Environmental Performance Benchmarking Across Healthcare Sub-Sectors: A Comparative Analysis of Emissions, Energy, Water, and Waste Footprints

Surinder Deswal[1*], Phalguni Deswal[2]

[1]Professor, Civil Engineering Department, National Institute of Technology Kurukshetra, India.
[2]Independent Researcher, India.
*Corresponding Author

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Abstract

The healthcare sector accounts for approximately 4.4% of global greenhouse gas emissions, yet comparative analyses of environmental performance across its distinct sub-sectors remain scarce. This paper presents the first comprehensive comparative descriptive and exploratory statistical analysis of environmental performance across five healthcare sub-sector groupings—Pharmaceutical & Biotechnology Companies, Medical Equipment & Supplies Companies, Health Care Providers & Services Companies, Pharmaceutical & Biotechnology and Medical Equipment & Supplies Companies (mixed), and Biotech/Innovator Pharma Companies—using data from eight leading companies (Pfizer, Regeneron, Siemens Healthineers, Philips, Smith+Nephew, CVS Health, Johnson & Johnson, and BioNTech) over the 2019–2025 period. Key findings reveal that Health Care Providers & Services exhibit the lowest emission intensities across all scopes (2025 total intensity: 66.9 $t.CO_2e/million\ USD\ revenue$*) while generating the highest absolute Scope 3 emissions, driven by extensive supply chains. Pharmaceutical & Biotechnology companies demonstrate the highest Scope 3 emission intensities (Pfizer: 54.5* $t.CO_2e/million\ USD\ revenue$ *in 2025), with Scope 3 constituting 80–90% of total emissions across most sub-sectors. Energy transition trajectories vary markedly: Biotech/Innovator Pharma showed the most dramatic renewable energy adoption (from 7.1% in 2019 to 75.2% in 2025), while Pharmaceutical & Biotechnology lagged significantly (from 9.5% to 68.7%). Water withdrawal and waste generation intensities reveal that Pharmaceutical & Biotechnology companies are the most resource-intensive (Pfizer: 0.43* $thousand\ m^3/million\ USD$ *water intensity; 1.77* $tons/million\ USD$ *waste intensity in 2025), whereas Health Care Providers & Services exhibit the lowest intensities (CVS Health: 0.016* $thousand\ m^3/million\ USD$*; 0.011* $tons/million\ USD$*). These findings establish benchmark environmental performance profiles for healthcare sub-sectors, providing empirically grounded references for future research, policy development, and corporate sustainability target-setting aligned with the Paris Agreement and Sustainable Development Goals.*

Keywords: *Healthcare sub-sectors; Environmental performance; GHG emissions intensity; Resource intensity; Scope 3 emissions; sustainability benchmarking; SDGs*

INTRODUCTION

The healthcare sector occupies a paradoxical position in the global climate crisis. Dedicated to protecting and improving human health, it simultaneously contributes substantially to the environmental degradation that undermines population health worldwide. The healthcare sector's climate footprint is equivalent to approximately 4.4% of global net greenhouse gas (GHG) emissions – roughly 2 gigatonnes of carbon dioxide equivalent (CO_2e) annually, comparable to the emissions from 514 coal-fired power plants (HCWH Europe, 2019, 2025a). This figure exceeds the aviation industry's share and has continued to rise as the sector expands (Lottering, 2026).

The imperative for healthcare decarbonisation has been firmly established within international policy frameworks. The Paris Agreement, adopted in 2015, set clear global targets for emission reduction and sustainability to limit warming to 1.5°C (DDW, 2025; Deswal, 2025b; Uras, 2025). At the 26th Conference of the Parties (COP26) in 2021, the critical role of health systems in achieving the Paris Agreement's climate goals was explicitly emphasized (HCWH, 2021; HSPM, 2025). The 2030 Agenda of the

United Nations and its Sustainable Development Goals (SDGs) – particularly SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) – provide complementary frameworks for action (Deswal and Deswal, 2025; Uras, 2025). The World Health Assembly has further reinforced these commitments, with resolution WHA77.14 (2024) calling for a global WHO plan coherent with the Paris Agreement (HSPM, 2025).

Major financial and industry authorities, including the Global Industry Classification Standards (GICS) and the Sustainability Accounting Standards Board (SASB), identify "Health Care" as a primary industry sector (HCWH Europe, 2025a). Within this broader umbrella, three principal groups are recognised based on distinct business models and associated risks: Pharmaceutical & Biotechnology, Medical Equipment & Supplies, and Health Care Providers & Services (Deswal and Deswal, 2026). These sub-sectors exhibit vastly different environmental profiles, yet comparative analyses across these groupings remain conspicuously absent from the academic literature. The SASB has developed industry-specific sustainability accounting standards for each of these healthcare sub-sectors, addressing metrics including greenhouse gas emissions, energy management, water withdrawal, and waste generation (SASB, 2013). However, empirical comparative studies applying these frameworks across sub-sectors have not been systematically undertaken.

To situate this study within the broader evidence base, several prior investigations merit attention. Lenzen *et al.* (2020) provided the first global assessment of healthcare's environmental footprint, quantifying supply-chain contributions across multiple impact categories, yet they did not disaggregate findings by sub-sector. Pichler *et al.* (2019) compared healthcare carbon footprints across OECD countries, identifying large variations driven by energy mixes and healthcare delivery models, but their analysis remained at the national level. Sherman *et al.* (2020) offered a comprehensive review of sustainability strategies in healthcare settings, emphasising the need for standardised metrics and targets, while Eckelman *et al.* (2020) estimated the public health damage attributable to healthcare pollution in the United States, linking emissions to morbidity and mortality. More recently, the Lancet Countdown (Romanello *et al.*, 2021) has tracked health–climate nexus indicators but has not provided sub-sectoral benchmarks for healthcare industries. These studies collectively highlight the gap in sub-sector-specific, company-level comparative analyses – a gap that this paper directly addresses.

This paper addresses this critical gap by presenting the first comprehensive comparative descriptive and inferential statistical analysis of environmental performance across five healthcare sub-sector groupings. The analysis encompasses eight leading companies – Pfizer and Regeneron (Pharmaceutical & Biotechnology); Siemens Healthineers, Philips, and Smith+Nephew (Medical Equipment & Supplies); CVS Health (Health Care Providers & Services); Johnson & Johnson (Pharmaceutical & Biotechnology and Medical Equipment & Supplies); and BioNTech (Biotech/Innovator Pharma) – over the period 2019 to 2025. The dataset includes greenhouse gas (GHG) emissions (Scope 1, 2, and 3) (Deswal, 2025a), emissions intensities, energy consumption and renewable energy shares, energy intensity, water withdrawal and intensity, and waste generation and intensity. Through descriptive statistics, trend analysis, and exploratory comparative analysis, this study establishes empirically grounded environmental performance benchmarks for each healthcare sub-sector, providing a foundational reference for future research, corporate sustainability strategy, and policy development.

MATERIALS AND METHODS

Data Source and Sample

The dataset was compiled from company websites, including Sustainability / Corporate Social Responsibility (CSR) / Environmental Social Governance (ESG) Reports, Annual Reports, Financial Disclosures, Integrated Reports, policy documents/position statements, data summary reports, infographics and other disclosures such as information obtained directly from company websites, etc., in the public domain and cover the period 2019–2025 of eight companies representing five healthcare sub-sector groupings, as classified by GICS and SASB frameworks (SASB, 2013) (Table 1):

- *Pharmaceutical & Biotechnology Companies* (n=2): Pfizer, Regeneron.
- *Medical Equipment & Supplies Companies* (n=3): Siemens Healthineers, Philips, Smith+Nephew.
- *Health Care Providers & Services Companies* (n=1): CVS Health.
- *Pharmaceutical & Biotechnology and Medical Equipment & Supplies Companies* (n=1): Johnson & Johnson.
- *Biotech/Innovator Pharma Companies* (n=1): BioNTech.

The observation period spans 2019 to 2025, capturing pre-pandemic baselines, pandemic-era disruptions, and post-pandemic recovery trajectories.

Variables and Metrics

The following environmental performance metrics were analysed:

- *GHG Emissions*: Scope 1 (direct emissions), Scope 2 (indirect emissions from purchased energy), Scope 3 (value chain emissions), and total emissions ($t.CO_2e$)
- *GHG Emissions Intensity*: Emissions per million USD revenue ($t.CO_2e/million\ USD\ revenue$) (Deswal and Deswal, 2026a)
- *Energy Consumption*: Total energy consumption (Terajoules, TJ)
- *Renewable Energy Share*: Percentage of renewable energy consumption
- *Energy Intensity*: Energy consumption per million USD revenue ($TJ/million\ USD$) (Deswal and Deswal, 2026b)
- *Water Withdrawal*: Total fresh water withdrawal ($1{,}000 \times m^3/year$)

Table 1: Annual revenues / net sales of the healthcare companies during the period 2019 to 2025.

Healthcare Sub-sectors	Company Name	Revenues / Sales during a Financial Year[#] (in billion USD)						
		2019	2020	2021	2022	2023	2024	2025
Pharmaceutical & Biotechnology	Pfizer	40.91	41.65	81.29	100.33	59.55	63.63	62.58
	Regeneron	6.56	8.50	16.07	12.17	13.12	14.20	14.34
Medical Equipment & Supplies	Siemens Healthineers[*]	16.26	16.48	21.24	22.80	23.41	23.26	26.67
	Philips	19.21	19.74	20.24	18.72	19.62	18.74	20.31
	Smith+Nephew	5.14	4.56	5.21	5.22	5.55	5.81	6.16
Health Care Providers & Services	CVS Health	256.78	268.71	292.11	322.37	357.78	372.81	402.10
Pharmaceutical & Biotechnology; and Medical Equipment & Supplies	Johnson & Johnson (J&J)	82.06	82.58	78.74	79.99	85.16	88.82	94.19
Biotech / Innovator Pharma	BioNTech	0.12	0.55	22.39	18.18	4.13	2.93	3.27

[#]Financial Year: January 1 to December 31. [*]Financial Year: October 1 to September 31 of the following year.

- *Water Intensity*: Water withdrawal per million USD revenue ($thousand\ m^3/million\ USD$) (Deswal and Deswal, 2026b)
- *Waste Generation*: Total waste generated ($metric\ tons/year$)
- *Waste Intensity*: Waste generation per million USD revenue ($tons/million\ USD$) (Deswal and Deswal, 2026b)

Analytical Approach

The analysis employed both descriptive and inferential statistical methods:

Descriptive Statistics: Means, ranges, and percentage changes were calculated for each metric across sub-sectors and time periods. Trend analysis was conducted using year-on-year percentage changes.

Comparative Analysis: Cross-sub-sector comparisons were performed using normalised metrics (intensity measures) to control for differences in company size and revenue. Absolute values were also analysed to contextualise the scale of environmental impacts.

Given the varying sample sizes across groups (particularly single-company groups), descriptive comparisons were prioritised alongside inferential statistics (Atalla et al., 2025).

All revenue data were expressed in billions of USD (Table 1) to enable intensity calculations. Intensity metrics were calculated as the ratio of environmental impact to revenue (million USD), following standard practice in sustainability reporting and enabling meaningful cross-company and cross-sub-sector comparisons.

RESULTS AND DISCUSSION

GHG Emissions: Absolute and Intensity-Based Analysis

Scope 1 and Scope 2 Emissions

Across the observation period, all companies demonstrated declining Scope 1 and Scope 2 emission trajectories, though with substantial variation in both absolute levels and rates of reduction (Fig. 1).

Pharmaceutical & Biotechnology Companies: Pfizer's Scope 1 emissions declined from 695,107 $t.CO_2e$ in 2019 to 614,274 $t.CO_2e$ in 2025, representing an 11.6% reduction. Regeneron's Scope 1 emissions increased from 57,500 to 89,990 $t.CO_2e$ over the same period—a 56.5% increase—reflecting significant operational expansion. Pfizer's Scope 2 emissions declined more substantially, from 570,388 $t.CO_2e$ in 2019 to 134,232 $t.CO_2e$ in 2025, a 76.5% reduction driven by renewable electricity procurement. Regeneron's Scope 2

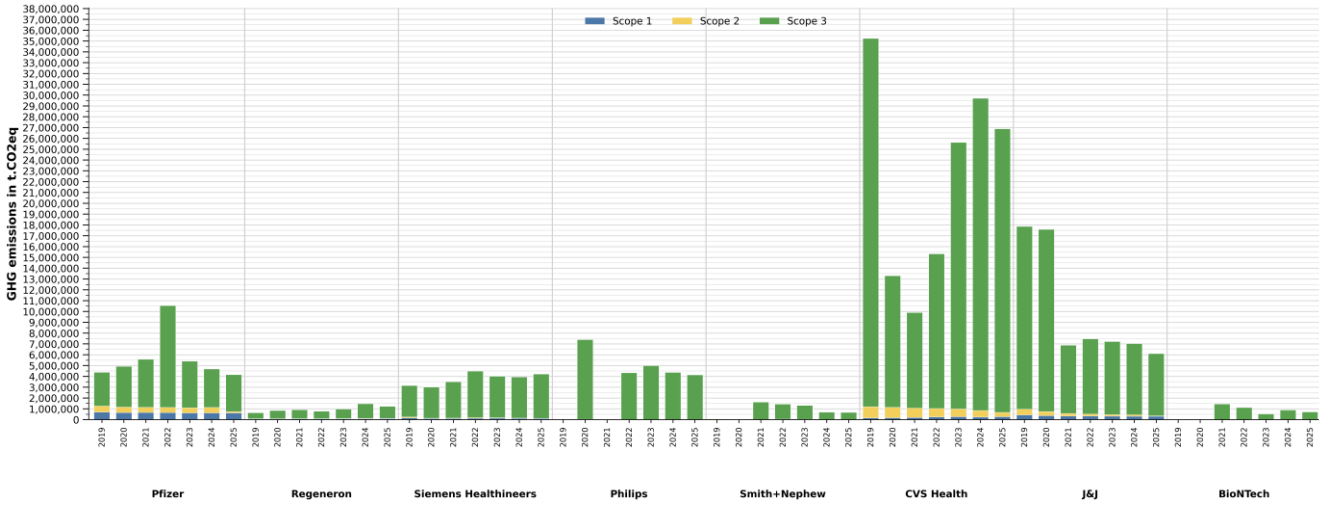

Fig. 1: Annual scope-wise GHG emissions of eight healthcare sector companies during the period 2019-2025.

Note: Stacked bars represent total emissions per year, with Scope 1 (direct emissions), Scope 2 (energy-related indirect emissions), and Scope 3 (value chain emissions) shown as components.

emissions increased from 22,700 to 35,020 $t.CO_2e$ (54.3% increase).

Medical Equipment & Supplies Companies: Siemens Healthineers reduced Scope 1 emissions from 162,000 $t.CO_2e$ in 2019 to 102,576 $t.CO_2e$ in 2025 (36.7% reduction), while Philips achieved more dramatic reductions from 32,000 to 17,685 $t.CO_2e$ (44.7% reduction). Smith+Nephew's Scope 1 emissions fluctuated but showed a net increase from 9,888 to 13,606 $t.CO_2e$ (37.6% increase). Scope 2 reductions were particularly pronounced: Philips reduced Scope 2 emissions by 86.1% (from 14,000 to 1,948 $t.CO_2e$), while Siemens Healthineers achieved a 71.8% reduction (from 85,000 to 23,971 $t.CO_2e$).

Health Care Providers & Services: CVS Health's Scope 1 emissions increased from 157,199 to 268,591 $t.CO_2e$ (70.9% increase) between 2019 and 2025, reflecting business expansion. However, Scope 2 emissions declined substantially from 1,036,690 to 407,592 $t.CO_2e$ (60.7% reduction).

Mixed Group (J&J): Johnson & Johnson demonstrated consistent reductions across both scopes: Scope 1 declined from 426,074 to 315,322 $t.CO_2e$ (26.0% reduction), while Scope 2 achieved a remarkable 92.1% reduction from 542,756 to 42,811 $t.CO_2e$.

Biotech/Innovator Pharma: BioNTech, as a smaller and rapidly growing company, showed increasing absolute emissions across both scopes: Scope 1 from 607 to 2,209 $t.CO_2e$ (264% increase) and Scope 2 from 2,748 to 5,794 $t.CO_2e$ (111% increase).

Scope 3 Emissions

Scope 3 emissions—those occurring across the value chain—dominate the carbon footprint of all sub-sectors (Fig. 1), consistent with broader industry patterns where Scope 3 represents as much as 80% of total pharmaceutical emissions. As noted in the literature, reducing operational emissions from healthcare alone will not achieve net zero; a sector-wide approach is essential (Uras, 2025).

Pharmaceutical & Biotechnology: Pfizer's Scope 3 emissions fluctuated significantly, peaking at 9,419,427 $t.CO_2e$ in 2022 before declining to 3,408,946 $t.CO_2e$ in 2025 (Fig. 1). This 2022 peak was driven by upstream Category 1 emissions (purchased goods and services), which reached 8,247,663 $t.CO_2e$ that year. Regeneron's Scope 3 emissions increased from 559,850 to 1,103,000 $t.CO_2e$ (97.0% increase) over the period.

Medical Equipment & Supplies: Siemens Healthineers' Scope 3 emissions increased from 2,907,000 to 4,085,146 $t.CO_2e$ (40.5% increase). Philips showed more variable Scope 3 emissions, ranging from 4,311,196 $t.CO_2e$ in 2022 to 4,122,626 $t.CO_2e$ in 2025 (Fig. 1). Smith+Nephew's Scope 3 emissions declined from 1,614,573 $t.CO_2e$ in 2021 to 647,532 $t.CO_2e$ in 2025 (59.9% reduction).

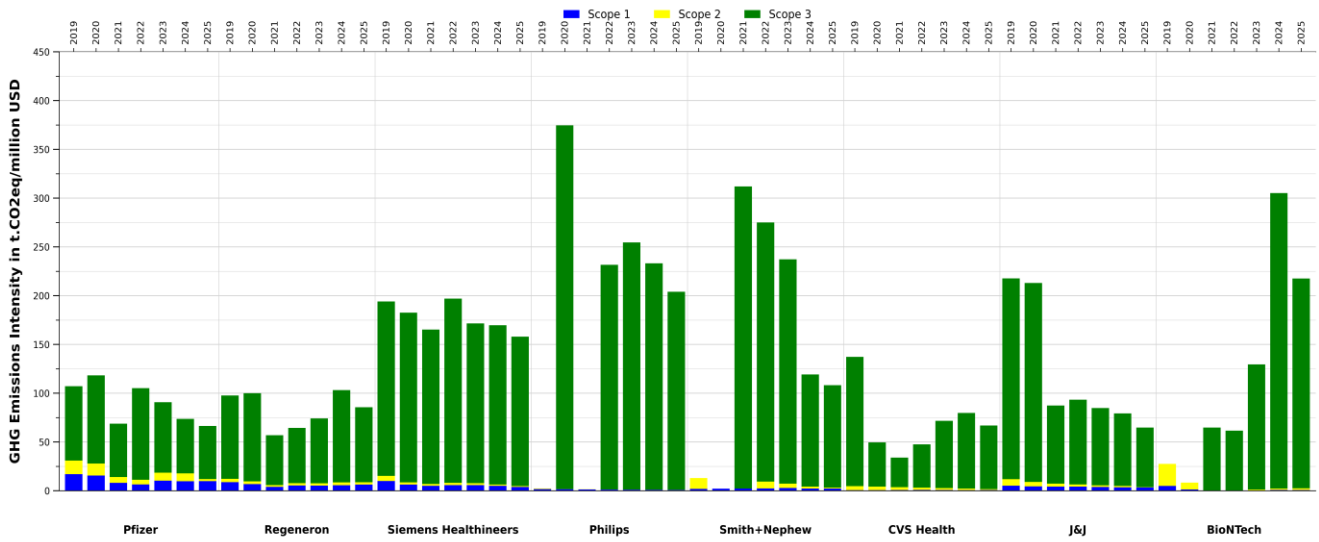

Fig. 2: Annual scope-wise emission intensities (EIs) of the eight healthcare companies during the period 2019-2025.

Table 2: Total GHG emission intensity ($t.CO_2e/million\ USD\ revenue$).

Healthcare Sub-sectors	Company	2019	2025	Change
Pharmaceutical & Biotechnology	Pfizer	107.1	66.4	-38.0%
	Regeneron	97.6	85.6	-12.3%
Medical Equipment & Supplies	Siemens Healthineers	194.0	157.9	-18.6%
	Philips	374.6 (2020)	204.0	-45.6%
	Smith+Nephew	275.0 (2022)	108.2	-60.7%
Health Care Providers & Services	CVS Health	137.2	66.9	-51.3%
Mixed (Pharma & MedTech)	J&J	217.7	64.8	-70.2%
Biotech/Innovator Pharma	BioNTech	64.75 (2021)	217.6	+236.0%

Health Care Providers & Services: CVS Health's Scope 3 emissions were by far the largest in absolute terms, peaking at 34,048,234 $t.CO_2e$ in 2019 before declining to 26,207,461 $t.CO_2e$ in 2025—a 23.0% reduction (Fig. 1). Category 1 (purchased goods and services) dominated these emissions, accounting for 95–98% of total Scope 3 throughout the period.

Mixed Group (J&J): Johnson & Johnson's Scope 3 emissions declined from 16,892,158 to 5,744,868 $t.CO_2e$ (66.0% reduction) over the period, driven primarily by reductions in upstream Category 1 emissions and downstream Category 11 emissions.

Biotech/Innovator Pharma: BioNTech's Scope 3 emissions increased from negligible levels in 2019–2020 to 703,634 $t.CO_2e$ in 2025, reflecting the company's rapid growth trajectory (Fig. 1).

Emissions Intensity

Fig. 2 provides a more nuanced picture of decarbonization progress of all eight companies across sub-sectors by presenting emissions intensities for all three scopes during the study period. Whereas Table 2 presents total GHG emissions intensities ($t.CO_2e/million\ USD\ revenue$) across sub-sectors for 2019 and 2025, providing the most meaningful basis for cross-sub-sector comparison.

Health Care Providers & Services (CVS Health) exhibited the lowest total emission intensity in 2025 at 66.9 $t.CO_2e/million\ USD\ revenue$, followed closely by Pfizer (66.4) and Johnson & Johnson (64.8). Medical Equipment & Supplies companies showed the widest variation, with Philips at 204.0 and Smith+Nephew at 108.2 $t.CO_2e/million\ USD\ revenue$. Biotech/Innovator Pharma (BioNTech) had the highest intensity at 217.6 $t.CO_2e/million\ USD\ revenue$ in 2025, reflecting its smaller revenue base relative to emissions.

Energy Consumption and Renewable Energy Transition

Total Energy Consumption

Absolute energy consumption varied dramatically by company size (Fig. 3), with Pfizer consuming 17,527 TJ in 2019 (reducing to 15,547 TJ by 2025) and CVS Health consuming 12,220 TJ in 2019 (reducing to 10,161 TJ by 2025). Smaller companies showed proportionally larger increases: BioNTech's energy consumption grew from 47.7 TJ in 2019 to 379.9 TJ in 2025 (696% increase), reflecting its rapid expansion.

Renewable Energy Adoption

The transition to renewable energy sources represents one of the most significant differentiators between sub-sectors, with implications for Scope 2 emission trajectories. Healthcare organisations are increasingly recognising that decarbonisation is not only an environmental responsibility but a core expression of healthcare's ethical commitment to "*first, do no harm*" (HCWH Europe, 2025a). This ethical imperative is increasingly driving target-setting strategies across the industry (HCWH Europe, 2025b).

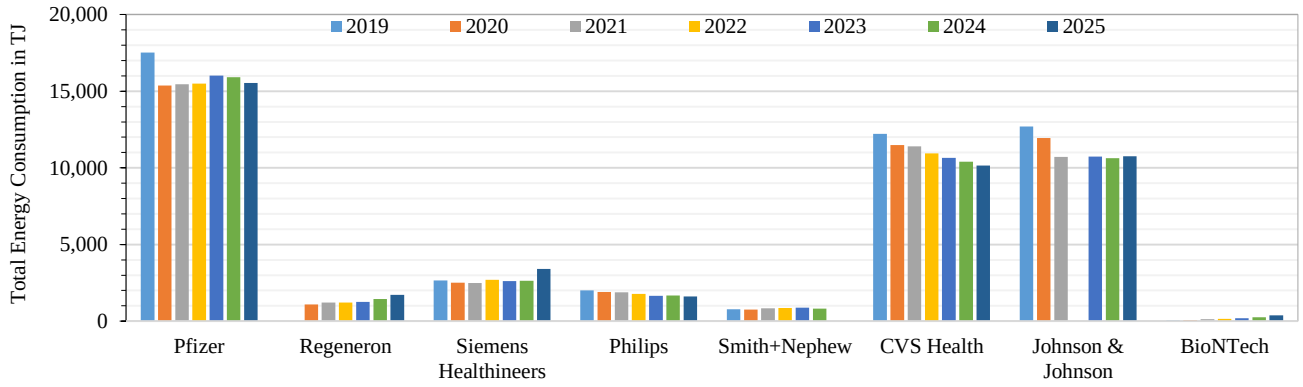

Fig. 3: Total energy consumption of the eight healthcare companies during the period 2019-2025.

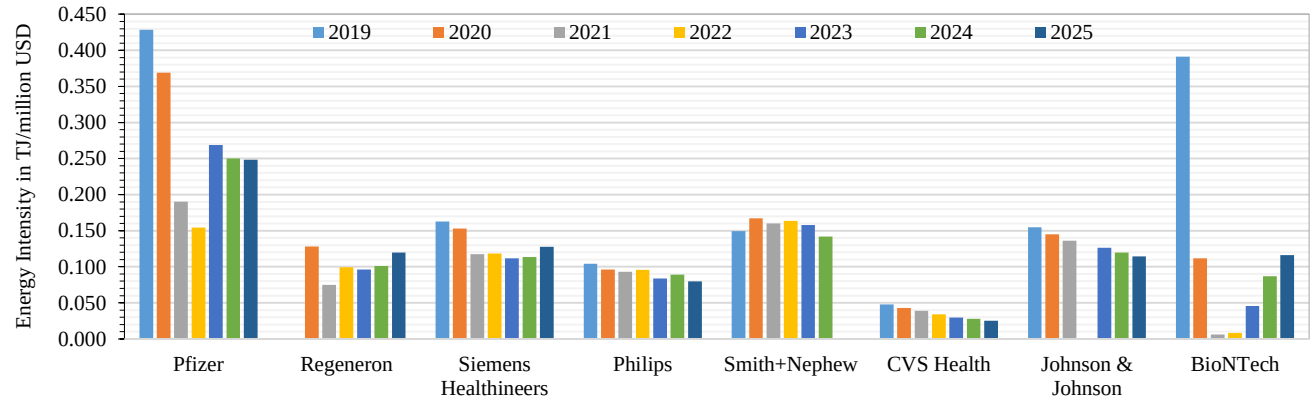

Fig. 4: Energy intensities of the eight healthcare companies during the period 2019-2025.

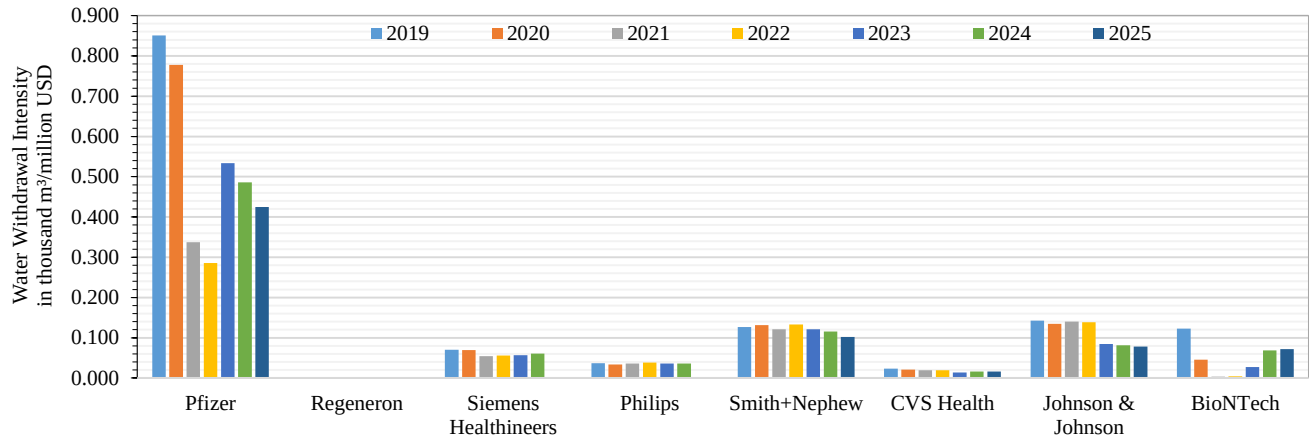

Fig. 5: Water withdrawal intensities of the eight healthcare companies during the period 2019-2025.

Biotech/Innovator Pharma demonstrated the most dramatic renewable energy transition, with BioNTech increasing its renewable share from 7.1% in 2019 to 75.2% in 2025—a gain of 68.1 percentage points. Medical Equipment & Supplies (Philips) maintained the highest renewable share throughout, reaching 80.1% by 2025. Pharmaceutical & Biotechnology (Pfizer) showed the most pronounced acceleration after 2023, increasing from 9.9% to 68.7% by 2025, consistent with its target of sourcing 80% of electricity from renewables by 2025 (Pfizer, 2025). Mixed Group (J&J) achieved 100% renewable electricity for operational needs by 2025, though its overall renewable energy share (including non-electricity energy sources) reached 46.0% (J&J, 2025).

Energy Intensity

Energy intensity ($TJ/million\ USD$) provides insight into operational efficiency independent of company size (Fig. 4). Pharmaceutical & Biotechnology companies showed the highest energy intensity (Pfizer: 0.248 in 2025), followed by Medical Equipment & Supplies (Siemens Healthineers: 0.128; Philips: 0.080; Smith+Nephew: 0.142 in 2023), with Health Care Providers & Services exhibiting the lowest (CVS Health: 0.025 in 2025). This hierarchy reflects the energy-intensive nature of pharmaceutical manufacturing versus the service-oriented operations of healthcare providers.

Water Withdrawal and Intensity

Water withdrawal patterns reveal significant sub-sector differentiation, with pharmaceutical manufacturing being the most water-intensive activity (Fig. 5).

Pharmaceutical & Biotechnology companies exhibit the highest water withdrawal intensities, with Pfizer at 0.425 $thousand\ m^3/million\ USD$ in 2025 – an order of magnitude greater than Health Care Providers & Services (CVS Health: 0.016). Pfizer achieved a 50.1% reduction in water intensity over the period. Medical Equipment & Supplies companies show moderate intensities (0.037–0.127 $thousand\ m^3/million\ USD$), while Health Care Providers & Services demonstrate the lowest intensities, consistent with their service-oriented rather than manufacturing-based operations.

Waste Generation and Intensity

Waste generation patterns (Fig. 6) mirror those of water withdrawal, with pharmaceutical manufacturing generating the highest waste intensities.

Pharmaceutical & Biotechnology companies exhibit the highest waste intensities, with Pfizer at 1.769 $tons/million\ USD$ in 2025. Health Care Providers & Services show dramatically lower intensities (CVS Health: 0.011 $tons/million\ USD$)—approximately 160 times lower than pharmaceutical companies. Biotech/Innovator Pharma (BioNTech) achieved the most substantial reduction (83.8%

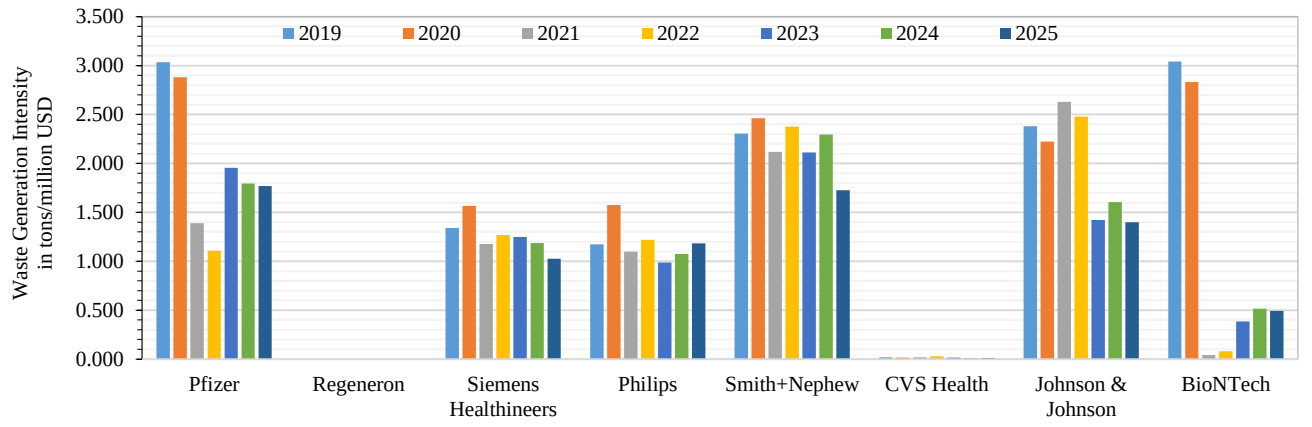

Fig. 6: Waste generation intensities of the eight healthcare companies during the period 2019-2025.

decrease from 2019 to 2025), though this reflects both improved waste management and revenue growth diluting the intensity metric.

DISCUSSION

Sub-Sector Environmental Performance Profiles

The analysis reveals distinct environmental performance profiles across healthcare sub-sectors, reflecting fundamental differences in business models, operational processes, and value chain structures.

Pharmaceutical & Biotechnology Group: These companies exhibit the highest resource intensity across multiple dimensions—energy, water, and waste—driven by the manufacturing-intensive nature of drug production. However, they also demonstrate significant progress in emission reductions (Pfizer: 38% total intensity reduction) and renewable energy adoption (Pfizer: from 9.5% to 68.7% renewable share). The dominance of Scope 3 emissions (80–90% of total) underscores the critical importance of supply chain decarbonisation—a finding consistent with broader pharmaceutical industry patterns. Pfizer's progress in engaging 72% of suppliers in science-based target setting (surpassing its 64% goal) represents a notable industry-leading approach (Pfizer, 2025).

Medical Equipment & Supplies Group: These companies occupy an intermediate position, with moderate resource intensities and generally stronger renewable energy adoption (Philips: 80.1% renewable share by 2025). The wide variation within this sub-sector—Philips achieving 45.5% total emission intensity reduction versus Siemens Healthineers' 18.6%—suggests that company-specific strategies and product portfolios significantly influence environmental performance. The substantial reduction in Scope 2 emissions across this sub-sector (Philips: 86.1% reduction) reflects aggressive renewable electricity procurement.

Health Care Providers & Services: It demonstrates the lowest environmental intensities across all metrics, consistent with their service-oriented rather than manufacturing-based operations. CVS Health's total emission intensity of 66.9 $t.CO_2e/million\ USD\ revenue$in 2025 places it among the lowest in the sample, despite its massive absolute emissions (primarily Scope 3 from purchased goods and services). The company's SBTi-validated target of 47% absolute emission reduction by 2030 and reported 29% reduction in Scope 1 and 2 emissions reflect meaningful progress (SM, 2025), though Scope 3 Category 1 emissions remain the dominant challenge.

Mixed Group (Pharmaceutical & Biotechnology and Medical Equipment & Supplies): Represented by Johnson & Johnson, the group demonstrates the most substantial improvement in total emission intensity (70.2% reduction from 2019 to 2025), achieving the lowest intensity in the sample (64.8 $t.CO_2e/million\ USD\ revenue$) by 2025. This performance reflects J&J's comprehensive sustainability strategy, including 100% renewable electricity for operational needs, a 38% reduction in absolute Scope 1 and 2 emissions since 2021, and recognition as the 10th most sustainable company globally (J&J, 2025).

Biotech/Innovator Pharma Group: It presents a unique profile characterised by rapid growth, increasing absolute emissions, but aggressive renewable energy adoption (BioNTech: from 7.1% to 75.2% renewable share). The company's high emission intensity (217.6 $t.CO_2e/million\ USD\ revenue$ in 2025) reflects its smaller revenue base relative to emissions, though this is expected to improve as the company matures and revenue scales.

Theoretical Contribution and Comparison with Literature

This paper makes several contributions to the literature on environmental sustainability in healthcare. First, while previous research has examined healthcare emissions at the aggregate sector level (HCWH, 2019; Lenzen *et al.*, 2020) or at the national level (Pichler *et al.*, 2019), this study provides the first sub-sector-level comparative analysis using standardised intensity metrics across a consistent set of companies over multiple years. Our finding that Health Care Providers & Services exhibit the lowest environmental intensities, despite high absolute Scope 3 emissions, confirms earlier observations about the service-manufacturing distinction (SASB, 2013) but quantifies this difference for the first time using empirical company-level data.

Second, our analysis extends the work of Eckelman *et al.* (2020), who estimated health damage from healthcare pollution, by identifying which sub-sectors are the most resource-intensive (Pharmaceutical & Biotechnology) and which have made the most progress in renewable energy transitions (Medical Equipment & Supplies and Biotech/Innovator Pharma). This sub-sectoral granularity is critical for designing targeted policy interventions and investment strategies.

Third, our results corroborate the emphasis placed by Sherman *et al.* (2020) on the need for standardised metrics and the dominance of Scope 3 emissions. By demonstrating that Scope 3 constitutes 80–90% of total emissions across most sub-sectors, we provide empirical support for the Lancet Countdown's (Romanello *et al.*, 2021) call for supply-chain decarbonisation as a priority for health-sector climate action. The wide variation in renewable energy adoption (from 9.5% to 80.1% renewable share) also aligns with Pichler *et al.*'s (2019) observation that energy-mix differences drive emission variations, but our company-level data reveal that these differences exist not only across countries but also across sub-sectors within the same country.

Finally, our study provides a benchmarking framework that can be used to assess progress against SASB industry-specific metrics, thereby bridging the gap between sustainability accounting standards and empirical performance data. This framework offers a replicable methodology for future research, enabling longitudinal tracking and cross-sectoral comparisons.

Practical Implications for Stakeholders

The findings carry actionable implications for diverse stakeholders:

- *For Healthcare Company Executives and Sustainability Officers:* The benchmarks established in this study provide reference points against which to assess their own performance. Pharmaceutical & Biotechnology companies should prioritise water and waste intensity reduction, while Medical Equipment & Supplies firms could focus on closing the intra-sub-sector performance gap. The dramatic renewable energy transitions observed (e.g., BioNTech, J&J) demonstrate that rapid progress is achievable, even for high-growth companies. Companies should also accelerate supplier engagement programmes to address Scope 3 emissions, which remain the largest decarbonisation frontier.
- *For Policymakers and Regulators:* The sub-sector-specific profiles suggest that a one-size-fits-all regulatory approach may be suboptimal. Policies should differentiate between manufacturing-intensive sub-sectors (Pharmaceutical & Biotechnology) and service-oriented ones (Health Care Providers & Services), with tailored targets for energy intensity, water withdrawal, and waste generation. Mandatory Scope 3 reporting standards and supply-chain due diligence requirements could accelerate progress where voluntary action has been insufficient. Furthermore, integrating health-sector emission targets into Nationally Determined Contributions (NDCs) – as demonstrated by Lao PDR (WHO, 2025a) – should be encouraged globally.
- *For Investors and Financial Analysts:* The intensity metrics offer a means to evaluate environmental risk and performance across healthcare investment portfolios. The wide variation in performance within the same sub-sector (e.g., Philips vs. Siemens Healthineers) indicates that company-specific sustainability strategies materially affect environmental outcomes, which may translate into differential regulatory and transition risks. Investors should prioritise companies with SBTi-validated targets and demonstrated progress on renewable energy adoption and supply-chain engagement.
- *For Healthcare Procurement Professionals:* Given that Scope 3 Category 1 (purchased goods and services) dominates emissions for Providers and many other sub-sectors, green procurement criteria and supplier scorecards should become standard practice. The benchmarks presented here can inform minimum performance thresholds for suppliers.

Implications for Paris Agreement and SDG Alignment

The Paris Agreement requires emissions reductions consistent with limiting global warming to well below 2°C and pursuing efforts to limit to 1.5°C (Deswal, 2025b, c). The healthcare sector's commitment to these goals has been reinforced through initiatives such as the COP26 Health Programme and the Science Based Targets initiative (SBTi), which helps companies align their climate activities with the Paris Agreement's global target of halving GHG emissions by 2030 and achieving net zero by 2050 (HCWH, 2021).

The companies in this analysis demonstrate varying degrees of Paris Agreement alignment. Pfizer has committed to net-zero by 2040, with near-term targets including 46% reduction in Scope 1 and 2 emissions by 2030 and 80% renewable electricity by 2025 (Pfizer, 2025). CVS Health has secured SBTi validation for its net-zero targets, aiming for 47% absolute Scope 1, 2, and 3 emission reduction by 2030 (SM, 2025; Deswal, 2025d). Johnson & Johnson has achieved 100% renewable electricity for operational needs (J&J, 2025).

BioNTech's rapid renewable energy transition from 7.1% to 75.2% demonstrates that even high-growth companies can accelerate decarbonisation. Furthermore, integrating health into Nationally Determined Contributions (NDCs) is critical for achieving these goals. For instance, Lao PDR's recent strengthening of health commitments to climate change in its NDC 3.0 exemplifies this necessary policy integration (WHO, 2025a), and ongoing webinars and guidance from the World Health Organization are building capacity for this integration globally (WHO, 2025b).

However, the persistent dominance of Scope 3 emissions across all sub-sectors presents the most significant challenge to Paris Agreement alignment. As the literature emphasises, reducing operational emissions from healthcare alone will not achieve net zero. A sector-wide approach is essential, tackling supply chain emissions from energy, pharmaceuticals, and medical devices (HCWH Europe, 2025a; Uras, 2025). Healthcare organisations are increasingly recognising that decarbonisation is not only an environmental responsibility but a core expression of healthcare's ethical commitment to "*first, do no harm*" HCWH Europe, 2025b). The WHO roadmap for healthcare decarbonisation provides a critical framework for this transition (HSPM, 2025).

Limitations

Several limitations should be acknowledged, and these constrain the generalisability and inferential strength of our findings.

First, and most critically, the sample size is limited, with single-company representation in three of the five sub-sector groupings (Health Care Providers & Services, Mixed Group J&J, and Biotech/Innovator Pharma). For these groups, the observed performance reflects the practices of one organisation and cannot be assumed to represent the broader sub-sector. For the Pharmaceutical & Biotechnology group (n=2) and Medical Equipment & Supplies group (n=3), the sample is still small, and results should be considered preliminary. This limitation precludes robust inferential statistical analysis (e.g., hypothesis testing) for sub-sector comparisons, and the descriptive comparisons presented should be interpreted as exploratory rather than definitive.

Second, data availability and reporting methodologies vary across companies and over time, with some companies reporting incomplete data for certain years and metrics (Deswal and Deswal, 2026c). For example, Philips did not report Scope 3 emissions for 2019, and Smith+Nephew reported waste data only from 2020 onward. We treated these

as missing values, but the resulting gaps may affect trend analyses.

Third, the 2025 data for many companies represent projections or early estimates rather than verified reported figures, introducing potential uncertainty.

Fourth, the analysis does not account for differences in geographic operations, regulatory contexts or energy-grid carbon intensities, all of which may influence environmental performance independently of corporate strategy (Deswal and Deswal, 2026c).

Fifth, the study focuses on intensity metrics (emissions per revenue), which, while enabling cross-company comparison, do not capture absolute emission reduction trajectories necessary for assessing Paris Agreement alignment. A company could reduce intensity through revenue growth without reducing absolute emissions – a phenomenon known as "*relative decoupling*" – which may be insufficient for meeting global climate goals.

Sixth, Scope 3 reporting is notoriously heterogeneous; companies use different estimation methodologies, include different categories, and apply different emission factors. We did not adjust for these methodological differences, meaning that cross-company Scope 3 comparisons should be interpreted with particular caution.

Finally, the study does not address other important environmental dimensions such as biodiversity impacts, chemical pollution, or circular economy indicators, which may be equally relevant for a comprehensive sustainability assessment.

POLICY RECOMMENDATIONS

Based on the findings and limitations, we propose the following policy recommendations targeted at different governance levels:

- *Standardisation of Environmental Reporting:* Regulators and standard-setters (e.g., International Sustainability Standards Board, European Financial Reporting Advisory Group) should mandate consistent Scope 3 reporting across healthcare sub-sectors, including mandatory disclosure of all 15 Scope 3 categories where applicable. This would enable meaningful benchmarking and allow investors and policymakers to track supply-chain emissions accurately. The existing SASB standards provide a foundation, but enforcement and audit requirements remain insufficient.
- *Sub-sector-Specific Decarbonisation Targets:* Given the vastly different environmental intensities across sub-sectors, policymakers should avoid uniform targets. For Pharmaceutical & Biotechnology, emphasis should be on water and waste intensity reduction alongside renewable energy. For Health Care Providers & Services, the priority should be supply-chain engagement and green procurement. National and regional climate policies (e.g., the EU Green Deal, US Inflation Reduction Act) could incorporate sub-sectoral benchmarks derived from this study to tailor incentives and penalties.
- *Supply-Chain Decarbonisation Mandates:* Given that Scope 3 emissions dominate, governments should introduce due diligence laws requiring large healthcare companies to set and report on supplier emission reduction targets, modelled on the German Supply Chain Due Diligence Act or the proposed EU Corporate Sustainability Due Diligence Directive. Public procurement policies in healthcare (e.g., national health service procurement) should prioritise suppliers with SBTi-validated targets and demonstrated emission reductions.
- *Accelerated Renewable Energy Procurement:* The wide variation in renewable energy adoption suggests that policy instruments such as green tariffs, power purchase agreement (PPA) facilitation, and tax incentives for on-site renewable generation could be particularly effective. Governments should support healthcare companies in securing long-term renewable PPAs, especially in regions with less mature renewable markets.
- *Integration of Health-Climate Nexus in NDCs:* Building on the WHO's guidance (WHO, 2025a, 2025b), national governments should explicitly include healthcare-sector emission reduction commitments in their NDCs under the Paris Agreement. This would elevate healthcare decarbonisation to a national priority and unlock international climate finance for health-system transformation.
- *Research and Data Infrastructure Investment:* Public agencies and international organisations (e.g., WHO, World Bank) should invest in establishing a publicly accessible, standardised database of healthcare environmental performance metrics, drawing on company disclosures and independent verification. This would facilitate continuous benchmarking, track progress over time, and support academic research.

Future Research Directions

This study opens several avenues for future research. First, longitudinal studies tracking the environmental performance of a broader panel of healthcare companies would enable more robust inferential analysis and identification of sub-sector-specific best practices. Second, research examining the relationship between environmental performance and financial performance within healthcare sub-sectors would inform investor decision-making and corporate strategy. Third, studies applying life cycle assessment methodologies to specific healthcare products and services would provide granular insights into emission hotspots and mitigation opportunities. Fourth, research investigating the integration of environmental sustainability into healthcare procurement and supply chain management would address the critical Scope 3 challenge. Fifth, comparative studies across geographic regions would illuminate the influence of policy frameworks, energy grids, and regulatory contexts on environmental performance.

CONCLUSION

This paper presents the first comprehensive comparative descriptive and exploratory statistical analysis of

environmental performance across five healthcare sub-sector groupings, establishing empirically grounded benchmarks that can be useful in future research and policy discourse. The key findings are:

- *Health Care Providers & Services* exhibit the lowest environmental intensities across all metrics (2025 total emission intensity: 66.9 $t.CO_2e/million\ USD\ revenue$; water intensity: 0.016 $thousand\ m^3/million\ USD$; waste intensity: 0.011 $tons/million\ USD$), though absolute Scope 3 emissions remain substantial due to extensive supply chains.
- *Pharmaceutical & Biotechnology Companies* demonstrate the highest resource intensities (water: 0.425 $thousand\ m^3/million\ USD$; waste: 1.769 $tons/million\ USD$) and Scope 3 emission dominance (80–90% of total emissions), yet show significant progress in emission intensity reduction (Pfizer: 38% reduction) and renewable energy adoption (from 9.5% to 68.7%).
- *Medical Equipment & Supplies Companies* occupy an intermediate position with moderate intensities and strong renewable energy performance (Philips: 80.1% renewable share), though substantial intra-sub-sector variation exists.
- *Mixed Group (Pharmaceutical & Biotechnology and Medical Equipment & Supplies)* achieved the most substantial emission intensity improvement (70.2% reduction from 2019 to 2025) and the lowest 2025 intensity (64.8 $t.CO_2e/million\ USD\ revenue$).
- *Biotech/Innovator Pharma Companies* demonstrate the most dramatic renewable energy transition (from 7.1% to 75.2% renewable share) alongside rapidly growing absolute emissions, highlighting the challenge of decoupling growth from emissions.
- *Scope 3 emissions* constitute the dominant share of total emissions across all sub-sectors, underscoring the critical importance of supply chain decarbonisation for achieving Paris Agreement-aligned emission reductions.

These findings provide a robust empirical foundation for future research, corporate sustainability strategy, and policy development. As the healthcare sector continues its necessary transition toward net-zero emissions, comparative performance benchmarking across sub-sectors will be essential for identifying best practices, accelerating learning, and ensuring that the sector's commitment to protecting human health extends to protecting the planetary health upon which all life depends.

ORCID iD

Surinder Deswal : 0000-0001-7256-142X

Phalguni Deswal : 0009-0006-1748-9641

Disclaimer

The study is purely for academic purposes, and the findings should be viewed within each company's operational realities and reporting practices.

Data Availability Statement

Data used in this study can be found in public pharmaceutical company reports. Further, the data presented in this study can be made available by the first author on request.

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The present research did not receive any financial support to conduct the research.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy, have been completely observed by the authors.

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