FutureBridge

CHEMICALS, MATERIALS & NATURAL RESOURCES

25

INNOVATIONS

YEARS TO NET-ZERO

A quarter century to build a better future

25 Innovations Enabling Net-Zero

With 25 years until 2050, let's showcase examples of innovative technologies designed to achieve net-zero transition... if fully scaled

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> To mitigate climate extremes, we've **25 years** to transform industry into sustainable, net-zero and circular.

Introduction

FutureBridge enables our clients to not only optimize innovation, but to navigate the complex ecosystems, economics and markets needed to succeed at scale.

Throughout 2025 we'll showcase examples of players commercializing 25 sustainable innovations and explore the key challenges and cross-functional dynamics instrumental to our industry's successful global transformation.

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Human innovations are awesome in their sheer scale, optimism and ingenuity. Yet we find ourselves in a world where extreme weather, pollution, waste, resources, energy, water and geopolitical dynamics are damaging us such that the year 2050, *without transformational change,* is a future we cannot afford.

It is against this backdrop that we find ourselves banking on the '*deus ex machina'* of industrial technological innovation. Fortunately, incredible R&D means our innovation toolbox today draws upon biotechnology, engineering, renewables, recycling, digitalization/AI such that we can harness molecules and processes previously inconceivable to industry.

The '*gods in the machine*' have borne technological fruit with concepts such as EVs, plastics/gases-as-feedstocks and bio-based chemicals. In the next decade, we could realize a world where the air itself - and the pollution it contains - are chemical feedstocks; our windows redirect solar heat to power our devices and thus keep our homes cool; and net-zero cement walls are decorated with paints cleaning our air, eliminating germs/viruses and repairing themselves.

All these innovations exist today at small scale. We have the technologies, processes, know-how and engineering needed to build the 2050 world we deserve and need. Tomorrow's challenge is not to develop further technologies, but to derisk and accelerate the commodity-scale commercialization of the innovations created over the past quarter century. Over the coming months, we'll showcase many of these technological break-throughs while considering how best we might navigate the rocky Valley of Death which must be traversed if today's innovation is to become tomorrow's mature industry.

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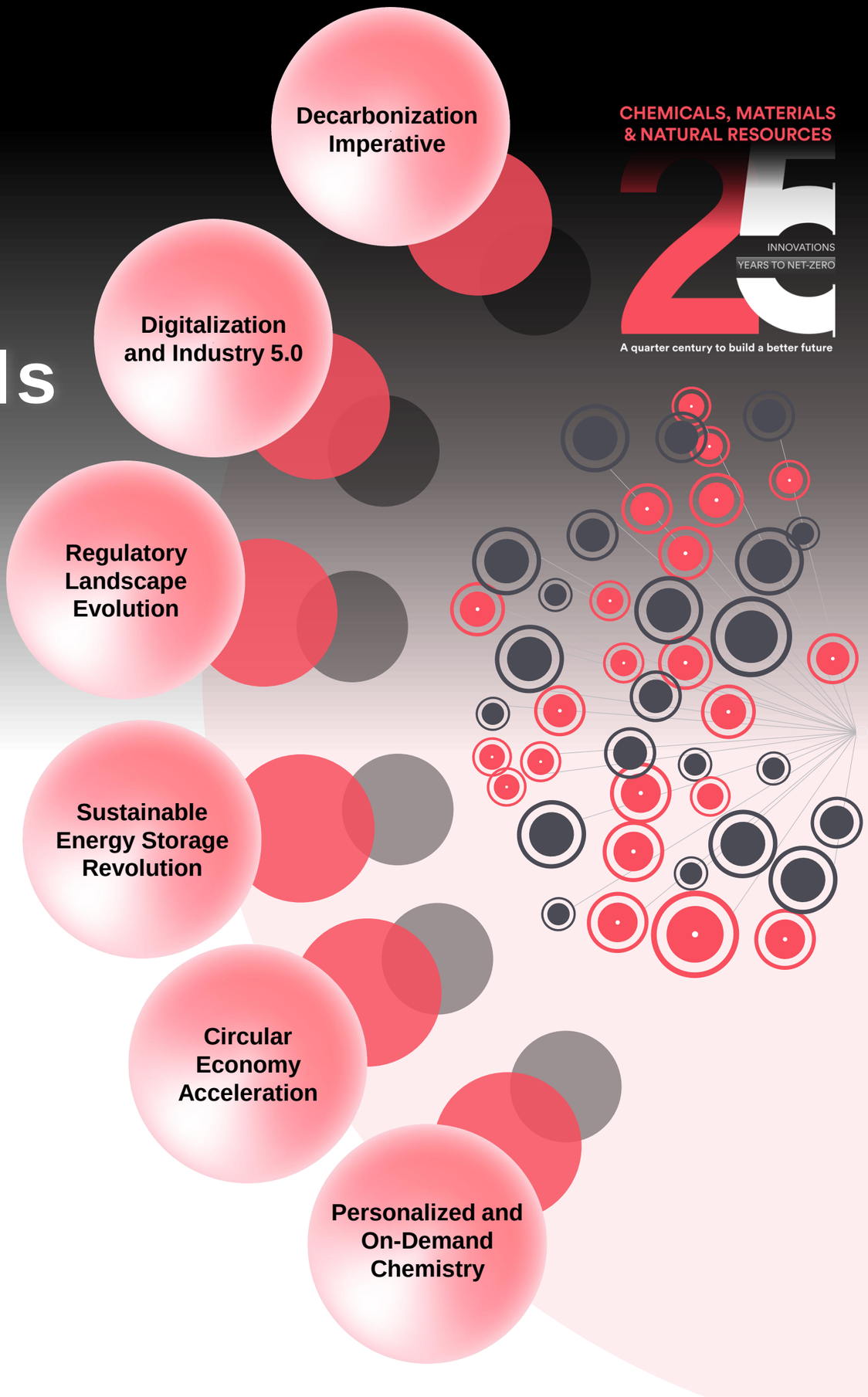
Transformative Forces in Chemicals & Materials



The chemicals and materials sector is undergoing transformation driven by de-fossilization, circular economy initiatives, and breakthroughs in sustainable energy storage. At the same time, regulatory shifts and innovations in personalized chemistry, AI and digitalization are reshaping globalized production and distribution models.

Industry goals and objectives seek greater sustainability and efficiency while recognizing the economic challenge of maintaining profitability without elusive 'green premiums'.

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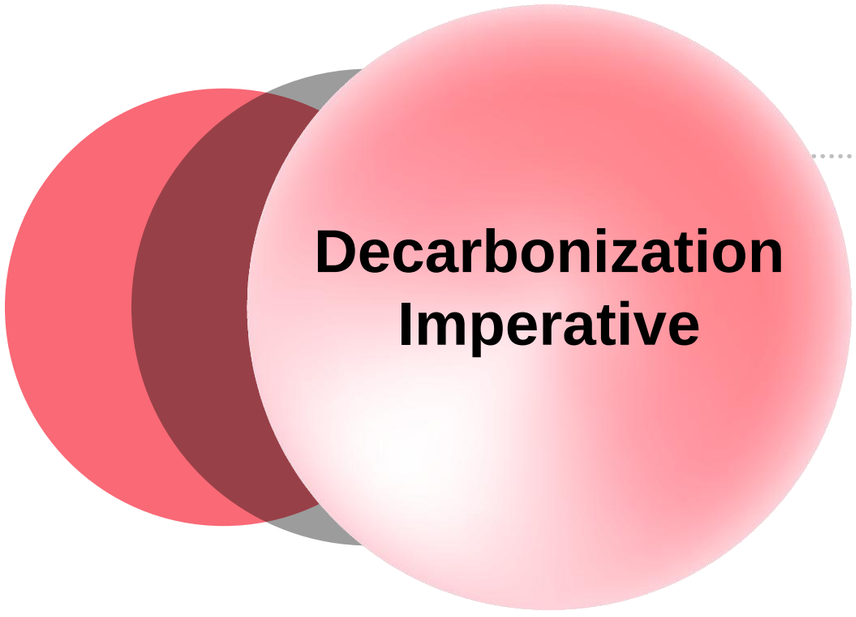
Decarbonization Imperative

Industry's commitment to net-zero emissions by 2050 remains fundamental. Although economic pressures continue to slow progress, this goal underpins unprecedented innovations in developing low-carbon technologies, processes and business models.



Electrification of Chemical Processes: Can renewable electricity increasingly power chemical reactions? Or is there a ceiling to the electrification juggernaut which may limit immense scales while driving a shift towards a modular, distributed manufacturing?

Green Hydrogen Integration: The industry is looking to hydrogen produced from renewable sources to be the feedstock and energy carrier of tomorrow – yet critical questions over scale-up, infrastructure, safety, economics and competition from power and fuel remain. Is this a bubble?

Carbon Capture and Utilization (CCU): CO2 is transitioning from waste pollutant to a valuable raw material for chemical synthesis. Why store when you can use in a circular system?

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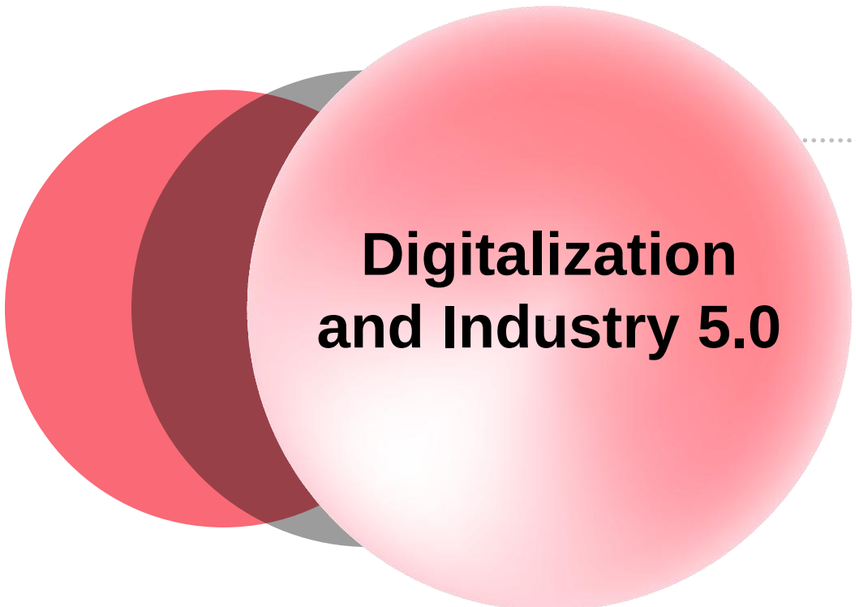
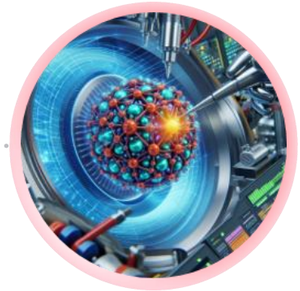
Digitalization and Industry 5.0

The convergence of digital technologies with physical and biological systems will redefine manufacturing and innovation processes. From AI powered design tools to data analytics for predictive maintenance, merging these tools with robotics and automation will ease the burden of material scouting, waste reduction and performance enhancement.





AI-Driven Material Discovery: Machine learning algorithms will dramatically accelerate the development of new chemicals and materials. But can an AI imagined matrix or material – rather than molecule – transition into manufactured reality?

Quantum Computing Applications: Quantum simulations will enable the design of materials with unprecedented precision and efficiency.

Autonomous Chemical Plants: Self-optimizing production facilities will maximize efficiency and minimize waste.

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Regulatory Landscape Evolution

As Europe continues to drive the push towards sustainability, evolving and more stringent regulations will continue to shape industry practices and thus drive innovation. Sustainable regulatory measures are enforcing the application of renewable energy, sustainable alternate materials, material recycling, and energy-efficient practices.

Regulatory Landscape Evolution

Global Harmonization of Chemical Regulations: Standardized international frameworks will streamline compliance and trade. How can these be achieved?

Extended Producer Responsibility: Manufacturers will be increasingly accountable for the entire lifecycle of their products. The goal being for downstream players to support upstream chemical transformation.

Predictive Toxicology: Advanced modelling techniques will enable better prediction and prevention of chemical hazards as part of design principles.

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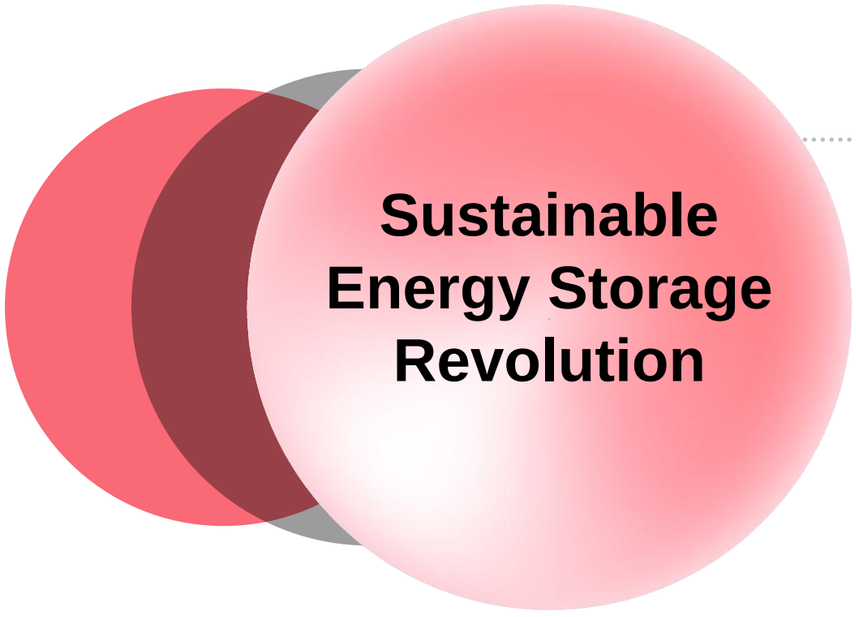
Sustainable Energy Storage Revolution

The chemicals and materials industry plays a pivotal role in enabling clean energy transition through advanced energy storage solutions. Significant progress has been made to effectively store and revive energy with minimum losses, but high costs remain a challenge.

Next-Generation Batteries: Beyond lithium-ion technologies are emerging, offering higher energy density and improved sustainability.



Chemical Energy Storage: Novel materials for storing energy in chemical bonds will provide long-duration storage solutions.

Thermal Energy Materials: Advanced phase-change materials will enable efficient storage and thermal energy management. A challenge increasingly critical as global temperatures rise and AI accelerates cooling demands.

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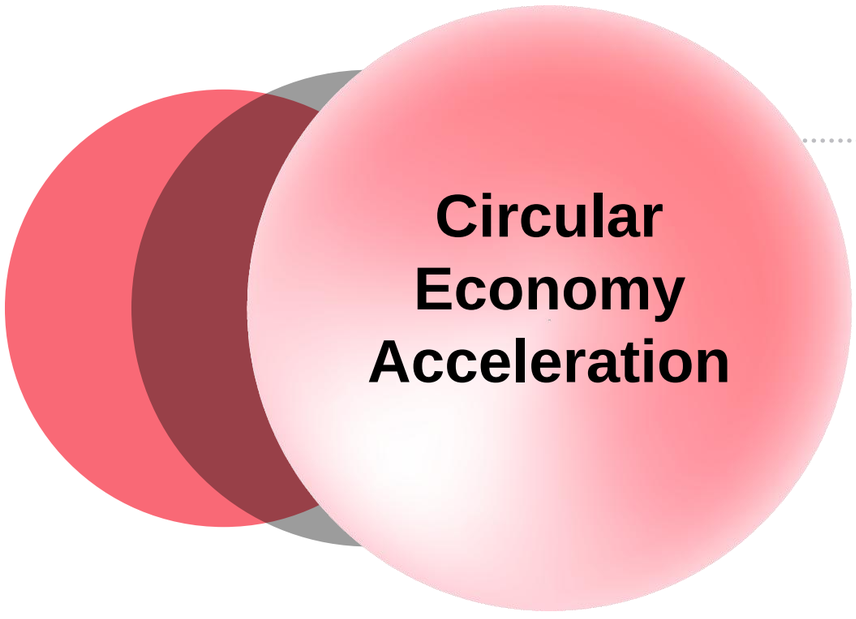
Circular Economy Acceleration

2050 goals are underpinned by circular economy principles which will be fully integrated into every aspect of industry. “Take-make-dispose” linear supply-chains will be outliers as we work towards cycling carbon endlessly within industrial material supply-chains.

Closed-loop Systems: Advanced recycling technologies and circular product designs will become standard. Supply chains could prioritize origin vs. destination to scale segregation of non-virgin and virgin carbon, enabling economies of scale.



Material Passports: Digital tracking will optimize material recovery and reuse, thereby laying the groundwork for scalable closed-loop systems. Mass balance systems will catalyze progress supported by Scope 3 communications, consumer awareness and regulatory pressures.

Waste as a Resource: By 2050, all waste will be treated as a valuable resource, restoring the pre-petroleum mindset. Advances in industrial biotechnology and chemical engineering will ensure efficient use of every carbon atom (and ideally biomass oxygen as well).

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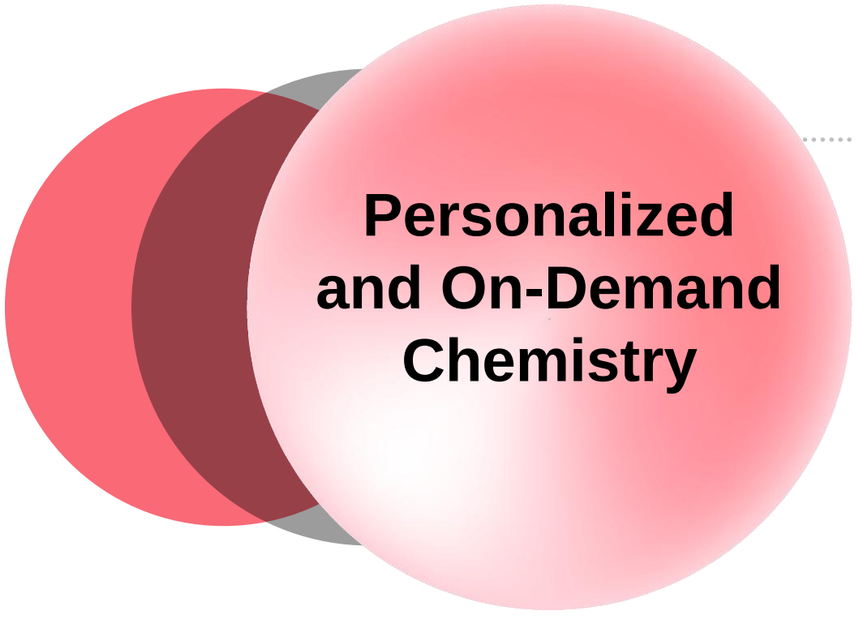
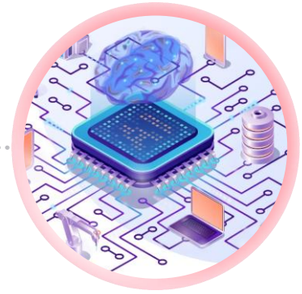
Personalized and On-Demand Chemistry

In the context of sustainable development, personalized chemicals optimize resource/energy use while lowering environmental footprints. Chemistry 'on-demand' will strengthen the industrial end-user or consumer experience while minimizing chemical overproduction and reducing logistics. Indeed, with biotechnology and AI, we can reimagine chemistry from first principles – *think differently*.



Modular and Flexible Production: Small-scale, adaptable manufacturing units will enable rapid response to changing market demands and give logistically uneconomical places access to chemicals and materials.

3D Printing: Additive manufacturing techniques will allow for on-site production of specialized chemicals, polymers and further materials.



Tailored Formulations: AI-driven systems will create personalized adaptable products for individual consumers or specific applications.

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The Road to Net-Zero will be paved with today's emerging technologies

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Join us in exploring how today's innovations could become tomorrow's reality

Over the coming months, we'll showcase enabling technologies and the factors underpinning their challenging scale-up as the road to net-zero demands increasingly innovative bold actions.

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