Sustainable Markets Initiative

DECARBONISING HEALTHCARE SUPPLY CHAINS

RECOMMENDATIONS ON HOW TO DRIVE EMISSIONS REDUCTIONS ACROSS HEALTHCARE SUPPLY CHAINS

A REPORT BY THE SUSTAINABLE MARKETS INITIATIVE HEALTH SYSTEMS TASK FORCE, IN COLLABORATION WITH BCG

PREFACE: THE SUSTAINABLE MARKETS INITIATIVE HEALTH SYSTEMS TASK FORCE

Sustainable Markets Initiative.
In his former role as His Royal Highness The Prince of Wales, His Majesty King Charles III launched the Sustainable Markets Initiative (SMI) at Davos in January 2020. The SMI is a network of global CEOs across industries working together to build prosperous and sustainable economies that generate long-term value through the balanced integration of natural, social, human, and financial capital. These global CEOs see themselves as the 'Coalition of the Willing' helping to lead their industries onto a more ambitious, accelerated, and sustainable trajectory. Read more here.

Terra Carta.
In his former role as His Royal Highness The Prince of Wales, His Majesty King Charles III launched the Terra Carta at the One Planet Summit in January 2021. The Terra Carta serves as the mandate for the SMI and provides a practical roadmap for acceleration towards an ambitious and sustainable future; one that will harness the power of Nature combined with the transformative power, innovation, and resources of the private sector. Currently there are over 500 CEO-level supporters, including the first C40 city of Athens, Greece. The Terra Carta has served as the inspiration for the Terra Carta Design Lab. The Terra Carta is a roadmap for public, private, and philanthropic collaboration and open to all countries, cities, companies, organizations, and schools who wish to support it. Read more here.

SMI Health Systems Task Force.
The SMI Health Systems Task Force was launched at the 26th United Nations Climate Change Conference (COP26) with the central aim of accelerating the delivery of net zero, patient-centric health systems that improve individual, societal, and planetary health. The public-private partnership brings together CEOs and leaders from AstraZeneca, GSK, Merck, Novo Nordisk, Roche, Samsung Biologics, Sanofi, the Karolinska Institutet, National Health Service (NHS) England, the Sustainable Healthcare Coalition, UNICEF, the University of Pavia, and the World Health Organization (WHO).

The SMI Health Systems Task Force is also a partner of the WHO's Alliance on Transformative Action on Climate and Health (ATACH), a platform that over 60 countries have committed to at the Minister of Health level to strengthen climate resilience and lower the emissions of health systems.

Additional information on the SMI Health Systems Task Force can be found here.

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ABOUT THIS PAPER

The climate crisis is one of the most pressing risks to global health:[1] rising temperatures are resulting in an increase in hospital admissions and heat-related deaths; extreme weather events such as flooding and droughts are disrupting food systems, displacing people, and undermining access to healthcare; and changing patterns of water-borne and vector-borne diseases are threatening decades of progress in infectious disease control.[2] Climate change is also exacerbating the incidence of many non-communicable diseases (NCDs), including cardiovascular and respiratory illnesses, through increased air pollution, extreme heat, and other factors.[1][3]

Climate change affects us all, but populations living in low- and middle-income countries are the most severely impacted.[4] The health risks associated with climate change also disproportionately affect the most vulnerable and disadvantaged in our societies, such as children, displaced populations, and people with underlying health conditions.[1][2][4]

Climate change causes millions of deaths every year – findings from 2019 indicate that over 9 million global deaths are attributable to air pollution and over 5 million deaths are associated with non-optimal temperatures.[5][6] Limiting global warming to well below 2 degrees Celsius can avoid further impact on global health.[7] Healthcare stakeholders must play their part by accelerating the delivery of patient-centric, equitable, net zero health systems.

The SMI Health Systems Task Force is committed to collaborating across and beyond the healthcare sector to drive concrete action to reduce emissions and propose targeted recommendations to health leaders worldwide. Its work is driven by the conviction that a whole system approach is needed to decarbonise healthcare, with targeted actions focused on product manufacturing and distribution, innovative clinical research and development, all the way to delivery of patient care.

This paper highlights the major sources of emissions across healthcare supply chains, and how these can be addressed. It focuses on small molecule drugs and biologics products, rather than med-tech devices and equipment supply chains, but many of the recommendations made here remain relevant to these supply chains.

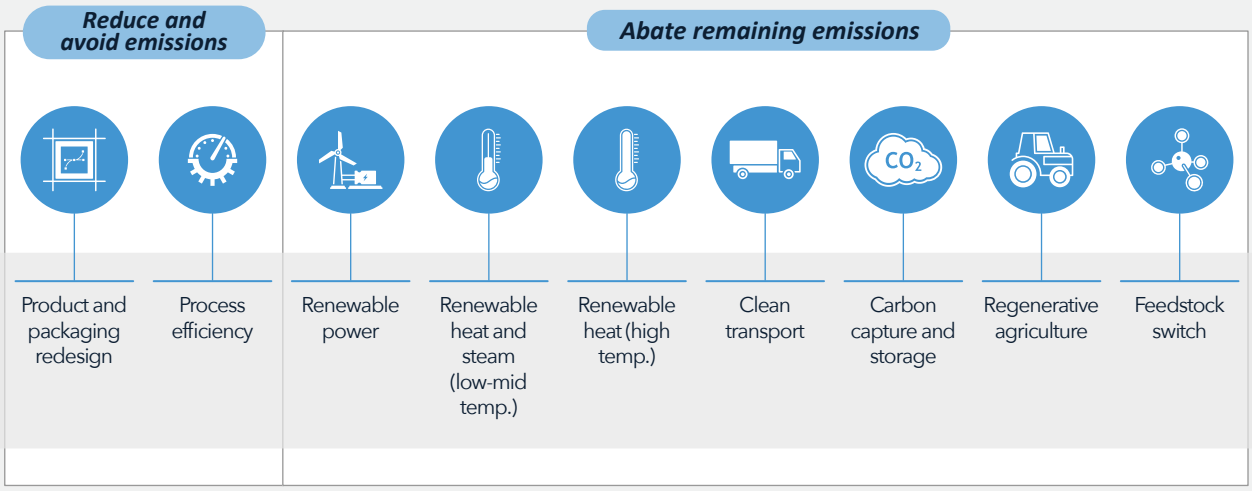
Additional perspectives on how to reduce emissions across health systems can be found in the associated whitepapers:

- **"Accelerating the Delivery of Net Zero Health Systems"** is an overview of practical recommendations and actions from the Task Force in support of net zero health systems
- **"Decarbonising Patient Care Pathways"** highlights how choices in patient care can drive emissions reduction
- **"The Digital Solution for Sustainability in Clinical Research"** showcases how digital solutions can help abate clinical trials emissions

EXECUTIVE SUMMARY

Supply Chains Drive the Majority of Healthcare Emissions. The healthcare sector generates approximately 4% to 5% of total global emissions, over half of which are driven by supply chains.[8] The majority of these emissions are generated by early-stage processes, such as raw material extraction and processing. It is therefore essential for manufacturers to work alongside their suppliers to decarbonise supply chains for healthcare systems to reach net zero.

Nine Levers to Decarbonise Supply Chains



Source: BCG analysis based on literature review and case experience, CO_2.AI, IEA, IPCC, WEF, ETC, MPP, Agora

Reducing emissions using these levers across supply chains comes with several challenges:

- **Calculating biopharma supply chains emissions is challenging**, and standardised tools and public emission factors are not yet available
- **Supply chains are complex with multiple layers of suppliers**, and biopharma companies often only drive a small share of raw materials demand. This makes it challenging to influence the entire supply chain to decarbonise
- **Much of the early-stage product manufacturing takes place in parts of Asia**, where power grids are currently fossil-heavy and green energy sources are less prevalent in comparison to other regions
- **The healthcare industry is highly regulated**; as a result, changes to products and manufacturing processes can involve long and complex processes
- **Many decarbonisation levers are currently expensive** and have low availability in key geographies. However, technology continues to evolve rapidly, while the cost of new technologies is reducing

The SMI Health Systems Task Force is Taking Action.

The Task Force recognises the need to act now to overcome these challenges, and its private sector members, with support of public sector partners, are taking collective, concrete action to accelerate the decarbonisation of supply chains.

Private sector members of the Task Force are committing to:

- **Set near-term emissions reduction targets** aligned with the 1.5°C pathway and commit to **achieve net zero emissions by 2045**[a]
- Switch to **80% to 100% renewable power** for their own operations by 2030[a], and **jointly evaluate renewable corporate power purchase agreements** in China and India in 2023
- Jointly **explore green heat solutions by 2025** to accelerate the adoption of effective and scalable technologies
- **Transition car fleets to zero-emission vehicles by 2030** and explore **green transportation corridors by 2025**[b]
- Align on a set of **common supplier standards**[c] to support emissions reduction across entire supply chains
- Align on a **common framework to perform lifecycle assessments (LCA)** – with private sector members also committed to publishing product-level LCA data across their product portfolio to increase transparency on treatment emissions

The Task Force is also committed to collaborating with stakeholders across health systems and has outlined practical recommendations to drive emission reductions as follows:

- **Pharma, biopharma and med-tech companies** can track and disclose product level emissions, set targets to decarbonise their own operations, and engage with suppliers to abate upstream supply chain emissions
- **Governments and policymakers** can create the right incentives and environment to accelerate the transition to low carbon supply chains (e.g. by funding green energy projects and pricing carbon), and set standards to promote efficient use of resources and energy
- **Regulatory bodies** can support the accelerated approval of carbon dioxide (CO_2) reducing improvements to products and processes, and mandate reporting on emissions (e.g. through green labelling)
- **Health authorities and payers** can include sustainability as a criterion in procurement and reimbursement decisions and set ambitious green supplier standards

By bringing healthcare sector leaders together, the Task Force hopes to demonstrate practical steps and actions to reduce the carbon footprint of healthcare and ultimately improve public health and societal outcomes.

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a. At present, Samsung Biologics is committing to achieve net zero and switch to 100% renewable power by 2050 at the latest given local market constraints, and is actively working to reach these targets as early as possible. **b.** Green transportation options that are being explored by the Task Force include SAF offtake agreements to reduce air freight emissions, opportunities to design short sea routes to replace long haul trucking, and co-shipping opportunities to shift air freight to sea freight. **c.** These supplier standards apply only to suppliers of the healthcare business of each private sector member.

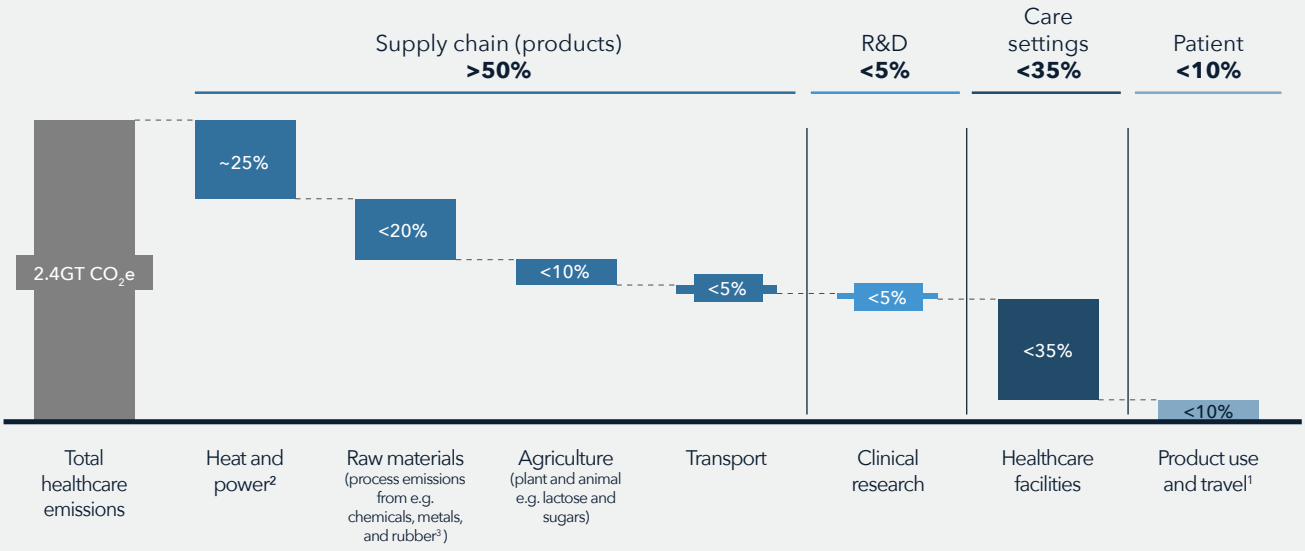
Climate Change: The Challenge for Healthcare

The healthcare sector is responsible for about 4% to 5% of total global emissions,[9] the equivalent of the 5th highest-emitting country in the world after China, US, India, and Russia.[8] [9]

The ageing of the population, the rise of chronic NCDs, and rapid urbanisation all contribute to an increased demand for healthcare, challenging health systems to deliver care more effectively and sustainably.[10] [11] [12] To achieve net zero, it is vital that all players – including manufacturers, governments, policymakers, regulatory bodies, health authorities, and payers – play their part in reducing emissions while improving health outcomes.

Health systems are complex, and their decarbonisation will require reducing emissions at each step of the value chain, including R&D, supply chains, and patient care. This paper looks at the largest emissions driver in the healthcare sector, healthcare supply chains, which account for over 50% of emissions (see Exhibit 1).

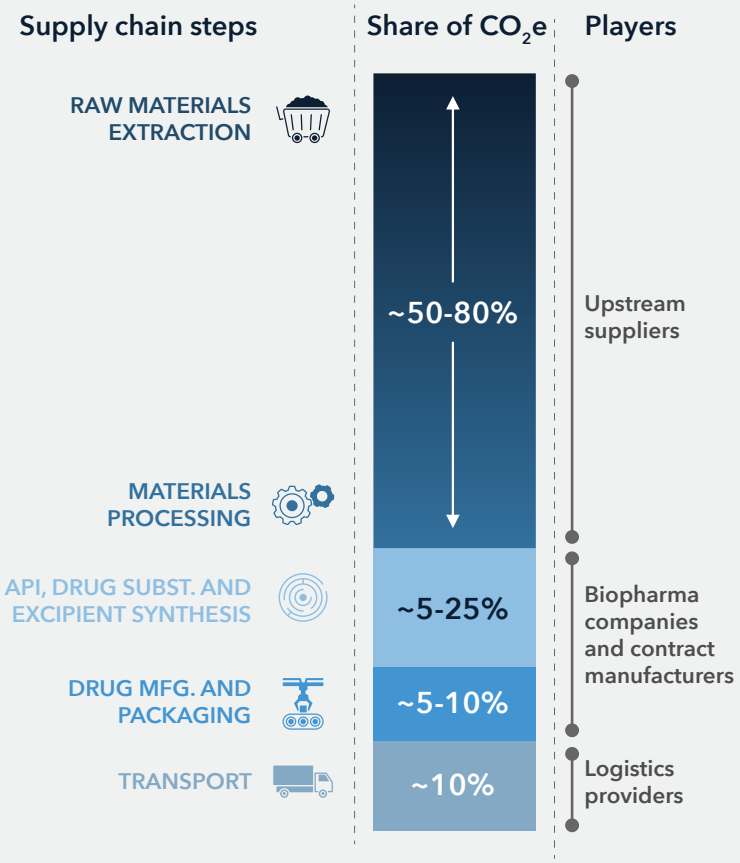
EXHIBIT 1 | Supply chains emissions contribute more than 50% of healthcare emissions



1. Includes patient and visitor travel as well as product use (e.g. inhalers) 2. Including power used for cooling 3. Process emissions from manufacture and raw material extraction, also includes, metals, textiles, mining, wood etc.
Source: Health Care Without Harm/Arup (2019); Health Care Without Harm/World Bank (2017); UK National Health Service/Lancet (2020); The Lancet Countdown on Health and Climate Change (2020, 2018); Environmental Research Letters: International Comparison of Health Care Carbon (2019); Health Affairs: Health Care Pollution And Public Health Damage In The United States: An Update (2020); BCG analysis based on literature review and case experience

EMISSIONS DRIVERS WITHIN SUPPLY CHAINS

EXHIBIT 2 | Most emissions created in early stages



Note: Analysis focused on product supply chain (small molecule and biologic drugs only, not medical devices and equipment); Source: BCG analysis based on literature review and case experience, CDP, company sustainability reports

Reducing emissions across supply chains will require a holistic approach as approximately 50% to 80% of greenhouse gas (GHG) emissions from biopharma companies are generated by upstream suppliers in the early stages of materials extraction and processing (see Exhibit 2 and Appendix B).

This paper focuses on product supply chains for small molecule and biologic drugs which are complex and involve many intermediate stages of production that are highly product specific. As a result, emissions intensity can vary significantly between products. There are, however, several high-level steps common across supply chains that drive the majority of emissions (see Appendix C for details).

Raw Materials Extraction. Most small-molecule drugs are derived from hydrocarbons, such as crude oil and gas. The extraction process of oil and gas is typically associated with methane emissions and refining also uses fossil-based heat (450°C). For biologics, agricultural crops are often the raw materials used (e.g. sugars, gelatin, lactose, starch, etc.). Emissions in agriculture come from fertilisers as well as land-use change (deforestation). The extraction of raw materials used to produce packaging (e.g. sand for glass, ores for metals) also generates emissions.

Materials Processing. Transforming hydrocarbons into key base chemicals used in Active Pharmaceutical Ingredients (API) or excipient synthesis generally uses temperatures of about 850°C, typically generated from fossil fuels, as well as large amounts of electricity. Packaging materials such as metal, plastic, and glass are all processed from raw materials in emissions intensive processes.

API, Drug Substance, and Excipient Synthesis. This process typically includes multiple steps to extract, synthesise, and purify the API, biologics, or excipients of interest, which usually require moderate heat or steam (< 150°C). Some API synthesis processes consume large volumes of solvents, making the end product highly emissions intensive.

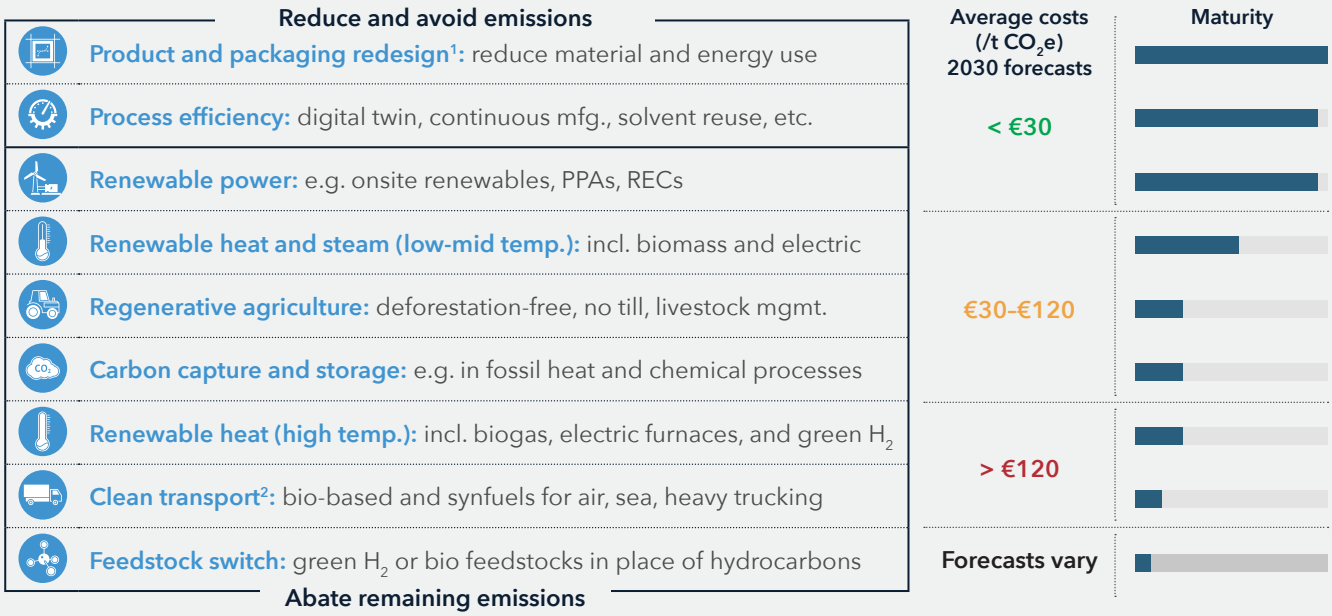
Final Drug Manufacturing and Packaging. Active ingredients and drug substances are combined with excipients and packaged as final products. Heating, ventilation, and cooling, alongside rigorous cleaning to maintain sterile conditions, are the largest emissions drivers in this step.

Transport. At many stages of the supply chains, substances are shipped, flown, or trucked between facilities. Pharmaceutical supply chains tend to be international, and some require temperature-controlled transport. This results in high volumes of air freight[13] which generates ~40x as many emissions as sea freight, although some pharmaceutical companies have already made significant progress in shifting away from air travel.[13] [14] [15]

NINE LEVERS TO REDUCE SUPPLY CHAINS EMISSIONS

There are nine main levers to reduce emissions in the biopharma product supply chain (see Exhibit 3).

EXHIBIT 3 | Nine levers to reduce emissions in supply chains



1. Large cost range, redesigning packaging can save money, reformulating medicines with approval processes can be very expensive. 2. Technological options are currently expensive and low maturity; modal shift is a large lever and negative cost; Note: Costs are indicative and refer to average values in 2030; Source: BCG analysis based on literature review and case experience, CO2.AI, IEA, IPCC, WEF, ETC, MPP, Agora, academic papers

1 Product and Packaging Redesign

Rethinking product design, such as by changing formula and dosage requirements, can reduce emissions significantly. This can also reduce ongoing costs but often requires time and effort to gain regulatory approval for changes. A similar approach can be taken with packaging, for both the design and materials used. For example, Sanofi reduced the size of its packaging and replaced plastic with cardboard for its flu vaccine, reducing emissions by 15%.[d]

d. Based on internal company data.

2 Process Efficiency

The following efficiency measures can reduce emissions, with the potential to save costs:

- **Manufacturing excellence.** Continuous improvement of manufacturing practice using data-driven approaches to optimise processes can increase efficiency, yield, and reduce waste
- **Digital twins.** Creating digital replicas of production processes allows improved systems design, reduced testing periods, better monitoring and predictive maintenance to reduce waste and CO_2 emissions
- **Continuous manufacturing.** Combining multiple production stages into a single, continuous production line increases output, cuts costs, and reduces emissions. Sanofi recently opened a plant with 80% less CO_2 emissions than its 1st generation facility[16]
- **Thermal and electric efficiency.** Best-in-class technology can be used to increase electricity efficiency, increased insulation can reduce thermal losses and waste heat can be recycled using heat pumps, particularly in the stages of chemical and API production which require heating and cooling
- **Solvent recycling and reuse.** can cut emissions significantly, given volumes used in API synthesis
- **Synthesis process change.**[e] Redesigning processes with green chemistry principles can optimise material and energy consumption. For example, reducing synthesis steps for ibuprofen production from six to three,[17][18] or using improved catalysts[19]

3 Renewable Power

Renewable Power has the potential to reduce total emissions by about 20% to 30% across supply chains, and will play a growing role in decarbonisation as industries electrify processes (e.g. chemicals electricity demand in Germany could grow by more than 10x by 2050).[20][21] Renewable power now has the lowest levelised[f] cost of energy of any source and is increasingly cost-competitive in markets such as the EU and US.[22] To switch to renewable power, companies can build onsite projects (e.g. solar), buy renewable energy certificates or join renewable power-purchase agreements.

e. It may also be possible to substitute synthetic chemistry production processes with enzyme-catalysed reactions (using protein enzymes instead of traditional catalysts), which are usually efficient, highly selective, and occur under mild conditions.[52] **f.** The levelised cost of electricity represents the average net present cost of electricity generation for a generator over its lifetime.

4 Renewable Low- to Mid-Temperature Heat and Steam

Renewable Low- to Mid-Temperature Heat and Steam can be decarbonised using two technologies:

- **Electrification**. Electric heat pumps can replace natural gas, generally at economic cost parity[g] for temperatures below 85°C. Electric steam boilers can be used to decarbonise temperatures of up to 500°C
- **Biomass** can be deployed for temperatures of up 500°C at a cost of ~€60 per tonne of CO_2 equivalent (tCO_2e) abated.[d] However, currently price and availability vary by geography (e.g. there is limited availability in Asia)

5 Renewable High-Temperature Heat

High-temperature heat (over 500°C) is much more difficult to decarbonise with available technologies. This lever will primarily be deployed within the upstream supply chain (e.g. in chemicals, glass, and metals manufacture) as high heats tend not to be used in API or final product manufacture.

- **Biogas** can replace natural gas without changes to facilities. Biogas has low availabilities in some regions and is expected to have a marginal abatement cost of ~€120/tCO_2e by 2030.[23] Despite the costs, some companies have already made commitments to use biogas, including AstraZeneca which announced a clean heat partnership to fuel its UK operations in 2021[24]
- **Electrification**. High-temperature heat produced by electricity is not generally commercially available today, although it is in pilots for some industries (e.g. steam crackers for chemicals) and in the plans for others (e.g. glass).[25] [26] [27] Cost forecasts vary with a range of ~€100 to €200/tCO_2e abated in 2030[20]
- **Green or blue hydrogen** burned as a substitute for natural gas can generate very high temperatures. This technology is still sub-scale today and is likely to remain expensive in the next ten years, with a forecast marginal abatement cost of ~€350/tCO_2e abated by 2030[h]

6 Regenerative Agriculture

Ensuring that agricultural inputs are not causing deforestation, and are produced with regenerative practices, can significantly cut emissions. Farmers of plant-based inputs can adopt practices such as no-till agriculture, cover cropping, tree intercropping, and silvopasturing (integrating trees and livestock) to capture more carbon in the soil.

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g. BCG case experience, expert interviews, and analysis. **h.** Green hydrogen is produced by electrolysing water with renewable electricity. Blue hydrogen is hydrogen from natural gas with the emissions captured. BCG analysis, assuming €3.75/kg of green hydrogen, ~€3 for production and ~€0.75 for delivery & €25/mwh for natural gas. Cost /tCO_2e abated could be half this in the most optimistic scenario (or more than double in higher cost scenarios).

7 Carbon Capture and Storage (CCS)

Given the cost and difficulty of decarbonising high-temperature heat (e.g. in chemicals, glass, and metals), and direct process emissions along the supply chain today, most paths to net zero will involve significant use of CCS, which is deployed to capture CO_2 and store it long term.[i] The total costs of CCS are forecast to range from €30 to €100 per ton of CO_2 (t/CO_2) emissions[j] by 2030 depending on the purity of the CO_2 streams involved.[k] Costs may, however, be significantly higher if the scale of the facility is small (<5 million tons per annum). The distance to storage facilities as well as the cost of storage will also impact total CCS cost, but to a lesser extent.[g]

8 Clean Transport

Several actions can be taken to reduce emissions from transport:

- **Modal shift**. Air freight is about 40x more emissions intensive than sea freight, and is also 4x to 5x more expensive.[14][28] Shifting freight from air to sea, road, or rail can save on freight costs and reduce emissions (with a saving today of ~€100/tCO_2e abated for a shift from air to sea freight). Companies have already started to make this change (e.g. AstraZeneca shifted its freight from 5% sea to 65% from 2012 to 2022, and Merck reduced medicine transport from 65% by air in 2018 to 10% in 2021).[29][15][l] Modal shift from long haul trucking to shipping and short haul electric will also lower transport emissions
- **Electrify short-distance transport**. New generations of electric short-haul lorries are at total cost-of-ownership parity with internal combustion engine vehicles today and can reduce fuel-combustion emissions to zero.[30] Battery-powered electric vehicles are the solution for most journeys of less than 400 kilometres[m]
- **Invest in bio-based or synfuels for longer hauls**. Most third-party providers offer bio-based[n] sustainable fuel options to decarbonise long-distance travel (air, sea, and heavy-road). These solutions remain expensive. Sustainable aviation biofuel currently costs ~€200/tCO_2e abated on top of normal aviation fuel cost. Synthetic fuels are beginning to attract investment and are expected to emerge on the market in the next ten years. Cost premium forecasts range from €100 to over €600/tCO_2e by 2030[o]

i. CCS involves capturing CO_2 and storing it by pumping it into depleted oil or gas reservoirs or into aquifers and rock formations. **j.** Capture costs from BCG energy transition hub model and BCG CO_2 Emissions Model (based on PRIMAP-hist and PRIMAP-crf databases from Eur. Database of Global Atmospheric Research). IEAGHG, NPC, BCG analysis for transport and storage costs an average of ~€15/tCO_2. **k.** The more concentrated a stream of CO_2 is, the cheaper it is to use or store because less purification needs to be done. **l.** Based on internal company data. **m.** Net impact on CO_2e will vary depending on how green the grid used to charge electric vehicles is. **n.** Feedstock for biofuels should be waste-derived (e.g. animal dung or municipal) and not compete with food and animal feedstock.[31] **o.** Mission possible partnership and BCG analysis.

9 Feedstock Switch

Feedstock switch involves substituting non-renewable feedstocks with renewable ones. These feedstocks can have lower sourcing, processing, and disposal emissions.[p] Examples include:

- **Bionaphtha**, derived from hydrotreated vegetable oil or biogas can replace naphtha derived from oil and gas, but remains expensive today (2-3x that of naphtha)[31][32]
- **Biomass**, such as woodchips, could become an attractive feedstock for chemicals (e.g. ethylene) as studies suggest that biomass could be used cost effectively for synthesis[33]
- **Green hydrogen** could also play a significant role as a feedstock, where used as a direct input (e.g. for ammonia), or where used to generate complex hydrocarbons (e.g. ethylene) by being reacted with carbon dioxide which might lead to a cost of about €220/tCO_2e abated when the technology matures[34]

p. Sourcing emissions (such as fugitive methane from oil & gas extraction) can be avoided by using renewable feedstocks. Process emissions (those released during production) and end-of-life emissions (those released when a product is burnt or otherwise broken down) can be abated by altering feedstocks to those only containing carbon that was only recently taken from the atmosphere and which therefore is not additionally warming when released back into the atmosphere on processing or disposal.

WHY DECARBONISING SUPPLY CHAINS IS NOT EASY

There are several challenges to tackle in reducing healthcare supply chains emissions (see Exhibit 4).

EXHIBIT 4 | Five main challenges to tackling supply chains emissions

Source: BCG analysis based on literature review and case experience

1. Calculating biopharma supply chain emissions is challenging

Today, there is no common database of emissions factors to help biopharma companies, API producers, or earlier-stage chemicals companies calculate and track their carbon footprint. As a result, downstream pharmaceutical companies have no starting point for their lifecycle assessments. Although several LCA standards have been developed, there is no common standard currently that is consistently used across the industry. This makes benchmarking and measurement of emissions reductions difficult.

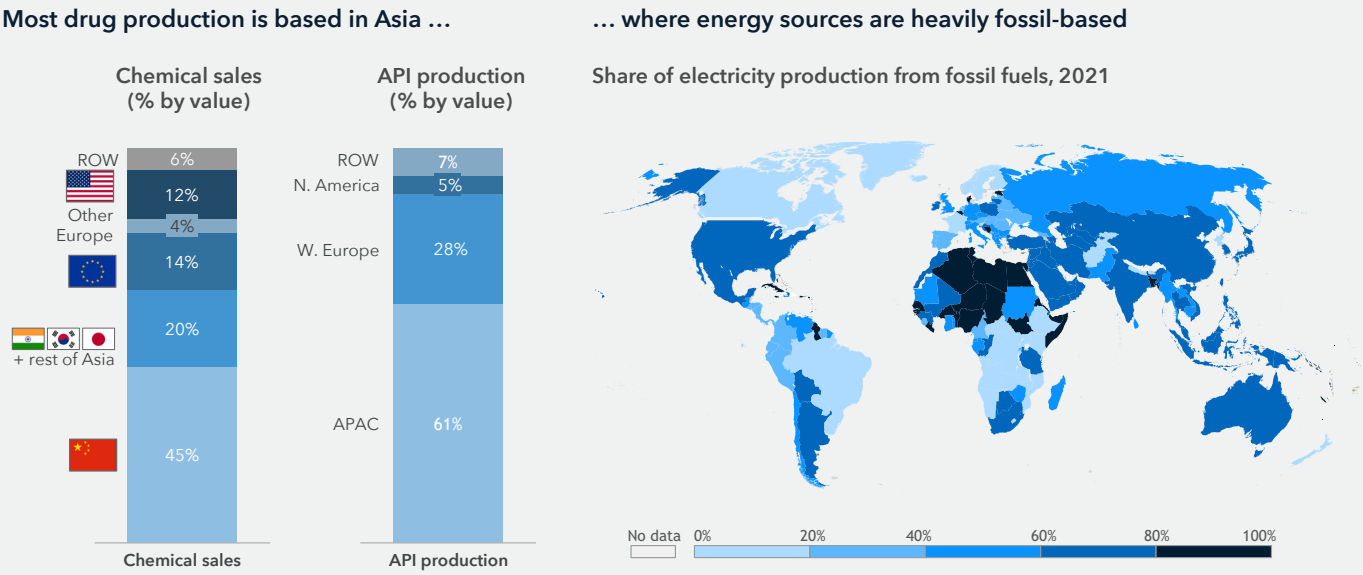
2. Supply chains are complex with multiple layers of suppliers

This can often mean that biopharma companies only drive a small share of raw material demand, even from key suppliers. For example, ammonia is needed to produce the nitric acid used to manufacture paracetamol, but around 80% of ammonia produced is used for fertiliser.[35] This makes it challenging for individual companies to influence and incentivise the decarbonisation of supply chains.

3. A high volume of manufacturing takes place in Asia where access to green energy is limited versus other regions

Many suppliers for pharmaceuticals are based in the Asia Pacific region, where access to renewable electricity and heat is less prevalent than in other geographies (see Exhibit 5). However, recent regulatory developments are facilitating access to renewable power in markets such as China, including through the use of corporate renewable power purchase agreements.[36]

EXHIBIT 5 | Many producers in Asia where grids are fossil-heavy



Source: BCG analysis based on literature review and case experience, European Fine Chemicals Group website; Our world in data based on BP statistical review of World Energy and Ember (2022); OurWorldInData.org/energy

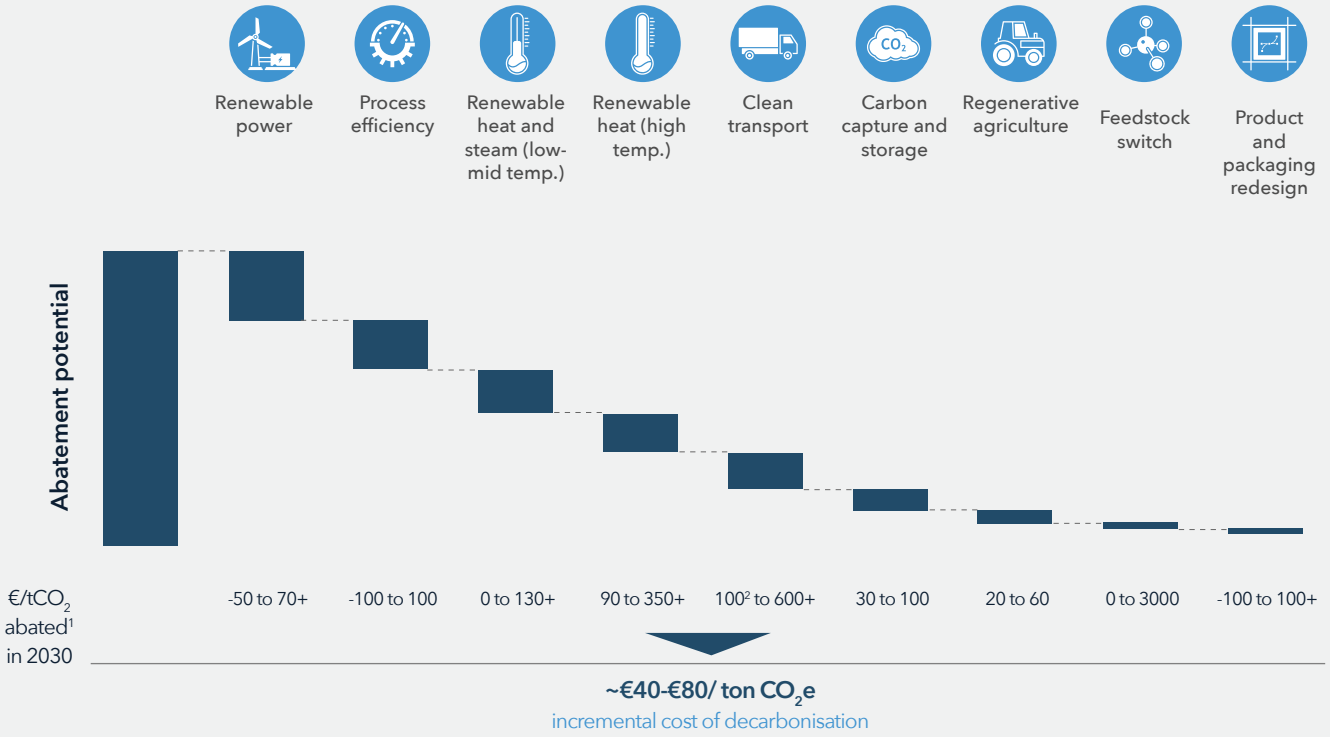
4. The healthcare industry is highly regulated

Changes to a product's design or manufacturing process generally requires regulatory approval. This introduces multi-market complexity, and can be a time consuming and uncertain process. However, some regulators do offer fast track processes for minor changes and those approved by other agencies (e.g. between EMA and MHRA).[37]

5. Many of the levers of decarbonisation are currently expensive

Many of the levers of decarbonisation are currently expensive and are either not yet available or have low availability in key geographies. Decarbonising high-temperature heat and carbon capture technologies will likely remain expensive for the next ten years.[38] Implementing manufacturing efficiency measures and switching to renewable power can, however, be done at low incremental costs in many geographies, and even save costs over time.[38] Overall, the incremental cost of decarbonising supply chains is projected to be €40-€80/tCO_2e abated by 2030 (see Exhibit 6).

EXHIBIT 6 | Deploying decarbonisation levers is forecast to cost an average of ~€40-€80[1]/tCO_2e p.a. by 2030



1. Calculated by summing the lever prices multiplied by their abatement potential 2. Can be significantly negative by including modal shift

Note: Decarbonisation costs are a range around projections for 2030

Source: BCG analysis based on literature review and case experience, CO2.AI, IEA, IPCC, WEF, ETC, MPP, Agora, academic papers

Many of the levers of decarbonisation are currently expensive and are either not yet available or have low availability in key geographies. Decarbonising high-temperature heat and carbon capture technologies will likely remain expensive for the next ten years.[38] Implementing manufacturing efficiency measures and switching to renewable power can, however, be done at low incremental costs in many geographies, and even save costs over time.[38] Overall, the incremental cost of decarbonising supply chains is projected to be €40-€80/tCO_2e abated by 2030 (see Exhibit 6).

Although investing in decarbonisation typically comes at an initial cost, there is also a significant risk to inaction. In the context of increasingly stringent and widespread regulations, companies delaying investment in decarbonisation and relying on buying offsets or paying carbon taxes will ultimately be faced with rising costs, with the price of carbon currently forecast to reach €40-€70/tCO_2 by 2030.[q]

Furthermore, technology availability and cost continue to evolve much faster than predicted.

Renewable technologies have persistently matured faster, and prices fallen further than predicted, forcing forecasts to be updated year on year. The current solar photovoltaic volumes forecast for 2030 is 36x what it was in 2002, with costs 3x lower.[r] Steep learning curves are also expected in other green technologies, such as electric and hydrogen long distance freight vehicles, with both forecast to be at total cost-of-ownership parity before 2030.

q. Although projections are ranged and varied, most experts include €40-€70/tCO2 in their price range for carbon taxes and offset prices for 2030, sources include Expert Interviews, Ecosystems Marketplace report 2019, Bloomberg, Princeton, World Bank Group - Climate Change 2015, CDP report 2020. **r.** BCG analysis on IEA World Energy Outlook reports for capacity projections, BNEF for cost projections, and IRENA for actuals.

SMI HEALTH SYSTEMS TASK FORCE ACTIONS TO DECARBONISE SUPPLY CHAINS

The SMI Health Systems Task Force recognises the need to act now to decarbonise healthcare supply chains and is taking concrete action to reduce emissions.

Setting Ambitious Emissions Reduction Targets Across All Scopes.
The Task Force's private sector members are committing to set near-term targets aligned with the 1.5°C pathway and achieving net zero by 2045[s] across all three scopes. Members are also committing to switch to 80% to 100% renewable power for their own operations[s] and transition car fleets to zero-emission vehicles by 2030.

Aligning on a Common Methodology for Life Cycle Assessments (LCAs).
LCAs provide a detailed view of environmental impacts of products across their life cycle. Task Force members are committed to align on a common framework to perform LCAs – with private sector members also committed to publishing product-level LCA data across their product portfolio to increase transparency on treatment emissions (see *Decarbonising Patient Care Pathways*).

Aligning on Common Supplier Standards.[t]
To achieve their respective net zero targets, and reduce emissions across the entire supply chain, Task Force members have agreed on a set of common supplier standards, which include commitments to:

- Assess and disclose Scope 1, 2 and 3 emissions
- Set near-term science-based targets aligned to the 1.5°C pathway
- Cascade standards and targets to upstream suppliers, including emissions disclosure
- Switch to renewable power
- Explore options to source renewable heat
- Decarbonise transport solutions with SBTi-aligned commitments (for transport suppliers)
- Reduce water usage, and set targets for water efficiency
- Set targets to reduce waste and energy and increase reuse of materials in manufacturing

Task Force members will work collaboratively with suppliers to achieve emissions reduction targets, acknowledging each supplier's starting point and sustainability maturity. By jointly setting clear supplier standards, the Task Force aims to increase focus on and incentivise decarbonisation efforts across the supply chain.

s. At present, Samsung Biologics is committing to achieve net zero and switch to 100% renewable power by 2050 at the latest given local market constraints, and is actively working to reach these targets as early as possible. **t.** These supplier standards apply only to suppliers of the healthcare business of each private sector member.

Many Task Force members are already working with suppliers to reduce Scope 3 emissions. For example, AstraZeneca is asking key suppliers to set science-based targets, GSK has launched its Supplier Sustainability Programme in September 2022, Merck launched its global Supplier Decarbonisation Programme in February 2021, and Novo Nordisk is supporting suppliers to switch to renewable power.[39] [40] [41] [42]

Exploring New Solutions to Decarbonise Transport, Electricity, and Heat. Task Force members are collaborating to identify, pilot, and scale new solutions for green transport, electricity, and heat. Reducing emissions in these areas is key, as they represent around 65% of the total abatement potential across the healthcare supply chains (see Exhibit 6). The Task Force is exploring three decarbonisation avenues:

- **Supporting innovative solutions to decarbonise transport** such as exploring joint Sustainable Aviation Fuel off-takes and jointly piloting new green transport corridors in partnership with logistics providers
- **Evaluating renewable corporate Power Purchase Agreement (PPAs)** in China and India in 2023. These PPAs will also be open to suppliers, and facilitate access to renewable electricity in these markets
- **Piloting green heat technologies**. Green heat solutions are still sub-scale – especially for high heat. The Task Force is committed to leverage its scale and work with providers to explore green heat solutions by 2025 to accelerate the adoption of effective and scalable technologies

Going forward, Task Force members will continue working together to ensure the delivery of these commitments. Through these actions, the Task Force hopes to demonstrate how biopharma and med-tech companies, as well as their suppliers and other stakeholders, can work together to take concrete steps to decarbonise healthcare supply chains.

HOW ALL STAKEHOLDERS CAN COME TOGETHER TO SUPPORT THE DECARBONISATION OF SUPPLY CHAINS

Each stakeholder has a role to play to reduce emissions across healthcare supply chains (see Exhibit 7):

EXHIBIT 7 | All stakeholders can support decarbonisation

Pharma, biopharma, and med-tech companies can:
- Track and disclose product-level GHGs
- Set Scope 1-2 targets, decarbonise ops (e.g. renewable power, heat, etc.)
- Set Scope 3 targets and supplier standards
- Redesign products, packaging, and processes for lower lifecycle emissions
- Fund green tech R&D / pilots

Governments and policymakers can:
- Support energy transition (e.g. incentives / subsides, R&D funds)
- Price carbon (e.g. carbon tax, CBAM, cap and trade)
- Regulate for efficiency (e.g. energy efficiency standards)

Regulatory bodies can:
- Accelerate approvals for CO_2e-reducing product improvements
- Mandate reporting on emissions (including via green labelling)

Health authorities and payers can:
- Include sustainability as a criterion in purchasing and coverage decisions
- Set green supplier standards

Source: BCG analysis based on literature review and case experience

Pharma, biopharma, and med-tech companies can track and disclose product-level emissions to create a deeper understanding of emissions drivers in the sector.[u] They can use this understanding to "walk the talk" by setting Scope 1 and 2 targets and decarbonising their operations. To reduce Scope 3 emissions, companies can engage and collaborate with suppliers, and set clear supplier standards.

Governments and policymakers can support the transition to low carbon supply chains by working with industry to provide the right incentives and enabling environment. For example, policymakers can price carbon to send a clear message across the whole economy and supply chains and incentivise manufacturers to get the most out of their inputs by setting efficiency standards.

u. More information on the opportunity for LCAs to support decarbonisation in Decarbonising Patient Care Pathways

Regulatory bodies can actively provide clear guidance on the regulatory pathway to follow, support and accelerate approvals for CO_2 reducing improvements to products and processes. They can also mandate reporting on emissions. As a start, the scope of the EU's Environment Risk Assessment (ERA) and the US Food and Drug Administration's Environmental Assessments (EAs) could be expanded to include emissions.[43][44] Regulators could also encourage or start to require emissions labelling on products. Both would be forcing functions for suppliers and manufacturers to calculate and report product-level carbon footprint, and better allow payers, providers, and patients to make informed treatment choices.

Health authorities and payers can include sustainability as a criterion in procurement and reimbursement decisions alongside cost and quality, while balancing sustainable procurement with their obligation to serve patients and procure new and innovative drugs. They can also use their substantial influence to set supplier standards. For example, NHS England, as the first health system to establish net zero targets, has established a Net Zero Supplier Roadmap, and will progressively require suppliers to disclose targets and emission levels as well as following a carbon reduction plan.[45] More such actions are expected given the widespread commitments to reduce health systems emissions.[46]

Delivering on the SMI Health Systems Task Force's ambition to accelerate the delivery of net zero health systems will require unprecedented collaboration from all stakeholders within and beyond the healthcare sector. By taking concrete, collective action and proposing practical recommendations to decarbonise supply chains, the Task Force is looking to inspire others to act to drive down emissions and protect public health.

SMI HEALTH SYSTEMS TASK FORCE CONTRIBUTORS

The SMI Health Systems Task Force thanks the members of the Task Force's Supply Chain working group for their contribution to this whitepaper, and for their role in coordinating contributions from their organisations:

AstraZeneca — Juliette White

Roche — Batu Berkok, Lucy Pickett, Matthew Winterman

GSK — Lewis Howard, Renata Scofield

SAMSUNG BIOLOGICS — James Choi

MERCK — Verena Buback

sanofi — Annabelle Harreguy-Balace, Jose Francisco Vallejo Carrera

novo nordisk® — Dorethe Nielsen, Eike Raft Vinther, Jane Rasmussen

Sustainable Healthcare Coalition — Fiona Adshead, Keith Moore

BCG BOSTON CONSULTING GROUP

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APPENDIX A: METHODOLOGY AND USE OF DATA

The recommendations presented in this paper are based on an extensive review, stakeholder interviews, and input from the SMI Health Systems Task Force members.

Several public sources were triangulated to estimate the healthcare industry's emissions, and how they break down across the value chain. The Lancet 2020 Countdown report[v] estimate was used as a baseline for total healthcare emissions (2.4Gt CO_2e) given it is based on recent analysis of the emissions of over 180 countries and well supported by other estimates.[9] [8] [47] [48] [w] Healthcare emissions were then split across supply chain, R&D, patient care setting and direct patient emissions using Health Care Without Harm's Health Care Climate Footprint paper.[8] [x] Emissions were split within supply chains using CDP emissions data and sustainability reports in combination with BCG case experience.

The split of GHG emissions across the healthcare value chain provides a high-level, indicative view of the main sources of healthcare emissions. To increase confidence in these estimates, the top-down approach detailed above should be complemented with a bottom-up assessment of emissions sources using product-level emissions datasets. This detailed analysis was not performed as part of this paper given the scarcity of publicly available product-level Life Cycle Assessments.

v. The Lancet Countdown and HCWH used an environmentally extended multiregional input-output (EE MRIO) method[53]. This allows an understanding of how money spent in one sector triggers spending in another (e.g. how spending on packaging can trigger spending in the glass industry). Spending within these EE MRIO models is then paired with emissions factors which give an estimate or an average for how many emissions are associated with each $ spent on a certain economic activity. **w.** There were a cluster of estimates within the literature with estimates of emissions making up 4.4% to 5.0% of global emissions, although a range of estimates for global emissions were used (36 to 52 $GtCO_2e$) meant that the range of emissions estimates for healthcare in $GtCO_2e$ was 1.6 to 2.6. The Lancet Countdown estimate was also selected because the year of emissions it was analysing was the most recent (2017), and it was based on the emissions from the largest number of countries (189). **x.** The total (2.0$GtCO_2e$ in 2014) was brought in line with the Lancet total (2.4$GtCO_2e$) by adding in anaesthetic gasses, inhalers, visitor, and patient travel, as well as emissions growth from 2014 to 2021.

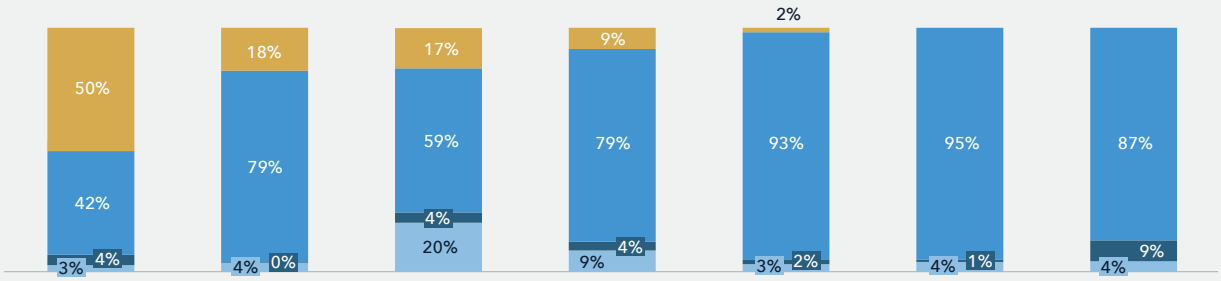
APPENDIX B: SMI HEALTH SYSTEMS TASK FORCE MEMBERS' EMISSIONS PROFILES

Across the SMI Health Systems Task Force members, approximately 80% of emissions for biopharma companies are Scope 3 upstream emissions (see Exhibit 8). Members are already taking action to decarbonise their own operations, by switching to renewable power and heat, and reducing transport emissions. Members have also set ambitious Scope 3 targets and are engaging with suppliers to address upstream emissions.

EXHIBIT 8 | ~80% of biopharma emissions in upstream supply chain

BioPharma Scopes 1-3 emissions from public sources (%), scope 3 targets and Science Based Targets

S3 downstream (product use) driven by inhalers



	GSK[3]	AstraZeneca	Merck	sanofi	Roche[5]	novo nordisk[4]	Samsung Biologics
S3 target[1]	Net Zero 2030	Net Zero 2045	Climate neutral 2040	Net Zero 2050	-18% 2025	Net Zero 2045	-26% 2026
SBTi[2]	1.5C NZ committed	1.5C NZ 2045	1.5C	1.5C NZ committed		1.5C	

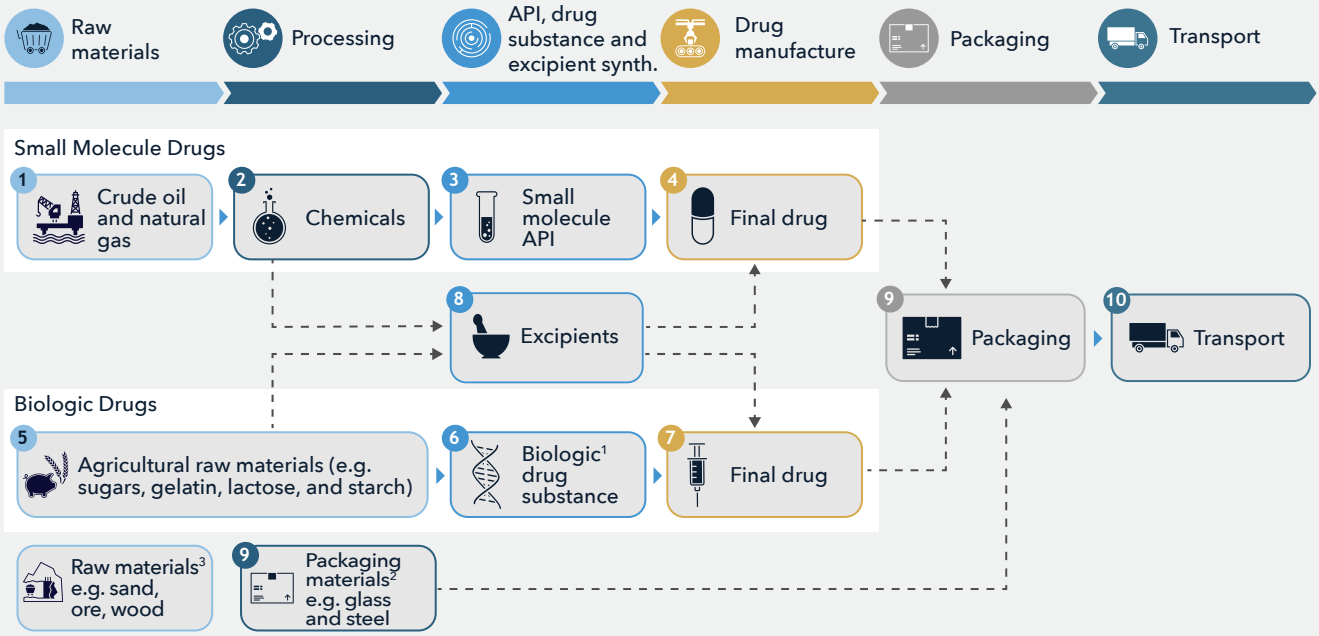
Operations (Scope 1) | Supply chain (Scope 3 upstream)
Purchased power & heat (Scope 2) | Product use (Scope 3 downstream)

1. Scope 3 target set and by what date as of October 2022 2. Whether the company is aligned to SBTI – either set or committed as of October 2022 3. Based on Scope 3 % distribution data 4. 2021 CDP Scope 3 data and Scope 1 and 2 from Sustainability Report 5. Currently developing Net Zero ambitions
Note: For Scope 2 market-based figure taken unless specified; Scope 3 emissions combine both upstream and downstream emissions; 2021 data used or more recent where available
Source: CDP, company websites, company sustainability reports, BCG analysis

APPENDIX C: PRODUCTION PROCESSES FOR SMALL MOLECULE AND BIOLOGIC DRUGS

Product supply chains are complex and involve many intermediate stages of productions that are highly product specific. There are however several high-level steps common across product supply chains that drive the majority of emissions, for both small molecule drugs and biologics (see Exhibit 9).

EXHIBIT 9 | High-level production process for drugs



1. Also including small molecule drugs from biological sources, either grown (e.g. penicillin) or extracted (e.g. heparin from pig tissue and morphine from poppies) 2. Also plastics from chemicals although link left off diagram for clarity 3. Also clays and salts variously used as excipients and active ingredients
Source: BCG analysis based on literature review and case experience

Small-molecule drugs are primarily derived through synthetic chemistry from petrochemical input.[y] There are four major stages of production:

1. Crude oil and natural gas extraction and processing
Most small-molecule drugs are derived from hydrocarbons, such as crude oil and natural gas, which are associated with "fugitive" methane emissions in the process of extraction. Crude oil is refined at about 450°C (using fossil heat) into naphtha, which along with natural gas, is turned into base chemicals.

2. Chemical production
Turning hydrocarbons into key base chemicals typically requires fossil-based temperatures of about 850°C, as well as a lot of electricity. Three major production processes, steam-cracking naphtha, steam methane reforming and chlor-alkali electrolysis, create the most common base chemicals need for biopharma and drive up to two-thirds of chemicals emissions.[49]

3. API synthesis
Here base chemicals are transformed into APIs through multistep processes, such as filtration, purification, distillation, cleaning, and drying. These processes all require electricity, heat (typically less than 150°C), and/or steam. In some cases, large amounts of solvents are also required, making the end product highly emissions intensive. Emissions intensities of API synthesis vary widely depending on number of production steps, processes and inputs involved. For a sample of 20 anaesthetics, API emissions intensities ranged from 11 kg of CO_2e to 3,000 kg of CO_2e per kilogram of API, with a median of about 80 kg of CO_2e per kilogram of API, which is over 40 times more emissions-intensive than steel production.[50]

4. Final drug manufacturing
Most small-molecule drugs are derived from hydrocarbons, such as crude oil and natural gas, which are associated with "fugitive" methane emissions in the process of extraction. Crude oil is refined at about 450°C (using fossil heat) into naphtha, which along with natural gas, is turned into base chemicals.

Biologic drugs are larger and more complex molecules that are typically grown from cell cultures or small organisms. Because producing biologics typically requires lower temperature heat, fewer steps, and smaller quantities of lower-emitting ingredients than small-molecule drugs, they often produce fewer emissions.[51][z] There are three major steps in biologics manufacturing:

5. Processing of agricultural raw materials
Biologics raw materials tend to be agricultural crops. These are processed into more refined products, such as fructose, and used as a growing medium for cell cultures. Emissions in agriculture largely come from fertilisers, as well as land-use change (deforestation). Where agricultural materials are animal-derived, there will be emissions directly from livestock (enteric fermentation).

y. A minority of small-molecule drugs (such as antibiotics like penicillin) are grown in such a way that the emissions drivers are similar to biologics'. Some, such as heparin, are extracted from animal tissue, and the main emissions drivers are agricultural. **z.** Can create different environmental stresses (e.g. by consuming more water).

6. Biologic drug substance production

Cell cultures are mixed with a growth medium (a nutrient-rich broth with sugar water refined from agricultural inputs) and fermented to produce a larger volume of product (typically after 20 to 30 days), at temperatures below 50°C. The product is isolated and purified, often involving centrifuging and chromatography. The highest temperatures used are for the steam (<150°C) needed to clean vats and instruments.

7. Final drug manufacturing

Biologics tend to be injected,[52] and therefore the active ingredient will be mixed with excipients (such as preservatives and water for injection), packaged in primary packaging (glass vials with steel needles), and then in secondary packaging (cardboard). None of these operations are particularly energy-intensive, but the incineration of contaminated waste does require high fossil-based heat.

8. Excipients

Medicines always contain components other than the active substance. These constituents, known as excipients, serve a variety of functions, such as binding and suspending, sweetening, preserving, and coating. Excipients often account for most of a medicine's weight and therefore drive a significant portion of end-to-end emissions, even if they are less emissions-intensive per kg than an average API. Most excipients are plant-based products (sugars, cellulose, and starch), but they can also be animal-derived (fatty acids, proteins, and lactose), petrochemicals (mineral waxes and oils), or inorganic excipients (talc and salts). All these produce emissions in the extraction and processing stages.[aa] Power is required, and steam and heat are needed in hydrolysis, boiling, and distillation.

9. Packaging materials

The process of putting finished products into packaging is not emissions-intensive; the greater emissions drivers are maintaining a sterile environment with heating ventilation and cooling (HVAC) and cleaning. But producing packaging materials can be emissions intensive (e.g. glass is emissions intensive to produce but paper is not). In some cases—such as injectable biologics in glass vials, and small molecule drugs in inhalers—packaging materials can constitute the majority of the product's end-to-end footprint. The main materials used for packaging are glass, plastic, cardboard, and metal. All require energy to produce, but glass, many metals, and plastic all require heat of more than 850°C, which is usually created using fossil-based sources. Iron and steel release process emissions intrinsic to their production process.

10. Transport

At every stage of the supply chain, substances are shipped, flown, or trucked between facilities. Pharmaceutical supply chains, tend to be international, with high volumes of input materials produced in Asia and sent to Europe to be transformed into the finished product. Short timeframes and controlled conditions are a priority in pharmaceuticals, resulting in high volumes of air freight, which is the mode of transport with highest emissions (air freight typically generate ~400 g of CO_2e per ton per kilometre versus ~10 g of CO_2e for sea freight).[13][14] Cold chain requirements, which are often unavoidable given the nature of some medicines, imply energy for cooling and bulkier/heavier packaging for insulation that also contributes to high transport emissions.

aa. Not including water for injection, which is usually manufactured onsite.

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