong economic returns, particularly when DALYs are considered. This makes sense given their small impact on mortality.

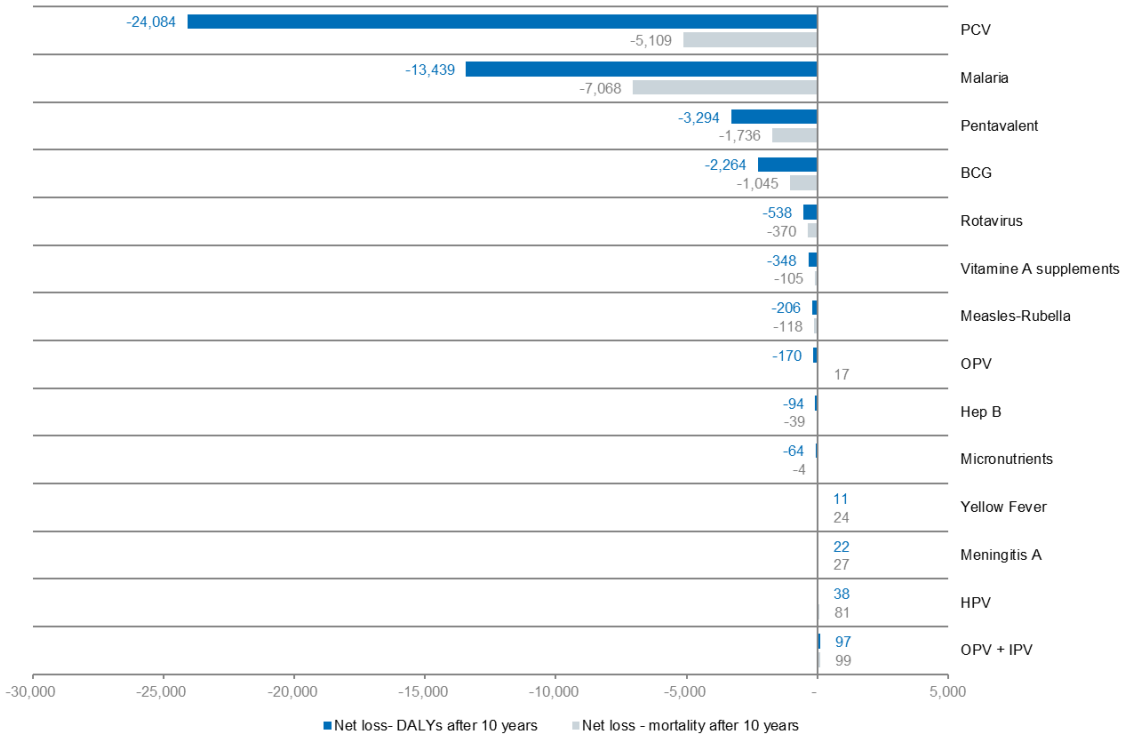
Conversely, interventions like yellow fever, meningitis A, and HPV show limited short- to medium-term economic returns, especially when only mortality is considered. However, these findings are sensitive to the time horizon and underlying assumptions. For example, the benefits of HPV vaccination accrue decades after initial infection, making short-term evaluations less informative.

Figure 2.1 NPV of each intervention over a five-year period, discounted at 3% in million USD*



* For HPV, the cost–benefit analysis assumes a 10-year time horizon due to lagged health effects.

Figure 2.2 NPV of each intervention over a ten-year period, discounted at 3% in million USD*



*The time horizon for HPV deviates due to the lagged health effects and is therefore here 20 years.

3 Routine immunisation with BCG vaccine

3.1 Description of the intervention

Neonatal Bacille Calmette-Guérin (BCG) vaccine offers protection against severe forms of tuberculosis (TB).[4,5,6] TB is an infectious disease caused by the bacillus *Mycobacterium tuberculosis*, which is transmitted through airborne particles expelled by individuals with active pulmonary TB.[7] It primarily affects the lungs but can also impact other parts of the body such as the brain, bones, and lymph nodes. Common symptoms include a persistent cough, fever, night sweats, fatigue, weight loss, and coughing up blood. If untreated, TB can lead to severe complications including meningitis and organ damage. Despite ongoing control efforts, Ghana continues to experience a high burden of TB, including drug-resistant strains and TB-HIV co-infections. TB is a leading cause of mortality from infectious disease, particularly affecting vulnerable populations such as children and individuals with compromised immune systems.[8]

The BCG vaccine is administered as a single intradermal injection, typically in the upper arm.[9] In line with the WHO recommendations, the vaccine is given at birth or as soon as possible thereafter.[10] The Ghana Health Service (GHS) immunisation schedule for infants includes administration of the BCG vaccine to neonates.[11,12] Vaccine efficacy varies considerably between studies, but in the context of this study the study team assumes it to be at 80%.[13]

3.2 Baseline situation

As of 2024, Ghana had achieved a national vaccination coverage of 94%.[14] According to the Ghana Immunisation Strategy for 2025-2030 tabled in **Appendix C**, the expected coverage rate until 2030 is 100%, which the study team uses as baseline coverage rate.[15] Assuming an 80% efficacy, the expected protected share of the newborn population in Ghana every year is estimated at 80% in the baseline scenario.[16]

Despite the high coverage, TB incidence remains substantial. In 2023, an estimated 43,000 new TB cases were reported, corresponding to an incidence rate of 129 cases per 100,000 population.[17] The

4 World Health Organization, 'BCG', <https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/vaccines-quality/bcg>.
5 World Health Organization, 'Bacillus Calmette–Guérin (BCG) vaccination coverage', <https://immunizationdata.who.int/global/wiise-detail-page/bacillus-calmette-gu%C3%A9rin-(bcg)-vaccination-coverage?CODE=GHA&YEAR=>.
6 UNICEF, 'Bacillus Calmette-Guérin (BCG) Market and Supply Update', UNICEF Supply Division, October 2023, p.<https://www.unicef.org/supply/media/22761/file/BCG-Market-update-october-2024.pdf>.
7 UNICEF, 'Bacillus Calmette-Guérin (BCG) Market and Supply Update', UNICEF Supply Division, October 2023, p.<https://www.unicef.org/supply/media/22761/file/BCG-Market-update-october-2024.pdf>.
8 World Health Organization Regional Office for Africa, *Country Disease Outlook: Ghana*, WHO AFRO, Brazzaville, August 2023, <www.afro.who.int/sites/default/files/2023-08/Ghana.pdf>.
9 UNICEF, 'Costs of Fully Vaccinating a Child – Countries Eligible for Gavi Vaccine Prices', August 2024, <https://www.unicef.org/media/161751/file/Standard%20costs%20of%20fully%20vaccinating%20a%20child_UNICEF_2024.pdf.pdf>
10 UNICEF, 'Bacillus Calmette-Guérin (BCG) Market and Supply Update', UNICEF Supply Division, October 2023, p.<https://www.unicef.org/supply/media/22761/file/BCG-Market-update-october-2024.pdf>.
11 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', *Public Health Challenges*, vol. 3, no. 2, 19 May 2024.
12 Aniagyei, Wilfred, et al., 'BCG Vaccination-Associated Lower HbA1c and Increased CD25 Expression on CD8+ T Cells in Patients with Type 1 Diabetes in Ghana', *Vaccines*, vol. 12, no. 5, 24 April 2024, p. 452.
13 Tran, V., J. Liu and M. A. Behr, 'BCG Vaccines', *Microbiology Spectrum*, vol. 2, no. 1, 2014, pp. MGM2–2013.
14 Government of Ghana, *Ghana National Immunization Strategy 2025–2030* (draft), as received by UNICEF via email, September 2025.
15 Ibid.
16 Tran, V., J. Liu and M. A. Behr, 'BCG Vaccines', *Microbiology Spectrum*, vol. 2, no. 1, 2014, pp. MGM2–2013.
17 World Health Organization, 'TB Report Mobile App – WHO 2024 Global Tuberculosis Report', Mobile app, <https://play.google.com/store/apps/details?id=uk.co.adappt.whotbreport&hl=en>.

incidence fluctuates across age groups and is compounded by co-infections with HIV and drug resistance (i.e. multidrug-resistant or rifampicin-resistant TB, abbreviated to MDR/RR-TB).[18] Of the estimated total of 12,200 TB-related deaths in Ghana in 2023, approximately 2,300 were among individuals living with HIV.[19] This study does not differentiate between HIV and non-HIV cases.

Vaccine costs in the baseline

Assuming the expected 100% coverage rate from 2026 and onwards of all newborns in Ghana, and considering that the unit costs are 2.86 USD, as tabled in **Appendix D**, the study team estimates a total current vaccination programme cost of roughly USD 2.5 million in 2025. This translates into an average cost of USD 2.86 per fully vaccinated child.[20] A summary of all cost and cost elements related to vaccination, as well as the sources used, can be found in **Appendix D**.

3.3 No vaccination scenario

If the programme were halted, the protected share of newborns would decline to zero percent. This would increase the size of the newborn population that is at risk of becoming infected of TB. According to our estimates, this would lead to an additional 1,800 TB cases in the first post-withdrawal year, compared to the baseline scenario.

Because unprotected infants grow into unprotected toddlers, pre-schoolers and so forth, the susceptible pool would continue to expand each year, driving a steadily rising paediatric TB burden for as long as vaccination remains suspended. After five years, this compounding effect would result in around 9,400 yearly additional cases relative to continued vaccination, and after 10 years the excess burden would exceed 20,000 yearly additional cases. Over the total span of 10 years, the simulation estimates a cumulative excess of approximately 105,000 paediatric TB cases.

Averted vaccine implementation costs

Halting the programme would avert the current vaccination costs, which is currently estimated at roughly USD 2.5 million per year. Correcting for a 2% annual inflation, this would rise to about USD 3.6 million by 2035.

Increased healthcare costs

Not everyone who has contracted TB seeks healthcare. Assuming that approximately 44% of all paediatric TB cases in Ghana actually seeks healthcare, which includes both hospitalisation and outpatient care. This leads to approximately an additional 800 cases in year one, 4,100 cases in year five, and 8,800 cases per year in year 10 after halting the intervention.[21] Over the total span of 10 years, the simulation estimates a cumulative excess of roughly 46,000 additional healthcare-seeking cases. Evidence from LMICs indicates that 14% of paediatric TB cases require hospital admission.[22]

The study team assumes that a stay for someone who contracted TB lasts on average 15 days.[23] The average cost of one TB case with hospitalisation is assumed to cost approximately USD 1,242.

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18 Ibid.
19 Ibid.
20 United Nations Children's Fund, *Standard Costs of Fully Vaccinating a Child: Countries Eligible for Gavi Vaccine Prices*, UNICEF, New York, August 2024, <www.unicef.org/media/161751/file/Standard%20costs%20of%20fully%20vaccinating%20a%20child_UNICEF_2024.pdf.pdf>.
21 World Health Organization, 'TB Report Mobile App – WHO 2024 Global Tuberculosis Report', Mobile app, <https://play.google.com/store/apps/details?id=uk.co.adappt.whotbreport&hl=en>
22 Cortez, A. O., A. C. Melo, L. O. Neves, K. A. Resende and P. Camargos, 'Tuberculosis in Brazil: One Country, Multiple Realities', *Jornal Brasileiro de Pneumologia*, vol. 47, no. 2, 2021, e20200119.
23 Ibid.

One outpatient TB case is estimated to cost approximately USD 13.[24,25] Weighing for the rate of hospitalisation of TB and the share of cases that seeks care, this leads to an average USD 178, which covers facility and treatment costs for (non-)hospitalised episodes.

This sums to an incremental health system burden of about USD 0.3 million in year one, and scales to approximately USD 1.9 million per year in year five and USD 4.5 million annually in year ten as successive unprotected birth cohorts accumulate. These costs fall on both government and households. Over the total 10-year horizon, the cumulative incremental health system burden amounts to roughly USD 18.3 million (net present value).

Increased productivity losses during illness

Childhood TB does not only affect the children who fall ill, it also imposes a substantial burden on their families, particularly caregivers. The study team assumes that when a child is hospitalised, their caregiver is absent from work for the entire 15-day hospital stay. For children treated as outpatients, the study team assumes that each episode results in one day of caregiver absence from work. Taking into account the proportion of TB cases that require hospitalisation, the study team estimates that, on average, each TB case results in 2.54 days of lost productivity for caregivers.

Altogether, the avoided cases spare families about 12 unpaid caregiving years in the first year, shielding largely low-income households from lost earnings. This would increase to cumulatively 65 years in the year 2030, and an estimated 140 lost caregiver years compared with the baseline scenario. Valuing time at GDP per-capita output per day, the implied productivity loss is approximately USD 30,000 in the first year, rising to USD 181,000 in 2030 and USD 450,000 in 2035 as annual case numbers climb. Over the total ten-year time horizon, the cumulative productivity loss is estimated to be more than USD 2.0 million.

Value of additional life years lost

Ghana's childhood TB case-fatality rate is estimated at 8%.[26] As vaccination coverage drops, and TB cases rise, so will the number of TB-related fatalities. Using a value-of-a-statistical-life-year (VSLY) approach, the net present value (NPV) of life-years lost from approximately 136 additional deaths in 2026 is USD 19 million. As incidence compounds, the NPV rises to approximately USD 109 million in 2030 and USD 262 million in 2035. These estimates reflect remaining life expectancy at age of death, which is assumed to be 65.5 years at birth and declines linearly with age.

Value of additional DALYs

Childhood TB carries an average disability weight of roughly 7.5 DALYs per case.[27] The additional TB cases therefore lead to an additional 13,500 DALYs after the first year of reduced vaccine coverage. This cumulates to an additional 210,000 DALYs after 5 years, and an additional 800,000 DALYs after 10 years. This accumulates to a monetised loss of approximately USD 31 million in 2026 only, a loss of USD 188 million after 5 years, and a loss of USD 467 million after 10 years.

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24 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

25 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

26 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

27 Ibid.

3.4 Conclusion

The analysis clearly demonstrates that discontinuing neonatal BCG vaccination in Ghana would result in substantial long-term costs, far outweighing the short-term savings from averted programme expenses. While the immediate financial gain from halting vaccinations is estimated at USD 3 million in the first year, this is set off by the cumulative burden of increased healthcare costs, productivity losses, and, most significantly, the value of life years and DALYs lost.

After one year without vaccination, the net economic loss is estimated at **USD 17 million** when considering mortality alone, and **USD 30 million** when DALYs are included. **By the tenth year**, the total net loss reaches **USD 1,046 million** based on mortality, **and USD 2,264 million** when accounting for DALYs.

When calculating the cost-to-benefits ratio, the study team finds that BCG yields an estimated economic return of USD 7 for every dollar spent in the first year, climbing to USD 40 by year ten including mortality alone. If the study team includes DALYs, this ratio increases to USD 12 for every dollar spent in year 1 and over USD 85 within a decade.

Table 3.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Averted vaccination costs	3	13	27
Averted health care costs	-0	-5	-18
Averted productivity loss during treatment	-0	-0	-2
Averted VSLY saved	-19	-281	-1,052
Value of averted DALYs	-32	-534	-2,270
Net gain or loss (only mortality)	**-17**	**-274**	**-1,046**
Net gain or loss (including DALYs)	**-30**	**-527**	**-2,264**
ROI (only mortality)	-7	-22	-40
ROI (including DALYs)	-12	-41	-86

4 Routine immunisation with Pentavalent vaccine

4.1 Description of the intervention

The intervention entails routine immunisation with the pentavalent vaccine. The pentavalent vaccine is a combination vaccine used to protect against five diseases, namely Diphtheria, Tetanus, Pertussis (Whooping Cough), Hepatitis B, and Haemophilus influenzae type B (Hib) and is an important protector against these diseases for children under the age of 5.[28]

These five diseases affect the health of those that are infected in various ways:[29]

- Diphtheria is a highly contagious bacterial infection transmitted through respiratory droplets, that can cause breathing difficulties, heart failure, and possibly death;
- Tetanus is a disease that enters the body through wounds and cuts and affects the central nervous system, causing muscle stiffness with potential breathing problems and possibly death;
- Pertussis is a respiratory disease that is highly contagious and leads to breathing problems and potentially fatality, especially in infants;
- Hepatitis B is a viral liver infection, transmitted by fluids and blood, a leading cause of liver cirrhosis and liver cancer;
- Hib is a deadly bacteria transmitted through sneezing and coughing, causing Hib disease, Hib pneumonia and Hib meningitis.

The pentavalent vaccine is primarily administered to infants and children younger than 2 years of age. The vaccine is administered as an intramuscular injection and consists of three doses, at six, 10, and 14 weeks of age, as noted in the GHS immunisation schedule for infants.[30,31] Vaccine efficacy differs across the different diseases the pentavalent protects against. In this study, an unweighted average of the various diseases is used as overall vaccine efficacy, which equals 87.2%.[32,33] This simplification likely overestimates efficacy against pertussis but provides a balanced approximation.

4.2 Baseline situation

As of 2024, Ghana's national coverage for the pentavalent vaccine was approximately 95%, a level expected to remain stable through 2030, as can be seen in **Appendix C.** This corresponds to about 800,000 infants receiving the full three-dose schedule annually, with numbers gradually increasing as the population grows. Assuming an average vaccine efficacy of 87.2% across the five diseases, this means that under baseline conditions, approximately 83% of the target population is effectively protected.

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28 Gavi, 'Pentavalent vaccine support', April 2024, <https://www.gavi.org/types-support/vaccine-support/pentavalent>.
29 Ibid.
30 UNICEF, 'Costs of Fully Vaccinating a Child – Countries Eligible for Gavi Vaccine Prices', August 2024, <https://www.unicef.org/media/161751/file/Standard%20costs%20of%20fully%20vaccinating%20a%20child_UNICEF_2024.pdf.pdf>.
31 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin, and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', *Public Health Challenges*, vol. 3, no. 2, 19 May 2024.
32 Ekrami Noghabi, M., M. J. Saffar, S. Rezai, H. Saffar, H. Saffar, F. Hosseinzadeh, A. Nadi Ghara and M. S. Rezai, 'Immunogenicity and Complications of the Pentavalent Vaccine in Iranian Children', *Frontiers in Pediatrics*, vol. 9, 2021, pp. 716779.
33 The various efficacies of the pentavalent vaccine are per disease: Diphtheria 94%, Pertussis 64%, Tetanus 100%, Hepatitis B 99%, Hib 80%.

The combined incidence of diphtheria, tetanus, pertussis, hepatitis B, and Hib varies by age group. Among children under one year of age, the **average estimated incidence of the five diseases** is approximately 1,658 cases per 100,000 population, declining to 861 cases per 100,000 among children aged one to five years, 401 cases per 100,000 among those aged five to nine years, and 1,863 cases per 100,000 among individuals older than ten years.[34,35]

Pertussis and hepatitis B account for the largest share of this burden, representing about 41.5% and 54.1% of cases respectively, while Hib, diphtheria, and tetanus contribute smaller proportions.[36]

Vaccine costs in the baseline scenario

The cost per fully vaccinated child is estimated at USD 11.09 in 2025, as can be found in **Appendix D**. Based on 95% projected coverage, this corresponds to a total programme cost of approximately USD 9.4 million in 2025, increasing to USD 11.3 million by 2030 and USD 13.5 million by 2035 as the birth cohort grows and inflation is considered.

4.3 No vaccination scenario

If routine pentavalent vaccination were discontinued, coverage would fall to zero%, leaving successive birth cohorts unprotected against diphtheria, tetanus, pertussis, hepatitis B, and Hib. In the first year following withdrawal, the model estimates approximately 73,000 additional cases across the five diseases combined, rising to about 240,000 cases annually by 2030 and roughly 350,000 cases by 2035 as unprotected cohorts accumulate and transmission intensifies. Over a ten-year horizon, this translates into an estimated cumulative excess of approximately 2,290,000 cases

Averted vaccine implementation costs

Halting the programme would avert current vaccination expenditures estimated at approximately USD 9.8 million in the first year, increasing to about USD 11.3 million by 2030 and USD 13.5 million by 2035 in line with cohort growth and price dynamics. Discounted over time, the NPV of averted programme costs is estimated at USD 48.1 million after five years and USD 97.8 million after ten years.

Increased healthcare costs

Care-seeking and clinical severity vary across the component diseases. The following parameters are considered:

34 Feikin, D. R., C. B. Nelson, J. P. Watt, E. Mohsni, J. D. Wenger and O. S. Levine, 'Rapid Assessment Tool for Haemophilus influenzae Type b Disease in Developing Countries', *Emerging Infectious Diseases*, vol. 10, no. 7, 2004, pp. 1270–1276.
35 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.
36 Ibid.

Table 4.1 Key parameters for the diseases that the pentavalent vaccine protects against

Disease	Percentage seeking care	Hospitalisation rate	Avg. length of stay (days)
Diphtheria	100%[37]	100%[38]	8[39]
Tetanus	100%[40]	95%[41]	10[42]
Pertussis	61%[43]	15%[44]	5[45]
Hepatitis B	2%[46]	1%[47]	5[48]
Hib	56%*[49]	10%*[50]	3*[51]

*For Hib these numbers were taken for pneumonia, as that is the main syndrome Hib protects against.

Weighting by their relative prevalence in the combined burden, the resulting average treatment cost is approximately USD 32.65 per case.[52,53] Applying this to the projected excess caseload yields incremental health-system outlays of about USD 2.5 million in year one, USD 8.8 million in 2030, and USD 14.6 million in 2035. Over the evaluation horizon, the discounted cumulative burden is estimated at USD 25.2 million after five years and USD 73.1 million after ten years.

Increased productivity losses during illness

Each hospitalised episode is assumed to remove a caregiver from work for the full average length of stay. After weighting by care-seeking, hospitalisation rates, and disease prevalence, this corresponds to an average productivity loss of 0.002 productive years per case. On this basis, families would forgo approximately 130 productive years in the first year, 420 in 2030, and 630 in 2035, accumulating to more than 4,000 years over ten years. Valued at GDP per-capita output per day, this implies losses of approximately USD 0.3 million in year one, USD 1.1 million in 2030, and USD 2.0 million in 2035, with discounted cumulative losses of about USD 3.2 million after five years and USD 9.8 million after ten years.

Value of additional life years lost

Mortality risk also differs across the five conditions. Using a weighted average case-fatality ratio of 0.6%, the programme interruption is projected to result in approximately 430 additional deaths in the

37 World Health Organization Regional Office for Africa, *Diphtheria Outbreaks: Comprehensive Guidance for the Public Health Preparedness and Response in the WHO African Region*, WHO:AFRO/EPR:2024-02, WHO, Brazzaville, February 2024.
38 Ibid.
39 Ibid.
40 Ohama, Victor Hideo, Alexandre Mantovani Bezerra, Eduardo Figueiredo de Castro and Sandra Regina Schwarzwälder Sprovieri, 'Tetanus Generates High Spending on Hospital Admissions', Faculty of Medical Sciences of Santa Casa de São Paulo, <https://fcmsantacasasp.edu.br/english/tetanus-generates-high-spending-on-hospital-admissions/>, accessed 16 June 2025.
41 Ibid.
42 Ibid.
43 Hesse, I.F., Mensah, A., Asante, D.K., Lartey, M., and Neequaye, A., 'Characteristics of Adult Tetanus in Accra', *West African Journal of Medicine*, vol. 22, no. 4, 2003, pp. 291–294, https://doi.org/10.4314/wajm.v22i4.28049.
44 Lopez, M.A., Cruz, A.T., Kowalkowski, M.A., and Raphael, J.L., 'Trends in hospitalizations and resource utilization for pediatric pertussis', *Hospital Pediatrics*, vol. 4, no. 5, 2014, pp. 269–275, https://doi.org/10.1542/hpeds.2013-0093.
45 Hesse, I.F., Mensah, A., Asante, D.K., Lartey, M., and Neequaye, A., 'Characteristics of Adult Tetanus in Accra', *West African Journal of Medicine*, vol. 22, no. 4, 2003, pp. 291–294, https://doi.org/10.4314/wajm.v22i4.28049.
46 Spearman, C.W., Andersson, M.I., Bright, B., et al., 'A New Approach to Prevent, Diagnose, and Treat Hepatitis B in Africa', *BMC Global Public Health*, vol. 1, no. 24, 2023, https://doi.org/10.1186/s44263-023-00026-1.
47 The study was not able to find a source on the hospitalisation rate and length of stay for Hepatitis B and has therefore made these assumptions.
48 Spearman, C.W., Andersson, M.I., Bright, B., et al., 'A New Approach to Prevent, Diagnose, and Treat Hepatitis B in Africa', *BMC Global Public Health*, vol. 1, no. 24, 2023, https://doi.org/10.1186/s44263-023-00026-1.
49 Williams, Sonja, Sarah Gousen and Carol DeFrances, *National Hospital Care Survey Demonstration Projects: Pneumonia Inpatient Hospitalizations and Emergency Department Visits*, National Health Statistics Reports, no. 116, National Center for Health Statistics, Hyattsville, MD, 24 August 2018.
50 Ibid. .
51 Ibid.
52 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.
53 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

first year, 1,400 per year by year five, and 2,100 per year by year ten.[5455] Valued using the VSLY approach, the NPV of life-years lost is approximately USD 60.1 million in the first year, rising to USD 212.5 million in 2030 and USD 351.6 million in 2035, with discounted cumulative totals of USD 600.7 million after five years and USD 1,751.2 million after ten years.

Value of additional DALYs

After weighting by disease prevalence, the average disability burden is estimated at 0.51 DALYs per case.[56,57] The additional caseload therefore produces approximately 37,400 DALYs in the first year, 121,400 in 2030, and 181,900 in 2035, cumulating to about 1.2 million DALYs over ten years. Monetised at the study's DALY valuation, this corresponds to losses of approximately USD 89.2 million in year one, USD 325.3 million in 2030, and USD 548.4 million in 2035, with discounted cumulative losses of USD 1,013 million after five years and USD 3,309 million after ten years.

4.4 Conclusion

The analysis demonstrates that discontinuing pentavalent vaccination would result in substantial health and economic consequences, outweighing the short-term savings from averted programme costs. While halting vaccination would save approximately USD 10 million in the first year and USD 98 million over ten years, these savings are offset by the cumulative burden of increased healthcare costs, productivity losses, and, most significantly, the value of life years and DALYs lost.

After one year without vaccination, the net economic loss is estimated at **USD 53 million** when considering mortality alone, and **USD 82 million** when DALYs are included. **By the tenth year**, the total net loss reaches **USD 1.74 billion** based on mortality, and **USD 3.29 billion** when accounting for DALYs. These figures emphasise the large impact of interrupting protection against five severe diseases.

When expressed as a cost-benefit ratio, discontinuation results in a strongly negative return: for every dollar spent, this leads to a loss of approximately 6 USD in the first year, worsening to USD 19 by year ten when considering mortality only, and USD 34 when DALYs are included.

Table 4.2 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	10	48	98
Total extra health care gains	-3	-25	-73
Total extra productivity gains during treatment	-0	-3	-10
VSLY saved	-60	-601	-1,751
Total value of DALYs averted	-89	-1,013	-3,309
Net gain or loss (only mortality)	**-53**	**-581**	**-1,736**
Net gain or loss (including DALYs)	**-82**	**-994**	**-3,294**
ROI (only mortality)	-6	-13	-19
ROI (including DALYs)	-9	-21	-34

54 World Health Organization Regional Office for the Eastern Mediterranean, 'Disease Burden: Haemophilus influenzae Type B', WHO EMRO, https://www.emro.who.int/health-topics/haemophilus-influenzae-type-b/disease-burden.html, accessed 12 June 2025.

55 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

56 Ibid.

57 World Health Organization Regional Office for the Eastern Mediterranean, 'Disease Burden: Haemophilus influenzae Type B', WHO EMRO, https://www.emro.who.int/health-topics/haemophilus-influenzae-type-b/disease-burden.html, accessed 12 June 2025.

5 Routine immunisation with Pneumococcal vaccine

5.1 Description of the intervention

The intervention includes the routine immunisation with the Pneumococcal Conjugate Vaccine (PCV) to protect against infections caused by *Streptococcus pneumoniae*. These include severe forms such as pneumonia, meningitis, and bacteraemia, but pneumococcal infections can also lead to less critical illnesses including sinusitis and otitis media.[58] The bacterium is mainly transmitted through respiratory droplets and colonises the human nasopharynx and knows up to 90 serotypes[59] The carriage of pneumococcal bacteria, or pneumococci, is associated with transmission and disease. *S. pneumoniae* is among the major causative organisms of meningitis in children of 1 month to 5 years of age, together with *Haemophilus influenzae* and *Neisseria meningitidis*.[60] [61] Simultaneously, *S. pneumoniae* is responsible for pneumonia cases and various other diseases depending on the serotype, which adds to the overall disease burden and complicates accurate attribution of illnesses to this bacterium.[62]

The primary target group of this intervention includes infants, which consists of 861,369 infants in Ghana in 2023.[63] The administration of the PCV is an intramuscular injection and follows a dosing schedule of three doses at six, 10 and 14 weeks of age in Ghana.[64,65] For the purposes of this study, vaccine efficacy is assumed to be 58%.[66]

5.2 Baseline situation

As of 2023, Ghana reached an average PCV vaccination coverage of 92%, which is expected to increase to 95% for the period 2025-2030, as can be seen in **Appendix C**. Given efficacy of 58%, this implies that roughly 55% of the target population is effectively protected in the baseline scenario.

For this analysis, the study team assumes an incidence of 844 per 100,000 people under the current high-coverage context.[67]

Vaccine costs at baseline

The average programme cost per fully vaccinated child is USD 17.78 in 2025, as can be found in **Appendix D.** With approximately 800,000 children vaccinated annually, total programme cost is USD

58 World Health Organization, 'Pneumococcal Conjugate Vaccines in Infants and Children under 5 Years of Age: WHO Position Paper – February 2019', *Weekly Epidemiological Record,* vol. 94–94, 22 February 2019, p. 85–104.
59 World Health Organization, 'Pneumococcal Conjugate Vaccines in Infants and Children under 5 Years of Age: WHO Position Paper – February 2019', *Weekly Epidemiological Record,* vol. 94–94, 22 February 2019, p. 85–104.
60 Kobayashi, Miwako, et al., 'Estimating the Economic Burden of Pneumococcal Meningitis and Pneumonia in Northern Ghana in the African Meningitis Belt Post-PCV13 Introduction', *Vaccine*, vol. 39, no. 33, 1 July 2021, p. 4685–4699.
61 Wahl, Brian, et al., 'Burden of Streptococcus Pneumoniae and Haemophilus Influenzae Type b Disease in Children in the Era of Conjugate Vaccines: Global, Regional, and National Estimates for 2000–15', *The Lancet Global Health*, vol. 6, no. 7, 13 June 2018, p. e744–e757.
62 World Health Organization, 'Pneumococcal Conjugate Vaccines in Infants and Children under 5 Years of Age: WHO Position Paper – February 2019', *Weekly Epidemiological Record,* vol. 94–94, 22 February 2019, p. 85–104.
63 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.
64 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin, and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', Public Health Challenges, vol. 3, no. 2, 19 May 2024.
65 Ibrahim, A. M., R. Owusu and J. Nonvignon, 'Sustainability of Pneumococcal Conjugate Vaccination in Ghana: A Cost-effectiveness Analysis in the Context of Donor Transition', *Frontiers in Public Health*, vol. 12, 2024, article 1383668.
66 Ibid.
67 Ibid.

15 million in 2025, rising to approximately USD 18 million by 2030 and approximately USD 22 million by 2035.

5.3 No vaccination scenario

If routine PCV vaccination were discontinued, coverage would drop to 0%, leaving all newborns unprotected. The number of susceptible children would rise quickly, increasing pneumococcal infections. In the first year following withdrawal, the model estimates approximately 183,000 additional cases. By 2030, the annual excess burden would reach approximately 383,000 cases, and by 2035 approximately 426,000 additional cases per year. Over ten years, the cumulative excess is approximately 3.6 million cases.

Averted vaccine implementation costs

Halting the programme would eliminate current vaccination expenditures: USD 15 million saved in year one, increasing to approximately USD 22 million by 2035 with inflation and demographic growth. Over ten years, the NPV (NPV) of averted vaccination costs is approximately USD 157 million.

Increased healthcare costs

Assuming that 55.5% of all cases seeks care, withdrawal of the vaccine yields approximately 100,000 additional healthcare-seeking cases in year one, approximately 212,000 in year five, and approximately 236,000 annually in year ten, totalling approximately 2 million extra treated cases over a decade.[68]

Of all cases, 10% require hospitalisation; the average hospital stay is 3 days.[69] Treatment costs are USD 248.46 per inpatient case and USD 13.30 per outpatient case.[70,71] Weighting by care-seeking and hospitalisation rates gives an average cost per case of USD 30.90. Resulting incremental health system costs are approximately USD 6 million in year one, approximately USD 13.6 million in 2030, and approximately USD 16.7 million in 2035; the ten-year NPV is approximately USD 109 million.

Increased productivity losses during illness

Illness imposes a substantial caregiving burden. Assuming caregivers lose 3 full workdays per hospitalised case and applying the provided weights, the model yields approximately 428 productive years lost in year one, approximately 898 in 2030, and approximately 997 in 2035, cumulating to more than 8,400 years over ten years. Valued at GDP per capita per day, this corresponds to approximately USD 1 million in year one, approximately USD 2.5 million in 2030, and approximately USD 3.2 million in 2035; the ten-year NPV is approximately USD 20 million.

Value of additional life years lost

For pneumococcal disease, the study team applies a case fatality ratio (CFR) of 1.1%.[72] Using the VSLY approach, the NPV of life-years lost is approximately USD 281 million in the first year, approximately USD 643 million in 2030, and approximately USD 775 million in 2035; the ten-year NPV is approximately USD 5.0 billion.

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68 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

69 Ibid.

70 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

71 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

72 Ibrahim, A. M., R. Owusu and J. Nonvignon, 'Sustainability of Pneumococcal Conjugate Vaccination in Ghana: A Cost-effectiveness Analysis in the Context of Donor Transition', *Frontiers in Public Health*, vol. 12, 2024, article 1383668.

Value of additional DALYs

Using an average of 2.42 DALYs per case, the additional cases imply approximately 440,000 DALYs in year one, approximately 930,000 in 2030, and approximately 1,000,000 in 2035, totalling approximately 8.7 million DALYs across ten years. Monetising these DALYs yields an estimated cumulative NPV of approximately USD 24 billion over the total ten-year time period.

5.4 Conclusion

The findings strongly indicate that halting routine PCV vaccination in Ghana would lead to significant long-term economic and health consequences, surpassing any short-term fiscal relief from reduced programme costs. Although the initial savings from discontinuing the vaccine are estimated at USD 15 million in the first year, these are quickly offset by increased healthcare expenditures (USD 6 million), productivity losses (USD 1 million), and mortality-related costs (USD 17 million). This results in a net economic deficit of approximately USD 9 million in year one, based on mortality alone.

Looking ahead, the annual mortality-only net loss escalates to **USD 2,246 million** by **2030** and reaches **USD 5,109 million** by **2035** when considering mortality only. Over a ten-year horizon, the cumulative net loss is projected at **USD 9.6 billion after five years**, and **USD 24.1 billion after ten years** when DALYs are monetised.

From a cost-benefit perspective, maintaining PCV coverage yields an estimated return of USD 18 for every dollar invested in the first year. Over ten years, this return grows to 34 per dollar based on mortality alone, and up to USD 154 per dollar when DALYs are included.

Table 5.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	15	77	157
Total extra health care gains	-6	-48	-109
Total extra productivity gains during treatment	-1	-9	-20
VSLY saved	-281	-2,266	-5,136
Total value of DALYs averted	-1,057	-9,608	-24,111
Net gain or loss (only mortality)	**-272**	**-2,246**	**-5,109**
Net gain or loss (including DALYs)	**-1,048**	**-9,588**	**-24,083**
ROI (only mortality)	-18	-30	-34
ROI (including DALYs)	-68	-125	-155

6 Routine immunisation with Rotavirus vaccine

6.1 Description of the intervention

Routine immunisation with the Rotavirus vaccine aims to protect infants against rotavirus gastroenteritis, a leading cause of severe diarrhoea and vomiting in young children. Rotavirus infection primarily affects the intestines and is responsible for a significant proportion of acute gastroenteritis cases and diarrhoea-related deaths globally. Transmission occurs predominantly via the faecal-oral route, either directly through person-to-person contact or indirectly through contaminated food and water sources. The disease burden is highest among children under the age of five, with severe cases often resulting in dehydration, hospitalisation, and in some instances, death.[73,74,75]

The Rotavirus vaccine is administered orally in the form of liquid drops. Depending on the vaccine brand, the full course consists of either two or three doses. [76] In Ghana, the GHS immunisation schedule includes two doses: the first at six weeks of age and the second at ten weeks. [77] This schedule aligns with WHO recommendations and is designed to provide early protection during the most vulnerable period of infancy. For the purposes of this study, vaccine efficacy is assumed to be 65% for fully vaccinated children.[78]

6.2 Baseline situation

As of 2024, Ghana had achieved a national Rotavirus vaccination coverage of approximately 67%, which is expected to rise to 95%, as can be seen in **Appendix C**, with an estimated 800,000 infants vaccinated annually. Assuming a vaccine efficacy of 65%, this translates to a protected share of roughly 62% of the newborn population each year under the baseline scenario.

Despite high coverage, the estimated incidence rate in 2023 was 10,000 cases per 100,000 population. Of these, approximately 9,290 were classified as non-severe rotavirus gastroenteritis cases, while 710 were severe cases requiring medical attention.[79] For the sake of the study, these incidence rates were kept constant over the years for the baseline scenario.

Vaccine costs at baseline

In terms of programme costs, the average cost per fully vaccinated child is estimated at USD 9.60 in 2025, as is tabled in **Appendix D**. With approximately 800,000 children vaccinated annually, the total programme cost is projected at USD 8 million in 2025. Accounting for inflation and scale-up, this

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73 World Health Organization, *Rotavirus Vaccines: WHO Position Paper – July 2021*, *Weekly Epidemiological Record*, vol. 96, no. 28, 16 July 2021, pp. 301–319, WHO, Geneva, <https://www.who.int/wer>.

74 Nonvignon, Justice, et al., 'Cost-Effectiveness of Rotavirus Vaccination in Ghana: Examining Impacts from 2012 to 2031', *Vaccine*, vol. 36, no. 47, 6 December 2017, p. 7215–7221. https://doi.org/10.1016/j.vaccine.2017.11.080.

75 Avoka, James A., et al., "Time Series Analysis of the Relationship between Diarrhea in Children and Rota 2 Vaccine in the Fanteakwa District of the Eastern Region of Ghana', *BMC Pediatrics*, vol. 21, no. 1, 19 February 2021. https://doi.org/10.1186/s12887-021-02540-3.

76 Nonvignon, Justice, et al., 'Cost-Effectiveness of Rotavirus Vaccination in Ghana: Examining Impacts from 2012 to 2031', *Vaccine*, vol. 36, no. 47, 6 December 2017, p. 7215–7221. https://doi.org/10.1016/j.vaccine.2017.11.080.

77 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin, and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', *Public Health Challenges*, vol. 3, no. 2, 19 May 2024. https://doi.org/10.1002/puh2.176.

78 Prunas, Ottavia, *et al.*, *Global Estimates of Rotavirus Vaccine Efficacy and Effectiveness: A Rapid Review and Meta-Regression Analysis*, *eClinicalMedicine*, vol. 81, 2025, Art. 103122.

79 Nonvignon, J., D. Atherly, C. Pecenka, M. Aikins, L. Gazley, D. Groman, C. T. Narh and G. Armah, 'Cost-effectiveness of Rotavirus Vaccination in Ghana: Examining Impacts from 2012 to 2031', *Vaccine*, vol. 36, no. 47, 2018, pp. 7215–7221.

figure is expected to rise to nearly USD 10 million by 2030 and approximately USD 12 million by 2035.

6.3 No vaccination scenario

If routine rotavirus vaccination were discontinued, coverage would fall to 0%, leaving all newborns unprotected. In the first year following withdrawal, the model estimates an additional 25,000 cases, including approximately 1,800 severe cases. By 2030, the annual excess burden would reach 74,000 cases (around 5,000 severe), and by 2035, approximately 80,000 additional cases per year, of which 6,000 would be severe. Over a ten-year horizon, this scenario would lead to a cumulative 700,000 extra cases, including 50,000 severe cases.

Averted vaccine implementation costs

Halting the programme would eliminate current vaccination expenditures, estimated at USD 8.5 million in the first year, rising to USD 11.6 million by 2035 due to inflation and demographic growth. Over the ten-year period, the NPV of averted vaccination costs is approximately USD 84.7 million.

Increased healthcare costs

Not all infected children seek care. Assuming that 20% of all cases seeks care, the withdrawal would result in about 9,000 additional healthcare cases in the first year, 26,000 in year five, and 29,000 annually in year ten, totalling 253,000 extra cases over the decade.[80]

One in 65 cases are hospitalised, and the average hospital stay is one day.[81] Treatment costs are estimated at USD 82.72 per inpatient case and USD 13.30 per outpatient case.[82,83] When weighted by care-seeking and hospitalisation rates, the average cost per rotavirus case is USD 3.73. This translates into an incremental health system burden of USD 0.1 million in year one, USD 0.3 million in 2030, and USD 0.4 million in 2035, with a cumulative NPV of USD 2.6 million over ten years.

Increased productivity losses during illness

Severe rotavirus episodes impose a significant caregiving burden. Assuming caregivers lose one full workday per hospitalised case, and weighting for hospitalisation rates, the average productivity loss is 0.02 productive years per case. This equates to approximately 400 productive years lost in year one, 1,100 in 2030, and 1,300 in 2035, accumulating to more than 11,000 years over ten years. Valued at GDP per capita per day, this represents USD 1 million in the first year, USD 3.2 million in 2030, and USD 4 million in 2035, with a cumulative NPV of USD 27 million.

Value of additional life years lost

Rotavirus mortality is concentrated among severe cases, with an estimated case fatality ratio of 6.5%.[84] As severe cases rise, so do deaths. Using the VSLY approach, the NPV of life-years lost is estimated at USD 17 million in the first year, USD 52 million in 2030, and USD 63 million in 2035, with a cumulative NPV of approximately USD 425 million over ten years.

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80 Parashar, U.D., Hummelman, E.G., Bresee, J.S., Miller, M.A., and Glass, R.I., 'Global Illness and Deaths Caused by Rotavirus Disease in Children', *Emerging Infectious Diseases*, vol. 9, no. 5, 2003, pp. 565–572, https://doi.org/10.3201/eid0905.020562.

81 Ibid.

82 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

83 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

84 Nonvignon, J., D. Atherly, C. Pecenka, M. Aikins, L. Gazley, D. Groman, C. T. Narh and G. Armah, 'Cost-effectiveness of Rotavirus Vaccination in Ghana: Examining Impacts from 2012 to 2031', *Vaccine*, vol. 36, no. 47, 2018, pp. 7215–7221.

Value of additional DALYs

Each rotavirus case carries an average disability weight equivalent to 0.31 DALYs.[85] The additional cases therefore result in 7,800 DALYs in the first year, 23,000 in 2030, and 25,000 in 2035, cumulating to 215,000 DALYs over ten years. Monetising these DALYs yields an estimated loss of USD 18.7 million in year one, USD 60.8 million in 2030, and USD 76.2 million in 2035, with a cumulative NPV of USD 593 million.

6.4 Conclusion

The analysis demonstrates that discontinuing routine rotavirus vaccination in Ghana would result in substantial economic and health losses, outweighing the short-term savings from averted programme costs. While halting vaccination would save approximately USD 8 million in the first year, these savings are eclipsed by the cumulative burden of increased healthcare costs, productivity losses, and, most significantly, the value of life years and DALYs lost.

After one year without vaccination, the net economic loss is estimated at **USD 9 million** when considering mortality alone, and **USD 11 million** when DALYs are included. **By the tenth year**, the total net loss reaches **USD 370 millio**n based on mortality, and **USD 538 million** when accounting for DALYs.

When expressed as a cost-benefit ratio, maintaining rotavirus vaccination yields an estimated economic return of over USD 2 for every dollar spent in the first year, rising to USD 5 by year ten when considering mortality only. Including DALYs, this ratio increases further to 7 USD after ten years.

Figure 6.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	8	42	85
Total extra health care gains	-0	-1	-3
Total extra productivity gains during treatment	-1	-12	-27
VSLY saved	-17	-193	-425
Total value of DALYs averted	-19	-244	-593
Net gain or loss (only mortality)	**-9**	**-164**	**-370**
Net gain or loss (including DALYs)	**-11**	**-216**	**-538**
ROI (only mortality)	-2	-5	-5
ROI (including DALYs)	-2	-6	-7

[85] Ibid.

7 Routine immunisation with Malaria vaccine

7.1 Description of the intervention

The intervention includes routine immunisation with the malaria vaccines (RTS,S/AS01 and R21/Matrix-M) to protect against malaria, a potentially deadly infectious disease. The Plasmodium falciparum parasite is the predominant malaria parasite in Ghana, which is transmitted by infected mosquitoes.[86] Infection by the parasite causes destruction of red blood cells, and can lead to anaemia, high fever, vomiting, diarrhoea, impaired consciousness, jaundice, multiple convulsions, coma, and possibly death.[87] [88] Children are less likely than adults in endemic regions to have acquired immunity against malaria, making infants and children under 5 years of age predominantly susceptible to malaria infections.[89] Moreover, people at higher risk for malaria are pregnant women, travellers, and people with HIV or AIDS.[90]

This intervention primarily targets infants, with a target group of approximately 900,000 infants in Ghana in 2023.[91] The vaccine is administered by intramuscular injection, given in multiple doses. Both RTS,S/AS01 and R21/Matrix-M vaccines are implemented in Ghana's immunisation programme efforts, depending on the region and availability.[92] [93] [94] Both malaria vaccines should be administered in a schedule of four doses starting at 5 months of age, with a minimum 4-week interval between doses and a last dose one year later.[95] [96] This study assumes 39% vaccine effectiveness (VE) for the analysis.[97]

7.2 Baseline situation

Ghana continues to carry a high malaria burden, with malaria ranked among the country's top three diseases seen in outpatient departments.[98] Numerous efforts have been undertaken by the Ghanaian Ministry of Health to reduce the burden of Malaria. In 2023, the vaccination coverage in Ghana reached 70% for the 3rd dose, and 46% for all four doses.[99] This study assumes four-dose coverage

86 Ministry of Health, Ghana Health Service, and National Malaria Elimination Programme, *National Malaria Elimination Strategic Plan (NMESP) 2024–2028*, Ministry of Health, Accra, Ghana, 2023, <https://nmcp.gov.gh>.

87 Oshagbemi, Olorunfemi A., et al., 'Estimated distribution of malaria cases among children in sub-saharan Africa by specified age categories using data from the Global Burden of Diseases 2019', *Malaria Journal*, vol. 22, no. 1, 5 December 2023. https://doi.org/10.1186/s12936-023-04811-z.

88 World Health Organization, 'Malaria', WHO Newsroom, 11 December 2024. <https://www.who.int/news-room/fact-sheets/detail/malaria>.

89 Oshagbemi, Olorunfemi A., et al., 'Estimated distribution of malaria cases among children in sub-saharan Africa by specified age categories using data from the Global Burden of Diseases 2019', *Malaria Journal*, vol. 22, no. 1, 5 December 2023. https://doi.org/10.1186/s12936-023-04811-z.

90 World Health Organization, 'Malaria', WHO Newsroom, 11 December 2024. <https://www.who.int/news-room/fact-sheets/detail/malaria.>

91 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.

92 UNICEF, 'Ghana Expands Malaria Vaccine Rollout', Ghana, News note, 24 September 2024 <https://www.unicef.org/ghana/press-releases/ghana-expands-malaria-vaccine-rollout.>.

93 Ampomah, Samuel, and Samuel Ampomah, 'GHANA HAS EXPANDED THE MALARIA VACCINE EXERCISE', Ministry of Health, 21 February 2023. <https://www.moh.gov.gh/ghana-has-expanded-the-malaria-vaccine-exercise/>.

94 World Health Organization, 'Malaria Vaccines (RTS,S and R21)', 8 April 2025. <https://www.who.int/news-room/questions-and-answers/item/q-a-on-rts-s-malaria-vaccine>.

95 Ibid.

96 World Health Organization, 'Malaria Vaccine Implementation Programme (MVIP) – Safety updates on Malaria vaccines', WHO Weekly Epidemiological Record, 11 August 2023. <https://www.who.int/groups/global-advisory-committee-on-vaccine-safety/topics/malaria-vaccines/malaria-vaccine-implementation-programme#:approximately :text=The%20vaccination%20coverage%20for%20one,for%20April%20to%20June%202021>.

97 World Health Organization, *Phase 3 trial results for malaria vaccine RTS,S/AS01*, 7 April 2017, Questions and answers, WHO, Geneva, accessed 3 June 2025.

98 Ministry of Health, Ghana Health Service, and National Malaria Elimination Programme, *National Malaria Elimination Strategic Plan (NMESP) 2024–2028*, Ministry of Health, Accra, Ghana, 2023, <https://nmcp.gov.gh>.

99 World Health Organization, 'Malaria vaccination coverage – Ghana, 2023-2023', Immunization Data. < https://immunizationdata.who.int/global/wiise-detail-page/malaria-vaccination-coverage?CODE=GHA&ANTIGEN=MALARIA4&YEAR=>.

rates to increase to approximately 70% from 2026–2030 in the baseline scenario, as can be seen in **Appendix C**.

Assuming a vaccine efficacy of 39%, this translates to a protected share of roughly 19.5% of the target population in 2025 and about 27% from 2026 onward under the baseline scenario.[100]

Vaccination costs at baseline

Assuming 70% coverage of newborns and unit costs of approximately USD 57 as is tabled in **Appendix D** per fully vaccinated child, the programme is expected to cost about USD 36 million in 2026.

This study assumes an indicative incidence of approximately 0.2 episodes per person-year (2023), corresponding to roughly 7 million new cases in 2025.[101]

7.3 No vaccination scenario

If routine vaccination ceases, the protected share of newborns drops to zero, expanding the cohort susceptible to malaria infection. In the simulation, this produces approximately 200,000 additional malaria cases in the first year relative to baseline, approximately 1.0 million additional cases per year by year five, and more than 1.7 million per year by year ten compared to the baseline. Over a 10-year horizon, this accumulates to approximately 10 million excess malaria cases compared to a scenario in which 70% coverage is maintained.

Averted implementation costs

Halting the programme would avert approximately USD 36 million per year initially. With 2% annual inflation and population growth, this rises to approximately USD 50 million by 2035. These are immediate budget savings assuming government financing of vaccine procurement and delivery under baseline.

Increased healthcare costs

Assuming that about 69% of malaria cases in Ghana seeks healthcare, this translates into approximately 140,000 additional healthcare-seeking episodes in the first year, approximately 739,000 in year five, and approximately 1.2 million annually in year ten after halting the programme.[102] Over ten years in total, the simulation points to more than 7 million additional healthcare-seeking cases.

Based on evidence from low- and middle-income setting, this study assumes that approximately 1.9% of malaria cases require hospital admission.[103] The study team assumes an average hospital stay of 2-3 days for malaria.[104] The cost per inpatient episode is approximately USD 165, and approximately USD 13 per outpatient episode.

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100 World Health Organization, 'Malaria: Phase 3 Trial Results for Vaccine RTS,S/AS01', www.who.int/news-room/questions-and-answers/item/phase-3-trial-results-for-malaria-vaccine-rtss-as01>, accessed 4 June 2025.

101 Oshagbemi, Olorunfemi A., et al., 'Estimated distribution of malaria cases among children in sub-saharan Africa by specified age categories using data from the Global Burden of Diseases 2019', *Malaria Journal*, vol. 22, no. 1, 5 December 2023. https://doi.org/10.1186/s12936-023-04811-z..

102 Based on care-seeking behaviour of fever. Lewis, T.P., Ndiaye, Y., Manzi, F., and Kruk, M.E., 'Associations Between Women's Empowerment, Care Seeking, and Quality of Malaria Care for Children: A Cross-Sectional Analysis of Demographic and Health Surveys in 16 Sub-Saharan African Countries', *Journal of Global Health*, vol. 12, 19 March 2022, article 04025, https://jogh.org/2022/jogh-12-04025.

103 Kabuya, J.B.B., Bond, C., Hauser, M., Sikalima, J., Phiri, B., Phiri, D., Matoba, J., Hughes, J., Banda, P.M., Lupiya, J.S., Chongwe, G., Thuma, P.E., Moss, W.J., and Ippolito, M.M., 'Supplementing Routine Hospital Surveillance of Malaria to Capture Excess Mortality and Epidemiological Trends: A Five-Year Observational Study', *Frontiers in Malaria*, vol. 2, April 2024, article 1340276.

104 Moffitt, C.A., Olupot-Olupot, P., and Onen, J.W., 'Adherence to Severe Malaria Treatment Guidelines in Children at a Ugandan Regional Hospital: A Baseline Assessment for a Malaria Treatment Quality Improvement Project', *Malaria Journal*, vol. 22, 25 February 2023, article 67, https://doi.org/10.1186/s12936-023-04507-4.

Weighting by the hospitalisation rate and the care-seeking share yields an average cost of approximately USD 12 per incident case (i.e. including non-seekers).[105,106] This amounts to an incremental health system burden of approximately USD 2.6 million in year one, rising to approximately USD 14.8 million per year by 2030 and approximately USD 26.7 million per year by 2035 as unprotected cohorts accumulate. Cumulatively over ten years, the NPV of the incremental burden is approximately USD 126.4 million.

Increased productivity losses during illness

Caring for a sick child removes caregivers from paid/unpaid productive activities. The study team assumes 2 days of caregiver time per inpatient episode and 1 day per outpatient episode. Given the hospitalisation and care-seeking rates, this corresponds to approximately 0.728 caregiver-days lost per incident case on average.

With the simulated excess incidence, this equates to approximately 401 caregiver-years lost in year 1, approximately 2,135 years by 2030, and approximately 3,480 years by 2035 (annual). Valued at GDP per-capita output per day, the implied productivity loss is approximately USD 1.0 million in the first year, rising to approximately USD 6 million in 2030 and approximately USD 11 million in 2035. Cumulative over ten years, the NPV of the lost productivity is estimated to be more than USD 53 million.

School absenteeism

Given malaria's high disease burden, it is important to consider not only productivity losses among parents but also the effects on children. To maintain methodological consistency, these effects are not included in the final CBA calculations; however, it is worth noting their relevance. Estimates for Africa suggest malaria accounts for roughly 5–8% of all school absences: about half of all preventable absenteeism.[107] Recurrent fever episodes, anaemia, convalescence, and clinic visits reduce instructional time and risk learning setbacks. Sustained efforts to reduce malaria prevalence are therefore likely to support continuity in schooling and yield long-term benefits for human capital and future productivity.

Value of additional life years lost

Using a child malaria case-fatality rate of 0.5%, the simulated excess incidence yields approximately 991 additional deaths in 2026.[108] Valued via the VSLY approach, the NPV of life-years lost is approximately USD 138 million in 2026, rising to approximately USD 802 million (annual) by 2030 and approximately USD 1.46 billion (annual) by 2035. These estimates incorporate remaining life expectancy assumed at 65 years at birth, declining linearly with age.

Value of additional DALYs

At an average DALY loss of approximately 0.45 per malaria case, the additional cases imply an addition of approximately 90,000 DALYs lost in year 1, approximately 480,000 DALYs lost in year 5, and approximately 780,000 DALYs lost in year 10 (annual).[109] Over ten years, this cumulates to approximately 4.8 million DALYs lost compared to the baseline scenario. Monetising DALYs as

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105 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

106 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

107 Halliday, K. E. et al. (2020). Impact of school-based malaria case management on school attendance, health and education outcomes: A cluster randomised trial in southern Malawi. BMJ Global Health, 5(1).

108 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

109 Ibid.

specified in the methodology gives approximately USD 214 million (2026), approximately USD 3.6 billion (year-5 cumulative), and approximately USD 13.6 billion (year-10 cumulative).

7.4 Conclusions

The evidence clearly shows that discontinuing routine malaria vaccination in Ghana would result in substantial and growing economic losses. While the first-year savings from averted vaccination expenses are estimated at USD 36 million, these are quickly offset by increased healthcare costs (USD 3 million), productivity losses during treatment (USD 1 million), and mortality-related losses amounting to USD 138 million. This leads to a net economic loss of **USD 142 million in year one** when considering mortality alone, and **USD 181 million** when DALYs are included.

Over time, the impact intensifies. **By year five, the net loss reaches USD 2.1 billion** based on mortality, and **USD 3.5 billion** when DALYs are monetised. **After a decade**, the cumulative net loss climbs to **USD 7.07 billion** (mortality only) and **USD 13.44 billion** when DALYs are included.

When expressed as a cost-benefit ratio, maintaining malaria vaccination yields an estimated economic return of over USD 4 for every dollar spent in the first year, rising to USD 19 by year ten when considering mortality only. Including DALYs, this ratio increases further to 38 USD after ten years. These estimates are conservative, as they exclude the longer-term economic costs of malaria-related school absenteeism on children's human capital and later-life earnings.

Table 7.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	36	179	364
Total extra health care gains	-3	-38	-126
Total extra productivity gains during treatment	-1	-15	-53
VSLY saved	-138	-2,063	-6,889
Total value of DALYs averted	-214	-3,625	-13,624
Net gain or loss (only mortality)	**-142**	**-2,117**	**-7,068**
Net gain or loss (including DALYs)	**-181**	**-3,500**	**-13,439**
ROI (only mortality)	-4	-12	-19
ROI (including DALYs)	-6	-21	-38

8 Routine immunisation with Measles-Rubella vaccine

8.1 Description of the intervention

The intervention consists of routine immunisation with the measles-rubella (MR) vaccine to protect against two highly contagious viral diseases: measles and rubella. Measles is transmitted through respiratory droplets and typically presents with fever, cough, conjunctivitis, and coryza.[110] While often self-limiting, measles can lead to severe complications such as pneumonia, otitis media, diarrhoea, blindness, and encephalitis, which can result in long-term disability or death.[111,112]

Rubella, also transmitted via respiratory droplets, generally causes mild illness in children, with symptoms including low-grade fever, rash, and mild conjunctivitis. [113,114] However, rubella infection during pregnancy carries a 90% risk of vertical transmission, which can result in miscarriage, stillbirth, or congenital rubella syndrome (CRS).[115] CRS is associated with severe birth defects, including blindness, deafness, intellectual disabilities, and congenital heart disease, making rubella the leading vaccine-preventable cause of birth defects globally.[116,117]

The MR vaccine is administered subcutaneously and targets children under 18 months of age. In Ghana, the routine immunisation schedule recommends two doses: the first at 9 months and the second at 18 months.[118,119] Vaccine effectiveness is high:[120]

- Measles: 93% after the first dose and 97% after the second dose.
- Rubella: 97% after the first dose and 100% after the second dose.

8.2 Baseline situation

As of 2025, Ghana's national coverage for the first and second doses of the measles-rubella (MR) vaccine is estimated at 95%, a level expected to remain stable through 2030, as can be seen in **Appendix C**. This corresponds to approximately 800,000 children receiving each dose annually, with numbers increasing gradually as the population grows. Assuming the earlier mentioned vaccine efficacy, this means that under baseline conditions, about 88% of children are protected after the first dose, and 92% after completing the second dose.

Measles and rubella are highly contagious diseases, and even small immunity gaps can lead to outbreaks. Between 2018 and 2024, the average incidence of measles was approximately 25 cases

110 World Health Organization, *Measles Outbreak Guide*, Geneva, 2022.
111 World Health Organization, 'Measles and Rubella WPRO', 27 August 2018, <https://www.who.int/westernpacific/health-topics/measles#tab=tab_2>.
112 World Health Organization, *Measles Outbreak Guide*, Geneva, 2022.
113 World Health Organization, *Introducing Rubella Vaccine into National Immunization Programmes: A Step-by-step Guide*, Department of Immunization, Vaccines and Biologicals, Geneva, September 2015, pp. 1-4.
114 World Health Organization, 'Measles and Rubella WPRO', 27 August 2018, <https://www.who.int/westernpacific/health-topics/measles#tab=tab_2>.
115 Ibid.
116 World Health Organization, *Introducing Rubella Vaccine into National Immunization Programmes: A Step-by-step Guide*, Department of Immunization, Vaccines and Biologicals, Geneva, September 2015, pp. 1-4.
117 World Health Organization, 'Measles and Rubella WPRO', 27 August 2018, < https://www.who.int/westernpacific/health-topics/measles#tab=tab_1>.
118 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.
119 Mohammed, Abdul G., et al., 'Coverage and Predictors of Full Measles-Rubella Immunization among Children Aged 24–59 Months in Northern Ghana: A Post Measles Outbreak Assessment', *BMC Public Health*, vol. 25, no. 1, 9 May 2025. https://doi.org/10.1186/s12889-025-22940-9.
120 Centers for Disease Control and Prevention, *Measles Vaccination*, U.S. Department of Health & Human Services, Atlanta, updated 2025, accessed 3 June 2025.

per 100,000 population, which is used as the baseline incidence for this analysis. For rubella, this was on average 1.6 cases per 100.000 population.[121]

Vaccine costs in the baseline scenario

The cost per fully vaccinated child is estimated at USD 3.07 in 2025, as tabled in **Appendix D**. Based on projected coverage, this corresponds to a total programme cost of approximately USD 2.6 million in 2026, increasing to USD 3.8 million by 2030 and USD 4.5 million by 2035 as the birth cohort grows and inflation is considered.

8.3 No vaccination scenario

If the MR vaccination programme were halted, coverage would decline to zero%, leaving all new birth cohorts unprotected. In the first year following withdrawal, the model estimates approximately 251 additional measles cases, and 47 additional rubella cases compared to the baseline scenario. Because unprotected cohorts accumulate over time, the annual excess burden would grow substantially, reaching about 9,000 measles cases and 250 rubella cases by 2030, and approximately 12,000 measles cases and 768 rubella cases by 2035. Over a ten-year horizon, the cumulative excess amounts to roughly 80,000 measles cases and 3,700 rubella cases.

Averted vaccine implementation costs

Halting the programme would avert current vaccination expenditures, estimated at approximately USD 3.2 million in the first year, rising to about USD 4.4 million by 2035. Over the ten-year period, the NPV of averted vaccination costs is estimated at USD 32.4 million.

Increased healthcare costs

For measles, it is assumed that 50% of cases seek care, resulting in approximately 1,700 additional healthcare episodes in the first year, 6,100 per year by year five, and 8,200 per year by year ten, for a cumulative total of about 58,000 episodes over ten years. The study team assumes 10% would require hospitalisation.

The average length of stay for hospitalised cases is assumed to be one day, with an estimated cost of USD 82 per inpatient case and USD 13 per outpatient case. When weighted by care-seeking and hospitalisation rates, the average cost per measles case is approximately USD 13.60.[122,123]

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For rubella, about 80% of cases are assumed to seek care, resulting in approximately 40 additional healthcare episodes in the first year, 200 by year five, and 600 by year ten, for a cumulative total of about 3,000 episodes over ten years.[124] Of these, 0.5% would require hospitalisation and 80% would be treated as outpatients.[125] The average length of stay for hospitalised cases is ten days, with an

[121] GhanaFact, 'Factsheet: Know More About the Measles and Rubella Mass Vaccination in Ghana', www.ghanafact.com/factsheet-know-more-about-the-measles-and-rubella-mass-vaccination-in-ghana/>, accessed 6 June 2025.

[122] World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>

[123] Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

[124] Mayo Clinic Staff, 'Rubella – Symptoms & Causes', Mayo Clinic, 11 May 2022, https://www.mayoclinic.org/diseases-conditions/rubella/symptoms-causes/syc-20377310, accessed 5 June 2025.

[125] Ibid.

estimated cost of USD 993 per inpatient case and USD 13 per outpatient case.[126,127,128] When weighted by care-seeking and hospitalisation rates, the average cost per rubella case is approximately USD 15.54. Overall, the incremental health system burden remains modest compared to other cost components, amounting to approximately USD 0.4 million in NPV by year five and USD 1.1 million by year ten.

Increased productivity losses during illness

For both diseases, each hospitalised episode is assumed to remove a caregiver from work for the full length of stay. Weighting by hospitalisation rates yields an average productivity loss of 0.0016 productive years per measles case and 0.0023 per rubella case. Given the relatively short length of stay and low hospitalisation rates for rubella, these losses do not materially affect the overall economic burden.

Value of additional life years lost

Measles carries a meaningful mortality risk, while rubella mortality in children is assumed to be zero. Applying a case fatality ratio of 1.06% for measles, the NPV of life-years lost is estimated at approximately USD 3.6 million in the first year, USD 14.4 million in 2030, and USD 21.9 million in 2035, cumulating to about USD 39.6 million after five years and USD 116.4 million after ten years.[129]

Value of additional DALYs

Each measles case carries an average of 0.92 DALYs, while each rubella case carries 0.26 DALYs.[130,131] The additional cases therefore generate approximately 2,200 DALYs in the first year, 8,200 in 2030, and 11,000 in 2035 for measles, and 12, 65, and 200 DALYs for rubella, respectively. Over ten years, this amounts to about 77,300 DALYs for measles and 1,000 DALYs for rubella. Monetising these DALYs results in an estimated loss of approximately USD 5.3 million in the first year, USD 22.1 million in 2030, and USD 35.0 million in 2035, with a cumulative NPV of USD 66.7 million after five years and USD 220.6 million after ten years.

8.4 Conclusion

The analysis clearly demonstrates that discontinuing the MR vaccination programme would result in substantial health and economic losses, outweighing the short-term savings from averted programme costs. While halting vaccination would save approximately USD 2 million in the first year and USD 16 million over ten years, these savings are eclipsed by the cumulative burden of increased mortality and disability.

After one year without vaccination, the net economic loss is estimated at **USD 4 million** when considering mortality alone, and **USD 4 million** when DALYs are included. By the tenth year, the total net loss reaches **USD 118 million** based on mortality, and **USD 206 million** when accounting for DALYs.

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126 Ibid.

127 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>

128 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

129 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

130 Ibid.

131 Damm, O., Witte, J., Wetzka, S., Prosser, C., Braun, S., Welte, R., and Greiner, W., 'Epidemiology and Economic Burden of Measles, Mumps, Pertussis, and Varicella in Germany: A Systematic Review', *International Journal of Public Health*, vol. 61, no. 7, 2016, pp. 847–860, https://doi.org/10.1007/s00038-016-0842-8.

When expressed as a cost-benefit ratio, maintaining the MR vaccination yields an estimated economic return of over USD 2 for every dollar spent in the first year, rising to USD 7 by year ten when considering mortality only. Including DALYs, this ratio increases further to 14 USD after ten years.

Table 8.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	2	8	16
Total extra health care gains	-0	-0	-1
Total extra productivity gains during treatment	-0	-0	-0
VSLY saved	-4	-40	-116
Total value of DALYs averted	-5	-67	-221
Net gain or loss (only mortality)	**-4**	**-40**	**-118**
Net gain or loss (including DALYs)	**-4**	**-59**	**-206**
ROI (only mortality)	-2	-5	-7
ROI (including DALYs)	-3	-8	-14

9 Routine immunisation with Yellow Fever vaccine

9.1 Description of the intervention

The intervention includes the routine immunisation with the yellow fever vaccine, to protect against the infectious viral disease yellow fever. Yellow fever is caused by an arbovirus, transmitted through infected mosquito bites, particularly day-biting *Aedes* and *Haemagogus* species mosquitoes.[132] [133] Infections with the virus can be asymptomatic, but common first phase symptoms include fever, muscle pain, headache, loss of appetite, nausea, and vomiting.[134] A second phase may occur after recovering from the initial symptoms, which includes high fever, jaundice, dark urine and severe abdominal pain due to affected liver, kidney and other body systems.[135] Although there is no treatment or cure, yellow fever is a vaccine preventable disease.[136]

The intervention primarily targets infants (approximately 900,000 children aged 0–1 in 2023).[137] The immunisation of the yellow fever consists of a single dose which provides life-long protection.[138] The GHS immunisation schedule for infants includes one dose of the yellow fever administered to infants at 9 months of age.[139] This study assumes a vaccine efficacy of 95%.

9.2 Baseline situation

Yellow fever remains a serious health threat in West Africa, where yellow fever cases are more frequently reported than in any other area worldwide.[140] The vaccination coverage for yellow fever in Ghana reached 87.6% in 2024.[141] In the baseline the study team assumes 95% coverage from 2025 onward, as can be seen in **Appendix C**. With a vaccine efficacy of 95%, this protects approximately 90% of the target population.[142]

West Africa bears a high YF risk. Ghana has experienced substantial variability in the number of cases per year: 21 cases (2022), 1 case (2023) and approximately 150 cases (2024) during an outbreak. For modelling, the study team takes a baseline of 75 cases per year.[143]

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132 World Health Organization, 'Yellow Fever', Newsroom Factsheet, 1 May 2023. https://www.who.int/news-room/fact-sheets/detail/yellow-fever.
133 Ibid.
134 Ibid.
135 Ibid.
136 Nwaiwu, Akuoma U., Alfred Musekiwa, Jacques L. Tamuzi, Evanson Z. Sambala, and Peter S. Nyasulu, 'The Incidence and Mortality of Yellow Fever in Africa: A Systematic Review and Meta-Analysis', *BMC Infectious Diseases*, vol. 21, no. 1, 23 October 2021. https://doi.org/10.1186/s12879-021-06728-x.
137 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.
138 World Health Organization, 'Yellow Fever', Newsroom Factsheet, 31 May 2023. <https://www.who.int/news-room/fact-sheets/detail/yellow-fever>
139 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin, and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', *Public Health Challenges*, vol. 3, no. 2, 19 May 2024. https://doi.org/10.1002/puh2.176.
140 Nwaiwu, Akuoma U., Alfred Musekiwa, Jacques L. Tamuzi, Evanson Z. Sambala, and Peter S. Nyasulu, 'The Incidence and Mortality of Yellow Fever in Africa: A Systematic Review and Meta-Analysis', *BMC Infectious Diseases*, vol. 21, no. 1, 23 October 2021. https://doi.org/10.1186/s12879-021-06728-x.
141 World Health Organization, 'Yellow fever vaccination coverage – Ghana, 2000-2024', Immunization Data, n.d. <https://immunizationdata.who.int/global/wiise-detail-page/yellow-fever-(yf)-vaccination-coverage?CODE=GHA&YEAR=>.
142 Gotuzzo, E., S. Yactayo and E. Córdova, 'Efficacy and Duration of Immunity after Yellow Fever Vaccination: Systematic Review on the Need for a Booster Every 10 Years', *The American Journal of Tropical Medicine and Hygiene*, vol. 89, no. 3, 2013, pp. 434–444.
143 World Health Organization, 'Yellow Fever (YF) Reported Cases and Incidence', <https://immunizationdata.who.int/global/wiise-detail-page/yellow-fever-(yf)-reported-cases-and-incidence?CODE=GHA&YEAR=>, accessed 3 July 2025.

Vaccination cost in the baseline scenario

Assuming 95% coverage of newborns and the unit costs below, as tabled in **Appendix D**, the programme costs approximately USD 3.9 million in 2025, which is approximately USD 4.48 per fully vaccinated child.

9.3 No-vaccination scenario

If routine vaccination ceases, the protected share of newborns falls to zero. According to our estimates, this yields approximately 48 additional cases in the first year relative to baseline. As unvaccinated birth cohorts age and accumulate, the annual excess grows to approximately 240 cases by year five and approximately 431 cases by year ten. Over ten years, this sums to roughly 2,500 additional YF cases compared to the baseline scenario of 95% coverage.

Averted implementation costs

Stopping the programme would avert approximately USD 4.0 million of vaccination cost per year initially. With 2% annual price growth and population growth, the averted spend rises to approximately USD 5.4 million by 2035. These are near-term budget savings assuming public financing under the baseline.

Increased healthcare costs

Assuming that about 69% of YF cases in Ghana seeks healthcare[144], this corresponds to approximately 33 additional healthcare-seeking episodes in year one, approximately 166 in year five, and approximately 297 annually in year ten after halting the programme. Cumulatively over 10 years, the simulation indicates more than 1,700 extra care-seeking cases. Evidence from low- and middle-income settings suggests that approximately 15% of YF cases require hospital admission.[145]

The study team assumes an average hospital stay of 4 days.[146] Costs are approximately USD 331 per inpatient case and approximately USD 13 per outpatient case.[147,148] Weighting by the hospitalisation rate and care-seeking share gives an average cost of approximately USD 57 per incident case (i.e. including non-seekers). Applying this to the simulated excess cases produces an incremental health system burden of approximately USD 3 thousand in year 1, rising to approximately USD 16 thousand per year by 2030 and approximately USD 31 thousand per year by 2035 as unprotected cohorts build up. Over 10 years, the NPV of the incremental burden is approximately USD 140 thousand. These costs fall on both government and households.

Increased productivity losses during illness

Caring for a sick child displaces paid and unpaid work. The study team assumes 4 caregiver days per inpatient episode and 1 day per outpatient episode. With the assumed care-seeking and admission rates, this averages approximately 1.29 caregiver-days lost per YV case. Given the excess cases, this equates to approximately 0.17 caregiver-years lost in year 1, approximately 0.85 years by 2030, and approximately 1.52 years by 2035 (annual). Valued at GDP-per-capita output per day,

144 Lewis, Todd P., et al., 'Associations between Women's Empowerment, Care Seeking, and Quality of Malaria Care for Children: A Cross Sectional Analysis of Demographic and Health Surveys in 16 Sub Saharan African Countries', *Journal of Global Health*, vol. 12, 19 March 2022, article 04025.

145 Simon, L.V., Hashmi, M.F., and Torp, K.D., 'Yellow Fever [Updated 7 August 2023]', in *StatPearls*, StatPearls Publishing, Treasure Island (FL), January 2025, https://www.statpearls.com/physician/cme/activity/91228.

146 Ribeiro, Ana Freitas, et al., 'Yellow Fever: Factors Associated with Death in a Hospital of Reference in Infectious Diseases, São Paulo, Brazil, 2018', *American Journal of Tropical Medicine and Hygiene*, vol. 101, no. 1, 2019.

147 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

148 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

the implied productivity loss is approximately USD 450 in the first year, rising to approximately USD 2,500 in 2030 and approximately USD 5,000 in 2035. Combined over ten years, this leads to a cumulative NPV of more than USD 20,000.

Value of additional life-years lost

Yellow fever has a case fatality ratio of approximately 5%.[149] Given the simulated excess incidence, the study team estimates approximately 2 additional deaths in 2025, increasing to approximately 20 in 2035. Using the VSLY approach (assumed remaining life expectancy 65 years at birth, declining with age), the NPV of life-years lost is approximately USD 325 thousand in 2025, rising to approximately USD 3.5 million annually by 2035. Aggregated over ten years, the NPV is approximately USD 15 million.

DALYs lost

Using an average DALY loss of approximately 4.06 per yellow fever case, the additional cases imply approximately 195 DALYs in year 1, approximately 974 DALYs in year 5, and approximately 1,750 DALYs in year 10 (annual).[150] Over ten years, this cumulates to more than 10,000 DALYs. Monetising DALYs per the methodology yields a ten-year NPV of approximately USD 29 million.

9.4 Conclusion

The analysis shows that discontinuing routine yellow fever (YF) vaccination in Ghana would yield modest short-term fiscal savings, estimated at USD 4 million in the first year and USD 40 million over a decade, but without significant economic downside. Due to the currently low incidence of yellow fever, the additional burden on the health system and economy remains limited even without vaccination.

Over ten years, the NPV of extra healthcare costs is just USD 0.14 million, with minimal productivity losses (USD 0.02 million). While the value of life years lost (USD 15.3 million) and DALYs (USD 28.7 million) is not negligible, these are still outweighed by the savings from averted vaccination costs. As a result, the net economic impact remains positive: **a gain of USD 24 million over ten years** when considering mortality alone, and **USD 10 million** when DALYs are included.

Table 9.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	4	19	40
Total extra health care gains	-0.01	-0.04	-0.14
Total extra productivity gains during treatment	-0.00	-0.006	-0.02
VSLY saved	-0.3	-5	-15
Total value of DALYs averted	-0.5	-5	-29
Net gain or loss (only mortality)	**+ 3.6**	**+ 15**	**+ 24**
Net gain or loss (including DALYs)	**+ 3.4**	**+ 12**	**+ 10**
ROI (only mortality)	-0.1	-0.2	-0.4
ROI (including DALYs)	-0.1	-0.4	-0.7

[149] Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.
[150] Ibid.

When expressed as a cost-benefit ratio, maintaining the YF vaccination yields an estimated economic return of USD 0.08 for every dollar spent in the first year, which indicates a loss. This loss per dollar decreases, but remains, to USD 0.4 by year ten when considering mortality only. Including DALYs, this ratio increases further to 0.7 USD after ten years.

10 Routine immunisation with Meningitis A vaccine

10.1 Description of the intervention

The intervention consists of routine immunisation with the meningococcal serogroup A conjugate vaccine (MenAfriVac®), which provides protection against meningitis caused by Neisseria meningitidis serogroup A. Meningitis is a severe, life-threatening infection involving inflammation of the membranes (meninges) surrounding the brain and spinal cord. [151,152] Symptoms vary but commonly include fever, neck stiffness, headache, confusion, sensitivity to light, nausea, and vomiting. In severe cases, seizures, coma, and permanent neurological deficits can occur. [153] The disease is transmitted through respiratory droplets from infected individuals and can spread rapidly in close-contact settings.[154]

Among children aged 1 month to 5 years, the major bacterial causes of meningitis include Streptococcus pneumoniae, Haemophilus influenzae, and Neisseria meningitidis.[155] Serogroup A meningococcal disease, historically responsible for large epidemics in the African meningitis belt, is effectively prevented by MenAfriVac®, which reduces both disease incidence and bacterial carriage.[156,157]

In Ghana, the routine immunisation schedule includes a single intramuscular dose of the meningococcal A conjugate vaccine administered between 9 and 18 months of age.[158] For the purpose of this analysis, vaccine efficacy is assumed to be 95%.[159,160]

10.2 Baseline situation

As of 2024, Ghana's national coverage for the meningococcal A conjugate vaccine was 86%. According to the Ghana Immunisation Strategy for 2025–2030, coverage is expected to reach 95%, as can be seen in **Appendix C**, corresponding to approximately 800,000 children vaccinated annually. Assuming a vaccine efficacy of 95%, this means that under baseline conditions, about 90% of the target population is effectively protected against meningitis serogroup A.

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151 Ali, Musah, et al., 'Spatial Epidemiology of Bacterial Meningitis in the Upper West Region of Ghana: Analysis of Disease Surveillance Data 2018–2020', *Clinical Infection in Practice*, vol. 16, 5 August 2022, p. 100160. https://doi.org/10.1016/j.clinpr.2022.100160.

152 Kaburi, Basil B., 'Evaluation of the Enhanced Meningitis Surveillance System, Yendi Municipality, Northern Ghana, 2010–2015', *BMC Infectious Diseases*, vol. 17, no. 1, 24 April 2017. https://doi.org/10.1186/s12879-017-2410-0.

153 World Health Organization, 'Meningitis', Newsroom Fact sheet, 1 April 2025 <https://www.who.int/news-room/fact-sheets/detail/meningitis.>.

154 World Health Organization, 'Meningitis', Health topics, 12 November 2019 <https://www.who.int/health-topics/meningitis#tab=tab_1>.

155 Kobayashi, Miwako, et al., 'Estimating the Economic Burden of Pneumococcal Meningitis and Pneumonia in Northern Ghana in the African Meningitis Belt Post-PCV13 Introduction', *Vaccine*, vol. 39, no. 33, 1 July 2021, p. 4685–4699. https://doi.org/10.1016/j.vaccine.2021.06.043.

156 World Health Organization, 'Meningococcal meningitis', Immunisation, Vaccines and Biologicals, 13 January 2021 <https://www.who.int/teams/immunization-vaccines-and-biologicals/diseases/meningitis.>.

157 Viviani, Simonetta, 'Efficacy and Effectiveness of the Meningococcal Conjugate Group A Vaccine MENAFRIVAC® in Preventing Recurrent Meningitis Epidemics in Sub-Saharan Africa', *Vaccines*, vol. 10, no. 4, 14 April 2022, p. 617. https://doi.org/10.3390/vaccines10040617.

158 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin, and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', *Public Health Challenges*, vol. 3, no. 2, 19 May 2024. https://doi.org/10.1002/puh2.176.

159 World Health Organization, *Efficacy of a Single-Dose MenA Conjugate Vaccine in Children Aged 9–24 Months*, GRADE Table 1: Efficacy of a single-dose MenA conjugate vaccination in immunocompetent children (9–24 months) against serogroup A meningococcal disease, WHO, Geneva, 2015.

160 The efficacy of the vaccine in Ghana has not been quantified currently. Therefore, we take the% age of receivers that have seroconversion at least a month after administration as a proxy.

Since the introduction of MenAfriVac® in 2012, Ghana has reported zero cases of meningitis serogroup A, resulting in an incidence rate of 0 cases per 100,000 population.[161]

Vaccine costs in the baseline scenario

The cost per fully vaccinated child is estimated at USD 3.63 in 2025, as is tabled in **Appendix D**. Based on projected coverage, this corresponds to a total programme cost of approximately USD 3.3 million in 2025, increasing to USD 3.7 million by 2030 and USD 4.5 million by 2035 as the birth cohort grows and inflation is considered.

10.3 No vaccination scenario

If routine immunisation with the meningococcal A conjugate vaccine were discontinued, coverage would fall to 0%, leaving the population vulnerable to the re-emergence of meningitis serogroup A. Historical data from the 2009–2010 outbreak, which recorded 911 cases, suggests that in the absence of vaccination, Ghana could experience similar outbreaks approximately once every decade. This corresponds to an estimated annual incidence of 0.304 cases per 100,000 population.

Based on this assumption, the model projects an additional 21 cases in the first year, rising to 55 cases annually by 2030 and 91 cases by 2035. Over a ten-year horizon, this would result in a cumulative 570 additional cases of meningitis serogroup A.

Averted vaccine implementation costs

Halting the programme would avert current vaccination expenditures, estimated at USD 3.2 million in the first year, increasing to USD 4.4 million by 2035. Over the ten-year period, the NPV (NPV) of averted vaccination costs is approximately USD 32 million.

Increased healthcare costs

Given the severity of meningitis, the study team assumes that 100% of cases seek care, with all cases requiring hospitalisation. The average hospital stay is five days, and the cost per inpatient case is estimated at USD 414. This results in an average healthcare cost of USD 414 per case.[162,163] Consequently, the incremental health system burden is approximately USD 0.008 million in the first year, USD 0.02 million in 2030, and USD 0.04 million in 2035, with a cumulative NPV of USD 0.2 million over ten years.

Increased productivity losses during illness

Each hospitalised case is assumed to remove a caregiver from work for five full days, equivalent to 0.01 productive years lost per case. Given the low number of cases, the resulting productivity losses are minimal and do not significantly affect the overall economic burden.

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161 University of Cambridge, 'Can meningitis A be eliminated in Ghana?: Insights from a stochastic model considering the possibility of reintroduction', <www.idmod.org/wp-content/uploads/2023/07/1-2C-2_Owusu_Meningococcal-serogroup-A.pdf>, accessed 5 June 2025.

162 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>

163 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

Value of additional life years lost

Meningitis carries a high fatality risk. Applying a case fatality ratio of 6.8%, the model estimates an NPV of life-years lost of USD 0.2 million in the first year, USD 0.5 million in 2030, and USD 1 million in 2035, with a cumulative NPV of approximately USD 4.8 million over ten years.[164]

Value of additional DALYs

Each meningitis case is associated with an average burden of 6.1 DALYs.[165] The additional cases therefore result in approximately 130 DALYs in the first year, 330 in 2030, and 550 cumulatively over ten years. Monetising these DALYs yields an estimated loss of USD 0.3 million in year one, USD 0.9 million in 2030, and USD 1.7 million in 2035, with a cumulative NPV of USD 9.7 million.

10.4 Conclusion

The analysis indicates that discontinuing routine immunisation with the meningococcal A conjugate vaccine would lead to modest short-term budget savings, estimated at USD 3 million in the first year and USD 32 million over a decade, without substantial economic downside under current low-incidence conditions. The additional costs from increased healthcare use, productivity losses, and mortality remain minimal, with total extra health system costs and productivity losses near zero, and mortality-related losses reaching only USD 5 million over ten years.

As a result, the net economic impact of discontinuation remains positive: a gain of **USD 3 million in year one**, **USD 14 million by year five**, and **USD 27 million by year ten** when considering mortality alone. Even when DALYs are monetised, the net gain remains positive at **USD 22 million over ten years.**

When expressed as a cost-benefit ratio, maintaining the meningococcal A conjugate vaccination yields an estimated economic return of USD 0.1 for every dollar spent in the first year, which indicates a loss. This loss per dollar decreases, but remains, to USD 0.15 by year ten when considering mortality only. Including DALYs, this ratio increases further to 0.3 USD after ten years.

Figure 10.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	3	16	32
Total extra health care gains	-0	-0	-0
Total extra productivity gains during treatment	-0	-0	-0
VSLY saved	-0	-2	-5
Total value of DALYs averted	-0	-3	-10
Net gain or loss (only mortality)	**+3**	**+14**	**+27**
Net gain or loss (including DALYs)	**+3**	**+13**	**+22**
ROI (only mortality)	-0.1	-0.1	-0.2
ROI (including DALYs)	-0.1	-0.2	-0.3

[164] World Health Organization, *Weekly Epidemiological Record*, no. 15, vol. 86, 8 April 2011, pp. 141–152, WHO, Geneva, <https://www.who.int/wer>.

[165] Global Burden of Disease Collaborative Network, Global Burden of Disease Study 2021 (GBD 2021) Results, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, < https://vizhub.healthdata.org/gbd-results/>.

11 Routine immunisation with HPV vaccine

11.1 Description of the intervention

The intervention consists of routine immunisation with the human papillomavirus (HPV) vaccine to prevent infections caused by high-risk HPV types, particularly HPV16 and HPV18.[166] HPV is a common viral infection of the reproductive tract, transmitted primarily through sexual contact, including skin-to-skin contact of the genital area and exposure to infected mucous membranes or bodily fluids. [167] While most HPV infections (70–90%) are asymptomatic and resolve spontaneously within one to two years, persistent infection with high-risk types can lead to precancerous lesions and, ultimately, cancer.[168]

HPV infection is the primary cause of cervical cancer, accounting for 99% of cases, with HPV16 and HPV18 responsible for approximately 70% of cervical cancers worldwide.[169] In addition to cervical cancer, HPV is associated with cancers of the oropharynx, head and neck, anogenital region, as well as conditions such as anogenital warts and recurrent respiratory papillomatosis. [170]

The primary target group for HPV vaccination is girls aged 9–14 years, ideally before the onset of sexual activity.[171] In Ghana, this cohort includes approximately 4.68 million girls as of 2023.[172] The vaccine is administered intramuscularly, with the WHO recommending a two-dose schedule (5–13 months apart) for girls aged 9–14 years, and a three-dose schedule for those aged 15 years or older, as well as for immunocompromised or HIV-infected individuals.[173,174]

11.2 Baseline situation

As of 2025, Ghana's national HPV vaccination coverage is estimated at 47%.[175] According to the Ghana Immunisation Strategy for 2026–2030, coverage is projected to increase to 90%, as can be seen in **Appendix C**, corresponding to approximately 400,000 girls vaccinated annually. Assuming a vaccine efficacy of 90%, this means that under baseline conditions, about 86% of the target population is effectively protected against high-risk HPV infection.[176]

166 Krings, Amrei, et al., 'Characterization of Human Papillomavirus Prevalence and Risk Factors to Guide Cervical Cancer Screening in the North Tongu District, Ghana', *PLoS ONE*, vol. 14, no. 6, 27 June 2019, p. e0218762. https://doi.org/10.1371/journal.pone.0218762.

167 World Health Organization, 'Human Papillomavirus Vaccines: WHO Position Paper (2022 Update)', Weekly Epidemiological Record, no. 50, 97, 16 December 2022, pp. 645–672. <https://iris.who.int/bitstream/handle/10665/365350/WER9750-eng-fre.pdf?sequence=1.>.

168 Ibid.

169 Krings, Amrei, et al., 'Characterization of Human Papillomavirus Prevalence and Risk Factors to Guide Cervical Cancer Screening in the North Tongu District, Ghana', *PLoS ONE*, vol. 14, no. 6, 27 June 2019, p. e0218762. https://doi.org/10.1371/journal.pone.0218762.

170 World Health Organization, 'Human Papillomavirus Vaccines: WHO Position Paper (2022 Update)', Weekly Epidemiological Record, no. 50, 97, 16 December 2022, pp. 645–672. <https://iris.who.int/bitstream/handle/10665/365350/WER9750-eng-fre.pdf?sequence=1.>.

171 World Health Organization, 'Human papillomarvirus vaccines (HPV)', Immunisation, Vaccines, and Biologicals, n.d. <https://www.who.int/teams/immunization-vaccines-and-biologicals/diseases/human-papillomavirus-vaccines-(HPV).>.

172 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.

173 World Health Organization, 'Human Papillomavirus Vaccines: WHO Position Paper (2022 Update)', Weekly Epidemiological Record, no. 50, 97, 16 December 2022, pp. 645–672. <https://iris.who.int/bitstream/handle/10665/365350/WER9750-eng-fre.pdf?sequence=1.>.

174 World Health Organization, 'Human papillomarvirus vaccines (HPV)', Immunisation, Vaccines, and Biologicals, n.d. <https://www.who.int/teams/immunization-vaccines-and-biologicals/diseases/human-papillomavirus-vaccines-(HPV).>.

175 In the absence of definitive, up-to-date data on HPV coverage in Ghana, we use a UNICEF article to approximate coverage. For the target cohort of girls aged 9–14 on a two-dose schedule, the 2.5 million doses reportedly delivered imply about 47% coverage. This is an indicative estimate, and higher future uptake is assumed in projections.

176 Kamolratanakul, S., and P. Pitisuttithum, 'Human Papillomavirus Vaccine Efficacy and Effectiveness against Cancer', *Vaccines*, vol. 9, no. 12, 2021, article 1413.

Despite these efforts of cervical cancer in Ghana is estimated at 17.57 cases per 100,000 population, making it one of the leading causes of cancer-related morbidity and mortality among women.[177] Persistent HPV infection is the primary driver of this burden, underscoring the importance of achieving and maintaining high vaccination coverage.

Vaccine costs in the baseline scenario

The cost per fully vaccinated girl is estimated at USD 11.07 in 2025, as is tabled in **Appendix D**. Based on projected coverage, this corresponds to a total programme cost of approximately USD 4.4 million in 2026, increasing to USD 6.9 million by 2035 and USD 8.5 million by 2045 as the eligible cohort grows and inflation is considered.[178]

11.3 No vaccination scenario

If the HPV vaccination programme were discontinued, coverage would fall to 0%, leaving all adolescent girls unprotected against high-risk HPV infection. Given the long latency period between infection and cancer development, the health impact would manifest gradually but increase sharply over time. The model estimates an additional 68 cervical cancer cases by 2035, rising to 71 cases annually by 2040 and 216 cases annually by 2045. Over a 20-year horizon, this would result in a cumulative 1,085 additional cases of cervical cancer.

Averted vaccine implementation costs

Halting the programme would avert current vaccination expenditures, estimated at USD 3.2 million in the first year, increasing to USD 6.1 million by 2035 and USD 8.5 million by 2045. Over the long term, the NPV (NPV) of averted vaccination costs is approximately USD 44.1 million after 10 years and USD 90.6 million after 20 years.

Increased healthcare costs

Assuming 100% of cases seek care, the withdrawal would result in approximately 15 additional healthcare cases in 2035, 67 by 2040, and 206 annually by 2045, totalling 1,031 extra cases over 20 years. All cases are assumed to require hospitalisation, with an average stay of seven days.[179,180] The cost per inpatient case is estimated at USD 579.75,[181,182] resulting in incremental healthcare costs that remain relatively small compared to other cost components.

Increased productivity losses during illness

Each hospitalised case is assumed to remove a caregiver from work for seven full days, equivalent to 0.019 productive years lost per case. Given the relatively low number of cases, the resulting productivity losses are minimal and do not significantly affect the overall economic burden.

Value of additional life years lost

Cervical cancer carries a high fatality risk. Applying a case fatality ratio of 30%, the NPV of life-years lost is estimated at USD 0.5 million by 2030, USD 3.4 million in 2035, and USD 11.7 million in 2045,

177 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, < https://vizhub.healthdata.org/gbd-results/>.

178 Because onset of cancer typically occurs later in life, the scope of the CBA for the HPV intervention has been extended to 2045. In the first ten years, little additional cases due to 0% coverage will occur, and so the benefits of vaccinating will only be apparent with a long enough time horizon.

179 Nartey, Y., Amo-Antwi, K., Adomako, J., et al., 'Cervical Cancer in the Greater Accra and Ashanti Regions of Ghana', *Journal of Global Oncology*, vol. 3, 2017, pp. 782–790, https://doi.org/10.1200/JGO.2016.005744.

180 Cancer Council NSW, 'What to Expect After Surgery for Cervical Cancer', Cancer Council, 11 January 2024, <https://www.cancercouncil.com.au/cervical-cancer/treatment/surgery/what-to-expect-after-surgery/, accessed 5 June 2025>.

181 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

182 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

with a cumulative NPV of USD 33.1 million over 20 years under the assumption of immediate mortality.[183] If deaths occur five years after infection, this estimate reduces to USD 8.9 million.

Value of additional DALYs

Each cervical cancer case is associated with an average burden of 17.38 DALYs. The additional cases therefore result in approximately 265 DALYs in 2035, 1,231 in 2040, and 3,762 in 2045, cumulating to 19,000 DALYs over 20 years. Monetising these DALYs yields an estimated loss of USD 0.6 million in 2035, USD 3.2 million in 2040, and USD 11.0 million in 2045, with a cumulative NPV of USD 52 million.[184]

11.4 Conclusion

The analysis suggests that discontinuing HPV vaccination does not appear cost-saving within the 20-year time horizon considered. While halting the programme would save approximately **USD 4 million in the first year** and **USD 91 million over 20 years**, these savings are not fully offset by the additional costs of healthcare, productivity losses, and the monetised value of life years and DALYs lost within this period. The cumulative net loss remains positive from a financial perspective because the health and economic consequences of HPV infection, primarily cervical cancer, manifest decades after initial infection.

This finding likely reflects two key factors:

3. **The long latency period of HPV-related cancers**, meaning that the full burden of disease and associated costs would occur beyond the 20-year horizon used in this analysis.
4. **The relatively high cost of HPV vaccines**, which makes the short- to medium-term financial return less apparent compared to other vaccines targeting acute childhood diseases.

Expressed as cost-benefit ratios, discontinuation results in negative returns over time: approximately USD 0.04 for every dollar spent after 10 years and USD 0.4 by year 20 under the instant death assumption, and USD 0.6 when DALYs are included.

Table 11.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	10 years	20 years
Prevented vaccination costs	4	44	91
Total extra health care gains	-	-0	-1
Total extra productivity gains during treatment	-	-0	-0
VSLY saved - instant death	-	-2	-33
VSLY saved - death after 5 years	-	-0	-9
Value of averted DALYs	-	-2	-52
Net gain or loss (only mortality, instant death)	**4**	**42**	**57**
Net gain or loss (only mortality, death after 5 year)	**4**	**44**	**81**
Net gain or loss (including DALYs)	**4**	**42**	**38**
ROI (only mortality, instant death)	0.0	0.0	-0.4
ROI (only mortality, death after 5 years)	0.0	0.0	-0.1
ROI (including DALYs)	0.0	-0.1	-0.6

[183] Global Burden of Disease Collaborative Network, Global Burden of Disease Study 2021 (GBD 2021) Results, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, < https://vizhub.healthdata.org/gbd-results/>.
[184] Ibid.

12 Routine immunisation with Hepatitis B vaccine

12.1 Description of the intervention

The intervention consists of routine immunisation with the Hepatitis B vaccine to prevent infection with the Hepatitis B virus (HBV), a serious viral pathogen that attacks the liver and can cause both acute and chronic disease.[185] Acute infection may present with symptoms such as jaundice, dark urine, nausea, vomiting, and abdominal pain, while chronic infection significantly increases the risk of cirrhosis and primary liver cancer.[186,187] Transmission occurs primarily through perinatal exposure and contact with infected blood, making infants and young children particularly vulnerable.[188]

The primary target group for this intervention is newborns.[189] In Ghana, the immunisation schedule includes a birth dose administered intramuscularly within 24 hours of birth, followed by two to three additional doses at four-week intervals during infancy.[190,191] For the purpose of this analysis, vaccine efficacy is assumed to be 91.3%, corresponding to the rate of seroprotection achieved after full immunisation.[192]

12.2 Baseline situation

As of 2024, Ghana's national coverage for the Hepatitis B birth dose was 95%. Coverage is projected to increase to 99%, as can be seen in **Appendix C**, corresponding to approximately 900,000 infants vaccinated annually, with numbers rising as the population grows. Assuming a vaccine efficacy of 91.3%, this means that under baseline conditions, about 90% of the newborn population is effectively protected against Hepatitis B infection.[193]

Despite these high coverage levels, Hepatitis B the estimated incidence rate is 1,697 cases per 100,000 population, although this varies across age cohorts.[194] Chronic Hepatitis B infection is a major driver of liver disease and hepatocellular carcinoma, which impose a substantial burden on the health system and affected households.

Vaccine costs in the baseline scenario

The cost per fully vaccinated child is estimated at USD 2.78 in 2025, as is tabled in **Appendix D**. Based on projected coverage, this corresponds to a total programme cost of approximately USD 2.4

185 World Health Organization, 'Hepatitis B', WHO Newsroom, 9 April 2024. <https://www.who.int/news-room/fact-sheets/detail/hepatitis-b.>.
186 Kusi, Kwadwo Asamoah, et al., 'World Hepatitis Day 2021 –Screening and Vaccination against Hepatitis B Virus in Accra, Ghana', *BMC Public Health*, vol. 23, no. 1, 16 June 2023. https://doi.org/10.1186/s12889-023-16108-6.
187 World Health Organization, 'Hepatitis B', WHO Newsroom, 9 April 2024. https://www.who.int/news-room/fact-sheets/detail/hepatitis-b.
188 Ibid.
189 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.
190 World Health Organization, *Global hepatitis report 2024: action for access in low- and middle-income countries*. Geneva, 2024, Licence: CC BY-NC-SA 3.0 IGO.
191 Kusi, Kwadwo Asamoah, et al., 'World Hepatitis Day 2021 –Screening and Vaccination against Hepatitis B Virus in Accra, Ghana', *BMC Public Health*, vol. 23, no. 1, 16 June 2023. https://doi.org/10.1186/s12889-023-16108-6.
192 Efua, S. D. V., *et al.*, *Hepatitis B Virus Vaccination Post-Serological Testing and Seroprotection Among Vaccinated Health Care Workers in Accra, Ghana*, *Vaccine: X*, 16, 2023, Art. 100294.
193 Vivian Efua, S. D., D. Armah and W. Delali Adwoa, 'Hepatitis B Virus Vaccination Post Serological Testing and Antibody Levels of Vaccinated Health Care Workers in Accra, Ghana', *Vaccine: X*, vol. 14, 2023, article 100294.
194 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, < https://vizhub.healthdata.org/gbd-results/>.

million in 2025, increasing to USD 2.9 million by 2030 and USD 3.5 million by 2035 as the birth cohort grows and inflation is considered.

12.3 No vaccination scenario

If the Hepatitis B birth dose programme were discontinued, coverage would fall to 0%, leaving all newborns unprotected against infection. This would significantly increase the number of susceptible individuals and lead to a sharp rise in new cases. In the first year following withdrawal, the model estimates an additional 26,000 cases, rising to 100,000 cases annually by 2030 and 240,000 cases by 2035. Over a ten-year horizon, this would result in a cumulative 1.2 million additional cases of Hepatitis B infection.

Averted vaccine implementation costs

Halting the programme would avert current vaccination expenditures, estimated at USD 2.6 million in the first year, increasing to USD 2.9 million by 2030 and USD 3.5 million by 2035. Over the ten-year period, the NPV (NPV) of averted vaccination costs is approximately USD 25.5 million.

Increased healthcare costs

Assuming 2% of cases seek care, the withdrawal would result in approximately 20,500 additional healthcare cases in year one, 82,000 in year five, and 190,000 annually in year ten, totalling 980,000 extra cases over the decade. Of all cases, 1% is assumed to require hospitalisation. The average hospital stay is five days, with costs estimated at USD 414 per inpatient case and USD 13.30 per outpatient case. [195,196] When weighted by care-seeking and hospitalisation rates, the average cost per case is USD 2.27.

This translates into an incremental health system burden of USD 0.006 million in year one, USD 0.03 million in 2030, and USD 0.7 million in 2035, with a cumulative NPV of USD 2.7 million over ten years.

Increased productivity losses during illness

Each hospitalised case is assumed to remove a caregiver from work for five full days, equivalent to 0.0001 productive years lost per case. Given the low hospitalisation rate, the resulting productivity losses are negligible and do not significantly affect the overall economic burden.

Value of additional life years lost

Although Hepatitis B has a relatively low case fatality rate, the large number of infections results in a substantial mortality burden.[197] Applying a case fatality ratio of 0.04%, the NPV of life-years lost is estimated at USD 1.4 million in the first year, USD 6.0 million in 2030, and USD 15.5 million in 2035, with a cumulative NPV of approximately USD 61 million over ten years.

Value of additional DALYs

Each Hepatitis B case is associated with an average burden of 0.03 DALYs.[198] The additional cases therefore result in approximately 900 DALYs in the first year, 3,400 in 2030, and 8,000 in 2035, cumulating to 41,000 DALYs over ten years. Monetising these DALYs yields an estimated loss

195 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

196 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

197 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

198 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

of USD 2.0 million in year one, USD 9.0 million in 2030, and USD 23.2 million in 2035, with a cumulative NPV of USD 116.3 million.

12.4 Conclusion

The analysis shows that discontinuing the Hepatitis B birth dose programme would result in significant long-term health and economic losses, despite modest short-term savings. While halting vaccination would save approximately USD 3 million in the first year, these savings are quickly outweighed by the costs associated with increased morbidity, mortality, and disability.

After one year without vaccination, the net economic loss is estimated at **USD 1 million** when considering mortality alone. **By the tenth year**, the total net loss reaches **USD 39 million** based on mortality, and **USD 94 million** when accounting for DALYs.

Expressed as a cost-benefit ratio, maintaining Hepatitis B vaccination yields a strong economic case: discontinuation would result in a negative return of approximately USD 0.6 per dollar gained in the first year, worsening to a loss of USD 2.5 by year ten when considering mortality only, and a loss of USD 4.55 when DALYs are included.

Table 12.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	3	13	26
Total extra health care gains	-0	-1	-3
Total extra productivity gains during treatment	-0	-0	-0
VSLY saved	-1	-16	-61
Total value of DALYs averted	-2	-28	-116
Net gain or loss (only mortality)	**1**	**-5**	**-39**
Net gain or loss (including DALYs)	**0**	**-16**	**-94**
ROI (only mortality)	-1	-1	-3
ROI (including DALYs)	-1	-2	-5

13 Routine immunisation with OPV vaccine and IPV vaccine

13.1 Description of the intervention

Polio is a highly infectious, potentially disabling and life-threatening disease caused by the poliovirus.[199] The poliovirus is typically transmitted through oral contact with faecal material from infected persons, or less frequently through a common vehicle such as contaminated water or food.[200] Polio mainly affects children under 5 years of age.[201] Approximately one in every 200 polio infections leads to irreversible paralysis, due to the virus infecting the central nervous system and the spinal cord.[202] Among those paralytic polio cases, 5–10% leads to death when the breathing muscles become immobilised.[203]

The causative agent, poliovirus, exists in three serotypes: type 1, type 2, and type 3. Each serotype is immunologically distinct, meaning immunity to one does not confer protection against the others. Historically, type 2 was the most genetically unstable strain, and although it was declared eradicated in 2015, outbreaks of circulating vaccine-derived poliovirus type 2 (cVDPV2) remain a challenge in several countries, including Ghana.

Introduction of two distinct vaccines

In Ghana, the **oral polio vaccine (OPV)** was first introduced into the routine Expanded Programme on Immunisation (EPI) in 1978. The OPV contains a weakened form of live virus and protects against all three types of polioviruses, types 1, 2, and 3 of Wild Poliovirus (WPV).[204] It is highly effective at interrupting transmission, but in rare circumstances the attenuated virus can mutate and circulate, causing cVDPV outbreaks.[205]

OPV is administered orally, as liquid drops. The full administration consists of three or more doses, administered at birth, six weeks, 10 weeks and 14 weeks of age as included in the GHS immunisation schedule for infants.[206,207,208] Vaccine efficacy is assumed to be 92%.[209]

The **Inactivated Polio Vaccine (IPV)** is an injectable vaccine existing of inactivated WPV strains of each serotype.[210] The IPV only protects against poliomyelitis and does not induce mucosal immunity,

199 World Health Organization, 'Poliomyelitis', WHO Newsroom, 2 April 2025, <https://www.who.int/news-room/fact-sheets/detail/poliomyelitis>.
200 World Health Organization, 'Poliomyelitis', n.d., <https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/vaccine-standardization/poliomyelitis>.
201 World Health Organization, 'Poliomyelitis', WHO Newsroom, 2 April 2025, <https://www.who.int/news-room/fact-sheets/detail/poliomyelitis>.
202 Auzenbergs, Megan, et al., 'Vaccination Strategies against Wild Poliomyelitis in Polio-Free Settings: Outbreak Risk Modelling Study and Cost-Effectiveness Analysis', *BMJ Global Health*, vol. 10, no. 3, 1 March 2025, p. e016013.
203 World Health Organization, 'Poliomyelitis', WHO Newsroom, 2 April 2025, <https://www.who.int/news-room/fact-sheets/detail/poliomyelitis>.
204 World Health Organization, 'Poliomyelitis', n.d., <https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/vaccine-standardization/poliomyelitis>.
205 Center for Disease Control and Prevention U.S., 'Poliomyelitis', CDC Yellow Book: Health Information for International Travel, April 2025, < https://www.cdc.gov/yellow-book/hcp/travel-associated-infections-diseases/poliomyelitis.html>.
206 UNICEF, 'Costs of Fully Vaccinating a Child – Countries Eligible for Gavi Vaccine Prices', August 2024, <https://www.unicef.org/media/161751/file/Standard%20costs%20of%20fully%20vaccinating%20a%20child_UNICEF_2024.pdf.pdf>.
207 UNICEF, 'All You Need to Know about Childhood Vaccinations', UNICEF South Africa, n.d., <https://www.unicef.org/southafrica/unicef-parenting/health/parents-frequently-asked-questions-vaccines>.
208 Walana, Williams, Mahmoud Al-Azab, Iddrisu Baba Yabasin, and Alhassan Abdul-Mumin, 'Childhood Immunization in Ghana: Tracing the History and Projecting the Future', *Public Health Challenges*, vol. 3, no. 2, 19 May 2024. https://doi.org/10.1002/puh2.176.
209 Based on the efficacy of seven doses before the switch to IPV in Afghanistan. See: Chard, A. N., M. Martinez, A. Matanock and A. M. Kassem, 'Estimation of Oral Poliovirus Vaccine Effectiveness in Afghanistan, 2010–2020', *Vaccine*, vol. 39, no. 42, 2021, pp. 6250–6255.
210 Gavi, 'Vaccine profiles: Polio', 25 July 2022, < https://www.gavi.org/vaccineswork/routine-vaccines/extraordinary-impact-polio>.

unlike the OPV.[211] The administration of the IPV entails an intramuscular or subcutaneous injection. Two doses are included, and in Ghana the first dose is administered at 14 weeks of age, and the second dose four months later.[212,213] Vaccine efficacy is slightly higher than the OPV, and assumed to be 99%.[214]

In April 2016, following a globally coordinated effort, countries switched from trivalent OPV (tOPV, which protected against types 1, 2, and 3) to bivalent OPV (bOPV, which covers only types 1 and 3). This change was made because the type 2 component of tOPV was responsible for most outbreaks of cVDPV. To maintain population immunity against type 2, Ghana introduced the inactivated polio vaccine (IPV) into its routine schedule in June 2018, given at 14 weeks of age.[215]

The CBA approach

For this CBA, the study team adopt a two-step incremental approach:

1. **OPV versus no vaccination**
   This study first compares the historical introduction of the OPV with a counterfactual scenario of no vaccination at all. Following the widespread roll-out of OPV, this incidence is assumed to have declined substantially to 0.145 per 100,000, reflecting the combined residual burden of wild poliovirus and circulating vaccine-derived poliovirus type 2 (cVDPV2).[216]
2. **IPV versus OPV alone**
   The second stage evaluates the incremental benefits of IPV when administered alongside an OPV-based programme. In this scenario, the study team begins with the post-OPV incidence of 0.145 per 100,000 (wild poliovirus plus cVDPV2) and assumes IPV use further reduces the burden of wild poliovirus specifically to 0.012 per 100,000.[217]

This approach allows the study team to capture both the foundational public health benefits of OPV compared to no intervention, and the incremental advantages of IPV in minimising the risks of both wild poliovirus and vaccine-derived outbreaks.

13.2 Baseline situation

OPV (foundational programme)

As of 2024, national coverage for OPV in Ghana is approximately 95%, which will be maintained through 2030, as can be seen in **Appendix C**. This corresponds to about 800,000 infants vaccinated each year, with absolute numbers gradually increasing as the population grows. Assuming an OPV efficacy of 92%,[218] the protected share of the target population is approximately 87% under baseline conditions. For the Stage-1 comparison (OPV versus no vaccination), the pre-programme incidence of paralytic polio is set at 8 cases per 100,000 population in 1977; the post-roll-out residual burden

211 Auzenbergs, Megan, et al., 'Vaccination Strategies against Wild Poliomyelitis in Polio-Free Settings: Outbreak Risk Modelling Study and Cost-Effectiveness Analysis', *BMJ Global Health*, vol. 10, no. 3, 1 March 2025, p. e016013.

212 UNICEF, 'Costs of Fully Vaccinating a Child – Countries Eligible for Gavi Vaccine Prices', August 2024, <https://www.unicef.org/media/161751/file/Standard%20costs%20of%20fully%20vaccinating%20a%20child_UNICEF_2024.pdf.pdf>.

213 World Health Organization, 'Vaccination schedule for Poliomyelitis for Ghana', <https://immunizationdata.who.int/global/wiise-detail-page/vaccination-schedule-for-poliomyelitis?ISO_3_CODE=GHA&TARGETPOP_GENERAL=>.

214 Gavi, the Vaccine Alliance, 'Inactivated Polio Vaccine Support', <www.gavi.org/types-support/vaccine-support/inactivated-polio-vaccine>, accessed 12 June 2025.

215 Chard, A. N., M. Martinez, A. Matanock and A. M. Kassem, 'Estimation of Oral Poliovirus Vaccine Effectiveness in Afghanistan, 2010–2020', *Vaccine*, vol. 39, no. 42, 8 October 2021, pp. 6250–6255.

216 Ibid.

217 Odoom, J. K., D. O. Laryea, N. A. A. Ntim, K. Attiku, M. Adjabeng, E. O. Duker, C. N. Antwi, E. Gberbi, I. Baffoe-Nyarko, P. L. Adams, A. E. Dickson, J. D. Boakye, J. Y. Mensah, C. Odoom, S. A. Bimpong, D. Odame, G. D. Agboste, N. Odoom, F. Asiedu-Bekoe and E. Obodai, 'Polio Eradication in Ghana: Past, Present, and Future', *Frontiers in Tropical Diseases*, vol. 6, 2025, article 1577945.

218 In the calculations, the study team stratified the average efficacy of bOPV and tOPV. Source: Chard, A. N., M. Martinez, A. Matanock and A. M. Kassem, 'Estimation of Oral Poliovirus Vaccine Effectiveness in Afghanistan, 2010–2020', *Vaccine*, vol. 39, no. 42, 8 October 2021, pp. 6250–6255.

(wild poliovirus plus cVDPV2) is treated in the impact modelling, but the foundational baseline uses this 8 per 100,000 incidence rate.[219]

The cost per fully vaccinated child is estimated at USD 7.66 in 2025, as is tabled in **Appendix D**, implying total programme costs of approximately USD 6.5 million in 2025, USD 7.8 million in 2030, and USD 9.3 million in 2035.

IPV (incremental to OPV)

Ghana's IPV coverage is also approximately 95% in 2024 and projected to remain at that level through 2030, as can be seen in **Appendix C**. With IPV efficacy assumed at 99%, about 94% of the target population is effectively protected.[220] For the Stage-2 comparison (IPV plus OPV versus OPV alone), the starting incidence pertains to wild poliovirus only and is set at 0.012 per 100,000, reflecting the environment with OPV already in routine use.[221]

The cost per fully vaccinated child is estimated at USD 11.30 in 2025, as is tabled in **Appendix D**, yielding total programme costs of approximately USD 9.6 million in 2025, USD 11.5 million in 2030, and USD 13.8 million in 2035.

13.3 No vaccination scenario

OPV (foundational comparison: OPV versus no vaccination)

If the OPV programme were halted, coverage would fall to zero percent and the paralytic polio incidence is assumed to revert toward its pre-programme level. For this comparison, the study team assumes a baseline incidence of 8 per 100,000 children for paralytic polio in 1977, prior to the introduction of vaccination. In the first year after withdrawal, this would translate into approximately 46 additional paralytic cases relative to continued vaccination. As successive unvaccinated birth cohorts accumulate, the annual excess burden is projected to rise to about 700 additional cases by 2030 and approximately 800 by 2035. Over a ten-year horizon, the cumulative excess amounts to roughly 6,000 additional cases.

Averted vaccine implementation costs

Halting OPV would avert programme expenditures of approximately USD 6.7 million in the first year, increasing to about USD 7.8 million in 2030 and USD 9.3 million by 2035. Discounted over the horizon, the NPV of averted OPV costs is approximately USD 67.6 million over ten years.

219 Odoom, J. K., D. O. Laryea, N. A. A. Ntim, K. Attiku, M. Adjabeng, E. O. Duker, C. N. Antwi, E. Gberbi, I. Baffoe-Nyarko, P. L. Adams, A. E. Dickson, J. D. Boakye, J. Y. Mensah, C. Odoom, S. A. Bimpong, D. Odame, G. D. Agboste, N. Odoom, F. Asiedu-Bekoe and E. Obodai, 'Polio Eradication in Ghana: Past, Present, and Future', *Frontiers in Tropical Diseases*, vol. 6, 2025, article 1577945.

220 Gavi, the Vaccine Alliance, 'Inactivated Polio Vaccine Support', <www.gavi.org/types-support/vaccine-support/inactivated-polio-vaccine>, accessed 12 June 2025.

221 Odoom, J. K., D. O. Laryea, N. A. A. Ntim, K. Attiku, M. Adjabeng, E. O. Duker, C. N. Antwi, E. Gberbi, I. Baffoe-Nyarko, P. L. Adams, A. E. Dickson, J. D. Boakye, J. Y. Mensah, C. Odoom, S. A. Bimpong, D. Odame, G. D. Agboste, N. Odoom, F. Asiedu-Bekoe and E. Obodai, 'Polio Eradication in Ghana: Past, Present, and Future', *Frontiers in Tropical Diseases*, vol. 6, 2025, article 1577945.

Increased healthcare costs

Assuming all paralytic cases seek care and that 88% require hospital admission for an average of ten days, with unit costs of USD 830 per inpatient episode and USD 13 per outpatient episode, the weighted average treatment cost is approximately USD 730 per case.[222,223,224]

Applying this to the projected excess caseload yields incremental health system outlays of approximately USD 0.004 million in the first year, USD 0.5 million in 2030, and USD 0.7 million in 2035. The discounted cumulative burden is estimated at approximately USD 1.6 million after five years and USD 4.3 million after ten years.

Increased productivity losses during illness

Each hospitalised episode removes a caregiver from work for approximately ten days. Weighting by hospitalisation rates implies an average productivity loss of about 0.03 productive years per case. Given the scale of the caseload, these losses translate into annual costs that are minor relative to healthcare costs and mortality/DALY losses.

Value of additional life years lost

With an assumed case fatality ratio of 5% for paralytic polio, the value of additional life years lost is estimated at approximately USD 0.4 million in the first year, USD 6.2 million in 2030, and USD 8.0 million in 2035.[225] The discounted cumulative NPV amounts to about USD 17.0 million after five years and USD 45.5 million after ten years.

Value of additional DALY

Each paralytic case is assumed to carry an average burden of approximately 14 DALYs.[226] The additional cases therefore generate about 650 DALYs in the first year, approximately 9,700 in 2030, and around 11,000 in 2035, cumulating to roughly 84,000 DALYs over ten years. Monetised, this corresponds to approximately USD 1.5 million in the first year, USD 26.0 million in 2030, and USD 33.7 million in 2035, with discounted cumulative losses of about USD 79.1 million after five years and USD 233.4 million after ten years.

IPV incremental comparison to OPV

If IPV were removed while OPV remained in place, the incidence is assumed to rise from the post-OPV level to approximately 0.145 per 100,000. In the first year after IPV withdrawal this would lead to about 1 additional paralytic case relative to the OPV-only baseline, increasing to approximately 9 additional cases per year by 2030 and 10 per year by 2035. Over a ten-year horizon, this results in an estimated cumulative excess of roughly 74 cases.

Averted vaccine implementation costs

Discontinuing IPV would avert approximately USD 10.0 million in programme costs in the first year, rising to about USD 11.5 million in 2030 and USD 13.8 million in 2035. The ten-year discounted NPV of averted IPV costs is approximately USD 99.6 million.

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222 Estivariz, C.F., Link-Gelles, R., and Shimabukuro, T., 'Chapter 18: Poliomyelitis', *Epidemiology and Prevention of Vaccine-Preventable Diseases* (The Pink Book), Centers for Disease Control and Prevention, 1 May 2024,<https://www.cdc.gov/pinkbook/hcp/table-of-contents/chapter-18-poliomyelitis.html, accessed 1 July September 2025.>.

223 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>

224 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

225 Estivariz, C.F., Link-Gelles, R., and Shimabukuro, T., 'Chapter 18: Poliomyelitis', *Epidemiology and Prevention of Vaccine-Preventable Diseases* (The Pink Book), Centers for Disease Control and Prevention, 1 May.

226 Auzenbergs, M., Abbas, K., Peak, C.M., Voorman, A., Jit, M., and O'Reilly, K.M., 'Vaccination Strategies Against Wild Poliomyelitis in Polio-Free Settings: Outbreak Risk Modelling Study and Cost-Effectiveness Analysis', *BMJ Global Health*, vol. 10, no. 3, 2025, article e016013, https://doi.org/10.1136/bmjgh-2024-016013.

Increased healthcare costs

Applying the same care-seeking, hospitalisation profile, length of stay, and unit costs as for OPV, the average treatment cost remains approximately USD 730 per case. Given the small number of additional cases, the discounted cumulative health system burden is very small over both five and ten years.

Increased productivity losses during illness

With the same ten-day caregiving assumption and an average of about 0.03 productive years lost per case, the discounted cumulative productivity losses remain very small due to the low incremental caseload.

Value of additional life years lost

Using a 5% case fatality ratio, the value of life years lost is approximately USD 0.004 million in the first year, USD 0.07 million in 2030, and USD 0.1 million in 2035, with discounted cumulative totals of about USD 0.2 million after five years and USD 0.6 million after ten years.

Value of additional DALYs

Assuming approximately 14 DALYs per paralytic case, the incremental burden amounts to roughly 8 DALYs in the first year, about 120 in 2030, and around 138 in 2035, cumulating to approximately 1,035 DALYs over ten years. Monetised, this corresponds to approximately USD 0.02 million in the first year, USD 0.3 million in 2030, and USD 0.4 million in 2035, with discounted cumulative losses of about USD 1.0 million after five years and USD 2.9 million after ten years.

13.4 Conclusion

The CBA for polio vaccination highlights two findings: the fundamental benefits of OPV compared to not vaccinating at all, and the incremental benefits of introducing IPV alongside OPV.

OPV versus no vaccination

If OPV is discontinued, there would be short-term savings of approximately USD 7 million in the first year and USD 68 million over ten years. When considering only the value of additional mortality, these savings are not outweighed by additional costs. After one year without OPV, the net economic gain is estimated at USD 6 million. By the tenth year, the cumulative net gains reach USD 17 million. When also the value of DALYs is considered, the picture shifts to a net loss: after five and ten years, the monetary loss is estimated to be 48 million USD and 170 million USD, respectively.

Table 13.1 The NPV of costs and benefits of OPV in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	7	33	68
Total extra health care gains	-0	-2	-4
Total extra productivity gains during treatment	-0	-0	-0
VSLY saved	-0	-17	-45
Total value of DALYs averted	-2	-79	-233
Net gain or loss (only mortality)	**6**	**14**	**17**
Net gain or loss (including DALYs)	**5**	**-48**	**-170**
ROI (only mortality)	0	-1	-1
ROI (including DALYs)	0	-2	-4

Expressed as a cost-benefit ratio, maintaining OPV yields a return of approximately USD 0.74 for every dollar spent by year 10 when only mortality is considered. This return increases to USD 3.52 by year 10 when DALYs are included. These figures confirm that OPV remains a highly cost-effective intervention and a cornerstone of polio eradication efforts.

IPV versus OPV alone

The incremental benefits of IPV remain limited within the ten-year horizon. Discontinuing IPV would save approximately **USD 10 million in the first year** and **USD 100 million over ten years**. Because OPV already provides strong protection and the residual incidence of wild poliovirus is very low, the additional health burden from removing IPV is minimal. As a result, the monetised health benefits, both in terms of life years and DALYs, are far smaller than the vaccination costs avoided. The net position remains strongly positive for discontinuation, with cumulative savings of about **USD 97 million** even when DALYs are included.

Cost–benefit ratios confirm this finding: they remain well below one throughout the period, indicating that the short-term financial savings from halting IPV outweigh the incremental health benefits within this timeframe. This outcome reflects two factors: IPV is relatively expensive, and when OPV is already in use, there are very few additional cases for IPV to prevent. While IPV may still provide strategic value as an insurance measure against wild poliovirus reintroduction or cVDPV risks, its economic return is not evident in the short to medium term under current epidemiological conditions.

Table 13.2 The NPV of costs and benefits of IPV vs OPV in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	10	49	100
Total extra health care gains	-0	-0	-0
Total extra productivity gains during treatment	-0	-0	-0
VSLY saved	0	0	-1
Total value of DALYs averted	-0	-1	-3
Net gain or loss (only mortality)	**10**	**49**	**99**
Net gain or loss (including DALYs)	**10**	**48**	**97**
ROI (only mortality)	0.00	0.00	-0.01
ROI (including DALYs)	0.00	-0.02	-0.03

14 Child Vitamin A Supplementation

14.1 Description of the intervention

Vitamin A is an essential nutrient required for healthy vision and immunity, where deficiency is a major health concern, especially among children under 5 years of age.[227] Vitamin A deficiency can cause childhood blindness and an increased risk of death from common childhood illnesses, such as diarrhoea and measles.[228,229]

Vitamin A supplements are administered twice a year to children until they reach the age of five. In 2023, the target group in Ghana consisted of approximately 4.3 million children under five years old.[230] The study team assumes that vitamin A supplementation reduces the risk of illness in children. Specifically, it lowers the chance of diarrhoea by about 15% and reduces the risk of measles by more than half (55%) compared children who do not receive supplements.

14.2 Baseline situation

In Africa, an estimated 5% of all child deaths are attributable to vitamin A deficiency.[231] To address child malnutrition and vitamin A deficiency, 41% of children aged 6–59 months received two high-dose vitamin A supplements in 2022.[232] Nevertheless, the issue is still present in Ghana: according to the Ghana Micronutrient Survey 2017, 22% of children aged 6-59 months experience vitamin A deficiency.[233] The prevalence is higher in the Northern Belt of Ghana, where 31% of children in this age group are affected,[234] and lowest among children from wealthier households, at 9%.[235]

Currently, the incidence of measles among children aged 0–5 is approximately 80 per 100,000, with higher rates among one year-olds. Diarrhoea incidence is much higher due to repeat episodes: approximately 73,000 per 100,000 at age one and approximately 40,000 per 100,000 in ages 1–5. For children aged 5–10, the incidence exceeds 100,000 per 100,000.[236] The model applies weighted averages across ages and conditions to calculate an average incidence.

This incidence corresponds to the baseline situation with a 41% coverage rate. Using a risk ratio (RR) of 0.85 for diarrhoea and 0.45 for measles, and accounting for their relative incidence, the study team estimates that 41% of the population has about 84.9% chance of falling ill with either measles or diarrhoea compared to children who do not receive supplements.[237] The remaining 59% has the standard risk of illness. This means that the total risk of illness is approximately 94%, so roughly 6% of cases are prevented by vitamin A supplementation compared to no supplementation.

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227 Okyere, Joshua, et al., 'Trends and Inequalities in Children Aged 6–59 Months Who Received Vitamin A Supplementation: Evidence from the 2003, 2008 and 2014 Ghana Demographic and Health Survey', *Tropical Medicine and Health*, vol. 50, no. 1, 28 December 2022. https://doi.org/10.1186/s41182-022-00488-3.

228 UNICEF, 'Vitamin A', UNICEF Data, March 2023, <https://data.unicef.org/topic/nutrition/vitamin-a-deficiency/#_ftn2>.

229 Stevens, Gretchen A, et al., 'Trends and Mortality Effects of Vitamin A Deficiency in Children in 138 Low-Income and Middle-Income Countries between 1991 and 2013: A Pooled Analysis of Population-Based Surveys' *The Lancet Global Health*, vol. 3, no. 9, 29 August 2015, pp. e528–e536. https://doi.org/10.1016/s2214-109x(15)00039-x.

230 United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.

231 World Health Organization, *Guideline: Vitamin A supplementation in infants and children 6-59 months of age*. Geneva, 2011.

232 UNICEF, 'Vitamin A', UNICEF Data, March 2023, <https://data.unicef.org/topic/nutrition/vitamin-a-deficiency/#_ftn2>

233 University of Ghana, Groundwork, University of Wisconsin-Madison, KEMRI-Wellcome Trust, and UNICEF, *Ghana Micronutrient Survey 2017*, Accra, Ghana, 2017.

234 Ibid.

235 Ibid.

236 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, < https://vizhub.healthdata.org/gbd-results/>.

237 This number is close to 85% because the incidence of diarrhoea is so much higher than the incidence measles.

For simplicity, throughout this chapter, this decline is referred as the proportion of the population "protected" by supplementation, although it represents a reduced risk rather than absolute protection.

Programme costs in the baseline scenario

Assuming a coverage rate of approximately 41% and unit costs of USD 1.04, total programme spending is estimated at approximately USD 4 million in 2025.[238] This averages to approximately USD 10.40 per fully supplemented child for ten doses from birth to age five, as is tabled in **Appendix D**. The total supplementation cost in 2025 is therefore of around USD 3.8 million.

14.3 No intervention scenario

If supplementation were halted, the 'protected' share would fall to zero. Incidence would rise accordingly. The study team estimates that there would be approximately 130,000 additional cases of diarrhoea and measles in the first post-withdrawal year (compared to baseline), rising to approximately 140,000 in 2030 and approximately 155,000 in 2035. Since the benefits end when a child ages out of the programme (and no lasting post-supplement effect is assumed), the annual number of excess cases grows with the population rather than compounding across cohorts. Over ten years, this results in a cumulative excess of approximately 1.4 million cases.

Averted implementation costs

Halting the programme averts approximately USD 4 million in the first year. With 2% annual inflation, these savings would increase to approximately USD 5.3 million by 2035.

Increased healthcare costs

Assuming that 20% of diarrhoea cases and 50% of measles cases require medical care, This results in about 27,000 additional care-seeking episodes in year one, about 28,500 in year five, and about 31,000 annually in year ten , totalling around 280,000 cumulatively over ten years.[239] With a weighted hospitalisation rate of approximately 2%,[240] an average stay of one day, and unit costs of USD 82.82 for inpatient care and USD 13 for outpatient care, the average cost per care-seeking case is about USD 3.74.[241,242]

Incremental health system outlays are about USD 0.5 million in year one, about USD 0.6 million in year five, and about USD 0.7 million in year ten. This totals to about USD 5.3 million discounted over ten years.

Increased productivity losses during illness

Each care-seeking episode results in one day of work lost for a caregiver. This adds up to about 79 caregiver-years lost in year one, about 85 in 2030, and about 91 in 2035. Valued at GDP-per-capita output per day, cumulative losses over ten years exceed approximately USD 2.0 million. For

238 Kannan, A., Tsoi, D., Xie, Y., Horst, C., Collins, J., and Flaxman, A., 'Cost-Effectiveness of Vitamin A Supplementation Among Children in Three Sub-Saharan African Countries: An Individual-Based Simulation Model Using Estimates from Global Burden of Disease 2019', *PLOS ONE*, vol. 17, no. 4, 2022, article e0266495, https://doi.org/10.1371/journal.pone.0266495.

239 Pan American Health Organization, *Epidemiologic Surveillance of Diarrheal Diseases Due to Rotavirus: Field Guide* (Scientific and Technical Publication No. 623), Washington, DC, PAHO, 2010. Accessed 3 June 2025.

240 Ibid.

241 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

242 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

simplicity, hospitalisation is also assumed to result in only one caregiver day lost, reflecting the relatively mild nature of most illness episodes considered here.

Value of additional life-years lost

Using a weighted case fatality ratio of 0.07%, additional mortality results in an NPV of life-years lost of approximately USD 14.0 million from approximately 100 extra deaths in 2026.[243] This rises to approximately USD 16.0 million in 2030 and approximately USD 18.0 million in 2035. Over the total research period of ten years, the cumulative discounted amount would be approximately USD 136.0 million.

Value of additional DALYs

Applying an average disability weight of approximately 0.1 DALY per case implies approximately 12,900 additional DALYs in the first year and approximately 15,000 in year ten.[244] Monetised, this totals approximately USD 380.0 million over ten years (NPV).

14.4 Conclusion

The study team considers continued vitamin A supplementation for children 6–59 months a high-return investment for Ghana. Halting the programme would trade approximately USD 17.0 million in annual savings for substantially larger social losses: approximately 1.4 million additional cumulative diarrhoea/measles cases over ten years, approximately 280,000 extra care-seeking episodes, approximately a discounted USD 5.3 million in health system outlays, more than USD 2.0 million in caregiver productivity losses, and large welfare losses on VSLY (approximately USD 136.0 million NPV) and DALY (approximately USD 380.0 million NPV) metrics.

After one year without vitamin A supplementation, the net economic loss is estimated at **USD 11 million** when considering mortality alone. **By the tenth year**, the total net loss reaches **USD 104 million** based on mortality, and **USD 348 million** when accounting for DALYs.

Table 14.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%.

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	4	19	39
Total extra health care gains	-0.5	-3	-5
Total extra productivity gains during treatment	-0.2	-1	-2
VSLY saved	-14	-68	-136
Total value of DALYs averted	-31	-169	-380
Net gain or loss (only mortality)	**-11**	**-53**	**-104**
Net gain or loss (including DALYs)	**-28**	**-153**	**-348**
ROI (including mortality)	-4	-4	-4
ROI (including DALYs)	-8	-9	-10

Expressed as a cost-benefit ratio, withdrawing vitamin A supplementation yields a negative return of approximately USD 4 per dollar gained in the first year, increasing to a loss of USD 4 by year ten when considering mortality only, and a loss of USD 10 when DALYs are included.

[243] Imdad, A., Mayo-Wilson, E., Haykal, M.R., Regan, A., Sidhu, J., Smith, A., and Bhutta, Z.A., 'Vitamin A Supplementation for Preventing Morbidity and Mortality in Children from Six Months to Five Years of Age', *Cochrane Database of Systematic Reviews*, vol. 3, 2022, article CD008524.

[244] Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

These estimates are conservative: by assuming no prolonged effects beyond age six and no transmission externalities, the analysis likely understates the true health and economic losses from halting supplementation.

15 Micronutrient Supplementation Powders for Children

15.1 Description of the intervention

Supplementation of micronutrient powders for children prevents and reduces deficiencies in essential micronutrients. The fortification of children's food with micronutrient powder addresses issues related to minimum dietary diversity and high anaemia among children, and improves child nutrition status, child health, and reduce morbidity and mortality.[245,246] Infants and children are at highest risk for micronutrient deficiencies as their needed vitamin and mineral intake is high to support growth and development.[247] The effects of anaemia in the first two years of life can lead to irreversible physical and cognitive consequences, such as poor cognitive, motor, social-emotional and neurophysiological development.[248]

The intervention consists of single-dose packets containing around 15 vitamins and minerals in powder form, for children aged 6–23 months, which can be added onto semi-solid food for home, school or other consumption.[249,250] The intervention is targeted at increasing the micronutrient content of children's diet, without altering the usual dietary habits. The easy-use powders allow fortification of any type of food and have fewer side effects compared to liquid supplements.[251] The micronutrient powder sachets contain Iron, Vitamin A, Zinc, water, and possibly other essential vitamins and minerals.[252]

In Ghana, the target group consists of children 6–23 months of age, which are provided with a monthly supply of micronutrient powder. The micronutrient powders are provided together with healthy infant and child nutrition practices counselling, during monthly child welfare clinic sessions, in half of the Ghanian districts.[253]

Number of doses, method of administration and timing

One box contains 30 × 1 g sachets. Following WHO guidance to target no more than 90 sachets per child per six months, this implies three boxes per six-month period. Applied from 6 to 23 months, a fully supplemented child requires around 26 boxes in total.[254]

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245 UNICEF Ghana, 'Infant and Young Child Nutrition', <https://www.unicef.org/ghana/infant-and-young-child-nutrition>, accessed 5 June 2025.

246 United Nations Children's Fund, *Home Fortification with Multiple Micronutrient Powders for the Prevention of Iron Deficiency Anaemia in Early Childhood* (brief guidance note), Nutrition and Child Development Section, Programme Group, UNICEF, New York, July 2023.

247 World Health Organization, *Guideline: Use of multiple micronutrient powders for point-of-use fortification of foods consumed by infants and young children aged 6-23 months and children aged 2-12 years*, Geneva, 2016, Licence: CC BY-NC-SA 3.0 IGO.

248 United Nations Children's Fund, *Home Fortification with Multiple Micronutrient Powders for the Prevention of Iron Deficiency Anaemia in Early Childhood* (brief guidance note), Nutrition and Child Development Section, Programme Group, UNICEF, New York, July 2023.

249 World Health Organization, 'Multiple Micronutrient powders for point-of-use fortification of foods consumed by children 6-23 months of age', Interventions, e-Library for Evidence for Nutrition Actions, 9 August 2023, <ttps://www.who.int/tools/elena/interventions/micronutrientpowder-infants>.

250 United Nations Children's Fund, *Home Fortification with Multiple Micronutrient Powders for the Prevention of Iron Deficiency Anaemia in Early Childhood* (brief guidance note), Nutrition and Child Development Section, Programme Group, UNICEF, New York, July 2023.

251 Ibid. .

252 World Health Organization, *Guideline: Use of multiple micronutrient powders for point-of-use fortification of foods consumed by infants and young children aged 6-23 months and children aged 2-12 years*, Geneva, 2016, Licence: CC BY-NC-SA 3.0 IGO.

253 UNICEF Ghana, 'Infant and Young Child Nutrition', <https://www.unicef.org/ghana/infant-and-young-child-nutrition>, accessed 5 June 2025.

254 World Health Organization, *Guideline: Use of multiple micronutrient powders for point-of-use fortification of foods consumed by infants and young children aged 6-23 months and children aged 2-12 years*, Geneva, 2016, Licence: CC BY-NC-SA 3.0 IGO.

Supplementation efficacy

Effects are broad (anaemia, iron deficiency), but for modelling the study team uses iron deficiency only, due to data availability. The study team assumes a RR of 0.48 for iron deficiency (52% risk reduction).[255] Anaemia-related morbidity and mortality are not modelled, so results are conservative. At the time of analysis, the DHS Program was not accepting new data requests following the suspension of USAID funding; existing approvals retained access only. Consequently, DHS could not be newly requested for this study.

15.2 Baseline situation

In Ghana, several efforts have been undertaken to address childhood micronutrient deficiencies, including breastfeeding protection and promotion and dietary diversity programs.[256] Despite these efforts, the prevalence of anaemia and micronutrient deficiencies in Ghana are still high. Among children aged 6-23 months, the national prevalence of anaemia is reported to be 35.6%, whereas iron deficiency prevalence is 21.5% and vitamin A deficiency prevalence is 20.8%.[257] The mortality associated with nutrient deficiencies is considerate, where 24% of child mortality cases in Ghana was reported to be a result of malnutrition in 2020.[258] Additionally, a study reported a 16.5% mortality rate of children aged 0-59 months that were admitted to hospitals with severe acute malnutrition in Ghana.[259]

Supplementation coverage at baseline (and protected share). Coverage is 41%. The operational "protected share" is calculated as coverage × (1 − RR). For iron deficiency (RR = 0.48), the protected share is around 21% (0.41 × 0.52), implying a residual risk of around 79% relative to a no-programme scenario. As in the rest of this chapter, the term "protected share" is used for simplicity, but it should be understood as a reduction in risk rather than absolute protection.

The analysis assumes an annual incidence of approximately 32,000 per 100,000 among children 0–2 years. This reflects current conditions with 41% coverage; the protected share above explains why incidence under the programme is lower than in a no-supplementation counterfactual.

Programme costs in the baseline scenario

Assuming approximately 41% coverage and a 0.61 unit cost, as is tabled in **Appendix D,** total programme spending is approximately USD 2.7 million in 2025, averaging approximately USD 3.64 per child per year, assuming that a box is given every two months from 6–23 months.[260]

15.3 No intervention situation

If supplementation were halted, the protected share would fall to zero and incidence would rise accordingly. The study team estimates approximately 70,000 additional iron-deficiency cases in the first post-withdrawal year versus baseline, approximately 75,000 in 2030, and approximately 81,000 in 2035. Because benefits end when a child ages out of the programme (and no lasting post-

255 World Health Organization, *Use of multiple micronutrient powders for point-of-use fortification of foods consumed by infants and young children aged 6–23 months and children aged 2–12 years*, WHO guideline, Geneva, World Health Organization, 16 December 2016, accessed 3 September 2025.

256 UNICEF Ghana, 'Infant and Young Child Nutrition', <https://www.unicef.org/ghana/infant-and-young-child-nutrition>, accessed 5 June 2025.

257 Azagba-Nyako, et al., 'Review of Current Strategies to Address Micronutrient Deficiencies (MNDs) in Ghana: A Scoping Review', *Journal of Nutrition and Metabolism*, vol. 2025, no. 1, 1 January 2025. https://doi.org/10.1155/jnme/6652716.

258 UNICEF Ghana, *Budget Brief – Nutrition*, UNICEF, Accra, 2021, <https://www.unicef.org/ghana/media/4316/file/BudgetBrief-Nutrition.pdf>

259 Asare, H., J., et al., 'Mortality in Relation to Profiles of Clinical Features in Ghanaian Severely Undernourished Children Aged 0–59 Months: An Observational Study', *British Journal of Nutrition*, vol. 125, no. 10, 2 September 2020, pp. 1157–1165. https://doi.org/10.1017/s0007114520003396.

260 United Nations Children's Fund, *Multiple Micronutrient Powder Supply and Market Update*, Market Note, UNICEF Supply Division, Copenhagen, July 2021, < https://www.unicef.org/supply/media/22386/file/Multiple-Micronutrient-Powder-Market-Note-July-2021.pdf>.

supplement effect is assumed), annual excess cases grow with population rather than compounding across cohorts. Cumulatively, the ten-year excess is approximately 0.75 million cases. This choice reflects the absence of reliable estimates of persistent post-supplement effects or transmission externalities.

Averted implementation costs

Halting the programme averts approximately USD 2.7 million in the first year, rising with 2% annual inflation and population growth to approximately USD 3.8 million by 2035. These are immediate public-budget savings, assuming government financing in the baseline.

Increased healthcare costs

Assuming that 20% of iron-deficiency cases seek care, this yields approximately 14,000 additional care-seeking episodes in year one, approximately 15,000 in year five, and approximately 16,000 in year ten, which leads to approximately 150,000 cumulatively over ten years. With a 2% hospitalisation rate, one-day average stay, and unit costs of USD 82.82 (inpatient) and USD 13 (outpatient), the average cost per case (including non-seekers) is approximately USD 4.05.[261,262,263]

Incremental health system outlays are approximately USD 0.3 million in year one, approximately USD 0.35 million in year five, and approximately USD 0.4 million in year ten. approximately Over ten years, total cumulative costs are USD 1.5 million (NPV). These costs fall on both government and households.

Increased productivity losses during illness

The assumption is made that each hospitalised and each care-seeking outpatient episode removes a caregiver from work for one day. Lost time totals approximately 38 caregiver-years in year one, approximately 41 in 2030, and approximately 44 in 2035. Valued at GDP-per-capita output per day, cumulative losses over ten years exceed approximately USD 1 million.

Value of additional life-years lost

Based on IHME data, the study assumes 0% case-fatality directly attributable to iron deficiency; thus, VSLY losses is equal to 0 in this analysis.[264]

Value of additional DALYs

The study uses approximately 0.04 DALY per case. [265] This implies approximately 3,000 DALYs lost in 2026, rising to approximately 3,400 in 2035. Monetised, the ten-year loss totals approximately USD 87,5 million (NPV).

15.4 Conclusion

Halting the programme would free approximately USD 2.7 million a year but drive approximately 150,000 additional iron-deficiency care-seeking cases over ten years. The resulting burdens include approximately USD 3 million (NPV) in incremental health system spending, USD 1 million in caregiver

261 For iron deficiency, no reliable data are available on the proportion of individuals who seek care or are admitted to hospital. In this model it has therefore been assumed, based on expert opinion, that 20% of cases seek care and that 2% result in hospitalisation, for illustrative modelling purposes.

262 World Health Organization, 'WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery', Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>.

263 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

264 Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2021 (GBD 2021) Results*, Institute for Health Metrics and Evaluation (IHME), Seattle, 2022, <https://vizhub.healthdata.org/gbd-results/>.

265 Ibid.

productivity losses, and large welfare losses when DALYs are monetised (around USD 64 million NPV). VSLY losses are zero in this specification because deaths are not attributed directly to iron deficiency.

After one year without micronutrient supplementation, the net economic loss is estimated at **USD 4.7 million** when considering DALYs. **By the tenth year**, the total net loss reaches **USD 64 million.**

Expressed as a cost-benefit ratio, withdrawing supplementation yields a negative return of approximately USD 3 per dollar gained in the first year, which will slightly worsen in year 10, including DALYs.

In short, maintaining supplementation remains a high-value investment: it prevents substantial morbidity, reduces pressure on facilities, and preserves household productivity. The cost-benefit ratio remains positive (more than 1) in every modelled year.

Moreover, this is a minimum estimate of benefits: the analysis values iron deficiency only and assumes no prolonged effects beyond the programme age window; excluding anaemia-related outcomes and longer-run impacts likely understates the true economic return.

Table 15.1 The NPV of costs and benefits of reduced vaccinations in millions USD, discounted at 3%

Type of cost/benefit	1 year	5 years	10 years
Prevented vaccination costs	3	14	28
Total extra health care gains	-0.3	-2	-3
Total extra productivity gains during treatment	-0.1	-0.5	-1
Total value of DALYs averted	-7	-39	-88
Net gain or loss (including DALYs)	**-5**	**-27**	**64**
ROI (including DALYs)	-3	-3	-3

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Appendix

Appendix A: Detailed methodology

Simulation of additional disease case

The CBA is based on a static population model, which tracks the cumulative health impact of withdrawing each intervention from 2026 onwards. The analysis assumes a protected share of the population, defined as the product of vaccine coverage and vaccine efficacy. Vaccination is therefore modelled as reducing the number of individuals who become ill, rather than altering the severity or duration of illness among those who are infected despite vaccination.

Protection is treated as binary: individuals are either part of the protected group, with no risk of illness, or the unprotected group, bearing the full risk of disease burden. Each year, additional cohorts are left unprotected and remain at risk in subsequent years, causing the at-risk population to grow over time. Where possible, age-specific disease incidence is used to match each unprotected cohort with the appropriate health risk, ensuring accurate estimation of intervention effects.

This approach captures the full downstream effects of intervention removal. Most interventions are evaluated over a 10-year time horizon. Interventions with delayed health impacts, such as HPV vaccination, are followed for up to 20 years. Herd-immunity effects are excluded, in line with common practice for single-intervention CBAs. The analysis assumes constant intervention efficacy and unit costs over time. Potential interactions between interventions are not modelled.

Key elements of the CBA

Table 0.1 Key elements to of the CBA

Component	What it includes	Perspective
Programme expenditure	Vaccine price, freight, wastage allowance and delivery costs. When an intervention is removed these outlays become cost savings.	Health-sector
Facility costs averted	Country- and level-specific facility costs modelled using the WHO-CHOICE regression framework, using GDP per capita. The per diem facility cost was multiplied by the average length of stay.	Health-sector
Treatment costs averted	Additional costs of medications and diagnostics were estimated as a proportion (25%-50%) of total facility fees for inpatient care. These treatment costs were also used in estimating the cost of illness for outpatient care.	Health-sector
Productivity losses averted	Caregiver absenteeism and long-term labour-force withdrawal due to illness or disability, valued at average GDP per working day.	Societal
Premature mortality	Economic value of life-years saved, estimated with the VSL per life-year (VSLY); DALY-based valuation is explored in sensitivity analysis.	Societal
Disability	Years lived with disability after non-fatal cases, monetised within the DALY framework.	Societal

The following key departures from the Watts et al. methodology need to be mentioned:

- **Care-seeking and hospitalisation rates:** demographic and Health Survey (DHS) data are currently unavailable due to on-going review of US foreign assistance programs. Therefore, peer-reviewed studies were used to parameterise the proportion of cases seeking outpatient care and the probability of hospital admission.
- **Unit-cost inflation and currency:** facility costs derived from 2017 WHO-CHOICE regressions are inflated to 2023 Ghana cedis, converted to 2023 US dollars using period-average exchange rates, and subsequently expressed in 2025 US dollars based on the inflation adjustments described in Section 2.2.4.

Key inputs of the CBA

Table 0.2 Overview of key data inputs and sources

Category	Source	Description
Population and growth	UN World Population Prospects 2024[266]	Mid-year population by single year of age and sex, plus growth assumptions for the projection period. The growth rates the study bases it on are derived from the population growth of Ghana between 2018-2023, as can be found in **Appendix A.**
GDP per capita	World Bank World Development Indicators [267]	Converted to GDP per day to value productivity losses. GDP growth assumed at 3% per annum.
Disease incidence, case-fatality, disability weights	The most recent Ghana-specific data (WHO/UNICEF[268]) form the primary source, supplemented by IHME Global Burden of Disease 2024[269]; if neither is available, other sources are applied.	Baseline epidemiology for each vaccine-preventable disease and for micronutrient-related conditions.
Baseline intervention coverage	WHO Immunisation Data Portal[270] and UNICEF	Administrative historical coverage of intervention.
Intervention efficacy	Peer-reviewed studies conducted in Ghana or, where unavailable, in epidemiologically (comparable lower-middle-income) countries	Relative risk reductions translated into absolute cases.
Unit costs (vaccines, supplies, delivery)	UNICEF Supply Division price lists and Ghana Health Service cost norms	Financial cost per fully immunised child, including cold chain overhead. This included the following: • **Vaccine costs**: the procurement price of a dose of BCG vaccine. • **Injection supply costs**: the cost of injection-related supplies such as syringes and safety boxes. • **Vaccine + injection supply costs**: the combined cost of the vaccine and its associated injection supplies.

266 United Nations, World Population Prospects, Population Division, Department of Economic and Social Affairs, New York, available at: https://population.un.org/wpp/
267 World Bank, World Development Indicators, World Bank Group, Washington, D.C., available at: https://databank.worldbank.org/source/world-development-indicators
268 World Health Organization, Global Health Observatory, Geneva, available at: https://data.who.int/
269 Institute for Health Metrics and Evaluation, Global Burden of Disease Study (GBD), University of Washington, Seattle, available at: https://www.healthdata.org/research-analysis/gbd
270 World Health Organization, Immunization Data Portal, Geneva, available at: https://immunizationdata.who.int/

		• **Average delivery costs**: the resources required to deliver the vaccine to beneficiaries. A summary of all costs per intervention can be found in **Appendix C.**
Treatment cost per case	Peer-reviewed studies conducted in Ghana or, where unavailable, in epidemiologically comparable lower-middle-income countries. Facility costs (based on WHO-CHOICE regressions) estimated using WHO estimates.[271]	Total treatment cost per case estimated from length of stay and care-seeking behaviour reported in the literature, combined with facility and treatment unit costs.

Key calculations that were used for all interventions

Medical and health costs

Medical and health costs were calculated using the WHO-CHOICE model and is based on the COI approach used in Watts et al. (2021).[272] This approach provided average costs per inpatient bed-day at primary, secondary, and tertiary hospitals, as well as costs per outpatient visit in health centres and hospitals at all levels. A weighted average of these costs was constructed using the distribution of resources across facility types described in Ghana's UHC roadmap, resulting in an average cost per inpatient bed-day and per outpatient visit.

These unit costs were then applied to illness-specific assumptions. The cost per inpatient was obtained by multiplying the average bed-day cost by the assumed hospitalisation rate and average length of stay per illness. In addition, 25% or 50% of the facility cost was added to reflect treatment costs, following the approach set out in Watts et al. (2021).[273] Outpatient costs were estimated by multiplying the average outpatient visit cost by the proportion of cases seeking care for each illness.

The resulting cost per case formed the basis for estimating the total medical and health costs arising from the additional cases following halting the intervention.

Productivity losses of caretaker

Productivity losses were estimated by assuming that one inpatient day corresponds to one lost day of productivity for a caregiver, and one outpatient visit also corresponds to one lost day. For each case, the total number of caregiver days lost was calculated and multiplied by daily GDP per capita, thereby providing an estimate of the productivity costs associated with caregiving.

The Value of a Statistical Life Year

The Value of a Statistical Life Year (VSLY) is commonly used in benefit-cost analyses and reflects individuals' willingness to pay for small reductions in mortality risk. These values, aggregated across a population, provide an estimate of the value of saving one life. Unlike the COI approach, VSL also captures intangible aspects of life, such as leisure, wellbeing, and intergenerational contributions, thus providing a broader perspective on the benefits of averted mortality.

Due to the lack of direct VSL estimates in low- and middle-income countries (LMICs), the analysis applied the value-transfer method recommended in the Reference Case Guidelines for Benefit-Cost

271 World Health Organization, *WHO-CHOICE Estimates of Cost for Inpatient and Outpatient Health Service Delivery*, Economic Analysis and Evaluation Team, Department of Health Systems Governance and Financing, WHO, Geneva, 2010, <https://www.who.int/publications/i/item/WHO-CHOICE-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery>

272 Watts, Elizabeth, et al., 'Economic Benefits of Immunization for 10 Pathogens in 94 Low- and Middle-Income Countries from 2011 to 2030 Using Cost-of-Illness and Value-of-Statistical-Life Approaches', *Value Health*, vol. 24, no. 1, January 2021, pp. 78–85.

273 Ibid.

Analysis in Global Health and Development.[274] This method adjusts a high-income country (HIC) reference VSL to the LMIC context using the ratio of GDP per capita between the two countries, raised to the income elasticity of the value of risk reduction, conservatively set at 1.5. The U.S. VSL was taken as USD 13,000,000 in 2023.[275]

$$VSL_{Ghana} = \left(\frac{GDP\ per\ capita_{Ghana}}{GDP\ per\ capita_{US}}\right)^{e} * VSL_{US}$$

Applying 2023 GDP per capita estimates for the United States and Ghana resulted in a Ghana-specific VSL of USD 65,316.41. Assuming an average age of 32.75 years in Ghana (based on a life expectancy of 65.5 years), the average individual has approximately 32.75 years of life remaining. The Value of a Statistical Life Year (VSLY) was therefore estimated by dividing the VSL by the expected years of life remaining, giving USD 1,994.39 per life year.

In the analysis, VSLY was multiplied by the average years of life lost per death in the simulation to obtain the total mortality-related benefits. VSLY is projected to grow in line with expected GDP growth.

Value of a Disability Adjusted Life Year

DALYs per case were calculated by dividing the incidence rate per 100,000 by the DALYs per 100,000 and multiplying this by the total number of cases. The resulting DALY burden was then valued in monetary terms. This study equals the monetary value of one DALY to the GDP per capita in purchasing power parity (PPP) net of current health expenditure, following the approach of prior published studies.[276] This equals 2,310 USD in 2025. Constant annual growth factor was applied, assuming a 3% increase in GDP per capita, to reflect the expected rise in the value of a DALY over the projection period.

[274] Robinson, Lisa A., *et al.*, *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development*, Harvard T.H. Chan School of Public Health, Boston, May 2019.

[275] Kearsley, Aaron, *HHS Standard Values for Regulatory Analysis, 2024* (Data Point), Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health and Human Services, Washington, DC, January 2024.

[276] Kirigia, J. M., and Mwabu, G. M., 'The monetary value of Disability-Adjusted-Life-Years lost in the East African community in 2015', *Modern Economy,* vol. 9, no. 7, July 2018, pp. 1360-1377.

Appendix B: Population (0-10 years) in Ghana between 2018 and 2023

Table 0.3 Size of the population of Ghana per age group between 2018 and 2023[277]

Year/age	0	1	2	3	4	5	6	7	8	9	10
2018	842,048	842,789	850,490	845,185	835,179	822,808	803,743	781,291	756,774	735,512	720,397
2019	844,511	835,881	839,779	847,359	842,002	832,027	819,792	800,993	778,891	754,744	733,800
2020	847,742	838,783	833,194	836,947	844,394	839,014	829,130	817,111	798,630	776,881	753,056
2021	852,001	842,368	836,320	830,589	834,195	841,547	836,214	826,512	814,775	796,631	775,196
2022	855,949	846,817	839,985	833,792	827,936	831,448	838,792	833,612	824,178	812,756	794,920
2023	861,369	851,010	844,564	837,578	831,247	825,311	828,809	836,251	831,314	822,180	811,049

[277] Population statistics are derived from United Nations, 'World Population Prospects', Department of Economic and Social Affairs, Population Division < https://population.un.org/wpp/downloads?folder=Standard%20Projections&group=Most%20used>.

Appendix C: Ghana's National Immunisation Strategy

Table 0.4 Ghana's vaccine coverage targets for 2025-2030, in% ages, used as baseline coverage rate for this study[278]

Antigens	Baseline	Expected Coverage	Expected Coverage	Expected Coverage	Expected Coverage	Expected Coverage	Expected Coverage
	2023	2025	2026	2027	2028	2029	2030
BCG	94	100	100	100	100	100	100
Penta1	95.6	95	95	95	95	95	95
Penta2	94.0	95	95	95	95	95	95
Penta3	99.2	95	95	95	95	95	95
OPV-0	59.9	100	100	100	100	100	100
OPV-1	92.3	95	95	95	95	95	95
OPV-2	91.0	95	95	95	95	95	95
OPV-3	94.8	95	95	95	95	95	95
IPV	100	95	95	95	95	95	95
PCV-1	91.8	95	95	95	95	95	95
PCV-2	90.8	95	95	95	95	95	95
PCV-3	94.7	95	95	95	95	95	95
Rota-1	70.8	95	95	95	95	95	95
Rota-2	67.1	95	95	95	95	95	95
MR-1	88.4	95	95	95	95	95	95
MR-2	82.1	95	95	95	95	95	95
YF	85.1	95	95	95	95	95	95
MenA-1	85.8	95	95	95	95	95	95

[278] Government of Ghana, *Ghana National Immunization Strategy 2025–2030* (draft), as received by UNICEF via email, September 2025.

Appendix D: Detailed vaccine costs

Table 0.5 Vaccination costs, calculated by adding direct vaccine costs, injection supply costs and delivery costs, in 2025 USD[279]

Antigens	Vaccine costs	Injection supply costs	Average delivery costs	Total unit costs
	2025 USD	2025 USD	2025 USD	2025 USD
BCG	0.44	0.07	2.34	2.86
HepB	0.38	0.05	2.34	2.78
OPV	0.66	-	7.01	7.66
Penta3	3.91	0.16	7.01	11.09
PCV	10.6	0.16	7.01	17.78
IPV	6.51	0.11	4.67	11.3
Rota	4.93	-	4.67	9.6
MR	1.28	0.07	2.34	3.7
Malaria	46.98	0.37	9.34	56.72
MenA	1.23	0.07	2.34	3.63
HPV	5	0.05	6.01	11.07
YF	2.06	0.07	2.34	4.48

Table 0.6 Unit costs for Vitamin A supplements and Micronutrients, in 2025 USD[280,281]

Supplement	Unit cost	Number of units per year	Total cost per year
	2025 USD		2025 USD
Vitamin A	1.04	2	2.08
Micronutrients	0.61	6	3.64

279 UNICEF, 'Costs of Fully Vaccinating a Child – Countries Eligible for Gavi Vaccine Prices', August 2024, <https://www.unicef.org/media/161751/file/Standard%20costs%20of%20fully%20vaccinating%20a%20child_UNICEF_2024.pdf.pdf>.

280 Kannan, A., Tsoi, D., Xie, Y., Horst, C., Collins, J., and Flaxman, A., 'Cost-Effectiveness of Vitamin A Supplementation Among Children in Three Sub-Saharan African Countries: An Individual-Based Simulation Model Using Estimates from Global Burden of Disease 2019', *PLOS ONE*, vol. 17, no. 4, 2022, article e0266495, https://doi.org/10.1371/journal.pone.0266495.

281 United Nations Children's Fund, *Multiple Micronutrient Powder Supply and Market Update*, Market Note, UNICEF Supply Division, Copenhagen, July 2021, < https://www.unicef.org/supply/media/22386/file/Multiple-Micronutrient-Powder-Market-Note-July-2021.pdf>.

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