

Chemical Industry as an Enabler across Sectors

TECHNOLOGY BRIEFS

This publication was written by Carbon Minds and represents the outcome of a study commissioned by the International Council of Chemical Associations.

International Council of Chemical Associations

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PUBLICATION DETAILS

SUMMARY

This publication examines the enabling role of the chemical industry across five key sectors: Industry & Production, Building & Housing, Mobility & Transport, Nutrition & Agriculture, and Power Generation & Storage. It shows how chemical products, materials and process capabilities contribute to the performance and development of technologies across downstream value chains, and how both established and emerging innovations can support evolving industrial applications.

DISCLAIMER

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PLEASE CITE AS

Vögler, Oskar; Ossolińska-Baldach, Anna. Technology Briefs. Chemical Industry as an Enabler across Sectors. October 2026. Cologne. Last updated 14.10.2026

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COMMISSIONED BY

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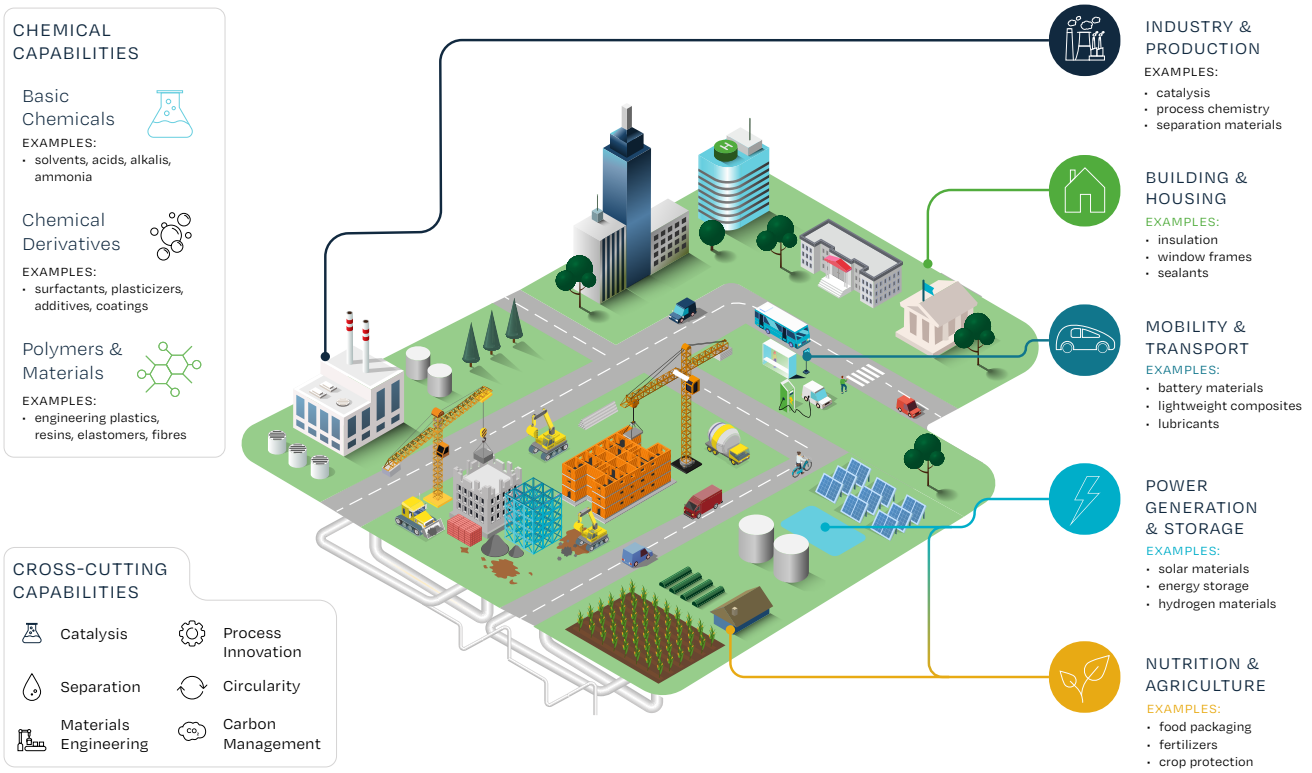
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CHEMICAL INDUSTRY AS AN ENABLER ACROSS SECTORS

FROM VISIBLE PRODUCTS TO EMBEDDED FUNCTIONS

Chemical products and materials are part of everyday life because they provide functions that products and systems rely on. They can help protect food, insulate buildings, protect surfaces, bind materials, and support energy storage and transfer. These functions make some contributions of chemistry easy to recognize in the products people use. Yet what is visible in a final product represents only part of the chemical industry's role. Many chemical products and capabilities perform their function earlier in the value chain or within a larger technological system, where they may never be apparent to the person using the final product.

This less visible role becomes clearer when looking at what makes such systems perform as intended. A catalyst used inside a production process can influence how selectively raw materials are converted and the conditions under which that conversion takes place. A membrane can determine which substances are separated or purified, while an electrolyte can influence how energy is stored and transferred within a battery. The chemical component itself may therefore remain largely unseen, while the function it provides is reflected in the performance of the wider system. By influencing how materials react, separate, flow, withstand external conditions, or store energy, chemistry can affect the efficiency, reliability, durability, safety, and resource use of the technologies in which it is embedded. Where these functions reduce energy or material requirements, limit process emissions, or enable lower-emission technologies, they can also contribute to more efficient and lower-emission systems beyond the chemical sector.



FROM CHEMICAL INNOVATION TO CROSS-SECTOR IMPACT

Because the performance of wider systems can depend on these underlying chemical functions, chemical innovation can have effects well beyond chemical production itself. Such innovation does not only involve the development of entirely new technologies. It also includes improvements to established materials and processes, for example through more selective catalysts, materials with tailored properties, improved separation processes, alternative feedstocks, or better integration of individual process steps. Improvements in these underlying functions can enhance existing applications, allow technologies to operate under different conditions, or make additional applications technically possible. Chemical innovation can therefore expand the range of options available to downstream sectors without implying that any one technology or pathway is suitable in every context.

These effects extend across sectors because many of the underlying functions are transferable between applications. Controlling reactions, designing materials with specific properties, separating and purifying substances, managing molecular or ionic transport, and integrating these functions into industrial processes are relevant to technologies used in very different parts of the economy. This publication follows these connections across five areas: Industry & Production, Building & Housing, Mobility & Transport, Nutrition & Agriculture, and Power Generation & Storage. The following chapters illustrate how established and emerging chemical products, materials, and process capabilities enable the performance and continued development of technologies in each area, while also showing how similar capabilities can connect otherwise distinct value chains. The technologies presented serve as examples of these broader enabling functions rather than recommendations for individual solutions or pathways.

INDUSTRY AND PRODUCTION



Industry and production covers energy- and resource-intensive manufacturing systems, including chemicals, cement, steel, refining, mining, industrial heat, process emissions, and material conversion. The main challenge is to reduce process-related emissions, energy demand, and fossil feedstock dependency while maintaining reliable production of materials and intermediates required by downstream sectors.

HOW THE CHEMICAL INDUSTRY ENABLES THIS SECTOR

The chemical industry enables transition pathways in industry and production through process chemistry, catalysis, separation technologies, alternative feedstocks, carbon management, and circular material flows. Advanced catalysts can increase selectivity, lower reaction severity, reduce by-product formation, and enable new reaction pathways for chemicals and fuels. Separation systems, including membranes, sorbents, solvents, and adsorption materials, support the capture, purification, and reuse of carbon dioxide, hydrogen, water, and process gases.

Chemical-sector capabilities are also central to replacing fossil feedstocks with biomass, captured carbon, waste-derived carbon, or recycled intermediates. Biotechnology and fermentation can convert sugars, residues, or syngas into platform chemicals, while thermochemical processes such as pyrolysis and gasification can transform mixed waste or biomass into feedstocks for chemical production. These mechanisms provide direct benefits through lower process intensity and indirect benefits through reduced reliance on primary fossil resources, improved resource efficiency, and stronger circularity across industrial value chains.

Promising technology clusters

NEW CATALYTIC PROCESSES – Catalytic technologies support more selective and energy-efficient production of chemicals, fuels, and intermediates by enabling alternative reaction pathways and milder operating conditions.

BIOMASS AS FEEDSTOCK – Biomass-based routes provide renewable carbon for polymers, aromatics, alcohols, organic acids, and other chemical building blocks, supporting feedstock diversification.

PROCESS EFFICIENCY – Process-intensification, heat-integration, membrane-separation, and optimization technologies help reduce energy use, material losses, and process emissions in industrial operations.

CARBON CAPTURE AND UTILIZATION – CCU technologies convert captured carbon dioxide into chemicals, fuels, polymers, or intermediates when suitable low-emission hydrogen, electricity, and process integration are available.

CARBON CAPTURE AND STORAGE – CCS technologies capture carbon dioxide from industrial or energy-related sources and transport it for permanent geological storage.

WASTE TO CHEMICALS – Chemical recycling, pyrolysis, gasification, and waste-derived feedstock routes convert residual materials into useful chemical inputs and support circular carbon flows.

Cross-sector relevance

The same technologies that improve industrial production also support other ICCA sectors. Catalysts and hydrogen technologies are relevant for mobility fuels, power storage, ammonia production, and carbon utilization. Biomass and waste-to-chemicals routes can supply packaging, construction materials, agricultural inputs, and mobility components. Carbon capture, membranes, and sorbents developed for industrial facilities can also be applied in energy systems, waste treatment, and circular material management.

Examples of technological capabilities

ADVANCED ZEOLITE CATALYSTS FOR ETHANOL-TO-BTX CONVERSION

Provide an alternative route to aromatic building blocks used in polymers, solvents, coatings, and other industrial products.

AMMONIA SYNTHESIS USING ADVANCED CATALYSTS AND MEMBRANES

Supports less energy-intensive nitrogen conversion and can enable smaller or more flexible production configurations.

CO_2 ELECTROLYSIS COMBINED WITH FERMENTATION

Converts captured carbon, water, and electricity into alcohols or other chemical intermediates for specialty chemicals and materials.

POLYMERIC HYDROGEN-SEPARATION MEMBRANES

Improve hydrogen purification and enable integration of hydrogen into chemical, refining, and fuel-cell value chains.

PYROLYSIS OF MIXED PLASTIC WASTE OR AUTOMOTIVE SHREDDER RESIDUE

Produces liquid hydrocarbon feedstocks that can be routed into existing or adapted chemical production assets.

MINERALIZATION OF ALKALINE SOLID WASTE

Converts reactive mineral residues and carbon dioxide into stable carbonate materials for industrial or construction applications.

BUILDING AND HOUSING



Building and housing must reduce operational energy demand, improve material performance, address embodied impacts from construction materials, and support circularity in long-lived building systems. The technical challenge is to combine efficiency, durability, safety, affordability, and end-of-life recovery across diverse building types, climates, and construction practices.

HOW THE CHEMICAL INDUSTRY ENABLES THIS SECTOR

The chemical industry enables transition pathways in buildings through advanced polymers, insulation materials, coatings, adhesives, sealants, additives, cement-related chemistries, and building-integrated energy technologies. Polymer engineering allows the development of high-performance insulation foams, aerogels, sealants, membranes, and composite systems that improve thermal performance and reduce heating and cooling demand. Coatings and additives can improve reflectivity, moisture resistance, corrosion protection, fire performance, and service life.

Chemical innovation also supports lower-impact construction materials by enabling alternative binders, supplementary cementitious materials, carbon mineralization, concrete admixtures, and recycled-content materials. In addition, specialty materials for building-integrated photovoltaics, transparent solar coatings, encapsulants, adhesives, and protective films can turn building envelopes into multifunctional systems that provide insulation, weather protection, and renewable electricity generation. These technologies create direct benefits in building performance and indirect benefits through durability, reduced maintenance, material substitution, and end-of-life recovery.

Promising technology clusters

ENERGY SOLUTIONS – Insulation materials, air-sealing systems, phase-change materials, coatings, and lighting-related materials reduce energy demand during building operation.

ALTERNATIVE ENERGY GENERATION – Photovoltaic materials, solar coatings, encapsulation systems, and building-integrated energy components enable on-site renewable electricity generation.

ADVANCED MATERIALS – High-performance polymers, composites, adhesives, sealants, and functional coatings improve durability, structural performance, and material efficiency in construction.

CARBON CAPTURE AND STORAGE / UTILIZATION – Carbon mineralization and CO_2-based curing or binder technologies can support lower-carbon pathways for cementitious and mineral construction materials.

WASTE TO CHEMICALS – Recycling technologies and recycled-content polymers support circularity in insulation, flooring, pipes, panels, sealants, and other construction-related products.

Cross-sector relevance

Building-related chemical technologies are closely connected to power generation, industry, and mobility. Photovoltaic materials and energy-storage components link buildings with electricity systems. Insulation foams, adhesives, coatings, and composites also support mobility lightweighting and industrial equipment. Carbon mineralization and recycled polymers connect construction with industrial carbon management and circular material flows.

Examples of technological capabilities

AEROGEL-BASED INSULATION PANELS

Improve thermal resistance in façades, roofs, floors, and retrofit applications where limited space constrains conventional insulation.

POLYURETHANE AND POLYISOCYANURATE INSULATION FOAMS

Reduce heat transfer in building envelopes and support operational energy efficiency.

RECYCLED POLYMERS FOR CONSTRUCTION PRODUCTS

Replace primary materials in pipes, panels, insulation components, flooring, and other building applications where performance requirements can be met.

BUILDING-INTEGRATED PHOTOVOLTAIC MATERIALS AND ENCAPSULANTS

Enable façades, roofs, glazing, or shading elements to generate electricity while performing architectural functions.

CARBON MINERALIZATION IN CONCRETE OR ALKALINE RESIDUES

Stores carbon in stable mineral forms and can support alternative construction-material pathways.

HIGH-PERFORMANCE SEALANTS AND AIR-BARRIER MEMBRANES

Reduce uncontrolled air leakage and improve the energy performance of building envelopes.

MOBILITY AND TRANSPORT



Mobility and transport must reduce energy use and emissions across road, rail, aviation, and maritime systems while meeting demanding requirements for safety, durability, range, payload, refueling or charging time, and cost. The transition challenge differs by mode: light-duty vehicles can be electrified more readily, while heavy-duty transport, aviation, and maritime applications require additional solutions such as advanced fuels, hydrogen, fuel cells, lightweight materials, and improved system efficiency.

HOW THE CHEMICAL INDUSTRY ENABLES THIS SECTOR

The chemical industry enables mobility transition pathways through battery materials, fuel-cell membranes and catalysts, hydrogen technologies, lightweight polymers and composites, sustainable fuels, lubricants, coatings, adhesives, and recycling systems. Electrochemistry and materials science are central to battery performance, including cathode and anode active materials, electrolytes, binders, separators, coatings, and thermal-management materials. Fuel-cell systems depend on ion-exchange membranes, catalysts, gas-diffusion layers, sealants, and water-management materials.

Chemical-sector capabilities also support transport efficiency through lightweight materials such as carbon fiber composites, engineering plastics, polyurethane foams, and metal-polymer hybrid structures. These materials can reduce vehicle mass while maintaining safety and mechanical performance. For aviation, maritime, and heavy-duty transport, chemical innovation contributes through hydrogen carriers, ammonia, methanol, biofuels, synthetic fuels, and fuel additives. Recycling technologies for batteries, plastics, tires, and composites provide indirect lifecycle benefits by recovering materials and reducing dependence on primary feedstocks.

Promising technology clusters

BATTERIES – Battery materials, electrolytes, separators, binders, coatings, and recycling technologies support electrification of road transport and selected rail, marine, and off-road applications.

LOW-EMISSION HYDROGEN AND HYDROGEN AND ENERGY STORAGE – Hydrogen production, purification, compression, storage media, ammonia carriers, and liquid organic hydrogen carriers support fuel-cell mobility and industrial fuel applications.

BIOFUELS AND WASTE TO CHEMICALS – Biogenic and waste-derived fuels provide options for transport modes that are difficult to electrify directly, including aviation, maritime, and some heavy-duty applications.

FUEL CELLS – Membranes, catalysts, electrodes, and balance-of-plant materials enable electrochemical conversion of hydrogen or other fuels into electricity for vehicles and transport systems.

Cross-sector relevance

Mobility technologies are strongly linked to power generation and storage because electrification depends on batteries, charging systems, and renewable electricity. Hydrogen, ammonia, and fuel-cell technologies connect transport with industrial hydrogen production, energy storage, and chemical feedstock systems. Lightweight polymers, coatings, and adhesives used in vehicles also contribute to buildings, industrial equipment, renewable-energy infrastructure, and packaging applications.

Examples of technological capabilities

CARBON FIBER-REINFORCED COMPOSITES AND ENGINEERING PLASTICS

Reduce vehicle mass while supporting structural performance in automotive, rail, aerospace, and marine applications.

AMMONIA OR LIQUID ORGANIC HYDROGEN CARRIERS

Support hydrogen storage and transport where compressed or liquefied hydrogen is technically or economically constrained.

SODIUM-ION BATTERY MATERIALS

Provide an alternative electrochemical storage route for stationary and selected mobility applications where resource availability and cost are relevant.

ANION-EXCHANGE MEMBRANES FOR FUEL CELLS

Enable alkaline fuel-cell configurations with potential to reduce reliance on high-cost catalyst systems.

LITHIUM-ION BATTERY ELECTROLYTES, SALTS, BINDERS, AND SEPARATOR COATINGS

Improve battery safety, lifetime, power density, and thermal stability for electric vehicles.

NUTRITION AND AGRICULTURE



Nutrition and agriculture must increase resource efficiency, reduce emissions from fertilizers, livestock, soils, and residues, improve water and soil quality, and support reliable food production under diverse regional conditions. The technical challenge is to reduce environmental impacts while maintaining productivity, nutrient availability, food safety, and resilience across agricultural and food-system value chains.

HOW THE CHEMICAL INDUSTRY ENABLES THIS SECTOR

The chemical industry enables transition pathways in nutrition and agriculture through fertilizer technologies, nutrient stabilizers, feed additives, crop-protection chemistry, water-treatment systems, biobased materials, fermentation, biotechnology, packaging, and waste valorization. Process chemistry and catalysis support more efficient production of ammonia and fertilizer intermediates. Additives such as urease inhibitors and nitrification inhibitors can improve nitrogenuse efficiency and reduce losses to air and water when applied under suitable agronomic conditions.

In livestock systems, amino acids, enzymes, and other specialty feed ingredients can improve feed formulation and reduce reliance on protein-rich raw materials. Biotechnology and fermentation support production of amino acids, microbial fertilizers, biostimulants, biobased chemicals, and alternative proteins. Chemical innovation also contributes to food-system circularity through packaging materials that reduce food losses, biodegradable or recyclable packaging, biomass conversion, and treatment of agricultural residues. These mechanisms provide direct benefits in agricultural input efficiency and indirect benefits through land-use efficiency, reduced nutrient losses, lower food waste, and improved use of residues.

Promising technology clusters

LOW-IMPACT, ENERGY-SAVING, AND EMISSIONS-REDUCING SOLUTIONS – Specialty feed ingredients, nutrient-management products, and performance chemicals improve efficiency in food and agricultural value chains.

PROCESS EFFICIENCY – More efficient ammonia production, fertilizer manufacturing, nutrient stabilization, and water-treatment processes reduce resource use and emissions associated with agricultural inputs.

BIOMASS AS FEEDSTOCK – Agricultural residues, sugars, lignocellulosic materials, and other biogenic resources can be converted into chemicals, fuels, materials, and soil-related products.

WASTE TO CHEMICALS – Agricultural residues, food-processing by-products, used cooking oils, and other organic waste streams can be converted into fuels, chemicals, fertilizers, or material inputs.

Cross-sector relevance

Agriculture-related chemical technologies connect strongly with industry, buildings, mobility, and energy. Biomass conversion supplies feedstocks for chemicals, fuels, and polymers. Biobased packaging and biodegradable materials link food systems with circular material flows. Ammonia technologies connect fertilizers with hydrogen, energy storage, and industrial production. Waste-to-chemicals pathways can convert agricultural and food residues into fuels or intermediates for mobility and manufacturing.

Examples of technological capabilities

AMINO ACID-ENRICHED ANIMAL FEED

Improves feed formulation and can reduce the need for crude protein inputs in live-stock production.

UREASE AND NITRIFICATION INHIBITORS

Slow nitrogen transformation and losses, supporting more efficient fertilizer use under appropriate field conditions.

LOW-TEMPERATURE AND LOW-PRESSURE AMMONIA SYNTHESIS

Supports less energy-intensive production of ammonia used in fertilizers and other nitrogen-based products can be met.

MICROBIAL FERTILIZERS AND BIOSTIMULANTS

Support nutrient availability, soil function, and crop productivity through biological mechanisms.

BIOBASED AND RECYCLABLE FOOD PACKAGING FILMS

Help reduce food losses and improve material circularity in food distribution.

CONVERSION OF AGRICULTURAL RESIDUES INTO BIOFUELS OR BIOBASED CHEMICALS

Creates additional value from biomass streams and reduces reliance on fossil carbon.

POWER GENERATION AND STORAGE



Power generation and storage must expand low-emission electricity supply, integrate variable renewable generation, improve grid flexibility, and provide energy carriers for sectors that cannot be directly electrified. The technical challenge is to combine renewable generation, short- and long-duration storage, hydrogen production, fuel cells, carbon management, and materials durability at system scale.

HOW THE CHEMICAL INDUSTRY ENABLES THIS SECTOR

The chemical industry enables power generation and storage through electrochemistry, advanced materials, hydrogen production, storage media, membranes, catalysts, sorbents, coatings, and recycling technologies. Battery systems require chemically engineered active materials, electrolytes, binders, separators, current collectors, coatings, and recycling processes. Hydrogen pathways require catalysts, electrolyzers, membranes, purification systems, compression materials, carriers, and storage media. Fuel cells depend on ion-conducting membranes, catalysts, electrodes, sealants, and corrosion-resistant materials.

Chemical innovation also supports renewable generation through photovoltaic materials, encapsulants, coatings, adhesives, and durability-enhancing materials for solar, wind, tidal, and other renewable infrastructure. For carbon-intensive generation assets or industrial energy systems, carbon capture technologies rely on solvents, sorbents, membranes, and mineralization routes. The direct benefits include improved conversion efficiency, storage capacity, stability, and durability. Indirect benefits include grid flexibility, sector coupling, renewable-energy integration, and reduced material losses through recycling and end-of-life recovery.

Promising technology clusters

ALTERNATIVE ENERGY GENERATION – Photovoltaic materials, perovskites, wind-turbine coatings, tidal composites, and other advanced materials improve renewable-energy generation performance and durability.

BATTERIES – Electrochemical storage technologies enable short- and medium-duration storage, grid balancing, renewable-energy integration, and electrified end-use systems.

LOW-EMISSION HYDROGEN – Electrolysis, methane pyrolysis, reforming with carbon capture, and hydrogen purification technologies provide energy carriers and industrial feedstocks.

FUEL CELLS – Fuel-cell membranes, catalysts, and electrodes enable electrochemical power generation for stationary, mobility, and backup-power applications.

HYDROGEN AND ENERGY STORAGE – Ammonia, liquid organic hydrogen carriers, metal-organic frameworks, porous coordination polymers, and other storage media support longer-duration or transportable energy storage.

Cross-sector relevance

Power generation and storage technologies are closely linked to all other ICCA sectors. Renewable electricity and hydrogen support industrial processes, transport electrification, building-integrated energy systems, and low-emission production of fertilizers and chemicals. Batteries connect the power and mobility sectors, while hydrogen connects power generation, industry, transport, and agriculture through ammonia and other derivatives. Advanced materials developed for energy infrastructure also support buildings, vehicles, industrial equipment, and circular material systems.

Examples of technological capabilities

SODIUM-ION BATTERY MATERIALS

Support large-scale electricity storage where sodium-based chemistries may offer material-availability advantages.

SOLID-STATE ELECTROLYTES AND ADVANCED SEPARATORS

Improve safety and performance in batteries for grid and transport applications.

WATER ELECTROLYSIS CATALYSTS AND MEMBRANES

Produce hydrogen from electricity and water for storage, industry, and mobility use.

AMMONIA AS A HYDROGEN CARRIER

Enables storage and transport of hydrogen-derived energy and can support power generation or fuel-cell applications.

METAL-ORGANIC FRAMEWORKS AND POROUS MATERIALS

Provide high-surface-area structures for gas storage, separation, and carbon capture applications.

PEROVSKITE PHOTOVOLTAIC MATERIALS AND ENCAPSULATION SYSTEMS

Improve potential efficiency, flexibility, and application range of solar generation technologies.

FROM INNOVATION TO IMPACT

Chemical innovation can improve existing technologies, enable new applications, and expand the range of technical options available to downstream sectors. Yet technical potential alone does not determine whether an innovation will create impact in practice. For a material or process to move from technical capability to industrial application, it must perform reliably under the specific conditions in which it will be used.

These application requirements extend beyond efficiency or technical performance alone. Materials and processes may need to meet specifications for quality, safety, durability, compatibility, and service life. They must also be manufacturable at the required scale and capable of being integrated into existing or evolving production systems. An innovation that performs well in isolation therefore also has to function as part of a wider technological and industrial system.

Integration into that wider system creates additional dependencies. Hydrogen-based applications need production, transport, and storage infrastructure; recycling routes depend on collection and processing systems. Reliable access to fuels and electricity to operate production systems, and to carbon and non-carbon feedstocks as building blocks for advanced chemistries, is equally important. The potential of an individual technology is therefore closely connected to the conditions surrounding its deployment.

These conditions also include economics, manufacturing capabilities, market requirements, and regional circumstances. Their importance differs between applications and locations, and they can influence both the pace and scale at which established and emerging technologies are adopted. Where chemical innovations enable more efficient and lower-emission systems, the extent of that contribution will likewise depend on how, where, and at what scale they are implemented. Industrial impact should therefore be understood not as the result of a technology alone, but as the outcome of technical performance combined with the infrastructure, resources, manufacturing systems, and economic conditions needed for its application.

For this reason, no single technology or combination of technologies is likely to be appropriate in every industrial context. Established technologies may continue to improve and find new applications, while emerging technologies can broaden the set of options available. Their respective roles will develop differently as technical requirements and deployment conditions evolve.

OUTLOOK FOR THE FUTURE

Because the deployment of technologies depends on changing technical, economic, regulatory, and regional conditions, future industrial development is unlikely to follow a single predetermined pathway. Instead, established technologies will continue to improve while emerging technologies expand the range of available options. Their respective roles will evolve as performance requirements, resources, infrastructure, markets, and production systems change.

As this range of options develops, the interfaces between traditionally separate sectors are likely to become increasingly important. Energy systems depend on advanced materials and electrochemistry, mobility connects materials with energy storage and infrastructure, and buildings increasingly combine structural and functional materials with energy technologies. Agricultural and industrial systems likewise connect chemistry with biotechnology, resource management, material recovery, and new forms of energy supply. Developments in one area can therefore create new requirements and opportunities in others.

These growing connections reinforce the enabling role of the chemical industry. Its contribution is not tied to any single product or technology, but to a broad base of capabilities for designing materials with specific properties, controlling chemical reactions, separating and purifying substances, converting different feedstocks, and integrating these functions into scalable processes. As technological requirements evolve, these capabilities can be adapted and combined in different ways to improve system performance, increase resource and energy efficiency, and enable lower-emission solutions across sectors.

Because the conditions for applying these capabilities differ between technologies, applications, and regions, individual solutions will progress at different rates and in different combinations. Future transitions are therefore best understood as an evolving portfolio of technological options rather than a single route. Across Industry & Production, Building & Housing, Mobility & Transport, Nutrition & Agriculture, and Power Generation & Storage, the chemical industry's enduring enabling role lies in providing the materials, functions, and process capabilities that allow this portfolio to develop and adapt as needs and conditions change.



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