Measuring the Carbon Footprint for Health Systems and Suppliers: A Collaborative Field Study by Providence Health System and Becton-Dickinson

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Abstract

The carbon emissions from assets owned by health systems are a small fraction of their total carbon footprint. The emissions produced by their suppliers of products, and services, such as electricity and transportation, are typically more than 10 times a hospital's direct emissions. In this study, a large health system and its major supplier of syringes applied the E-liability carbon accounting method to calculate the total emissions produced from manufacturing and transporting syringes to hospital sites, and from their subsequent use and disposal. The paper describes the steps followed to calculate accurate product-level embedded emissions across the two entities. The study found, as expected, that the emissions produced at each entity were much lower than those produced by their suppliers of materials, electricity, and transportation services. Senior managers, at both participating entities, concurred that product-level emissions data from the E-Liability calculations reveal multiple opportunities for lowering their carbon footprint. While the study focused only on a single supplier of a single product category (syringes) sold to a single customer, its methodology is generalizable to multiple suppliers of multiple products sold to multiple customers. It can also be used to calculate the product and operational emissions from treating a patient's medical condition.

The Challenge
Many health care systems are now attempting to reduce their carbon footprints.[12] But like most corporations and non-profit entities, the emissions from their owned assets account for only a small fraction of their total emissions. The Carbon Disclosure Project (CDP) reported that the 2023 supply chain emissions of its 23,000 reporting companies were 26× their direct emissions.[3] Health systems that want to lower their total carbon footprint must, therefore, receive accurate and verifiable information on the emissions generated in the production of products and services (such as electricity and transportation) they purchase. Health systems with such accurate emissions information from their major Tier-1 suppliers could make better informed decisions about the specific products and services they purchase, from whom, and their transport to hospital sites. But most controllable emissions, even for a health system's Tier-1 suppliers, occur far upstream, such as where raw materials are extracted or grown, and subsequently transported and processed into intermediate products. The challenge for health systems is how to obtain accurate and credible information on the carbon emissions embedded in their purchased products and services, and from their disposal.

The Goal
The project had dual goals. The immediate goal was for Providence Health & Services (PHS), a leading health system with 51 hospitals and more than 1,000 clinics, to obtain accurate information about the emissions in its high-volume purchases and disposals of syringes from Becton Dickinson (BD), a leading Tier-1 supplier. This required BD to assign its own emissions and those from its principal suppliers to the syringes it manufactured and distributed to end-use customers, such as PHS. Both organizations wanted to learn how E-liability carbon accounting[4] could be applied to supply such accurate product-level emissions measurements. While the study encompassed only one product category, sourced from a single supplier to a single customer, the learnings and insights from this study are extendable (i) by BD to all its high-carbon intensive suppliers of products and services, and (ii) by PHS, to its other high-volume Tier-1 suppliers of carbon-intensive products and services. Thus, a longer-term goal was to use this pilot project to develop and formalize the principles and generalizable practices that would enable, within a 3-to-5-year period, the carbon footprint of all health systems and their suppliers to be measured accurately, and used to guide and validate their decentralized decarbonization decisions.

The Team
The team consisted of the chief EHS/sustainability officer and a senior director of sustainability at BD, the executive director and program managers of environmental stewardship at PHS, and senior staff from E-ledgers Institute, a nonprofit with the mission to advance carbon emissions accounting practices.

Execution: Becton Dickinson
The BD team started by collecting the bill of materials (BOM) for seven high-volume syringes. The BOM enabled it to estimate the quantity of each material used to produce and package the seven products. Ideally, when the E-ledger system is widely adopted, each supplier would communicate the total emissions embedded in the raw materials and packaging purchased by BD. But the only information that suppliers currently provided was a spend-based allocation in which the supplier assigned its total cradle-to-gate emissions (measured with unknown and likely dubious accuracy) to customers proportional to the customer's annual spend with the supplier. Following this method, if a customer, such as BD, represented 4.8% of a supplier's revenues, it would be assigned 4.8% of that suppliers' emissions. Clearly, data of this quality are inadequate for BD's calculations and decarbonization decisions.

Rather than rely on spend-based allocations from its Tier-1 suppliers, the BD team referenced publicly available data, including published emissions factors and EPDs (environmental product declarations), to obtain average emissions per unit for each of its purchased raw materials. It then multiplied each material's emission factors by the BOM quantity of input materials purchased from the supplier.

The BD team then calculated the emissions from transporting the input materials from each supplier's site to the BD production facility. The calculation was based on the size of the vehicle transporting the material, the percentage of the vehicle's capacity filled by the raw material, the distance traveled – from supplier to the BD production facility – and the estimated CO_2 emissions per mile of travel.

The BD production facility performed four sequential processes: molding the resin into a syringe, marking the barrels with volume stripes, assembling the syringe (barrel, plunger rod and stopper), packaging the syringes, and sterilizing the packaged devices prior to shipment.

The team used the BOM quantity of each purchased material per unit of finished product to assign emissions in purchased materials to the seven syringe types. The emissions associated with wasted and scrapped materials were assigned, using data specific to each syringe type, to the finished products available for shipment to customers.

The team used BD's production system's measurement of energy usage by production department to assign the emissions from the electricity used by the four internal processes. For each department, the team allocated the emissions from energy usage down to individual machines. The team obtained the machine run times per unit of output from the factory's costing and production system, and used these to assign the allocated machine-level emissions (mostly from electricity used) to output products based on the production time, per unit, at each machine for each syringe type. This level of granularity was important since the different size barrels and plunger rods for each syringe type required differing mold press tonnages, different mold cycles, and different barrel marking rates, and ran at different rates on the assembly equipment. A general allocation assigned emissions not causally tied to the production process, such as facility-level fossil fuel and electricity usage, to each syringe type.

The seven syringes had quite different sizes, which affected the packaging machinery times, and associated emissions, associated with each syringe type. The team allocated the quantity of embedded emissions in the packaging materials, plus the packaging machinery's electricity emissions, to the quantity of syringes in each shipment package.

By following these steps, all the emissions embedded in purchased materials and from the energy used to convert raw materials into finished products were allocated, via causal and verifiable mechanisms, to output products.[1] This satisfied the "conservation of emissions" requirement, analogous to the conservation of energy law expressed in the 1st Law of thermodynamics. Table 1 shows the buildup of emissions embedded in Syringe B (data disguised via an indexed value):

[1] Ignores amortization and assignment of emissions embedded in the plant's capital equipment and the building itself.

Table 1: CO_2 emissions from representative syringe B

Syringe B	$kgCO_2$	kgCO2	gCO2/Unit	gCO2/Unit	Percent
Materials	16.2		11.9		77%
Resin		7.6		5.6	
Stopper		2.0		1.5	
Primary Packaging		3.3		2.4	
Secondary Packaging		3.2		2.4	
Shipment	0.0		0.0		0%
Electricity	3.3		2.4		16%
Molding		1.2		0.9	
Marking		0.1		0.0	
Assembly		0.1		0.1	
Packaging		0.1		0.1	
Sterilization		0.3		0.2	
Waste & Scrap	1.1		0.8		5%
General Allocation	0.4		0.3		2%
Total	21.0		15.4		100%

Table 2 summarizes the (indexed) emissions for all seven syringe types.

Table 2: CO_2 emissions for seven BD syringes (ordered in increasing size)

	A		B		C		D		E		F		G	
	gCO2	%	gCO2	%	gCO2	%	gCO2	%	gCO2	%	gCO2	%	gCO2	%
Materials	33.7	87	11.9	77	18.4	86	24.6	90	70.9	89	89.5	89	214.2	96
Shipment	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.1	0
Electricity	4.3	11	2.4	16	2.1	10	1.7	6	6.0	8	7.5	8	7.1	3
Waste & Scrap	0.2	1	0.8	5	0.7	3	0.8	3	0.1	0	0.1	0	0.2	0
General Allocation	0.6	1	0.3	2	0.3	1	0.2	1	2.2	3	2.8	3	2.7	1
Total	**38.8**	**100**	**15.4**	**100**	**21.5**	**100**	**27.3**	**100**	**79.2**	**100**	**100.1**	**100**	**224.1**	**100**

Execution: Syringe Transportation BD to PHS

PHS provided data on the annual volume of the seven syringes purchased by three geographically separated hospitals, and the location of the distribution center that served all three hospitals. The BD team estimated the driving distance from its manufacturing site to the three distribution centers, and multiplied the driving distance by 1.62 kg of CO_2 per mile, an estimated typical amount for a semi-truck or heavy-duty truck. The BD team, working with its internal logistics group, then calculated the quantity of space required by each type of syringe package. Dividing a truck's total transportation emissions by its cubic feet of capacity, and multiplying this ratio by the cubic feet occupied by each syringe type's package, yielded the transportation emissions per syringe package. The team divided the transportation emissions per package by the quantity of syringes in each package to calculate the emissions incurred to transport each syringe type to each PHS distribution center.

PHS calculated the fuel emissions to transport the seven BD syringes from its distribution center to the three hospital sites. The team interviewed commercial transporters to determine:

- The size and associated fuel consumption of trucks transporting materials from the distribution center to the hospital site.
- The estimated CO_2 emissions per gallon of fuel consumption, based on EPA GHG conversion tables
- The percentage of truck capacity used for deliveries containing the seven BD syringes. Less-than-truckload trips would have more emissions assigned to the packages on those trips.
- The number of trips made from each distribution center to its hospital site
- The percentage of trips that were empty on return to the distribution center. Empty back haul trips required the assignment of roundtrip fuel emissions to the delivered products.

Execution: Providence Health Systems
The PHS team assigned emissions associated with syringe storage space and the rooms where the syringes were used.[2] This required estimating the percentage of total floor space used for initial storage of purchased materials and subsequent storage in cabinets and clean rooms. The team divided total facility emissions for heating, air conditioning, and lighting, which was calculated annually by the facility's square footage and multiplied this ratio by the square footage used to store each BD syringe type.

The team considered assigning the emissions from employees' commuting and food purchasing to the personnel who used the syringes for patient care. But they decided not to include these emissions since they were not specific to syringe usage, and the emissions would be incurred independent of syringe usage.[3] Interviews with clinical staff revealed that a syringe pump was used in 0.05% of cases. The emissions associated with the energy to operate the syringe pump were calculated using publicly available data.[4]

The PHS team concluded by calculating the emissions associated with end-of-life disposal of packaging materials and used syringes. Disposal emissions were assumed proportional to weight, which was estimated to be equal between the packaging and the syringes within each package. Clinical staff estimated that 15% of syringes went directly to landfill, 25% were autoclaved and then sent to landfill, and 60% were incinerated. The emissions associated with each type of disposal were estimated using EPA conversion factors for waste treatment, including the emissions associated with transporting the used syringes to the waste treatment facility.

For packaging materials, the team estimated that 50% of waste was cardboard or pressboard that could be recycled, and 50% was paper or plastic that was sent to landfills. As with the syringe disposal, the team applied EPA waste treatment conversion factors to the two treatments, including transportation emissions.

Table 3 summarizes the cradle-to-grave emissions for the seven syringes at the three PHS sites.

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[2] Calculation ignores the amortization of emissions associated with the building materials and construction of the facility.
[3] Emissions from employee commuting and food consumption could be assigned to the medical conditions treated by the employees during a normal working day.
[4] Greenhouse Gas Equivalencies Calculator | US EPA Syringe Pump Power Consumption & Electricity Cost Calculator - 7.25 Hours | Joteo.net

Table 3: Cradle to Grave Emissions at three PHS Hospitals

	Hospital X		Hospital Y		Hospital Z	
	gCO_2/unit		gCO_2/unit		gCO_2/unit	
Syringe Manufacturing	50.0	69.0%	33.2	58.1%	50.1	57.7%
BD Transport to PHS DC	6.7	9.3%	7.2	12.7%	14.3	16.5%
PHS Transport DC to Hospital	2.7	3.7%	0.0	0.1%	0.2	0.2%
Syringe Storage & Use	5.5	7.6%	9.4	16.5%	13.6	15.6%
Disposal	7.5	10.4%	7.2	12.7%	8.7	10.0%
Total	72.5	100%	57.1	100%	86.8	100%

Discussion

The seven syringes shown in Table 2 are arrayed by increasing size, with A the smallest and G the largest. At first, it seemed counter-intuitive that syringe A's purchased materials and electricity emissions were higher than those for the next three larger syringes (B, C, and D). The team subsequently learned that A's small size required a different raw material and production process. For PHS, Table 3 shows that emissions in the syringes purchased by Hospital Y were much lower than those in the syringes purchased by Hospitals X and Z. This was a result of Hospital Y using a much lower percentage of Syringe A. These two findings illustrate the benefits from using E-liability carbon accounting to accurately trace emissions at the product level. If PHS had data only about average or spend-based emission factors, it would not have seen how to reduce emissions by encouraging hospitals in its system to decrease, when appropriate, use of syringe A.

Tables 2 and 3 reinforced the motivation for this study since the direct emissions at both BD and PHS were a small fraction of their controllable emissions. The transportation emissions to move syringes from BD's production site to PHS' distribution center and, subsequently, to the three hospital sites were higher than BD's manufacturing emissions (mostly from electricity consumption) and PHS's storage and use emissions at two of the three hospital sites. The unexpectedly high transportation emissions focused attention, at both entities, to decisions about syringe packaging and transportation.

The study also showed the high emissions caused by syringe disposal. Waste disposal emissions are typically quantified by the weight of materials sent for treatment or burial, but not by the specific products that generate the highest quantities of waste materials and emissions. E-liability's product-level emissions measurements of waste and disposal provide hospitals with data about which products have the highest waste and disposal emissions, enabling them to focus waste-reducing and disposal efforts on those products.

As noted earlier, reporting entities often use a "spend-based" method to estimate their carbon emissions from purchased goods and services, complemented with emission factors reported by the Environmental Protection Agency for multiple industrial categories. We compared the findings from this study's calculations of BD's manufacturing and downstream transportation emissions analysis to comparable spend-based emission estimations. We found significant variations, with spend-based estimations of carbon emissions ranging between 22% and 209% of the product-level emissions calculated by BD in this study. Such high variability casts doubt on whether health systems should continue to rely on the spend-based approach for calculating their environmental impact.

Hurdles

Carbon accounting is a new concept to many in health care, and education was required to make the case for a product level assessment. Health care organizations, with thousands of products and hundreds of vendors, are neither accustomed nor trained to calculate emissions at the individual product level. Obtaining granular product-level data was challenging, requiring multiple requests and much time. Working with transportation and logistics teams required specific estimations of trucks' capacity utilization, delivery routes, and mileages. Since these data were not typically tracked, data collection required extensive manual calculations and reporting. With new carbon accounting software now being introduced by ERP and specialized vendors, this limitation should be overcome over time. Hospitals, however, that want their IT solution to capture and report accurate product-level measurements should perform due diligence to ensure that technology solutions being considered have the requisite capabilities.

Limitations

The calculated emissions were not as accurate as they could have been because the project teams were unable to obtain accurate product-level emissions from several key suppliers. Instead, they relied on estimates and public data on emissions incurred by non-collaborating entities, such as their suppliers of resin, packaging, electricity, and transportation. This limitation can be addressed by having health and medical sector associations, and important downstream entities, such as BD and PHS, encourage wider adoption of E-ledgers carbon accounting.

The study focused only on a single supplier (BD) of a single product category (syringes) sold to a single customer (PHS). But the extension to multiple suppliers of multiple products sold to multiple customers is straightforward. No changes or additions are required to scale the methods described in this study to measure the emissions incurred in any health system supply chain, indeed the supply chain for any sector (Kaplan and Ramanna 2025). Measuring the flow of emissions from a Tier-2 supplier, say of resins, electricity, or transportation, to a Tier-1 manufacturing supplier, such as BD, to an end-use customer, such as PHS, generalizes and scales to all supply chains.

Given the limited product range for the study, project teams at both sites collected data manually and processed them on Excel spreadsheets. Were the scope of accurate carbon accounting to be extended to many more products, manufacturing locations, and hospital sites, the entities would likely need to invest in technologies for automated data capture and real-time, batch-by-batch, data processing.

Where to Start

An E-liability pilot project starts with four key steps:[5]

1. Identify the specific products or services for which emissions will be calculated.
2. Identify and gain cooperation of key suppliers of carbon-intensive inputs to the selected products or services
3. Identify and engage with other entities (e.g., downstream customers, technology enabler, assurance provider) critical to the success of the project
4. Create the internal infrastructure for the project: a project leader, a multi-disciplinary project team, and high-level executive sponsorship.

These initial steps are followed by data collection, data analysis, internal presentation of findings, development of action implications, and actions to reduce total carbon emissions in the entity's operations and supply chain.

Future Opportunities

Senior managers at both participating entities concurred that the granular E-Liability data revealed multiple opportunities for lowering their carbon footprint. Having access to the details of emissions accumulation along a value chain graph revealed opportunities for significant emissions reduction by, for example, shifting the mix of syringes ordered and used, optimizing the packaging and transportation of products from suppliers to customers, and providing clear guidance for product disposal. Future work would extend analysis to other products, and involve more suppliers, including those at Tier-2 and higher in the upstream supply chain, such as those producing resin, electricity, anesthesia, and implants.

Future work could also extend the analysis from the emissions in purchased products to emissions from treating high-volume medical conditions, such as those incurred for a total joint replacement, a complete cycle of oncological care, or a year's treatment for a chronic condition, such as diabetes or renal disease. In this way, "cost", the denominator in the value equation, would have two parameters for treating the condition: the traditional time-driven ABC financial cost calculation; and, the environmental cost, measured in the total CO_2 emissions for treating the condition, including those embedded in purchased products, services, transportation, waste, and disposal.

References

[1] Catalyzing Collective Action to Decarbonize Healthcare: Roadmap for Health Systems and MedTech Suppliers. 2023. Kaiser Permanente and Health Care Without Harm. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://supplier.kp.org/impactspending/wp-content/uploads/sites/2/2023/06/Catalyzing-Collective-Action-to-Decarbonize-Healthcare_FINAL_6-7-23.pdf (accessed December 23, 2025).

[2] Lee, Vivian S., Gerwig, Kathy, Hough, Emily, Kedar Mate, Biggio Robert, and Kaplan Robert S. Decarbonizing Health Care: Engaging Leaders in Change. NEJM Catal Innov Care Deliv. 2023;4(5) DOI: 10.1056/CAT.22.0433

[3] Boston Consulting Group and CDP. Scope 3 Upstream: Big Challenges, Simple Remedies. 2024 https://www.cdp.net/en/insights/strengthening-the-chain (accessed December 22, 2025)

[4] Kaplan, Robert S., and Karthik Ramanna. "Accounting for Climate Change." Harvard Business Review 99, no. 6 (November–December 2021): 120–131.

[5] E-liability Pilot Playbook, accessed at https://e-ledgers.institute/pilot-adoption/ (accessed December 23, 2025).