Industry Net Zero Accelerator Initiative

The "No-Excuse" Framework to Accelerate the Path to Net-Zero Manufacturing and Value Chains

WHITE PAPER

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Foreword

Achieving net zero in manufacturing and value chains is a global endeavour. Systemic collaboration is fundamental to accelerating the change.

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While many leading companies have already started their journey towards achieving net-zero emissions – namely, cutting their greenhouse gas emissions as much as possible and balancing the remaining by removing it from the atmosphere – no single business can reach net zero by itself. Systemic collaboration across and between value chains is fundamental to aligning and upgrading corporate strategies and industrial policies, and all stakeholders – even competitors – can find mutual benefit in ensuring their industries can continue operating in the future.

Industry has a significant role to play in achieving global carbon reduction targets as it encompasses all manufacturing and value chains and represents nearly 30% of global greenhouse gas emissions. To better understand how to accelerate the transition to net zero, the World Economic Forum Industry Net Zero Accelerator initiative team consulted extensively with experts from business, academia and government within the framework of the World Economic Forum Centre for Industry Transformation. This background research has given the team clear insight into where industry stands in its net-zero journey, the innovative strategies being implemented in manufacturing operations and value chains, the opportunities that companies see in the transition, and the barriers they face.

While individual organizations can make important contributions towards net zero, no company can manage the net-zero transformation of its manufacturing facilities and value chains alone if both individual and collective targets are to be achieved, in line with announcements during the United Nations Climate Change Conference of 2021 (COP26) and 2022 (COP27). Systemic collaboration is a vital component of the journey and needs to be prioritized at the supply-chain and cross-sectoral levels, as well as between the public and private sectors. In particular, several firms are demonstrating that driving decarbonization in their supply chains and supporting small and medium-sized enterprises are essential components of a successful strategy for driving the industry net zero journey – which results in mutual economic benefits, environmental benefits and risk mitigation.

More collaborative efforts are necessary to address the challenges ahead. In this context, the World Economic Forum has launched the Industry Net Zero Accelerator initiative in collaboration with Cambridge Industrial Innovation Policy (Institute for Manufacturing, University of Cambridge), Capgemini, Rockwell Automation and Siemens. The initiative provides a cross-industry, precompetitive and neutral platform to support businesses and other stakeholders to upgrade their net-zero strategies by enabling the dissemination of knowledge, best practices and experience – all focused on how to unpack the net-zero equation and aimed at accelerating the transition.

As the initiative's first output, this White Paper proposes a framework and reference guide to help shape and implement "no-excuse" strategic actions and encourage manufacturing ecosystem collaboration in achieving net zero. This framework represents a compendium of the key building blocks of successful industry net zero roadmaps, illustrated through real-world examples of existing firm-level and collaborative initiatives and strategies.

The scale of the challenge ahead ultimately requires a new mindset of innovation and action where successful industrial companies can lead by example. The initiative's team hopes this paper can inspire more businesses to join this community and play a role in the collaborative effort to exchange knowledge and best practices, and to stimulate and accelerate the transition towards net zero across industrial sectors.

Executive summary

Although the need for climate action is a growing concern for businesses, the move from talk to "no-excuse" action is still hindered by limited access to detailed information on how businesses can operationalize their commitments and address their carbon-emission challenges throughout their operations and supply chains.

Because getting to net-zero manufacturing and value chains covers many areas of action across functions within an organization and in diverse sectors, companies often find themselves discussing various issues, strategies and solutions in isolation and unable to consider all the related factors. What technological solutions are readily available in the market? What support schemes exist in specific sectors and countries? What regulations are likely to affect future business operations? System-level collaboration is a vital tool for finding the right answers to these questions, through interacting and collaborating with peers at the cross-industry level or with governments and other expert bodies.

To facilitate access to evidence and shape the dialogue between leaders and decision-makers, this White Paper proposes a reference framework – one that is core to the World Economic Forum Industry Net Zero Accelerator initiative – that brings together the relevant building blocks of successful industry net zero roadmaps. The framework aims to be a central tool for the initiative to engage leaders across industry sectors, government, academia and civil society to jointly shed light on global insights and best practices in response to the net-zero "how-to" challenge.

Complemented by real-world examples of initiatives and projects, the framework is based on 10 action pillars grouped into four stages:

Stage I
Build the foundations

1 Build a net-zero corporate strategy

2 Set the capability for carbon footprint monitoring

Stage II
Change the game internally

3 Accelerate energy efficiency in operations and transport and decarbonize energy sources

4 Pursue material efficiency in operations

5 Rethink product design and business models

6 Develop carbon capture solutions and offset mechanisms

Stage III
Drive systemic collaboration

7 Drive value-chain decarbonization (upstream and downstream)

8 Mobilize ecosystems for net-zero infrastructure and innovation

9 Address net-zero data and digital standards

Stage IV
Make it simple, inclusive and exciting

10 Implement and drive the net-zero culture and practices

Each stage of the framework consists of a combination of research-based insights, well-established action areas observed from companies across different manufacturing and value chains, and emerging themes where firms are seeking solutions and partnerships to move from concept to action. Although various industrial sectors have different contexts and drivers behind their emissions, this framework is intended to be applicable across key industries and geographies. All action areas within the framework are considered as interlinked and mutually supporting themes that are likely to be deployed in combination as part of any net-zero roadmap.

This White Paper constitutes the first output of the Industry Net Zero Accelerator initiative and includes the inputs from various stakeholders within the World Economic Forum International Centre for Industry Transformation. Forthcoming work by the initiative will bring together a larger community of action to pursue the collection of insights, methodologies, best practices and experiences on net-zero cross-industrial challenges. These could include, for example, manufacturing operations, experiences with data standards, indirect emissions (i.e. Scope 3) traceability, material efficiency and circularity, supply chain decarbonization support, new business models or net-zero compatible digital strategies. While this paper is targeted at supply chain and operating officers, further resources are available for chief executive officers at the Alliance of CEO Climate Leaders.[1]

The Industry Net Zero Accelerator initiative is partnering with the Estainium Association[2] to address value-chain data sharing challenges (e.g. product carbon footprint; carbon capture, storage, utilization and compensation) and will continue leveraging the net-zero framework presented here as a basis for further dialogue between private- and public-sector stakeholders.

1 Industry net zero in context

Net zero is at the top of most company agendas and is an important theme of public discourse. The term is now synonymous with climate action. But what does net zero mean? Where are industries in their transformation journey, and what drives businesses to address the key opportunities and barriers?

1.1 What is net zero?

Net zero refers to the balance between the amount of greenhouse gases (GHGs) produced and the amount removed from the atmosphere.[3] It is the internationally agreed-upon goal for mitigating global warming: the United Nations Intergovernmental Panel on Climate Change (IPCC) has determined the need for net-zero CO_2 by 2050 to avoid catastrophic climate change. The IPCC acknowledges that reducing all emissions to absolute zero by 2050 will be difficult, requiring not only significant emission cuts but also more intensive removal of CO_2 from the atmosphere.

At the industrial organization level, the Science Based Targets initiative (SBTi) has reported that reaching a state of net-zero emissions for companies implies two conditions:[4]

– Achieving a level of value-chain emissions reduction consistent with the depth of abatement achieved in scenarios that limit warming to 1.5°C with no or limited overshoot

– Neutralizing the impact of any source of residual emissions that remains unattainable by permanently removing an equivalent amount of atmospheric CO_2

GHG emissions are categorized into three groups or “scopes” by the Greenhouse Gas Protocol (Figure 1).[5]

FIGURE 1 GHG emission scopes in the manufacturing value chain and product life cycle

Source: Capgemini, based on the concept presented in *A Corporate Accounting and Reporting Standard: Revised Edition*, World Resources Institute and World Business Council for Sustainable Development, 2004.

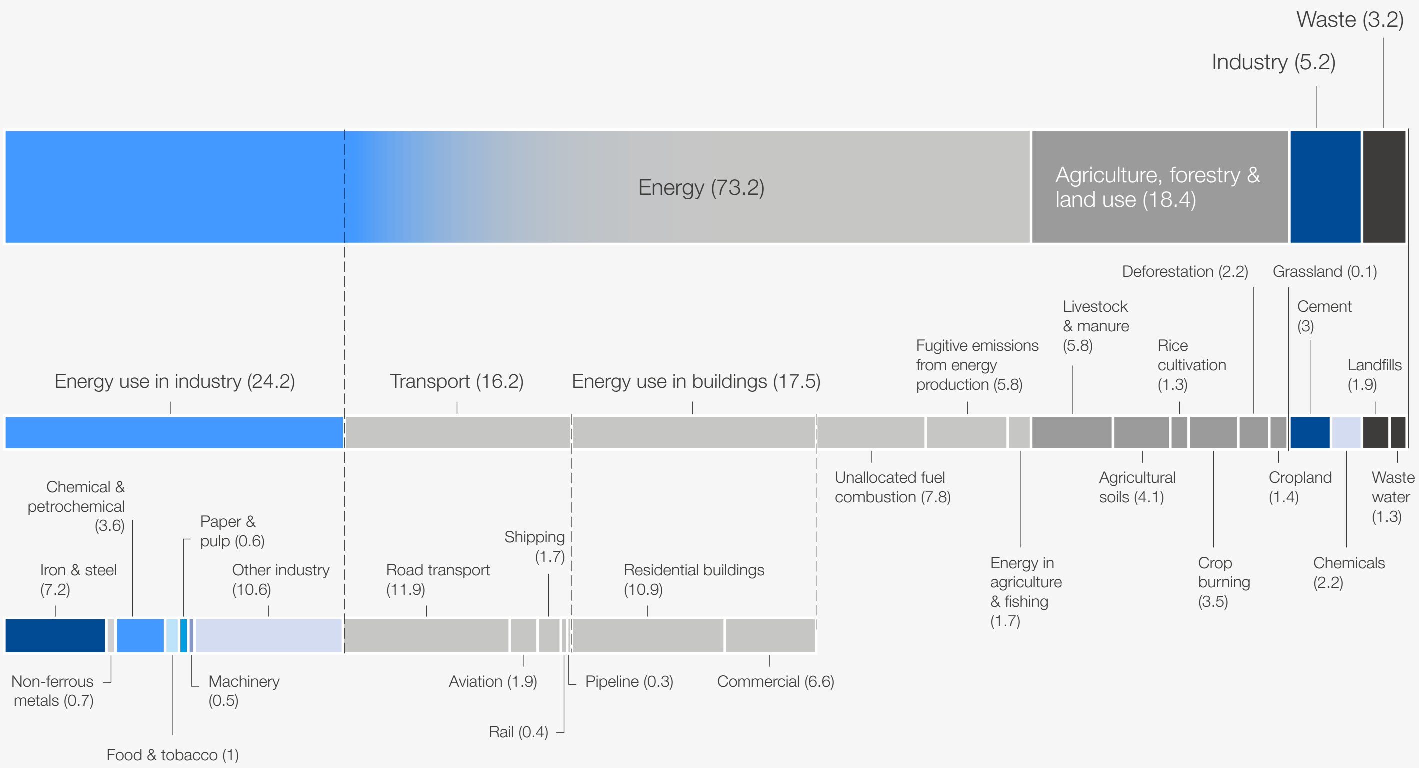
1.2 The current state of net zero in manufacturing industries and value chains

When looking at historical emissions, global net anthropogenic CO_2-equivalent emissions grew 54% from roughly 38 billion tonnes in 1990 to nearly 59 billion tonnes in 2019.[6] If this trend continues, the world will likely experience a temperature increase of between 4.1°C and 4.8°C by the year 2100.[7] Under the Paris Agreement, all economic sectors need to adhere to the 2°C or 1.5°C carbon reduction pathway, which translates into reducing global carbon-equivalent emissions from above 50 billion tonnes to net zero. That is the scale of the challenge faced by industry and other economic sectors.

When looking at the context of individual industrial subsectors, CO_2-equivalent emissions attributed to energy use in industry accounted for 24.2% of total global emissions in 2016, in addition to 5.2% CO_2-equivalent emissions generated from direct industrial processes (mostly from the production of cement, chemicals and petrochemicals) for a total of 29.4% of global emissions (Figure 2).

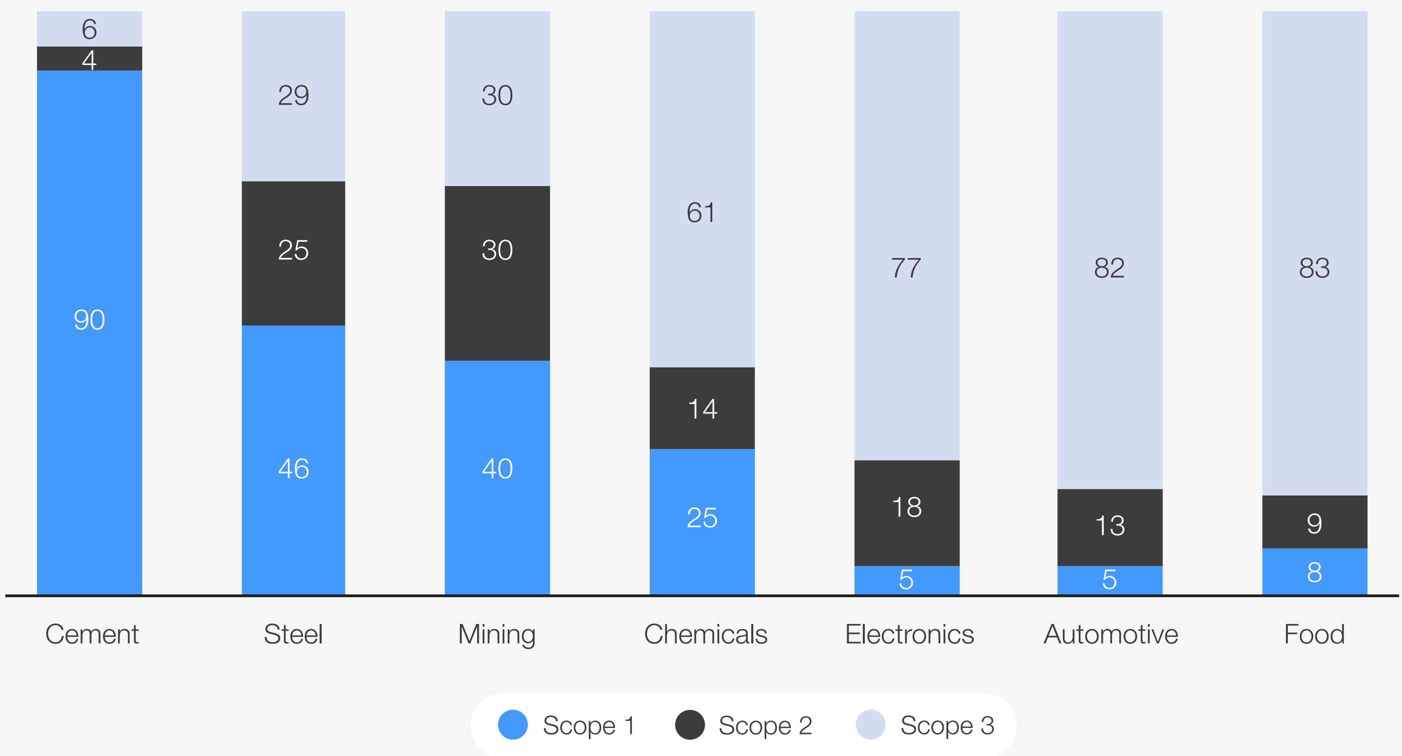
It is clear that different industries face different challenges (Figure 3). Whereas industries like cement, steel and mining have low Scope 3 emissions, this category becomes significant for other industries such as chemicals, electronics, automotive and food, which means that any net-zero efforts in those sectors are likely to require intense cooperation from suppliers, manufacturers and consumer brands.

FIGURE 2 | **Industry contribution to global GHG emissions (in blue), sectorial view, 2016 data (%)**



Source: World Economic Forum Industry Net Zero Accelerator initiative, adapted from information on the Our World in Data website and based on data from Climate Watch and the World Resources Institute.

FIGURE 3 | **CO_2-equivalent emissions by scope for selected industries, 2019 (%)**

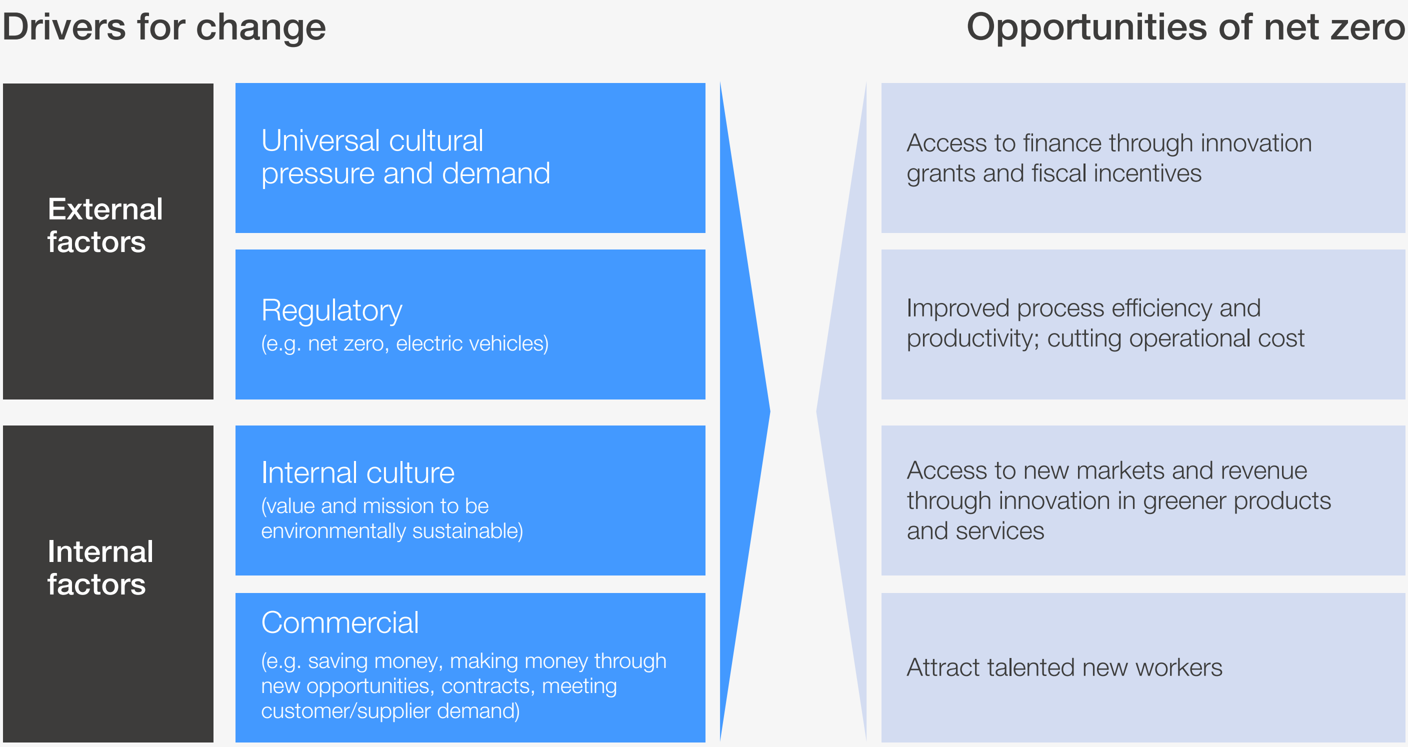


Source: Extracted from World Economic Forum, *Net-Zero Challenge: The Supply Chain Opportunity*, Insight Report, January 2021.

1.3 Business drivers and opportunities for achieving net zero

Drivers for actively pursuing and achieving net-zero targets can include a combination of external and internal factors (Figure 4).[8]

FIGURE 4 **Business drivers for change and business opportunities of net zero**



Source: Modified from Lloyds Bank, *From Now to Net Zero: A Practical Guide for SMEs*, 2022, and Make UK, *Manufacturing Sector Net Zero Roadmap*, 2022 (both accessed 24 November 2022).

As an example of cultural pressure, the United Nations Development Programme's Peoples' Climate Vote survey covering 50 countries and over half of the world's population showed that 64% of respondents agreed that climate change is a global emergency.[9] As a recent example of regulatory development, large companies and financial institutions in the United Kingdom are required to disclose climate-related financial information on a mandatory basis starting from April 2022.[10]

Given these changes, an industry survey carried out by Make UK, one of the country's largest industrial associations, showed that nearly half of manufacturers see the transition to net zero as offering key opportunities, which include:[11]

- Increasing access to finance through innovation grants and fiscal incentives targeted at encouraging investment in the green economy
- Improving process efficiency and productivity that could lead to cutting both carbon emissions and operational costs
- Maximizing innovation to develop and manufacture new products and services that target changing consumer preference for greener products and help to generate new revenue and access new markets
- Developing new supply chains to sustain new products and markets and access new revenue (e.g. biorefining; carbon capture, utilization and storage; hydrogen supply chain; circular steel supply chain)
- Attracting talented new workers to support industry's green transformation

1.4 Barriers to achieving net zero in manufacturing industries and value chains

Putting principles into "no-excuse" practice, firms face three key barriers – financial, technical and organizational – that hinder their ability to transition to net zero at the right pace and scale (Figure 5).

FIGURE 5 **Barriers to net zero in manufacturing operations and value chains**

	Key barriers	Experiences from operations leaders conducting net-zero transformations
Financial	– Increased operational expenditure – Additional capital expenditure for demonstration pilots and industrial deployment – Perception that technologies are too expensive – Limited access to funding – Lack of awareness of technologies and their potential financial benefits	**Electronics and automation** *"We make a lot of investment, but one huge challenge is the benefit and cost sharing across the value chain."* **Mining, metals and materials** *"While 20-year visibility is needed when we invest in new industrial equipment, it is a big challenge to forecast future green energy availability (electricity, gas, biomass, hydrogen …) and make the right technological choice."* **Chemicals and pharma** *"It is difficult to forecast the reward to get greener in an industry not yet pressurized by customers for greener products."* **Mining, metals and materials** *"We need sector-level R&D investment to decarbonize our processes – in many cases it also requires custom solutions depending on our industrial legacy."*
Technical	– Lack of common language, knowledge gap and culture – Technical difficulty integrating new technologies into existing plants – Shortages in skills (information and communications technology; specialized manufacturing activities and processes; technology adaption and integration; data analysis; managerial) – Management of geographical diversity	**Industrial equipment manufacturer** *"Difficulty to have harmonized data sharing of product carbon footprints across the value chain: the stake is to explain that confidential data exchange is possible without impacting IP for companies."* **Mining, metals and materials** *"The heterogeneity of laws, subsidies and taxes between geographies makes it difficult to implement decarbonization measures as fast as we want."* **Chemicals and pharma** *"High improvements in digitalization are needed to set measurements and monitor carbon emissions."* **Electronics and automation** *"The technology roadmap and the related investment intensity are still unclear – we need guidance on carbon capture for example."* **Electronics and automation** *"We face a difficulty in the cultural change: prioritize projects, educate and communicate within the organization."*
Organizational	– Partnerships with external ecosystems – Support of value-chain decarbonization – Organizational and individual resistance to change – Unclear implementation strategy – Top-down implementation management approaches with little involvement of workers – Lack of cooperation among business functions and departments	**Mining, metals and materials** *"Net zero is all about partnerships: they are necessary at every level, from governments, supply chain or energy solutions providers."* **Mining, metals and materials** *"Operations have a major responsibility in enabling the journey to net zero – moving responsibility from corporate to supply chain leaders makes a big difference."* **Electronics and automation** *"We need to collaborate with other industries at the country level to work together with governments to provide the energy, infrastructure and technical support needed."* **Chemicals and pharma** *"Upstream supply chain hot spots relate to logistics and packaging: we need to work on smaller packages and take-back, but many healthcare regulations do not allow it today."*

Source: Cambridge Industrial Innovation Policy (Institute for Manufacturing, University of Cambridge); World Economic Forum Industry Net Zero Accelerator initiative consultations with industry leaders and experts.

Barriers at the firm level are generally linked to gaps in contextual enablers, which may include regulatory or societal barriers, absent or insufficient entrepreneurial and innovation systems, inadequate institutional frameworks, and limited physical and digital infrastructure.

Although some of the key technologies underpinning net-zero operations already exist, others are still in early stages of development without clear roadmaps for entry into the market. "Ensuring that these technologies are successfully integrated and scaled-up into commercially available products and solutions represents a hurdle. Even if these applications manage to get to the market, creating awareness and demonstrating their functionality among industrial users remains a challenge."[12]

The net-zero challenge is, finally, a global orchestration challenge. Net zero is hard to achieve, but use cases, solutions and approaches can already help companies cut emissions. Private-sector players, the public sector and civil society need to align on key priorities and relentlessly collaborate to overcome barriers and drive the net-zero transformation.

2 Net-zero transformation: A guiding framework for collaborative action

Many businesses in global industries have not only committed to a net-zero future but have started implementing action plans, technologies and practices that could provide guidance for the broader industrial community.

Recognizing that businesses are at different stages of the journey towards net zero, the World Economic Forum Industry Net Zero Accelerator initiative team has created a framework that can serve as a reference guide to support awareness on mitigation actions, inspire strategic-level decisions and structure the dialogue between private- and public-sector stakeholders, thus facilitating further collaboration. The framework is based on 10 action pillars grouped into four stages (Figure 6):

FIGURE 6 **The "no-excuse" framework for industrial decarbonization**

Stage I
Build the foundations

1 Build a net-zero corporate strategy

2 Set the capability for carbon footprint monitoring

Stage II
Change the game internally

3 Accelerate energy efficiency in operations and transport and decarbonize energy sources

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Stage IV
Make it simple, inclusive and exciting

10 Implement and drive the net-zero culture and practices

Source: World Economic Forum Industry Net Zero Accelerator initiative.

Each stage of the framework is comprised of research-based insights, well-established action areas observed among manufacturing and value chains, and emerging themes where firms are starting to seek solutions and partnerships to move from concept to action. Although industrial sectors possess different drivers of carbon emissions and contextual circumstances, this framework seeks to be applicable across all industries and geographies. All action areas within the framework are considered as interlinked and mutually supporting themes that are likely to be deployed in combination and as part of any net-zero roadmap.

2.1 **Stage I:** Build the foundations

Action pillar 1 Build a net-zero corporate strategy

Basic steps that could help firms create a net-zero corporate strategy include establishing their carbon footprint baseline, setting carbon reduction targets and creating a reduction roadmap based on a strong business case. Several publicly available tools, methodologies and resources can help firms diagnose their starting point and set a direction for their journey.

Evaluate the firm's carbon footprint and set targets

The first step is to determine the firm's total GHG emissions generated annually, and which parts of the business are the major sources of emissions (e.g. processes, supply chain, logistics, product use). While metrics can be complex and uneven across industries, focusing on two main ones – CO_2-equivalent reduction per volume produced and direct CO_2-equivalent reduction – allows to quantify roadmaps and track achievements.

Initiatives such as the SBTi provide clear guidelines on how to set near- and long-term science-based targets. According to the SBTi, setting a science-based target includes the following key steps:[13]

– Commit: submit a letter establishing the intent to set a science-based target

– Develop: work on an emissions reduction target in line with the SBTi's criteria

– Submit: present the target to the SBTi for official validation

– Communicate: announce the target and inform stakeholders

– Disclose: report company-wide emissions and track target progress annually

Examples of tools, methodologies and standards for assessing carbon emissions:

– Greenhouse Gas Protocol Corporate Standard Scope 3 Evaluator Tool

– Carbon footprint tool (*Bilan Carbone*) of the French Agency for Ecological Transition (ADEME)

– Organisation Environmental Footprint (OEF) standard

– Carbon Trust's Carbon Footprint Calculator

– SME Climate Hub's Cool Climate Calculator

– International Organization for Standardization (ISO) net-zero guidelines

Create a net-zero roadmap with a clear governance structure, centred on opportunities and risks

As with any transformation programme, a roadmap is needed to identify and prioritize key net-zero levers. The roadmap helps to investigate, manage and communicate the linkages between specific initiatives and investments, product developments, business objectives and market opportunities. Net-zero roadmaps should have a governance and oversight process that drives the vision and allows for clear tracking of progress and carbon trajectory milestones. Addressing first the question of "what are the low-hanging fruits to start the net-zero journey" will help build confidence. In addition, decarbonization can begin with energy and materials efficiency with interesting returns on investment (ROIs) before implementation of complex technology.[14]

Build a net-zero business case

Typical net-zero projects are funded by a combination of internal investment, government incentives and correct pricing for increased consumer and customer benefits. Several industries are using the classic business case approach, quantifying not only energy cost reduction but also other benefits associated with decarbonization (e.g. market share increase, talent retention, reduced risk).[15] According to the IPCC, several emission-reducing options in the industrial sector are cost-effective and profitable, such as energy and material efficiency.[16]

Some companies apply an internal carbon price by tonne of emitted CO_2-equivalent (for the company, by country or by industry line). This practice can help prioritize projects internally, considering existing or future carbon taxes in some countries.[17] Considering sustainability as a profit centre could also serve to capitalize savings. For instance, savings achieved through efficiency programmes can be used to help fund more complex projects.[18]

Action pillar 2 | Set the capability for carbon footprint monitoring

Measuring and monitoring carbon emissions can be a demanding challenge for business and industry, particularly when looking at indirect Scope 2 and 3 emissions from external sources. This is, however, the most important step on the journey to net zero, as it provides clarity on priority areas of intervention and helps to monitor progress towards specific goals. Although developing internal capabilities for carbon footprint monitoring is important, firms must partner with independent suppliers that can certify performance for compliance with current regulations.

Create an internal capability and a digital platform to report and monitor GHG emissions

Operationally, consulted industrial leaders have reported that in most cases new capabilities had to be set internally to support carbon-emission monitoring. This included setting up various small teams located at corporate, supply chain and/or procurement levels, dedicated to set the digital platforms and data standards to measure, track and trace emissions, identify the hot spots, frame the action plan and monitor results. In particular, some companies are developing capabilities to overcome the challenge of data integrity through precise guiding principles on emission factors.[19]

Comply with existing or upcoming carbon reporting requirements

Leading countries that have adopted legal commitments to achieve net-zero carbon emissions by 2050 have started requiring proof of carbon reduction commitments from businesses willing to engage in government procurement contracts. Carbon reduction plans need to be completed according to best industry practice by, for example, adhering to the Greenhouse Gas Protocol's Corporate Accounting and Reporting Standard[20] and should be conducted to a satisfactory level of assurance.

The mainstream standards ISO 14064-3 and International Standard on Assurance Engagements (ISAE) 3410 can verify GHG emission reports, and these could be audited in the near future in various countries. For example, firms willing to bid for central government contracts in the United Kingdom are required to submit carbon reduction plans according to key standards, make them public and get them approved by corresponding authorities. These plans must include the supplier's current carbon footprint and its commitment to reduce emissions to achieve net zero by 2050. They should record and report Scope 1 and 2 emissions on an annual basis and introduce additional reporting against a subset of Scope 3 emissions. This measure is consistent with the UK government's commitment under the Climate Change Act and will play a significant role in the decarbonization of the United Kingdom as a whole.[21]

STORY

Data-driven CO_2 emission reporting for Scopes 1, 2 and 3

Unilever – Fast-moving consumer goods

Unilever, the multinational fast-moving consumer goods manufacturer, pledged to halve the overall GHG impact of its products by 2030. Given the variety of its products and industrial plants, and the wide distribution of its products across countries, the company needed to rely on reliable, robust and standardized data and reporting methodology in order to track and trace CO_2 emissions and monitor improvements.

Since 2008, the company has developed an Environmental Performance Reporting (EPR) tool to report CO_2 emissions on two levels: products and manufacturing sites. A team continuously updates the tool and ensures the most accurate data is used. At the product level, GHG emissions are calculated for 12 categories of products (beverages, deodorants, dressings, etc.), nine stages of the life cycle (primary packaging, secondary packaging, ingredients, inbound transport, manufacturing, distribution, storage at retail, consumer use and disposal), and across 14 countries where products are distributed. The GHG impact is calculated for a sample of each product category accounting for 80% of the sales volume, consolidated at country level and then at group level. According to Unilever, for each representative product, "internal and external data sources are used to describe the various life cycle activities and inputs (e.g. specification of product, energy for site of manufacture, consumer use data). … [Scope 3 consumer use] is determined based on either consumer habit studies or on-pack recommendations … [and] often varies by country." CO_2 impacts of purchased components (ingredients and packaging) are obtained from external databases or internal expert studies.

At the factory level, energy use data (gas, oil, electricity, steam) is collected from meter reads or invoices and aggregated as CO_2 emission reports in the EPR system at site, regional and global levels, leveraging emission factors from existing standards (IPCC, GHG protocol, International Energy Agency [IEA]). In 2021, 250 manufacturing sites in 64 countries reported their environmental performance.

Source: Unilever, "Unilever Basis of Preparation 2021", 2021; Unilever, "Climate Transition Action Plan", 2021 (both accessed 21 November 2022).

2.2 **Stage II:** Change the game internally

Action pillar 3 Accelerate energy efficiency in operations and transport and decarbonize energy sources

Accelerate energy efficiency

Energy accounts for at least 5% of an average manufacturing company's costs (or higher for energy-intensive sectors) and, while manufacturing firms are continuously searching for cost improvements, energy-efficiency measures could save between 10% and 30% of those energy costs.[22,23] In terms of carbon savings, the IPCC suggests that industry could achieve reductions of 15-30% compared to a baseline scenario.[24] The IEA goes even further, suggesting that energy efficiency measures could represent more than half of all industry's carbon-emission reduction contributions by 2050, with over 80% of these savings occurring in low- and medium-income countries.[25]

Research conducted among manufacturing companies across three sectors found that "environmental performance between manufacturing plants differed up to 500% between worst and best performing factories which make similar products using similar technology".[26] Making energy and waste visible in the factory through analytical energy consumption mapping within the process, utilities, building and logistics – and leveraging benchmarks between processes, time frames, product mix and sites, with external suppliers – can help target effective improvements. Introducing the concepts of "value-added energy" on the shop-floor and leveraging known lean management practices can also help to support change management.[27]

Energy savings can be generated from various sources, including:

– The improved sizing, control, optimization or retrofitting of existing generic carbon-intensive equipment and processes (e.g. motors, drives, boilers, furnaces, compressors, ventilation and heating systems),[28] and for common energy-intensive equipment in plants (Figure 7)

– Energy management systems and standards (e.g. ISO 50001)

– Energy recovery systems (e.g. waste heat recovery in process industry)

– Smart use strategies (e.g. internet of things [IoT]-based smart metering to monitor and regulate energy consumption) and equipment optimization (e.g. simulation or artificial intelligence [AI] models to optimize energy use)

– A better selection of equipment in production lines to support further efficiency improvement (e.g. longer lifetime, repairability, green energy source, energy and materials efficiency, capacity to separate scrap, etc.)[29]

FIGURE 7 | Examples of energy efficiency levers for common energy-intensive equipment in industrial plants

People awareness and training: training, shopfloor awareness, communication, etc.

Equipment enhancement (maintenance & capital expenditure): first-level maintenance, reliability-centred maintenance, green asset management, etc.

Energy management system (e.g. ISO 50001): energy efficiency team, governance, organization, etc.

Smart metering and energy performance management: smart metering policy, automated regulation, energy efficiency metrics, real-time monitoring, sharing best practices

Process control: statistical process control, standby mode, peak management, root-cause analysis for process parameter deviation, etc.

"Green" sourcing: energy contract optimization, energy production-mix optimization vs demand, procurement of greener equipment, etc.

Transversal levers

Examples of equipment-specific levers (non-exhaustive)

Process | Building & warehousing | Industrial utilities

Dryers

- Optimize declogging, check insulation integrity and chambers' sealing

- Optimize the rate of start and stop, drying specifications, compression pressure

- Install a heat recovery system and reuse the energy for preheating, predrying or other
- Consider alternative drying processes: *contact drying, radiation (infrared, high-frequency, microwave), solar energy (sun drying/solar panels), etc.*

Ovens

- Monitor the smoke composition and temperature

- Optimize the door openings
- Optimize the fuel quantity and process yield

- Install a heat recovery system and reuse the energy for preheating the oven or in other usage
- Apply a high emissivity ceramic coating *(improved heat transfer and distribution)*

Pumps

- Maintain engines *(lubrication, ventilation, coating, etc.)*
- Check the network integrity and identify leaks

- Optimize flow control *(valves, bypass circuit, variable speed, etc.)*

- Optimize the network's energy performance *(use high-efficiency motors, turn off unnecessary pumps, etc.)*
- Limit pressure loss *(pipe sizing, network length, etc.)*
- Optimize motor performance *(e.g. class IE3 or IE4)*

Compressed air

- Perform preventive maintenance *(compressors, condensate drains, filters, etc.)*
- Detect and fix leaks

- Optimize use of compressors, use smaller compressors for reduced needs *(e.g. during nights or weekends)*
- Divide the network into areas to adapt the pressure accordingly

- Install an electronic speed variator
- Limit pressure loss *(optimizing diameters of the pipes, length of the network, etc.)*
- Ensure the freshest air suction possible
- Install more efficient dryers or compressors
- Install heat recovery to reuse energy for heating rooms or hot water

Steam production

- Check steam traps frequently
- Ensure appropriate management of purges
- Identify and fix leaks on the steam network

- Reduce the network pressure when possible

- Insulate the feedwater tanks
- Install a heat recovery system of the heat lost during purges
- Set a micro-modulating burner to improve boiler efficiency
- Install a steam accumulator for variable demand
- Set an economizer to preheat water
- Install osmosis for higher boiler reliability and enhanced yield

Heating, ventilation, air conditioning & lighting

- Set up a temperature and pressure control according to needs
- Detect and fix leaks

- Optimize the temperature and ventilation levels according to spaces *(production, offices, etc.)*
- Limit new air intake and hot air extraction
- Optimize infrastructure thermal insulation and door openings
- Set proper air renewal rate frequency

- Install air destratifiers for high heights
- Install an energy recovery system on the output air to preheat the incoming air
- Install a variable speed on the ventilation to monitor its pressure, flow rate and air temperature
- Deploy a LED lighting plan

Refrigeration

- Use free-cooling when possible
- Control and repair leaks on the circuits
- Manage door types and openings to minimize air entry, ensure air distribution
- Control and fix the cooling circuit's insulation
- Set up a low-pressure/high-pressure float control
- Adjust the defrosting strategy

- Optimize the temperature and pressure according to process needs
- Install a variable speed on compressors, pumps, refrigerant flow control, etc.
- Optimize the evaporator and condenser sizing

- Use a heat-recovery system on the cooling unit
- Prefer evaporative or hybrid condensers rather than dry condensers for heavy installations

Lever type

- Control and first-level maintenance
- Optimize
- Modify

Source: Capgemini, adapted from resources from the French Agency for Ecological Transition (ADEME).

STORY

An inclusive approach to energy efficiency

Guidewheel/Nation Media Group

Success in decarbonization requires building solutions that work well for smaller manufacturers and manufacturers in all global contexts. As a public benefit corporation, Guidewheel provides a plug-and-play, affordable energy and factory operations platform, originally built across Stanford University (USA) and Nairobi, Kenya, and now growing globally quickly. The platform is structured to work within the constraints of industrial sites in more challenging global locations and supports small and medium-sized enterprises along with larger manufacturers.

By including its entire cost, including hardware, in a subscription that can pay for itself within operating expenditure (OpEx) budgets, the technology has been made accessible to smaller factories that can quickly achieve OpEx savings through active use of the platform. The platform uses sensors that work for older machines or machines without existing information technology (IT) and operational technology. The clip-on sensors measure the electrical draw of the equipment to track and monitor energy use in real time. The platform can also leverage the Long-Term Evolution standard if broader internet connectivity is unavailable.

Guidewheel collaborated with the printing plant of Nation Media Group, the biggest independent media house in East and Central Africa, located in Kenya. Alongside other sustainability efforts for solar energy and waste management, the company wanted to gain real-time visibility on energy across the plant, machines and utilities to realize further energy-saving potential. By focusing on reducing both its peak demand and energy waste from idling machines, the Group is achieving more than $30,000 in annual energy savings, equivalent to 42 tonnes of CO_2 per year.

Source: Consultation with Guidewheel.

Decarbonize heat and power sources

The decarbonization of heat and power is imperative to achieve carbon emission reduction targets. Decarbonizing process heat alone can mitigate about one-fifth of global CO_2 emissions.[30] Most of the industrial heat (and its associated CO_2 emissions) is generated through the combustion of coal, natural gas and oil for direct or indirect use via steam to drive processes such as fluid heating, distillation, drying and chemical reactions.[31] Using zero carbon heat, electrifying heat production, switching to low-carbon fuel or optimizing heat management could lead to significant reductions in this area (Figure 8), although key technoeconomic barriers will need to be addressed to approach parity with traditional fossil fuel-powered alternatives.

With respect to renewable electricity, the share of renewables in global electricity generation stood at 28.7% in 2021, still far from the 60.9% target.[32] A much faster deployment of all renewable electricity technologies is needed across all economic sectors, including manufacturing, and all regions of the world to address industry's needs. A 12% annual expansion would be needed between 2022 and 2030 to achieve the net-zero scenario goal set by the IEA; manufacturing has a key role to play in both the use of renewable electricity and the scale-up of global renewable generation capacity.[33] To this extent, some industries are developing their own renewable electricity means (e.g. solar parks, wind farms) in partnership with public authorities to cover their existing and future needs.

Decarbonize logistics and transport

In logistics and transport, beyond the efficiency obtained by optimizing routes and maximizing the filling of trucks, using low-carbon substitutes for fuel (ethanol, natural gas, biofuels, hydrogen and electricity) help decarbonization. The Center for Climate and Energy Solutions notes: "Challenges to full electrification include upfront costs of batteries and lack of charging infrastructure. Several countries, including the United Kingdom, China, and France, have announced bans on sales of cars and trucks that use petroleum, beginning in 2040. At the same time, major automakers like GM, Toyota, and Volvo have announced plans to electrify their entire offerings by the mid-2020s."[34] Collaboration with ecosystems of partners helps to identify transport-sharing opportunities. When possible, the switch to rail and navigation could support further reduction in carbon emissions.[35]

FIGURE 8 **Overview of levers and technologies for heat decarbonization and the main challenges for industrial implementation**

Zero-carbon Heat

	Solar thermal	Geothermal	Nuclear
Key challenges	Limited top temperature, intermittency, low areal density	Up-front risk, high-resolution resource understanding, deep resource access	Limited top temperature, safety, scale

Electrification of Heat

	Industrial Heat Pumps	Resistive Heating
Key challenges	Limited top temperature, high up-front costs, scale	N/A

Switch to Low-carbon Fuels

	Hydrogen	Ammonia	Biofuels	CO_2-derived Hydrocarbons
Key challenges	Combustion stability, production cost, storage and handling	Combustion properties, production cost, control of nitrogen oxide	Life-cycle emissions, production costs, handling of materials	Direct air carbon capture and production costs, synthesis technology and scalability

Better Heat Management

	Better Insulation	Heat Upgrading	Process Integration for Heat Recovery & Reuse	Radiative Cooling
Key challenges	Thermomechanical stability of materials, high temperature stability	High process capital cost, low yield, exergetically limited	High capital cost, limited to local integration, low economic value relative to material integration	Capital cost, system efficiency, aerial efficiency

Note: N/A = not applicable
Source: Adapted from Thiel, Gregory, and Addison Stark, "To decarbonize industry, we must decarbonize heat", *Joule*, 2021 (accessed 21 November 2022).

STORY

Tackling the waste heat recovery challenge

ArcelorMittal/Capgemini – Materials and metals

On its pathway to net zero, ArcelorMittal, an international leader in steel manufacturing, wanted to drastically reduce the waste heat across its manufacturing processes. In France, the French Agency for Ecological Transition (ADEME) estimates that 51 terawatt-hours (TWh) of heat (above 100°C) is wasted in industry, equivalent to 10% of France's consumption of electricity. Implementing waste heat recovery in industrial installations, however, presents real difficulties, which include the complexity, cost and reliability of recovery solutions.

ArcelorMittal forged a partnership with Capgemini and the French government to launch a heat recovery analysis project. The project developed a holistic approach (process, simulation models, AI algorithms and digital applications) to analyse a site industrial context, its operational data, and technical and economic data from solutions suppliers to deliver a report on the technical-economic and ROI performance of heat recovery solutions. The solution allows operations leaders to quickly identify the suitable technical solution for each site, evaluate the ROI, assess the reduction in CO_2 emissions and evaluate the recoverable energy that can be reclaimed.

The energy savings for ArcelorMittal have been estimated to be 10% per plant, corresponding to 0.67 TWh per year across all French plants. The model developed can be scaled to other process industries that are subject to waste heat.

Source: ADEME, "ANAGREEN: ANAlyse Globale de Récuperation d'ENergie", 2021; Capgemini, "ArcelorMittal Uses Data and Analytics to Pursue Energy Efficiency", 2021 (both accessed 21 November 2022).

Action pillar 4 | Pursue material efficiency in operations

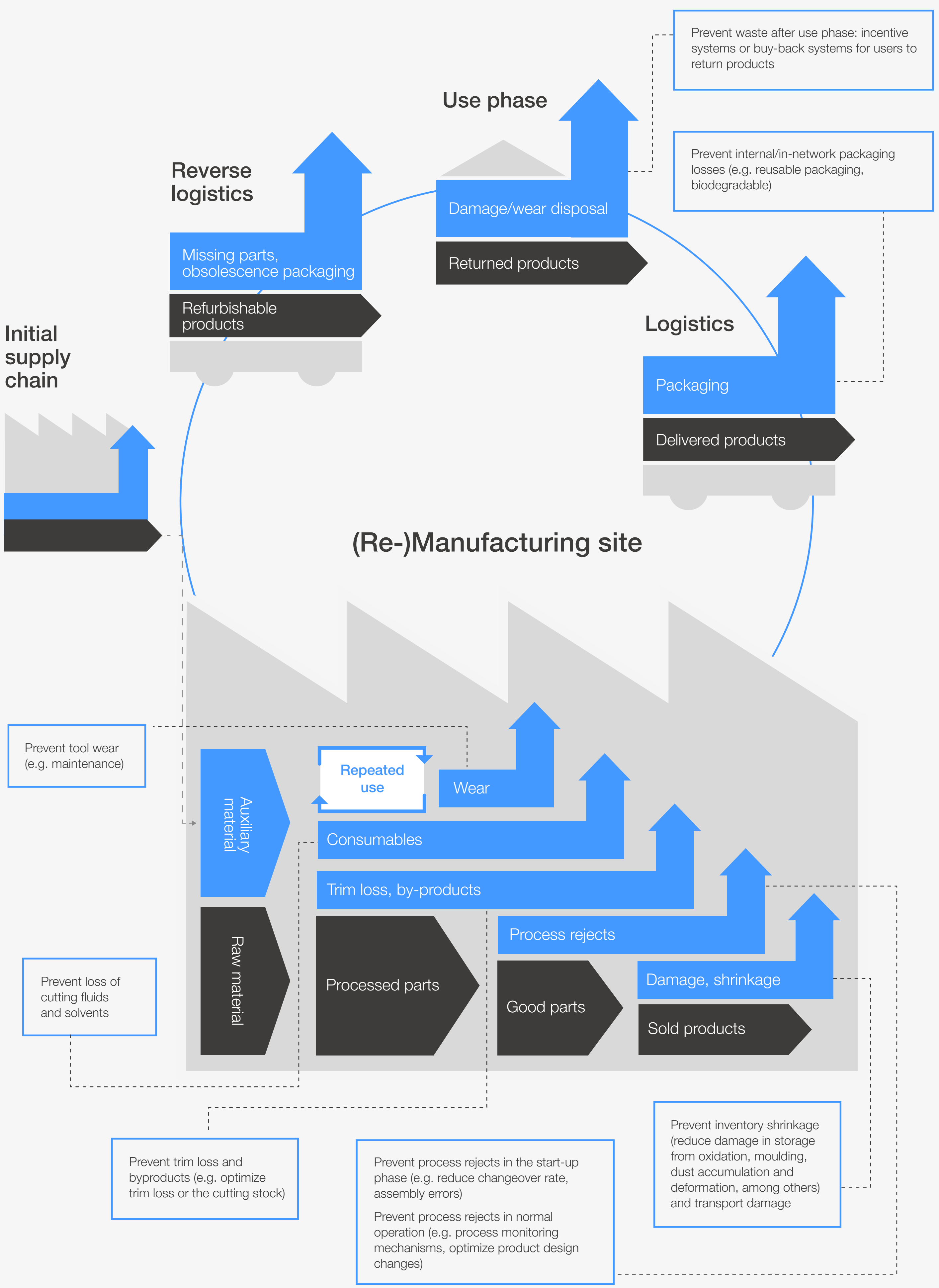
Material efficiency and circularity, namely the practice of encouraging reuse, recycling or sustainability in consumption and manufacturing, represent a significant opportunity to abate industrial emissions given the high energy intensity of materials production. Estimates of carbon emissions per tonne of material produced for the five most emitting materials (steel, cement, plastic, paper and aluminium) suggest that they could further reduce their emission intensity by 25-50% depending on various factors, such as future technical innovations in primary and secondary production and recycling rates.[36] Each of these strategies deserves careful exploration by businesses, especially as they could affect each other. For example, reducing yield losses might translate into lower availability of materials for recycling.

Reduce yield losses in operations

Studies on yield losses along the metals supply chain show high accumulated deficits. For example, for sheet metal-based products, nearly half of all liquid metal becomes scrap on its journey to a final product.[37] Comparable losses exist across other industrial processes and could be further explored; one study found that 90% of the resources processed to produce goods do not reach the person they are made for.[38]

Manufacturers must search for occasions to reduce yield loss within operations and along the production chain (Figure 9). Key opportunities include working with suppliers on material shapes and geometries that minimize waste, or promoting research and development (R&D) of new manufacturing processes that cut yield losses. For example: "Blanking and deep drawing cause the biggest waste of sheet metal for both steel and aluminium and can be replaced already by laser cutting and spinning".[39]

FIGURE 9 **Overview of material losses along the product life cycle and examples of waste prevention levers**



Source: World Economic Forum Industry Net Zero Accelerator initiative; Sheehan, Erin, et al., "Improving Material Efficiency for Ultra-efficient Factories in Closed-loop Value Networks", *Procedia CIRP*, vol. 40, December 2016, pp. 455-462 (accessed 21 November 2022).

Enable recycling and reuse in operations and across the supply chain

Strategies to pursue material circularity in operations include increased recycling and reusing materials and components in good condition. Recycling metals, paper and some plastics can save energy compared with producing new materials, but opportunities remain limited by technical challenges and the amount of material from end-of-life products available to recycle.[40] Developing waste sorting and recycling systems within factories is therefore an important lever. For example, a systematic segregation of metal waste at the equipment level can support later debris collection by suppliers, who can reuse the waste in their processing.[41]

Component reuse is currently a rare practice due to "incompatibility between past and present designs, and the relatively high cost of product disassembly and used-component management".[42] Potentially, products could also be used for a longer period of time if these components could be replaced easily and affordably.

STORY

Compact supply chains to reduce Scope 3 emissions

Foxconn – Electronics

The electronics manufacturer Foxconn realized that Scope 3 represented 86% of its emissions and that 20% of them came from aluminium and stainless-steel alloy consumption.

Understanding that significant improvements could be made from better waste management in its supply chain, Foxconn organized a reverse logistics process with suppliers to collect manufacturing aluminium debris from the company's sites and reuse it in its suppliers' melting process. This approach reduced the amount of raw aluminium used and required establishing a strong traceability system for the debris to verify its reuse and recycling in new products. This was achieved through a digital platform shared with suppliers, which allowed to track recycling rates together with products' carbon footprint.

The collaboration brought the parties multiple benefits. For Foxconn, material costs were reduced, as were the products' carbon footprint, allowing an increase in its market share in the electric vehicle and the computer/communication/consumer electronics (3C) industries. For its suppliers, the project guaranteed 100% traceable recycling and achieved 70% carbon emission reductions compared with outsourcing manufacturing. Foxconn's broader supplier engagement model related to digital empowerment improved energy efficiency, and joint-process R&D allowed it to achieve additional efficiency benefits.

Source: Consultation with Foxconn.

Action pillar 5 | Rethink product design and business models

Explore new product design strategies

The material efficiency strategies mentioned above can be supported by formalizing design and business approaches across departments and functions that could help businesses move from linear to circular economy models. A useful framework helps to categorize the various types of strategies (Figure 10).

At the product level, quantifying carbon emissions embedded within a product is possible through a life-cycle assessment. This methodology assesses the total environmental impact of a product, process or service through all stages of its life cycle, often taken to be from the extraction of raw material to the final disposal of the product (cradle to grave). Identifying emission hotspots through the product life can help to shape design decisions for carbon reduction.

Explore new business models

More examples of manufacturing firms exploring the commercial opportunity of leasing rather than selling goods have emerged in recent years. This could lead to reduced carbon emissions if the total number of products is reduced. Risks arise, however, if consumers engage in behaviour that involves multiple ownership contracts. Car-sharing services and document management systems for office use are representative examples of this trend. This and other circular business models are included in a useful framework (Figure 11).

FIGURE 10 | **Circular and low-carbon product design strategies**

Extend product life

Design long-life products
Ensuring a long utilization period of products by design

Design for customer attachment and trust
Creating products that will be loved, liked or trusted longer

Design for reliability and durability
Ensuring physical durability, for example the development of products that can take wear and tear without breaking down and experiencing failure

Design for product-life extension
Introducing service loops to extend product life, including reuse of the product itself, maintenance, repair and technical upgrading, and a combination of these

Design for ease of maintenance and repair
Enabling products to be maintained and/or repaired to retain functional capabilities

Design for upgradability and adaptability
Ensuring ability of a product to continue being useful under changing conditions by improving the quality, value and effectiveness or performance

Design for standardization and compatibility
Creating products with parts or interfaces that also fit other products

Design for dis- and reassembly
Ensuring that products and parts can be separated and reassembled easily

Circular material life

Design for a technological cycle
Developing products in such a way that the materials can be continuously and safely recycled into new materials or products; suitable for products that deliver a service

Design for a biological cycle
Designing with safe and healthy materials (biological nutrients) that create food for natural systems across their life cycle (biodegradability); suitable for products that are consumed or wear during use

Source: Modified from Bocken, Nancy, et al., "Product design and business model strategies for a circular economy", *Journal of Industrial and Production Engineering*, vol. 33, no. 5, 2016, pp. 308-320 (accessed 21 November 2022).

FIGURE 11 | Circular and low-carbon business model strategies

Business models to close resource loops

Extending resource value

Exploiting the residual value of resources: collecting and sourcing otherwise "wasted" materials or resources to turn them into new forms of value

Examples*: Interface – collecting and supplying fishing nets as a raw material for carpets; RecycleBank – providing customers with reward points for recycling and other environmentally benign activities*

Industrial symbiosis

Employing a process-oriented solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses

Examples*: Kalundborg Eco-Industrial Park; AB sugar and other sugar refiners – internal "waste = value" practices*

Design strategies to maximize product life

Access and performance model

Providing the capability or services to satisfy user needs without needing to own physical products

Examples*: car sharing; launderettes; document management systems (e.g. Xerox, Kyocera); leasing jeans and phones*

Extending product value

Exploiting the residual value of products – from manufacture to consumers, and then back to manufacturing – or collection of products between distinct business entities

Examples*: automotive industry – remanufacturing parts; Gazelle offering consumers cash for electronics and selling refurbished electronics; clothing return initiatives (e.g. H&M, Marks & Spencer Shwopping)*

Encourage sufficiency

Using solutions that actively seek to reduce end-user consumption through principles such as durability, upgradability, service, warrantees and reparability, and a non-consumerist approach to marketing and sales (e.g. no sales commissions)

Examples*: premium, high-service and quality brands, such as Vitsœ and Patagonia; energy service companies*

Classic long-life model

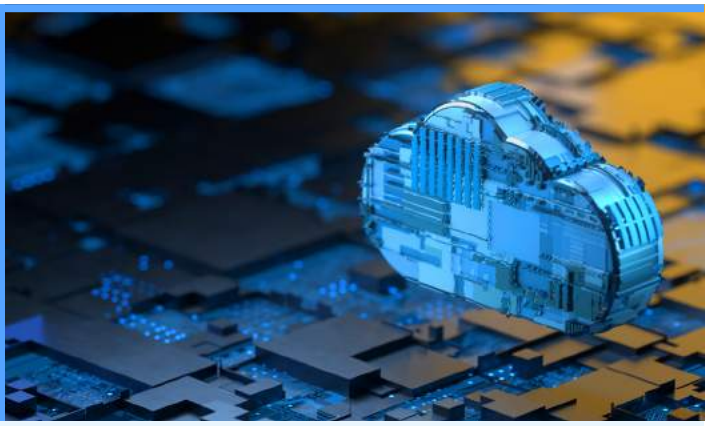
Adopting business models focused on delivering long product life – supported, for example, by design for durability and repair

Examples*: white goods (e.g. Miele's 20-year functional life span of appliances); luxury products claiming to last beyond a lifetime (e.g. luxury watches, such as Rolex or Patek Philippe)*

Source: Modified from Bocken, Nancy, et al., "Product design and business model strategies for a circular economy", *Journal of Industrial and Production Engineering*, vol. 33, no. 5, 2016, pp. 308-320 (accessed 21 November 2022).

STORY

Circular economy services driven by Fourth Industrial Revolution technologies



Flex – Manufacturing company

Flex's plant in Sorocaba, Brazil developed a holistic ecosystem that uses Fourth Industrial Revolution technologies to transform e-waste and reintroduce repurposed materials into the supply chain. Flex implemented solutions to enable circular economy services and eco-efficient operations throughout Brazil. They included:

– A cloud-based collaborative reverse logistics system, which enabled multiplayer collaboration and reduced service time and costs

– A circular materials lab, which provided material input identification to ensure the right quality of output materials

– Automatic separation equipment for minimum contamination of material

– IoT-based collection bins to display the correct time to collect containers filled with e-waste

– A digital e-commerce platform, which helped to commercialize excess inventory and bring repaired and refurbished products to market

– A digital market platform for waste-enabling industrial symbiosis to increase material volumes and reduce material costs

The company also implemented operational CO_2-emission dashboards to provide visibility of environmental savings for its customers.

Flex's Sorocaba factory was zero waste certified in 2018, with a 100% diversion rate. The process for remanufactured plastic parts enabled savings of up to 82% on energy usage and a 74% reduction in GHG emissions. These technologies also achieved more than 44,000 tonnes of CO_2-equivalent credits. Over 90% of recovered material goes back into the supply chain (1,300 tons of recycled material used in new products, 11,000 tons of recycled industrial waste and 16,000 tons of post-consumer recycled e-waste), with a raw material (plastic) cost reduction of more than $3.2 million. Additionally, more than 180 direct and 300 indirect green jobs were generated.

Source: Consultation with Flex.

STORY

A new "plant of the future" for circular economy business models

Renault – Automotive original equipment manufacturer (OEM)

In the context of profound changes in the automotive industry and an evolution towards the decarbonization of cars and mobility-as-a-service, the French automotive OEM Renault set a strategy to become a "circular mobility" provider and developed new preservation mechanisms to reduce exposure to scarcity for fleet electrification. Renault reimagined an entire plant in Flins, France, and created the Refactory – an 11,000 m^2 plant dedicated to its vehicle revalorization business models.

The Refactory is Europe's first circular economy factory dedicated to mobility. The plant has a four-pole structure:

- Retrofit: extend vehicle life by repairing, remanufacturing and retrofitting
- Re-energy: extend and optimize battery life and develop hydrogen-based mobility solutions
- Recycle: valorize spare parts through remanufacturing of vehicle parts, material recycling and battery repairing
- Restart: invest in systemic collaboration for innovation by establishing centres for process innovation, 3D printing and retrofitting, and creating an ecosystem with start-ups, academics and industrial partners

By the end of 2021, the plant already had 700 employees, reconditioned over 1,500 vehicles and repaired 2,000 batteries. The plant will dismantle an average of 10,000 vehicles annually, recondition 45,000 vehicles per year by 2023 and repair 20,000 electrical batteries per year by 2030.

Source: Renault Group, "Refactory: The Flins Site Enters the Circle of the Circular Economy", 25 November 2020; Renault Group, "Refactory Flins", 2022 (both accessed 21 November 2022).

Action pillar 6 | Develop carbon capture solutions and offset mechanisms

Assess carbon capture, utilization and storage opportunities

Carbon capture and sequestration (CCS) is a set of technologies that can help remove carbon emissions from difficult-to-eliminate sources. For emission-intensive manufacturing subsectors such as cement, chemicals, steel and aluminium, CCS represents a potentially significant solution to abate the impacts of existing processes while other low-carbon alternatives mature. Although this approach relies on common (non-critical) raw materials, sustained investment and support is needed to build the enabling infrastructure and to scale-up related supply chains at a global level.[43]

Most decarbonization pathways created by international organizations, such as the IPCC and IEA, include CO_2 removal as a necessary mitigation approach to avoid a global temperature increase beyond 1.5 °C. Commercial-scale carbon capture facilities are being built around the world, led by the United States and driven in part by a combination of tax credit incentives for carbon sequestration and federal R&D investments. The United States had 13 commercial-scale carbon capture facilities, half of worldwide capacity, in early 2021.[44] More efforts are needed, however, to expand carbon capture capacity around the world, and the manufacturing industry has a key role to play in this endeavour.

Implement offset mechanisms

Besides carbon capture, offsets and trading mechanisms are also being used around the world for regulatory reasons (e.g. complying to the European Union Emissions Trading System) or as voluntary corporate action.

- On the regulatory level, schemes such as the European Union Emissions Trading System (EU ETS) place limits on the right to emit specified pollutants (including GHGs) over an area, and companies can trade emission rights with that area. Covering about 36% of the EU's total GHG emissions, the EU ETS sets a limit on emissions from emission-intensive activities within the European Economic Area, such as electricity and heat production, cement manufacture, iron and steel production, oil refining and other industrial activities.[45] Although the success of such schemes is constantly debated, the annual European Environment Agency (EEA) briefing "Trends and projections in the EU ETS", published in January 2022, projected that ETS emissions will continue to decrease in the coming decades, albeit at a slower pace than historically.[46]

- On the voluntary level, several trading mechanisms exist around the world. For example, the United Nations Carbon Offset Platform for e-commerce allows a company, organization or regular citizen to purchase units (carbon credits) to compensate GHG emissions or to simply support action on climate.

Applied to manufacturing, this means a firm can buy carbon offsets to finance someone else to purchase and install equipment, to supply facilities with clean energy or to carry out other process changes not available to the buyer. Proceeds from carbon offset sales can fund diverse types of abatement activities, such as:[47]

- Installing carbon capture technologies in industrial facilities and landfills

- Building renewable energy installations at scale (e.g. wind, solar and geothermal plants)

- Installing battery storage capacity to use renewable energy during the night-time or peak demand times

STORY

Turning CO_2 emissions into value

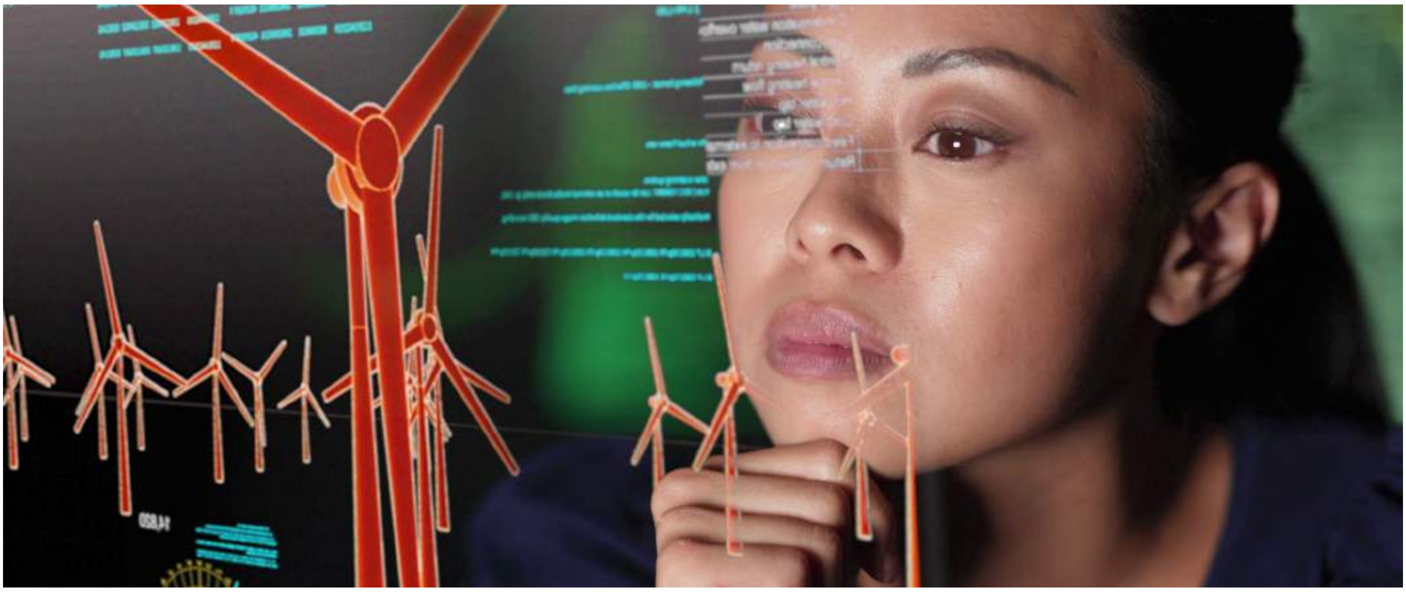
SABIC – Chemicals

SABIC, a global leader in diversified chemicals, set targets to reduce its GHG intensity by 25% and material loss intensity by 50% by 2025 from its 2010 baseline. In its industrial plants, CO_2 forms as an inevitable by-product of the ethylene glycol process. Rather than viewing carbon emissions as purely a challenge, the company identified an opportunity to create greater value by valorizing emissions into commercial products.

The company built a mega carbon capture and utilization plant that opened in 2015 at United, a SABIC affiliate. The plant uses SABIC'S proprietary technology to capture up to 500,000 metric tonnes of CO_2 per year from the production of ethylene glycol that would otherwise be emitted into the atmosphere. Taking advantage of the close proximity to its other Saudi Arabian manufacturing facilities, the plant purifies the collected CO_2 and sends it to other SABIC manufacturing affiliates to convert it into feedstock for valuable industrial applications: urea, a key agrinutrient that enables more plentiful harvests; methanol, a building block use daily for many other materials; and liquefied CO_2, used widely in the food and beverage industry.

This project exemplifies the Saudi government's drive to turn carbon emissions into sources of value by using the nation's vast hydrocarbon resources wisely and developing a "circular carbon economy".

Source: Consultation with SABIC.



2.3 **Stage III:** Drive systemic collaboration

Action pillar 7 Drive value-chain decarbonization (upstream and downstream)

Support suppliers' decarbonization journey

According to the Carbon Disclosure Project's (CDP) *Global Supply Chain Report 2021*, carbon emissions in a company's supply chain are, on average, 11 times higher than its operational emissions.[48] While 75% of companies reported their Scope 1 and 2 emissions and took actions to reduce them, only 20% of firms reported data for Scope 3, and only a minority asked their suppliers to report data, set targets and perform emissions abating actions.[49]

As these numbers indicate, Scope 3 supply chain decarbonization needs to be driven fast and at scale through improved procurement processes and training. This is obviously not a straightforward task, as supply chains could include hundreds or even thousands of firms. Some steps that could kick-start this transformation, as suggested by the CDP, include:[50]

– Leverage buying power to drive transparency by requesting environmental disclosure from suppliers, considering their maturity (e.g. SBTi-validated targets for most mature suppliers)

– Set clear expectations and strategically engage with vendors to drive action beyond pure data collection by asking suppliers to set carbon reduction targets and embedding key performance indicators into the supplier management process

– Cascade science-based targets through the supply chain by directly training suppliers through webinars and other activities

– Join forces with other purchasers to push suppliers to set their own targets, accelerate action and build momentum

The consultations with industrial leaders highlighted some best practices, such as applying internal "green" scores for materials, certification schemes for suppliers conducting important decarbonization efforts, and extensive collaboration on product design to reduce material quantity, use more sustainable materials, reuse and recycle carbon-intensive materials or reduce use of packaging.[51]

Influence consumer behaviour

On the consumer side, the relationship between consumer behaviour and climate change is complex and most consumers are not capable of determining which behavioural changes are worth making.[52] A recent literature review of the growing body of evidence on this subject suggests that consumers need considerable assistance if they are to change to a climate friendly way of life. The same review suggests "the biggest focus of governments and companies should be on making the climate friendly behavior the easy behavior by securing a correct reflection of carbon footprint in prices, climate friendly products that compare favorably to climate unfriendly alternatives, and trustworthy and comprehensible carbon labeling to make it easier to make climate friendly choices".[53] This also emphasizes the need to build trustworthy product carbon footprints across value chains to better shape consumer decisions.

STORY

Tackling the challenge of value-chain product carbon footprint

Estainium Association

As much as 90% of “cradle-to-gate” emissions originate in the supply chain, but upstream transparency is limited. Calculating product carbon footprints (PCF) with existing tools requires great effort, starting with gathering trustworthy and accurate data across supply chain partners.

Estainium is an open and non-profit association that precisely aims to resolve that challenge. Its mission is to drive industrial decarbonization holistically in a precompetitive, cross-industrial and cross-functional ecosystem that includes academia, small and medium-sized enterprises and large corporations alike. It builds on the technology of decentralized trust to avoid high cost, maintain data sovereignty and enable quick expansion with trustworthy information that can be shared along the supply chain with verifiable credentials.

The association selects a base infrastructure and operating model and develops necessary extensions for using the infrastructure for PCF and broader environmental, social and governance data sharing. It also aims to achieve interoperability between different PCF standards and reporting schemes and to develop a digital approach to connect carbon sink providers with manufacturers. Certifiers are included in the ecosystem as trust anchors to make PCF verifiable.

The association’s work is initially performed in three working groups that address the most pressing challenges: 1) Technology and Infrastructure; 2) Standards and Norms Compatibility; and 3) Carbon Capture, Use, Storage and Compensation. That unique constellation enables Estainium to develop practical solutions to overcome current and future challenges, for all stakeholders.

Source: Consultation with Estainium Association.

Action pillar 8 | Mobilize ecosystems for net-zero infrastructure and innovation

Identify opportunities to support net-zero infrastructure development

In a broad view, key assets comprising future net-zero infrastructure include the power system, industry, buildings, transport and digital/telecommunications. From an industrial perspective, achieving net-zero targets will require substantial changes to existing infrastructure for energy supply, hydrogen, heat networks and carbon capture. For example, estimates for the United Kingdom alone suggest investments of £40 billion per year are required in new low-carbon and digital infrastructure over the next 10 years, which is double the current capital requirements for UK infrastructure investments across energy, water and telecoms.[54]

As suggested by the Leadership Group for Industry Transition, an initiative launched by the Governments of Sweden and India at the UN Climate Action Summit in September 2019 and supported by the World Economic Forum, “the decarbonization of heavy industry calls for public-private cooperation to enable the following changes:

– The replacement of blast furnaces with a new system around hydrogen direct reduction for steel, shifting from fossil feedstock to ‘electric feedstock’ for chemicals, or rebuilding cement kilns for capturing CO_2 from flue gases,

– The use of biomass as an energy source for many applications in industry, with varying needs for further processing and substituting fossil feedstock for the chemical industry, and

– The building of infrastructure for supporting the supply of new energy carriers at scale, such as electricity, hydrogen or biogenic CO_2 and the abandonment or repurposing of old infrastructure (e.g. harbours for coal, pipelines, oil storage sites)”.[55]

A large share of net-zero infrastructure investments is likely to require patient capital as well as public-private partnerships to address development and deployment barriers for key technologies.[56] Facilitating the deployment of large-scale solutions, such as renewable energy sources, hydrogen, heat networks and CCS, will also require the development of entirely new assets. Some of these technologies, however, remain in a stage too early for infrastructure investment capital, with high technology risk, business model uncertainty, lack of clarity about revenue models and high upfront development capital.[57]

The development of net-zero infrastructure for industry offers direct opportunities for manufacturing firms, including:

– Participate in developing and manufacturing infrastructural technologies and components

– Adopt key technologies and solutions to decarbonize energy supply and/or capture carbon as a result of the enabling infrastructure being in place

– Adapt key technologies and solutions to particular firms' needs and context

Mobilize industrial ecosystems to drive net-zero innovation

As suggested by the IPCC, systemic approaches and collaboration within and across industrial sectors at different levels, such as sharing of infrastructure, information, waste and waste management facilities, heating and cooling, may provide further mitigation in certain regions or industry types. The formation of industrial clusters, industrial parks and industrial symbiosis represent emerging trends in this area.[58]

As mentioned by consulted stakeholders, several companies are already involved in collaborations on sector-level innovation and/or external partnerships – with suppliers, other industries, academia and energy providers – to co-develop the low-carbon processes needed for their net-zero targets, thus mitigating risks and sharing the costs and further benefits.

STORY

Systemic collaboration for disruptive innovation

Eramet – Materials and metals

As an international miner and manufacturer of manganese, titanium, ferronickel and lithium, Eramet is at the forefront of industry decarbonization by providing the raw materials necessary for the energy transition.

By developing low-carbon activities and implementing measures to decrease its emissions, the group reduced its Scope 1 and 2 carbon intensity by 39% compared to 2018 and has now decided to speed up the process by setting a new 15-year target to reduce total Scope 1 and 2 emissions by 40% by 2035 (compared with 2019 levels) and achieve carbon neutrality by 2050. Beyond energy efficiency and the use of decarbonized energy sources, the company has set a priority to use bioreductants in manganese alloy production to replace fossil carbon – with the challenge to access sustainably managed bioreducers compatible with its process constraints – and the development of CCS where cost remains an obstacle. To overcome the technological and cost barriers of both solutions, the company established a set of intelligent collaborations on disruptive innovation with other industrial sectors that bring mutual benefits:

– For CCS, a partnership with Air Liquide is under way for a multi-year contract to build a pilot CO_2 capture installation from the combusted gas of two manganese alloy-producing furnaces. Air Liquide brings the technology to firstly concentrate the CO_2 up to 60% after adaptation to the process in the pilot, and later reach over 99% in the industrial process by adding a cryogenic step. In the industrial installation, the liquefied CO_2 will be sent to storage in a profound geological layer.

– For bioreductants, the company needed to establish the knowledge to allow production of biocarbons with characteristics suited to production of manganese alloys in its current industrial furnaces. Eramet carried out R&D in cooperation with research institutes and academia in Norway and launched a demonstration project in 2021 to test the substitution of fossil fuels by a significant amount of biocarbon in industrial operations. Cooperation with other industrial partners has led to equipment and process pilots, paving the way for demonstration plants (provided funding will be obtained).

Source: Consultation with Eramet.

Action pillar 9 | Address net-zero data and digital standards

Ensure data availability, data integrity and the use of standards in carbon footprint accounting

A lack of shared reporting standards for carbon emissions across industry leads to low comparability and robustness in carbon accounting approaches, which could derail existing and future net-zero efforts. In addition to consistent standards and methodologies, technical solutions are needed that can enable seamless and secure data exchange between organizations and regulators. Ensuring data availability, integrity and confidentiality are paramount. Availability in a manufacturing sense means ensuring that key systems and assets to monitor an organizations' carbon footprint are operating effectively and reliably. Integrity stands for guarding against improper information modification or destruction, and includes ensuring information authenticity, whereas confidentiality is to prevent the unauthorized release of information.[59] Several key principles are required for carbon footprint monitoring to be successful (Figure 12).

Standards such as the Organisation Environmental Footprint (OEF) and the Product Environmental Footprint (PEF) are ongoing attempts by the European Commission to harmonize the calculation of the environmental footprint of products and organizations (including carbon). Once widely adopted, they could provide a good basis for cross-industry carbon footprint accounting.[60]

FIGURE 12 **Key principles for successful carbon footprint monitoring**

Relevance

Ensure monitored GHG emissions appropriately reflect the emissions of the organization and serve the decision-making

Accuracy

Ensure reported GHG emissions data reflects actual emissions; seek to reduce uncertainties in reports

Completeness

Measure and report on all GHG emission sources and activities from the businesses/operations

Transparency

Address issues in a factual and coherent manner, keeping a record of assumptions, calculations and methodologies used

Consistency

Use consistent methodologies to compare emissions over time

Source: Adapted from UK Government, Department for Environment, Food and Rural Affairs (DEFRA), *Guidance on how to measure and report your greenhouse gas emissions*, 2009 (accessed 21 November 2022).

Upgrade digital systems for net-zero transformation

Working towards a lower-carbon future will demand action on operational efficiency, improved production tactics and minimized waste – all of which can be accomplished with more intensive digitalization, analytics and AI technologies.

- Existing information technology (IT)/operational technology (OT) systems can already support the transformation. Enterprise resource planning (ERP) and manufacturing execution systems (MES) provide the yield information to visualize and eliminate waste.
- Equipment control systems and IoT sensors measure energy consumption. Several industries leverage energy management platforms coupled with smart metering to allow more comprehensive energy data monitoring and control in energy-intensive areas.
- Digital twins help accelerate the redesign of products and processes.
- AI and simulation applications support process energy, the optimization of materials consumption or logistics forecasting.
- Some industries are already testing digital simulation tools to make cost-benefit-CO_2 emission trade-offs in supply chain strategic decisions (e.g. relocation of sites, network design).

STORY

AI to enhance energy efficiency

Western Digital Corporation – Digital products manufacturer

Western Digital's Shanghai manufacturing site engages in R&D, packaging and testing of advanced flash memory products. In the context of growing demand, the company doubled the site's petabyte (PB) output between 2017 and 2021 while reducing its environmental footprint per PB to achieve corporate objectives. This result was enabled by multiple Fourth Industrial Revolution use cases, such as machine learning to dynamically optimize the performance of the water recycling plant and consumption prediction to detect abnormal energy consumption based on real-time operating data. These measures reduced water consumption by 62% and energy consumption by 51% per PB.

Source: Consultation with Western Digital Corporation.

STORY

Real-time digital twin for sustainability

Schneider Electric – Electronics and automation

Schneider Electric's Le Vaudreuil site has implemented industrial internet of things sensors connected to digital platforms, including real-time digital twins of plant installations, such as heating pumps and the lighting system. They unlock data to optimize energy management (-25%), reduce material waste (-17%) and minimize CO_2 emissions (-25%) with the objective to be net-zero carbon by 2025, without offset and ahead of Schneider Electric's global pledge. The smart factory is also equipped with a zero-reject water recycling station connected to cloud analytics and monitored by an AI model to forecast process drifts, leading to 64% water reduction.

Source: Consultation with Schneider Electric.

Consider the carbon footprint of digital IT and OT systems

Enterprise IT, including manufacturing IT and OT systems, contributes significantly to the world's carbon footprint. In 2019, 53.6 million tons of e-waste were generated worldwide, an increase of 21% in five years. Moreover, 89% of organizations recycle less than 10% of their IT hardware.[61] "Green IT" describes an environment-focused approach to the design, use and disposal of computer hardware and software applications and the design of accompanying business processes. It extends to activities such as responsible mining of rare metals used to develop IT hardware, water conservation and the application of circular economy principles across the technology life cycle.

According to Capgemini research, green IT use cases must be applied and are associated with cost savings. They include introducing an auto switch-off hardware/feature (14% cost saving), switching to a green architecture and framework (19% cost saving), rationalizing applications and data (11% cost saving), and managing data-centre cooling using AI to optimize data-centre utilization (9% cost saving). Green procurement of servers also leads to cost savings. Best-implementation practices include defining a sustainable IT strategy that aligns with the organization's sustainability strategy and creating a robust governance approach with a dedicated sustainable IT team.[62]

Despite significant growth in the carbon footprint of IT, only a minority of companies have a comprehensive sustainable IT strategy with well-defined goals and timelines.

STORY

Driving decarbonization through holistic digital transformation

Siemens – Energy and automation

To address sustainability challenges, Siemens Electronics Works Amberg, which the World Economic Forum recognized as a digital lighthouse, elaborated a specific framework that allows for breaking down corporate sustainability targets. This holistic view, referred to as the 5Ps of sustainability, considers the **p**ublic ecosystem, **p**lant infrastructure, **p**eople and culture, **p**rocess and the **p**roduct within the supply chain. This framework supports the commitment to achieve net zero by 2030, and even goes beyond that. Action taken on the five levels are as follows:

Public ecosystem: Public transportation is balanced with production shift schedules to support commuting, and public awareness for sustainability is supported by public presentations.

Plant infrastructure: Siemens implemented a holistic energy management system via a digital twin of the factory. The factory runs with green electricity, and all new buildings are certified by the Leadership in Energy and Environmental Design rating system. Digital dashboards were set up to monitor energy consumption, GHG emissions, waste and water.

People: Siemens installed an electric vehicle (EV) charging station for employees; the company also provides sustainability awareness training and climate neutral food in the canteen.

Process: At the factory level, digitalization supported greater energy efficiency through AI models to optimize such areas as production, inventory, waste and testing efforts. The energy management software CO_2 cockpit helps to monitor energy consumption and matches this data with the production data to calculate the CO_2 emissions per product. A digital name plate system helps to connect a product to its online representation, such as technical data, certificates and manuals. This saves tons of paper and plastic that enclose the final packaging, and the system serves to prepare future circularity models.

Product: Siemens developed a blockchain-based dynamic PCF management tool for secure and trustworthy end-to-end PCF requesting, aggregating and sharing along the supply chain. This supports Siemens as well as the industry in managing the PCF and in decarbonizing.

Thanks to those transformations, direct energy consumption was reduced by 5% (43% per volume produced), GHG emissions were reduced by 58% (77% per volume produced) and total material waste was reduced by 6% (43% per volume produced).

Source: Consultation with Siemens.

Action pillar 10 Implement and drive the net-zero culture and practices

Achieving net zero is a complex and unprecedented transformation that requires a genuine growth mindset and a profound transformation of business practices and culture. It involves all resources available across the entire supply chain, from suppliers to consumers, and at all levels, from CEOs to technicians.

According to author Peter Drucker, "Culture eats strategy for breakfast." It is therefore no surprise that recurring cultural barriers have been identified regarding industrial energy efficiency and, more broadly, decarbonization projects. Typical barriers include a lack of shared vision and role model leadership; limited incentives to encourage action in the short, middle and long term; and insufficient sustainability stakes anchored in the company culture.[63]

To overcome this challenge, businesses must rally their entire organization behind a compelling vision and keep positive momentum along the net-zero journey. Based on research by the Industry Net Zero Accelerator initiative team, leading businesses are leveraging the following best practices to address this need and accelerate their progress:

– **Create a compelling vision and drive it inclusively.** Because culture change cannot be achieved through top-down mandates but rather through trust, conviction and optimism, the vision needs to be relevant to both the heads and hearts of all stakeholders. Examples include highlighting how decarbonization will help differentiate a firm's products, increasing consumer loyalty, encouraging employee pride and mitigating the exponential operational risks related to climate change. Another important element is to formally embed the net-zero vision into the company's corporate objectives and priorities so that sustainability becomes the way people do their jobs and not a separate project. Finally, progress in sustainability must be integrated into the reward system so that every employee feels both empowered and accountable to contribute to the journey with the right sense of urgency.

– **Develop green skills and talents.** This starts with the upskilling of the incumbent workforce. The need is particularly visible in the automotive industry, where the transition to EVs requires existing employees to acquire new skills in EV manufacturing, battery production or energy storage. Beyond the significant adaptation of their training programmes (upskilling is as much about unlearning as it is about learning), it is equally important that companies adapt their recruiting and career development systems to attract and retain the diverse spectrum of talent needed to drive this green transition. Demand for green talent will indeed soon outpace supply; according to LinkedIn research, the share of green talent in the global workforce increased from 9.6% in 2015 to 13.3% in 2021 (a growth rate of 38.5%), and new climate policies and commitments are expected to create millions of new jobs in the next decade.[64]

– **Make the journey exciting.** To keep people inspired, energized and thriving all along the complex journey to net zero, leaders should:

1. **Foster a growth mindset**, promoting learning, creativity and agility at all levels – keeping in mind that the net-zero journey is inherently volatile, uncertain, complex and ambiguous

2. **Break down the journey**, developing a high-level roadmap to keep the organization focused not just on the end vision but also on the various phases of progress expected along the way

3. **Relentlessly educate and communicate**, using a blend of storytelling and analogies to decipher the often cryptic and intimidating aspects of net-zero language

4. **Celebrate progress**, not just in the output metrics but also in capability areas, whether they relate to upskilling organizations, upgrading infrastructure or establishing new systems; and visibly recognize and reward employees' efforts, making them feel at the heart of the process to improve sustainability.[65]

STORY

The net-zero journey and the imperative of corporate organizational culture and operational framework

Procter & Gamble – Fast-moving consumer goods

In 2007, Procter & Gamble (P&G) set its first goal to reduce GHG emissions from its manufacturing facilities. The company has expanded and accelerated these efforts to address GHG emissions across the life cycle of its products and operations.

In 2021, P&G set a new ambition to achieve net-zero GHG emissions across its supply chain and operations, from raw materials to retailer distribution, by 2040, as well as interim 2030 goals to make meaningful progress in this decade. The company's conviction was that "the task ahead is urgent, difficult, and much bigger than P&G alone, but we're ready to take on the challenge". P&G decided to not only focus on reducing its footprint but also to leverage its scale to foster unprecedented collaboration across its value chain. It established a new Product Supply Innovation Center as a hub for collaboration for a network of local suppliers, tech companies, R&D institutions and leading universities to accelerate the development of supply chain decarbonization solutions that are global, scalable and modular.

By leveraging a culture of total employee involvement combined with the P&G Integrated Working System, which focused on eliminating losses and investing in technology to upgrade the company's processes, P&G has achieved a 56% reduction in Scope 1 and 2 GHG emissions, exceeding its SBTi-validated goal of 50% reduction versus the 2010 baseline.

Understanding the power of collective collaboration, the company extended the It's Our Home campaign from consumers to employees and external partners. P&G's internal It's Our Home Sustainability Awards programme recognizes individuals, businesses and regions who are leading work to deliver the company's Ambition 2030 sustainability goals and reinforces the integration of sustainability as running through, rather than just attached to, the business.

Source: Consultation with P&G; P&G, "Environmental Sustainability"; P&G, "Environmental"; P&G, *Ambition 2030: It's Our Home*, 2021; P&G, "It's Our Home: Net Zero 2040", 2021; P&G, "P&G Accelerates Action on Climate Change Toward Net Zero GHG Emissions by 2040", 2021 (all accessed 21 November 2022).

3

Industry Net Zero Accelerator initiative: Next steps

Collaboration is fundamental to upgrading net-zero strategies and unlocking the full potential of net-zero efforts.

Companies have shown that rethinking operations and business models helps to improve their efficiency and enhance their competitive advantage. Achieving net zero, however, is something no company can achieve alone.

System-level collaboration is a vital component of the journey, whether it occurs at the cross-industry, value-chain, governmental or organizational level. This view was confirmed in the initiative's interviews with leaders from industry, government and academia. Many companies have already demonstrated that collaboration in an industrial ecosystem can result in mutual economic and environmental benefits as well as risk dilution – for example, sharing technologies or developing reverse logistics within a value chain to reuse and recycle material waste. Some companies are even partnering with their competitors to tackle the most challenging barriers, such as creating partnerships to co-innovate and to develop low-carbon products, green energy infrastructure, and carbon capture and storage infrastructure.

To address climate change, future collaborative efforts will be necessary. The World Economic Forum Industry Net Zero Accelerator initiative will continue to engage leaders across industry sectors as well as government, academia and civil society to jointly shed the light on global insights and best practices in response to the industry net zero challenge.

Forthcoming work includes:

- Bringing together a community of action to organize problem-solving activities on the toughest cross-industrial challenges of net zero; these include topics prioritized by the community, such as data standards, Scope 3 carbon emissions traceability, material efficiency and circularity, supply chain decarbonization support, new business models and a net-zero compatible digital strategy
    - The initiative is partnering with the Estainium Association to address value-chain data sharing challenges, such as product carbon footprint, carbon capture, storage and utilization, and compensation. The Estainium Association has launched a series of "Emission-to-Sink Process" publications to create synergies to address the challenges.[66]
- Pursuing the collection of insights, methodologies, best practices and experiences from the industrial community and academia that will benefit the broader community to decarbonize operations and value chains, including leveraging the net-zero framework presented in this White Paper that serves as a basis for dialogue between private- and public-sector stakeholders
- Celebrating the successes of industrial leaders who demonstrate outstanding progress in their journey to net zero, as a means of inspiring the broader industrial community
- Promoting private- and public-sector efforts in supporting net zero in areas and geographies that require additional resources to move at the same pace as larger companies, notably among small and medium-sized enterprises and those in developing countries

Recognizing the complexity and scale of the net-zero challenge, the aim is to help businesses and governments upgrade their net-zero strategies and update industrial policies by providing a neutral platform for collaboration and knowledge dissemination. There has never been a more urgent time to make a difference. The hope is that this White Paper can inspire more businesses to join this community and play a role in the collaborative effort to exchange knowledge and best practices to stimulate and accelerate change across industrial sectors.

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