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Carbon footprint of antenatal HBV diagnostic strategies, the Gambia

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Carbon emissions associated with antenatal testing for hepatitis B prophylaxis eligibility, the Gambia

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Abstract

Objective To estimate the carbon footprint of three diagnostic strategies to identify pregnant women eligible for antiviral prophylaxis to prevent hepatitis B vertical transmission in the Gambia.

Methods In 2024, we conducted a life cycle assessment of a point-of-care polymerase chain reaction (PCR) test using plasma, and a rapid diagnostic test for

hepatitis B core-related antigen (HBcrAg) using plasma and capillary blood across three hospitals (rural, suburban and urban) and a suburban health centre. We included all products and processes in each diagnostic strategy. The functional unit was an antenatal testing episode assessing eligibility for antiviral prophylaxis, beginning after positive hepatitis B surface antigen screening. We estimated carbon emissions in grams of carbon dioxide equivalent (g CO_{2e}) ± uncertainty.

Findings Mean carbon emissions per strategy were significantly different between point-of-care PCR and the rapid diagnostic tests (*P*-value: 0.028): 1619.0 ± 200.6 g CO_{2e} (PCR), 520.4 ± 59.1 g CO_{2e} (plasma-based rapid diagnostic test) and 374.3 ± 50.4 g CO_{2e} (capillary-based test). Higher emissions with the PCR test were mainly driven by its reliance on air conditioning (759.1 g CO_{2e} compared with 125.2 g CO_{2e} for plasma-based rapid diagnostic test and 24.3 g CO_{2e} for capillary-based test), the test itself (290.0 g CO_{2e} versus 129.0 g CO_{2e} for rapid diagnostic tests) and PCR-specific requirements including diagnostic device (47.0 g CO_{2e}) and additional patient travel to collect results (255.8 g CO_{2e}).

Conclusion Our findings suggest that HBcrAg rapid diagnostic tests can reduce emissions substantially compared with point-of-care PCR. Our study demonstrates that life cycle assessments are feasible in resource-constrained settings and highlights the importance of integrating sustainability into hepatitis B diagnostic strategies.

Introduction

In 2024, the World Health Assembly recognized climate change as an urgent threat to global health.¹ By intensifying extreme weather events, climate change worsens mental health and increases disease transmission and mortality.^{2,3} The World Health Organization (WHO) estimates that 250 000 additional deaths annually will occur between 2030 and 2050, mainly from malnutrition, malaria, diarrhoea and heat-related illnesses.² These impacts are expected to disproportionately affect populations in low- and middle-income countries.⁴ Urgent action to reduce greenhouse gas emissions is vital to mitigate these effects.

Despite contributing an estimated 4.6% of global carbon emissions,⁵ the health-care sector's environmental impact is often overlooked in health technology assessments, which are the main tool used by health systems to inform the adoption of health technologies or interventions and reimbursement decisions.⁶ While most research on health-care-related emissions has focused on hospitals,⁷ medical equipment,^{8,9} consumables,¹⁰ treatment,¹¹ pharmaceuticals¹² and hospital waste,¹³ diagnostics are underexplored. Few studies have compared the greenhouse gas emissions of diagnostic tools used for the same clinical indication.^{14,15}

Diagnostic tools are essential for managing infectious diseases, particularly in low- and middle-income countries, where health systems face increasing clinical and environmental challenges such as high infectious disease burden, constrained health-care

resources and infrastructure, and growing environmental pressures on health systems. Hepatitis B virus (HBV) infection, responsible for an estimated 1.1 million deaths in 2022, is the second leading infectious cause of death globally after tuberculosis.¹⁶ In many low- and middle-income countries, especially in sub-Saharan Africa, prevention of mother-to-child transmission (PMTCT) of HBV is central to achieving hepatitis B elimination.¹⁶ PMTCT involves antenatal screening for hepatitis B surface antigen (HBsAg), quantification of HBV deoxyribonucleic acid (DNA) to identify women eligible for antiviral prophylaxis and administration of a hepatitis B birth-dose vaccine to all infants irrespective of maternal HBV status.¹⁷ While real-time polymerase chain reaction (PCR) is the reference method for HBV DNA quantification, its use is still limited in many low- and middle-income countries due to high costs, infrastructure needs and workforce shortages.¹⁷

The hepatitis B core-related antigen (HBcrAg) rapid diagnostic test (ESPLINE™, Fujirebio, Japan) is a promising alternative to PCR-based testing. This lateral-flow assay can use capillary blood, requires no laboratory infrastructure or electricity, and have a sensitivity of 93.1% (95% confidence interval, CI: 90.5–95.2) and specificity of 94.3% (95% CI: 93.0–95.4) in identifying women eligible for antiviral prophylaxis.¹⁸ This test was recently CE-marked, that is the product complies with all relevant European Union legislation, as a highly sensitive rapid test for the detection of hepatitis B e antigen (HBeAg; ESPLINE™ HBeAg-hs). Furthermore, in a micro-costing study in Burkina Faso, the HBcrAg rapid diagnostic test reduced testing costs by up to 40.0% compared with PCR.¹⁹ However, the environmental impact of the test, an important consideration for sustainable health systems, has not been assessed.

In this study, we compared the carbon dioxide equivalent (CO₂e) emissions of three diagnostic strategies for identifying HBsAg-positive pregnant women eligible for antiviral prophylaxis in the Gambia: (i) point-of-care PCR (Xpert® HBV Viral Load, Cepheid, United States of America) using plasma; (ii) the HBcrAg rapid diagnostic test using plasma; and (iii) the HBcrAg rapid diagnostic test using capillary blood. Using a process-based life cycle assessment, we aimed to provide context-specific carbon footprint data to guide HBV prevention strategies in low- and middle-income countries.

Methods

Study setting

The Gambia, a low-income country in West Africa, has a population of 2.7 million. This analysis was conducted within two research projects: the TRI-MOM (Triple Elimination Model of Mother-to-Child Transmission of HIV, Syphilis, and HBV) and its ancillary study, PROTECT-B (Performance and Feasibility of Hepatitis B Core-Related Antigen Rapid Test). Ethical approval was obtained from the Gambia Government/MRC Joint Ethics Committee (ref: 30302).

Started in 2022, TRI-MOM evaluates the integration of hepatitis B PMTCT into routine antenatal care alongside human immunodeficiency virus (HIV) and syphilis screening in the Gambia and Burkina Faso. The project selected four health-care facilities in the Gambia's Western Region to reflect different settings (Fig. 1): Bwiam General Hospital (rural), Banjulinding Health Centre (suburban), Bundung Maternal and Child Health Hospital (urban) and Brikama District Hospital (suburban). After informed consent, pregnant women were screened for HIV, syphilis and hepatitis B using two rapid diagnostic tests: Bioline HIV/syphilis duo and Determine HBsAg 2 (Abbott, Illinois, USA). At three facilities, HBsAg-positive women were tested using a point-of-care PCR for HBV DNA and the women with viral loads $\geq 200\,000$ IU/mL received tenofovir disoproxil fumarate as antiviral prophylaxis. At Banjulinding, where PCR was unavailable, a treat-all approach was used in which all HBsAg-positive women received tenofovir disoproxil fumarate. Samples from HBsAg-positive women were systematically sent to the Medical Research Council Unit the Gambia laboratory for HBV DNA testing.

PROTECT-B, conducted between 2024 and 2025, was designed to validate HBcrAg rapid diagnostic test performance using venous plasma and finger-prick capillary blood, with a point-of-care PCR performed on venous plasma as the reference. The HBcrAg rapid diagnostic test was introduced into routine antenatal care and performed on-site in HBsAg-positive women. Although the results were not used to guide treatment, care pathway modelling assumed HBcrAg-positive women would receive same-day tenofovir disoproxil fumarate, consistent with a simplified test-and-treat approach.

Scope and functional unit

We conducted a life cycle assessment following the Product Life Cycle Accounting and Reporting Standard,²⁰ the Greenhouse Gas Accounting Sector Guidance for Pharmaceutical Products and Medical Devices²¹ and ISO 14044:2006.²² Greenhouse gas emissions were expressed as CO_{2e}, the study's main outcome.²⁰ The functional unit was a single antenatal testing episode to determine eligibility for peripartum antiviral prophylaxis, beginning after a

positive HBsAg screening test and ending with receipt of results from either the point-of-care PCR or rapid diagnostic test.

System boundary

This life cycle assessment followed a cradle-to-grave approach, covering the following stages: 1: raw material acquisition and pre-processing; 2: inbound transportation; 3: production; 4: assembly and packaging; 5: outbound transportation; 6: last-mile transportation; 7: product use; and 8: end-of-life and waste management.²³ We used both primary and secondary data. Between 1 July and 31 August 2024, we obtained field data from the Gambia for stages 6 to 8, and sourced data for stages 1 to 5 from a Unitaid assessment of the point-of-care PCR for *Mycobacterium tuberculosis* and rifampicin resistance (Xpert® MTB/RIF, Cepheid, USA) assay²³ and the manufacturer of the HBcrAg rapid diagnostic test, both of which are consistent with the Greenhouse Gas Protocol.²⁰ Fig. 2 shows the system boundary and included processes.

Stage 1 included consumables and equipment for blood collection and testing. For the HBcrAg rapid diagnostic test, we excluded buffer solution emissions due to negligible weight (<0.001 g). For point-of-care PCR, we omitted reagents, as data were unavailable for these components. Stage 2 considered transport of raw materials to manufacturers. Stages 3 and 4 covered production, assembly and packaging of test components and consumables, including gloves, swabs, pipettes, tubes and the PCR device. Stage 5 assumed sea freight from manufacturers to the Gambia. Stage 6 covered last-mile distribution from the Banjul Ferry Terminal to the National Public Health Laboratory, and onward to regional health directorates and health-care facilities. Stage 7 included electricity use for blood collection and testing (for example, lighting, fans, air conditioning, refrigerators, centrifuges, biosafety hoods and PCR equipment), transport to external laboratories when PCR was off-site (i.e. Banjulinding) and patient return travel if their test results were not available on the same day as their initial HBsAg screening results. We excluded storage emissions due to minimal space requirements. We included staff commuting and meals. Stage 8 covered medical waste transport and treatment (autoclaving, shredding or incineration), both on-site and off-site. We also included end-of-life disposal of the PCR device, but excluded peripheral electronics (e.g. laptops, scanners and centrifuges), assuming continued use beyond the operational life of the PCR device. We also considered waste management staff travel.

Data collection

We collected activity data and emission factors for all components within the system boundary of each diagnostic strategy. Activity data included electricity use (in kWh), material weight (in kg), travel distances (in km) and time spent (in h). We collected primary data through direct observation and structured interviews, with informed consent, at the four study sites and through consultations with the health ministry and the Medical Research Council Unit the Gambia. Interviewees included health workers, laboratory staff, logistics staff, waste handlers and researchers. We pretested a structured questionnaire and refined after pilot testing at Medical Research Council Unit the Gambia. We compiled a detailed inventory of items and activities using process mapping and system boundary criteria.

For stage 6 (last-mile transport), we obtained vehicle types, routes and delivery frequencies from facility records; we extrapolated transport volumes from Medical Research Council Unit the Gambia data. For stage 7 (use phase), we documented and weighed all medical consumables (e.g. gloves, needles, pipettes and test kits) on-site with a Denver Instruments S-402® scale (Denver Instrument Co., Denver, USA). We recorded staff roles, commuting distances and transport modes, and measured task durations using stopwatches. We estimated electricity use (in kWh) based on manufacturer specifications and inputs from the biomedical engineer at the Medical Research Council Unit the Gambia, and apportioned per test by dividing total energy consumption by the average number of samples processed per use cycle (e.g. per centrifuge run). At Banjulinding, where on-site PCR was unavailable, we recorded sample referral details, that is distance travelled, mode of transport and sample volume. For patient return travel, we estimated average distances using residential data and Google Maps. We grouped transport modes as vans (14 seats), taxis (four seats) or walking. Based on interviews, most women used vans, about a fifth used taxis, and women living within 1 km of the health centre walked.

For stage 8 (end-of-life), we manually inspected and weighed all test-related waste, including packaging. However, we excluded waste from ancillary devices required to operate the PCR platform (e.g. laptop, desktop computer, barcode scanner and printer), as these items are typically repurposed or continue to be used beyond the lifespan of the PCR device itself. We recorded waste transport distances and disposal methods (autoclaving, shredding or incineration) based on facility-level waste data (October 2023–September 2024). We also recorded the travel of waste management staff.

We obtained emission factors, defined as coefficients expressing greenhouse gas emissions per unit of activity (g CO₂e per unit), from Fujirebio, previous studies²³ and the

Base Carbone database, version 23.4, produced by the French Agency for Ecological Transition. When unavailable, we used proxies based on comparable materials or processes, following standard methods and expert input.

Data quality assessment

Following the Greenhouse Gas Protocol,²⁰ we assessed data quality for five dimensions: technological, temporal and geographical representativeness; completeness; and reliability. We rated each indicator qualitatively from very good to poor (online repository).²⁴ We converted the ratings into quantitative uncertainty values, expressed as \pm percentage ranges, using the Bilan Carbone® method,²⁵ version 9 (online repository),²⁴ to estimate uncertainty for each activity data point. For emission factors, we used uncertainty values as reported by the French Agency for Ecological Transition or previous studies; for HBcrAg rapid diagnostic test, the manufacturer provided uncertainty estimates.

Data analysis

We used Excel (Microsoft, Redmond, USA) to compile activity data and emission factors for each product or process. We categorized emissions as test-dependent (consumables and test materials) or site-dependent (transport, use and waste management), to reflect whether they arise from the diagnostic product itself or from facility-level workflows and infrastructure (Table 1). We made the calculations in two steps. First, for each product or process within a functional unit, we estimated emissions by multiplying activity data by its emission factor. Uncertainty was calculated using:

$$U_i = \sqrt{U_{ADi}^2 + U_{EFi}^2} \quad (1)$$

where, U_i is the combined uncertainty (%) for the i th product or process, U_{ADi} is the uncertainty (%) in activity data and U_{EFi} is the uncertainty (%) in the emission factor.

Second, we obtained total carbon emissions per diagnostic strategy by summing all emissions from individual products and processes. We propagated overall uncertainty (%) from the individual uncertainties using the following formula:

$$U_{total} = \frac{\sqrt{(C_1 \times U_1)^2 + (C_2 \times U_2)^2 + \dots + (C_n \times U_n)^2}}{C_1 + C_2 + \dots + C_n} \quad (2)$$

where, U_{total} is the total propagated uncertainty (%), C_i is the emission of the i th product or process and U_i is its combined uncertainty (%).

We applied the U_{total} to the estimated CO_{2e} and report the uncertainty as \pm gram ranges. We adapted the propagation equations from the Greenhouse Gas Protocol which align with the Intergovernmental Panel on Climate Change method.²⁶

We used the Wilcoxon rank-sum test for pairwise comparisons between diagnostic strategies. We performed two sensitivity analyses, one excluding air conditioning during testing with rapid diagnostic tests and the other modelling savings in emissions when test results were provided during the same visit as HBsAg screening.

Results

Testing workflows

All facilities conducted antenatal screening on fixed days, beginning with venous blood collection for multiple tests, including HBsAg (Determine 2, Abbott, Illinois, USA). Care pathways following sample collection varied in the four sites (Box 1; Fig. 3 and online repository).²⁴

Waste stream

We documented the full waste stream at each site and identified two main management pathways: on-site and off-site processing. At Bwiam, all waste was incinerated on-site using the INCINER8 I8-M70 high-temperature incinerator (Inciner8 Limited, Burscough, England), at 850–1200 °C. At the other facilities, waste was segregated and transported to the centralized clinical waste treatment centre in Farato (Fig. 1). At this centre, infectious waste, accounting for 72.4% (29 442/40 685 kg) of total waste generated between October 2023 and September 2024, was autoclaved and shredded using the Ecosteryl 250 system (Ecosteryl, Mons, Belgium), designed to reduce waste by 80%; residual waste was sent to the Brikama dumpsite. Sharps waste, representing 27.6% (11 243/40 685 kg) of total waste, was transferred to the National Public Health Laboratory for incineration using the INCINER8 I8-M70 system.

Carbon footprint

At all sites, the carbon footprint per testing visit followed a consistent pattern: highest for the point-of-care PCR strategy, intermediate for the plasma rapid diagnostic test and lowest for the capillary rapid diagnostic test (Fig. 4). Average emissions were 1619.0 ± 200.6 g CO_{2e} for point-of-care PCR, 520.4 ± 59.1 g CO_{2e} for plasma rapid diagnostic test and 374.3 ± 50.4 g CO_{2e} for capillary rapid diagnostic test. Pairwise comparisons using the Wilcoxon rank sum

test showed significantly lower emissions for capillary rapid diagnostic test compared with PCR (P -value: 0.028) and for plasma rapid diagnostic test compared with PCR (P -value: 0.028), while the difference between capillary and plasma rapid diagnostic test was not statistically significant (P -value: 0.200).

Emission sources varied by strategy (Table 1, Fig. 5 and online repository).²⁴ For point-of-care PCR, the main contributor was energy use (54.1%; 894.8/1655.1), mainly from air conditioning (84.8% 759.1/894.8 of energy-related emissions), followed by the test cartridge and device (20.4%; 336.9/1655.1) and women's travel (11.5%; 190.4/1655.1). For plasma rapid diagnostic test, emissions came mainly from energy use (30.6%; 166.6/544.6), the test itself (23.7%; 129.0/544.6) and consumables (17.7%; 96.6/544.6). For capillary rapid diagnostic test, key contributors were the test (34.5%; 129.0/374.3), women's travel (16.7%; 62.5/374.3) consumables (13.4%; 50.3/374.3), energy use (11.8%; 44.1/374.3) and laboratory staff travel (7.1%; 26.6/374.3).

In all four sites, point-of-care PCR produced three to four times more emissions than rapid diagnostic testing strategies, mainly due to its reliance on air conditioning (759.1 g CO_{2e} for point-of-care PCR versus 125.2 g CO_{2e} for plasma rapid diagnostic test and 24.3 g CO_{2e} for capillary rapid diagnostic test); the test itself (290.0 g CO_{2e} for point-of-care PCR versus 129.0 g CO_{2e} for rapid diagnostic test); and PCR-specific requirements such as the PCR device (47.0 g CO_{2e}) and additional travel by women to collect viral load results in Banjulinding and Brikama (255.8 g CO_{2e}, averaged across the four sites).

The higher footprint of plasma rapid diagnostic test over capillary rapid diagnostic test was mainly due to extra consumables in testing preparation (gloves and transfer pipettes: 40.7 g CO_{2e}) and greater energy use for plasma separation (15.9 g CO_{2e}).

Carbon footprint by site

Carbon emissions showed less variation between sites using the same diagnostic strategy (Fig. 4). For point-of-care PCR, Bwiam had the lowest emissions, as testing occurred on the same day as HBsAg screening, avoiding extra travel for women. However, emissions were higher for last-mile transport, due to Bwiam's distance from the National Public Health Laboratory (Fig. 1) and from on-site incineration using the INCINER8 I8-M70 system.

For both rapid diagnostic test strategies, Bundung had the highest emissions, as it was the only site where women returned on a separate day to receive both screening and post-screening test results. Banjulinding had the second highest emissions for capillary rapid

diagnostic test, mainly due to the use of an air-conditioned laboratory, which increased energy-related emissions.

Sensitivity analysis

Since the HBcrAg rapid diagnostic test can be performed at room temperature, we modelled a scenario in Banjulinding excluding air conditioning. This model reduced the carbon footprint from 359.6 g to 262.3 g CO₂e for the capillary rapid diagnostic test, and from 454.0 g CO₂e to 335.4 g CO₂e for plasma rapid diagnostic test (Fig. 6). This model was not feasible for point-of-care PCR, which requires ambient temperatures lower than 30 °C for accurate performance.

In Bundung, where women routinely returned to collect results, we estimated emissions savings if performing the test and providing the results occurred on the same day as HBsAg screening. This model would reduce emissions by 250.1 g CO₂e for capillary rapid diagnostic test, 278.8 g CO₂e for plasma rapid diagnostic test and 250.1 g CO₂e for point-of-care PCR (Fig. 6).

Discussion

This study adds to the limited evidence on the carbon footprint of diagnostic strategies in a resource-constrained setting. Using a life cycle assessment, we found that the point-of-care PCR test generated the highest emissions per test, followed by the plasma-based rapid diagnostic test, with the capillary-based rapid diagnostic test having the lowest footprint. The elevated emissions from point-of-care PCR were mainly driven by its high energy requirements, particularly air conditioning to maintain laboratory temperatures lower than 30 °C, which is critical for optimal functioning of the point-of-care PCR platform.²⁷ Additional contributors included emissions from the test cartridge and device, as well as additional travel by women returning to collect point-of-care PCR results in facilities where same-day reporting was not available.

Few studies have assessed the environmental impact of diagnostics for the same clinical indication. Research in the United Kingdom of Great Britain and Northern Ireland comparing cervical cancer screening methods found self-sampling had lower emissions than clinician-based methods.¹⁴ In France, histology and immunohistochemistry were assessed to identify high-impact steps in pathology workflows.¹⁵ In the USA, prostate biopsy pathways incorporating prostate magnetic resonance imaging had substantially higher greenhouse gas emissions than ultrasound-guided biopsy alone due to the energy-intensive nature of magnetic

resonance imaging.²⁸ While these studies provide important examples of integrating environmental considerations into health technology assessment, all were conducted in high-income countries. Our study fills a gap by demonstrating that life cycle assessments are feasible in low- and middle-income countries and that simplified diagnostics, such as the HBcrAg rapid diagnostic test, may be both environmentally efficient and context-appropriate.

Capillary rapid diagnostic tests may reduce emissions by over 75.0% compared with point-of-care PCR, potentially saving about 1.25 kg CO₂e per test. Applying this saving to the Gambia's antenatal programme, which serves an estimated 3700 HBsAg-positive women annually,^{29,30} translates to an annual reduction of 4600 kg CO₂e, equivalent to about 18 000 km driven by a mid-sized car. These savings could scale up substantially if adopted across other HBV-endemic countries. Sensitivity analyses indicated that simple adaptations for rapid diagnostic test strategies, such as removing air conditioning or delivering results on the same day, could further reduce emissions by 20.0–30.0%.

Importantly, the rapid diagnostic test strategy not only has the lowest emissions but also offers the most resilient and resource efficient option. Unlike point-of-care PCR, rapid diagnostic testing does not rely on air conditioning or specialized equipment, making it less vulnerable to power outages or system failures, risks that are increasing with climate change. By minimizing technological dependencies, the rapid diagnostic test method aligns sustainability with operational resilience, supporting continuity of care even during blackouts or heatwaves. Choosing simpler, low-tech options can thus simultaneously advance climate and health-system goals in resource-constrained settings.

Our study has some limitations. Emission factors for upstream processes (i.e. processes occurring before on-site test use) relied on secondary sources or proxies, although we aligned with international standards. Our functional unit was a single antenatal testing episode; we did not assess diagnostic accuracy or downstream impact of missed diagnoses on health-care use or emissions. These considerations were beyond the scope of this analysis and will be explored in future work. Lastly, our study was not designed to generate nationally representative estimates and our findings may not be generalizable to settings with different health-care infrastructure, energy sources or waste management systems.

In summary, our study shows that diagnostic strategies for hepatitis B may differ markedly in their environmental impact. Rapid diagnostic test using capillary blood may offer a lower-carbon alternative to point-of-care PCR-based testing, with further reductions possible through context-appropriate workflow adjustments. Incorporating environmental

metrics into health technology assessments could support more sustainable and equitable approaches to infectious disease control in low- and middle-income countries.

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Competing interests:

YS has received research materials from Abbott Laboratories and Fujirebio. All other authors declare no competing interests.

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Box 1. Testing workflows for health facilities included in the study on carbon emissions associated with antenatal testing for hepatitis B prophylaxis eligibility, the Gambia, 2024

Bundung (urban maternal and child health hospital)

Screening was done on Mondays and all women were asked to return on Friday for their results. For women who were HBsAg-positive, reflex testing using the same plasma sample was performed during the week with both point-of-care PCR and plasma rapid diagnostic test. The capillary rapid diagnostic test required a finger prick on Friday. Results for both screening and post-screening tests were provided on Friday.

Brikama (suburban district hospital)

Women waited on-site for HBsAg results. If positive, reflex testing used the same plasma for point-of-care PCR and plasma rapid diagnostic test; the capillary rapid diagnostic test required a separate finger prick. Rapid diagnostic test results were available on the same day, whereas PCR results were delayed by 1–4 days, requiring a return visit.

Bwiam (rural general hospital) and Banjulinding (suburban health centre)

Reflex testing was not done. Instead, a second venous sample was collected after a positive HBsAg result. In Bwiam, all tests were completed on the same day and results were delivered during the same visit. At Banjulinding, the rapid diagnostic test was performed on-site, but PCR samples were sent to the laboratory of the Medical Research Council Unit the Gambia, requiring a return visit for results.

Table 1. Carbon footprint of antenatal diagnostic strategies to identify pregnant women eligible for hepatitis B antiviral prophylaxis by health care facility, the Gambia, 2024

Domain and item	Carbon dioxide emitted, g											
	Bwiam (rural general hospital)			Banjulinding (suburban health centre)			Brikama (suburban district hospital)			Bundung (urban maternal and child hospital)		
	Rapid diagnostic test		Point-of-care PCR	Rapid diagnostic test		Point-of-care PCR	Rapid diagnostic test		Point-of-care PCR	Rapid diagnostic test		Point-of-care PCR
	Capillary blood	Plasma		Capillary blood	Plasma		Capillary blood	Plasma		Capillary blood	Plasma	
Last-mile transportation	18.9	24.1	44.7	1.9	2.5	4.5	5.8	7.4	13.7	1.9	2.4	4.4
Consumables												
Sampling equipment												
Gloves	40.0	40.0	40.0	40.0	40.0	40.0	40.0	NA	NA	40.0	NA	NA
Cotton	1.7	1.7	1.7	1.7	1.7	1.7	1.7	NA	NA	1.7	NA	NA
Alcohol	0.9	0.9	0.9	0.9	0.9	0.9	0.9	NA	NA	0.9	NA	NA
Syringe and needle	NA	9.5	9.5	NA	9.5	9.5	NA	NA	NA	NA	NA	NA
Finger pricker	7.8	NA	NA	7.8	NA	NA	7.8	NA	NA	7.8	NA	NA
Blood sample tube	NA	11.5	11.5	NA	11.5	11.5	NA	NA	NA	NA	NA	NA
Testing preparation												
Gloves	NA	40.0	40.0	NA	40.0	40.0	NA	40.0	40.0	NA	40.0	40.0
Transfer pipettes	NA	NA	3.6	NA	NA	3.6	NA	NA	3.6	NA	NA	3.6
Pipette tips	NA	0.7	NA	NA	0.7	NA	NA	0.7	NA	NA	0.7	NA
Test												
HBcrAg rapid diagnostic test	129.0	129.0	NA	129.0	129.0	NA	129.0	129.0	NA	129.0	129.0	NA
Point-of-care PCR (HBV viral load cartridge)	NA	NA	290.0	NA	NA	290.0	NA	NA	290.0	NA	NA	290.0
Point-of-care PCR (machine, module IV)	NA	NA	NA	NA	NA	18.6	NA	NA	NA	NA	NA	15.2
Point-of-care PCR (machine, module XVI)	NA	NA	31.6	NA	NA	NA	NA	NA	35.3	NA	NA	NA
Printer (device)	NA	NA	4.7	NA	NA	10.9	NA	NA	5.3	NA	NA	8.9
Desktop (device)	NA	NA	9.0	NA	NA	NA	NA	NA	10.1	NA	NA	17.2
Laptop (device)	NA	NA	NA	NA	NA	19.4	NA	NA	NA	NA	NA	NA
Barcode scanner (device)	NA	NA	0.3	NA	NA	0.7	NA	NA	0.3	NA	NA	0.6
Product use												
Energy for sample conservation before point-of-care PCR HBV viral load test is done	NA	NA	NA	NA	NA	9.6	NA	NA	NA	NA	28.7	28.7
Energy to run a sampling room	27.2	1.8	1.8	0.2	0.2	0.2	23.8	NA	NA	23.8	NA	NA
Transportation of the sample to the Medical Research Council Unit the Gambia	NA	NA	NA	NA	NA	5.7	NA	NA	NA	NA	NA	NA

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Energy to run a laboratory	NA	151.1	912.2	101.5	135.8	842.2	NA	174.3	912.2	NA	174.3	872.4
Laboratory technician's travel	21.9	26.7	9.7	21.9	26.7	9.7	37.6	29.2	NA	25.2	19.6	NA
Skilled laboratory technician's travel	NA	NA	15.8	NA	NA	28.7	NA	NA	33.3	NA	NA	22.3
Women's travel	NA	NA	NA	NA	NA	306.1	NA	NA	205.4	250.1	250.1	250.1
Midwives' travel	12.1	12.1	12.1	39.1	39.1	39.1	47.7	47.7	47.7	48.7	48.7	48.7
End-of-life and waste												
Waste management staff travel	NA	NA	NA	1.5	1.5	1.5	1.5	1.2	1.2	1.5	1.2	1.2
Transportation of waste to management site and dumpsite	NA	NA	NA	7.3	6.3	20.6	6.5	1.8	3.4	8.8	4.3	8.4
Energy for waste management	21.9	39.0	62.1	6.8	8.6	13.0	6.8	4.6	9.0	7.8	4.6	9.0
Point-of-care PCR, machine end of life	NA	NA	4.9	NA	NA	2.9	NA	NA	5.6	NA	NA	2.4
Total ± uncertainty	281.4 ± 34.8	488.1 ± 48.8	1506.1 ± 199.6	359.6 ± 40.9	454.0 ± 45.3	1730.6 ± 182.0	309.1 ± 37.5	435.9 ± 48.5	1616.1 ± 208.6	547.2 ± 88.3	703.6 ± 93.8	1623.1 ± 212.2

HBcrAg: hepatitis B core-related antigen; HBV: hepatitis B virus; NA: not applicable; PCR: polymerase chain reaction.

Fig. 1. Map of the health facilities included in the study on carbon emissions associated with antenatal testing for hepatitis B prophylaxis eligibility, the Gambia, 2024

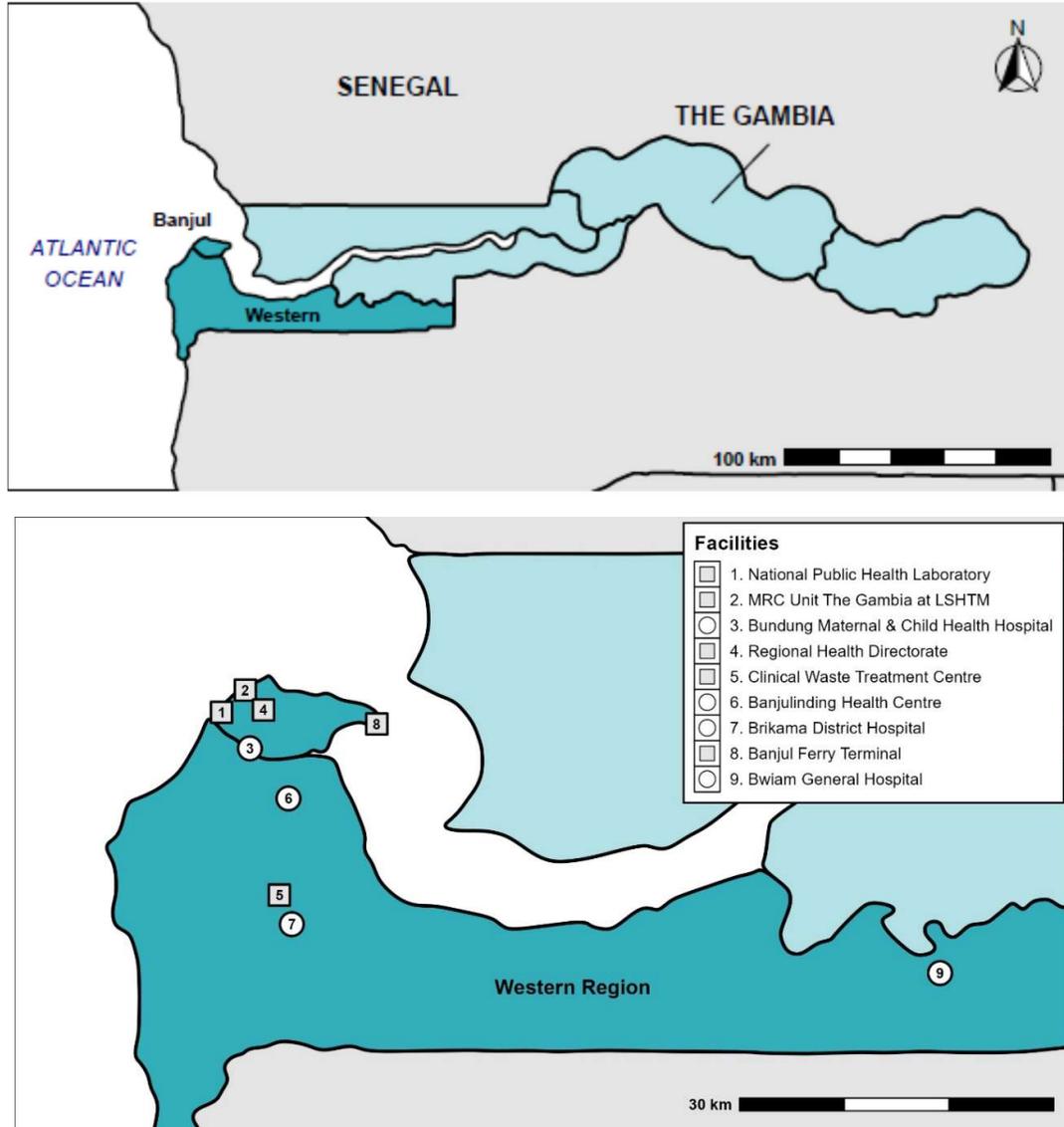
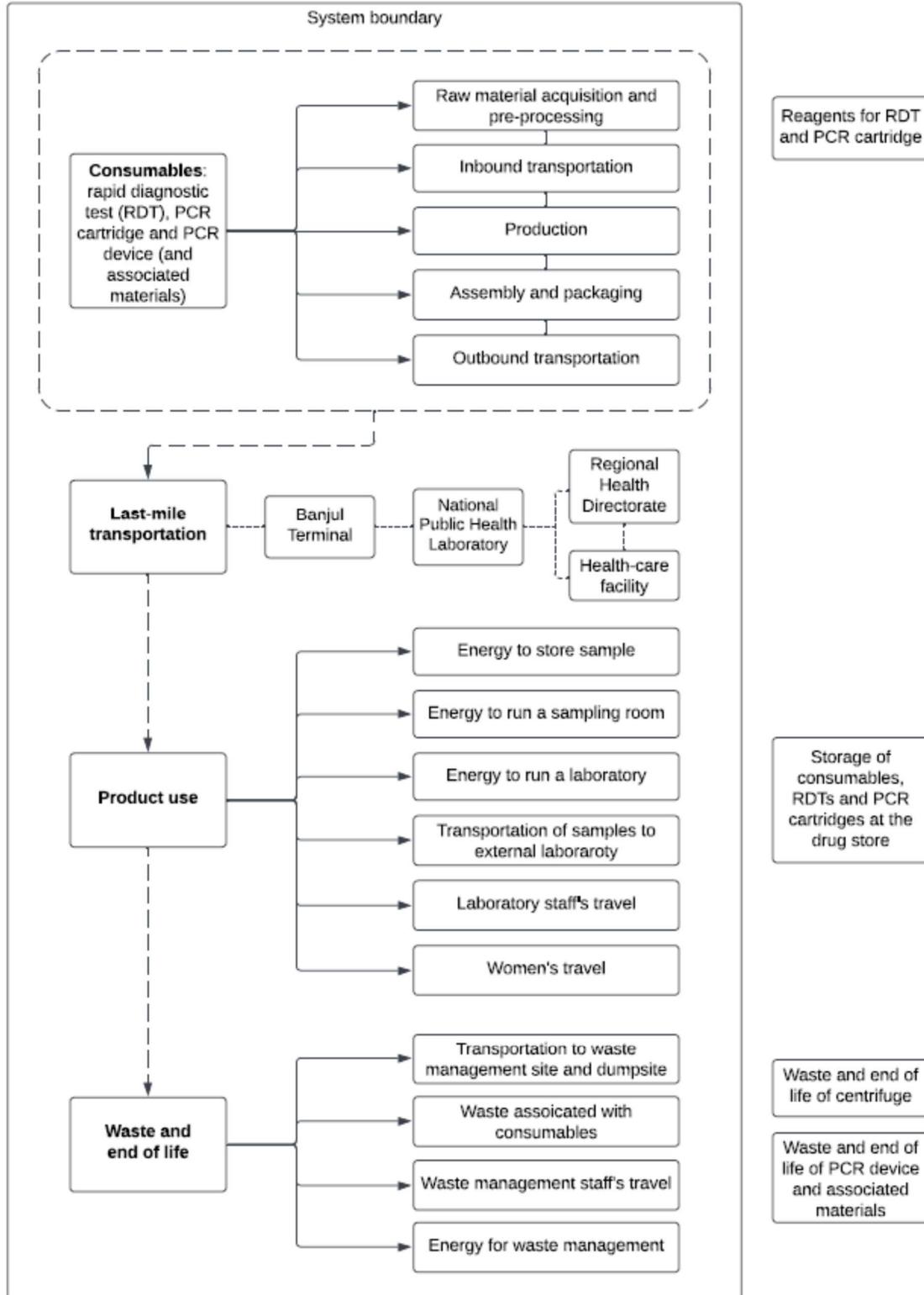
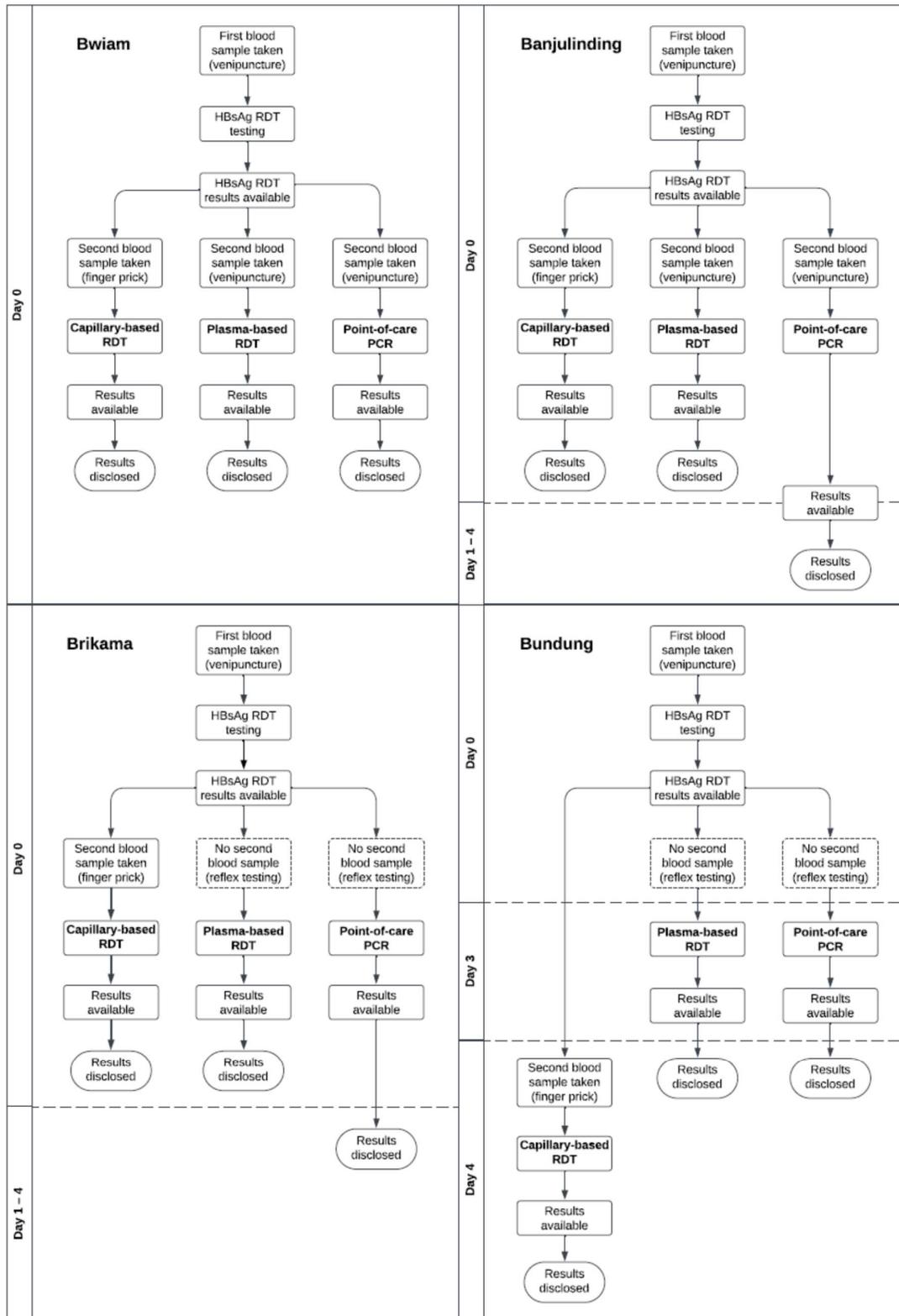


Fig. 2. System boundary of life cycle assessment of diagnostic strategies



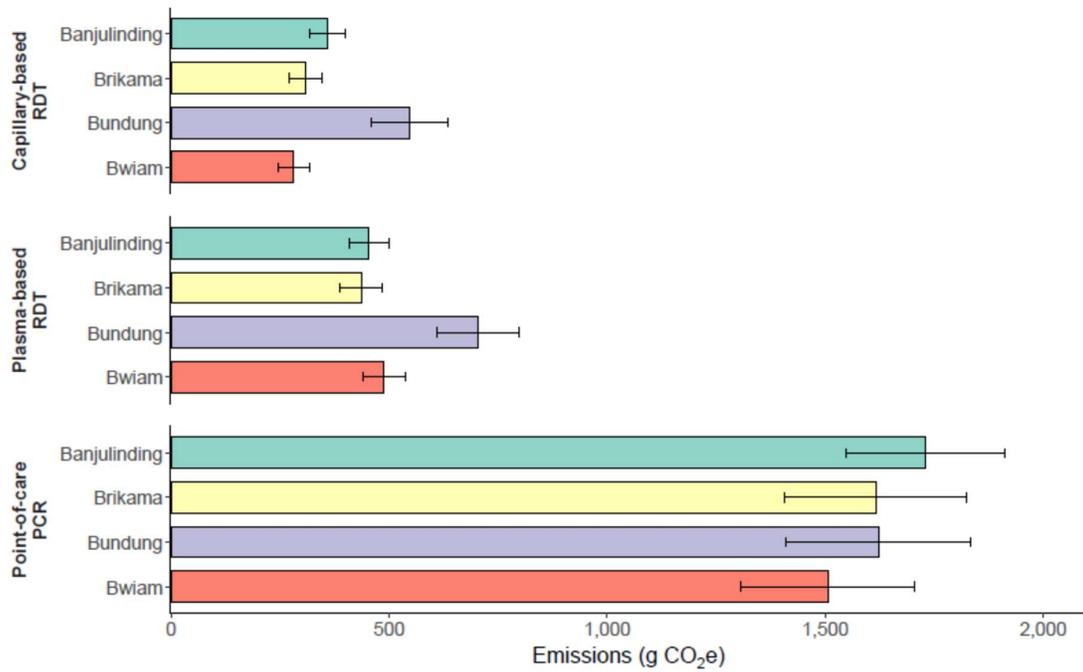
PCR: polymerase chain reaction.

Fig. 3. Workflows for identifying pregnant women eligible for hepatitis B antiviral prophylaxis in antenatal care, by health-care facility, the Gambia



HBsAg: hepatitis B surface antigen; PCR: polymerase chain reaction.

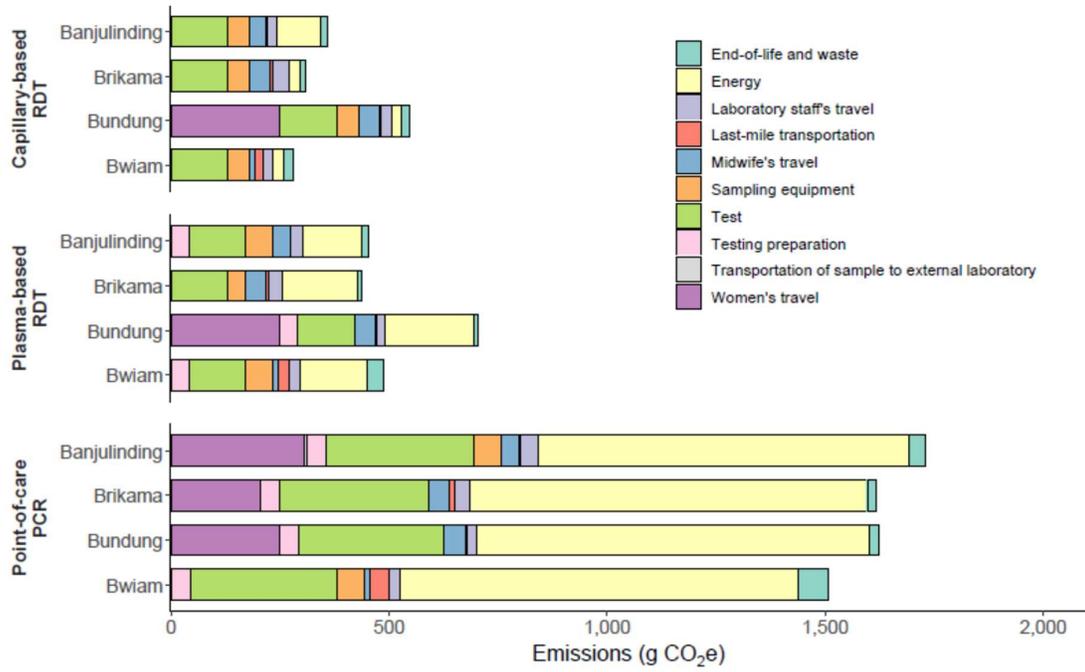
Fig. 4. Carbon footprint of hepatitis B antenatal diagnostic strategies in each health-care facility, the Gambia



CO₂e: carbon dioxide equivalent; PCR: polymerase chain reaction;

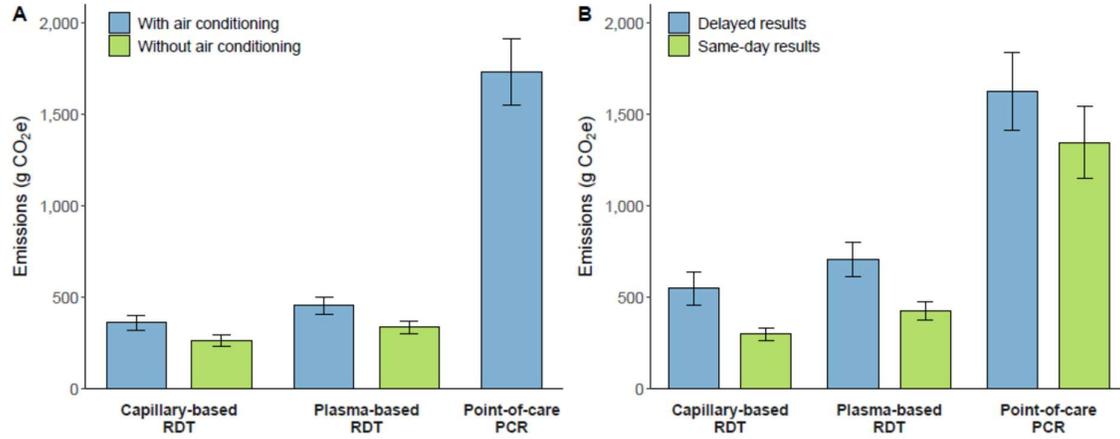
Note: The error bars indicate uncertainties.

Fig. 5. Source of carbon emissions of hepatitis B antenatal diagnostic strategies in each health-care facility, the Gambia, 2024



CO₂e: carbon dioxide equivalent; PCR: polymerase chain reaction.

Fig. 6. Total carbon footprint by diagnostic strategy, with and without air conditioning) and time to results at Bundung Maternal and Child Health Hospital, the Gambia, 2024



CO₂e: carbon dioxide equivalent; PCR: polymerase chain reaction.

Note: The error bars indicate uncertainties.