Data-Driven Tech Research for Business Finland

Future Watch
Emerging Climate Tech

Feb 2023

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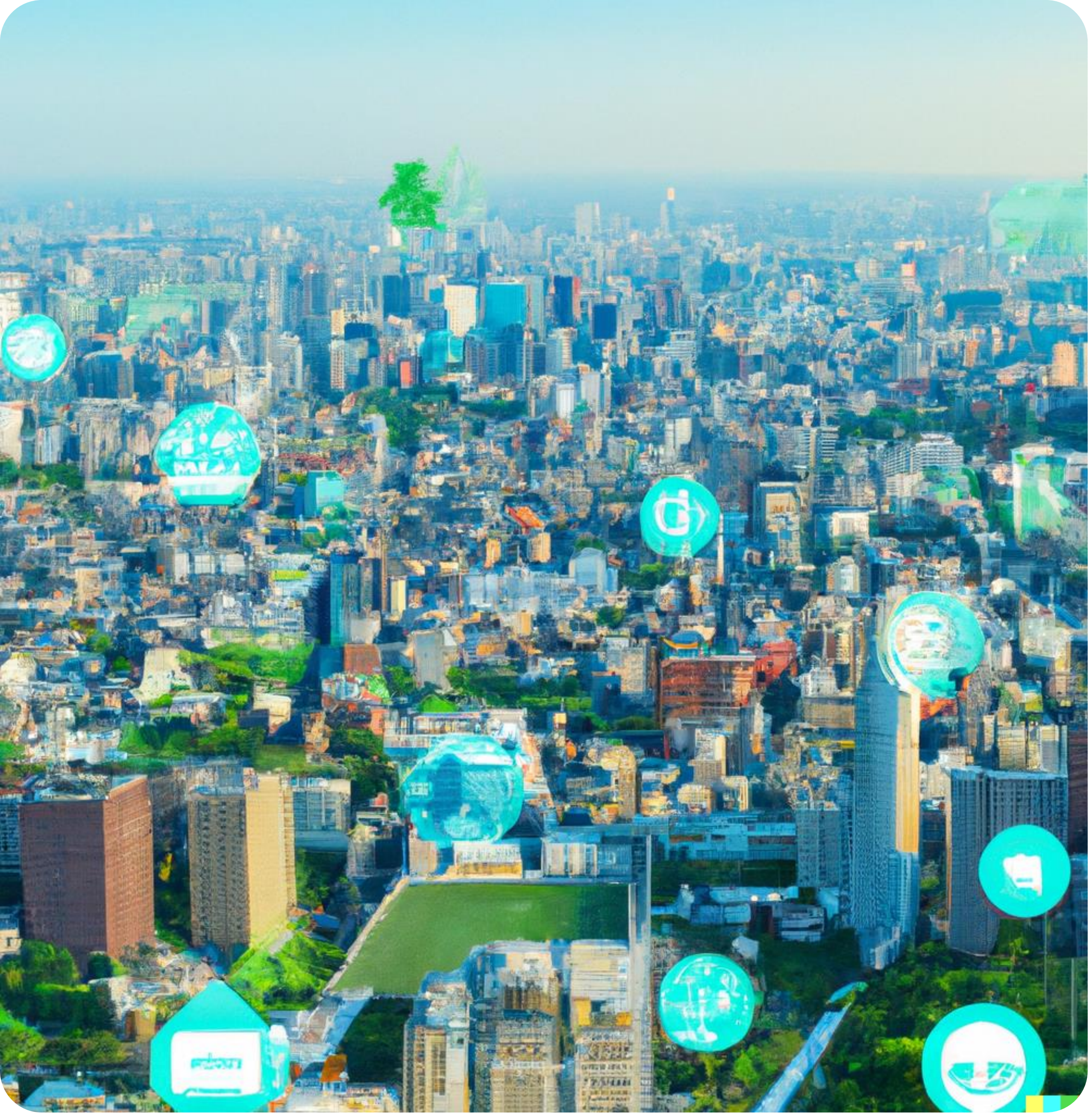

Future Watch
Emerging Climate Tech

Data-Driven Tech Research for Business Finland

This research focuses on climate technology advancements in manufacturing, mobility, and city environments.

The report explores both emerging and currently strengthening climate technologies globally and provides one tool to assess Finnish tech's global position and inform future innovation strategies.

The project is part of the pilot, where Business Finland explores new tools and methods for supporting customers with foresight #zero carbon mission #zero waste mission.

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Part 1

Research Summary

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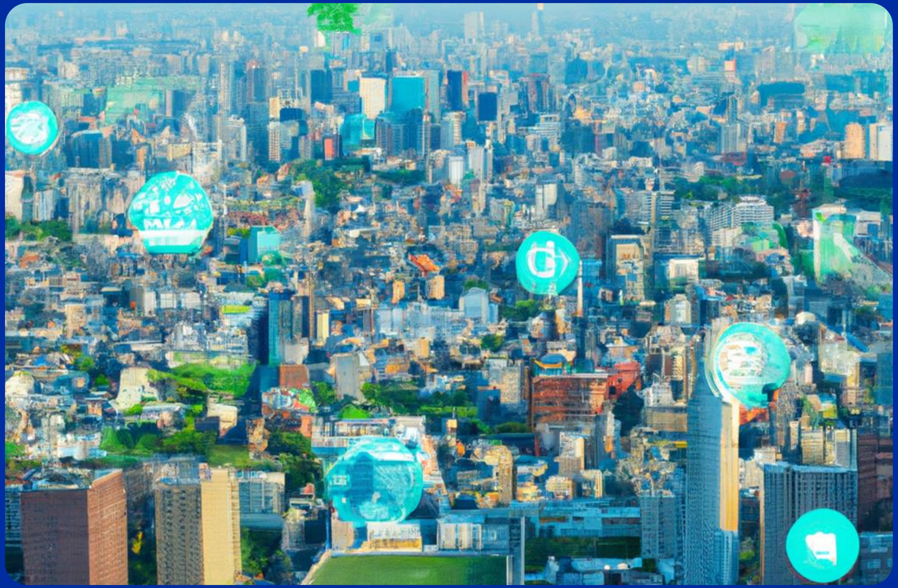
Quick Recap of the Focus

Emerging innovations in climate technology



Tech
No restrictions

Stage
Early-stage innovations

Geography
Global focus with special interest areas: India, China, the United States, Australia, Canada, South Korea, Japan, and the EU.

Focus

Climate technology advancements in manufacturing, mobility, and city environments.

Goal

This research explores both emerging and currently strengthening climate technologies globally to assess Finnish tech's global position and inform future innovation strategies.

Descriptive points

The project scope is set to technologies addressing the energy transition and emissions reduction.

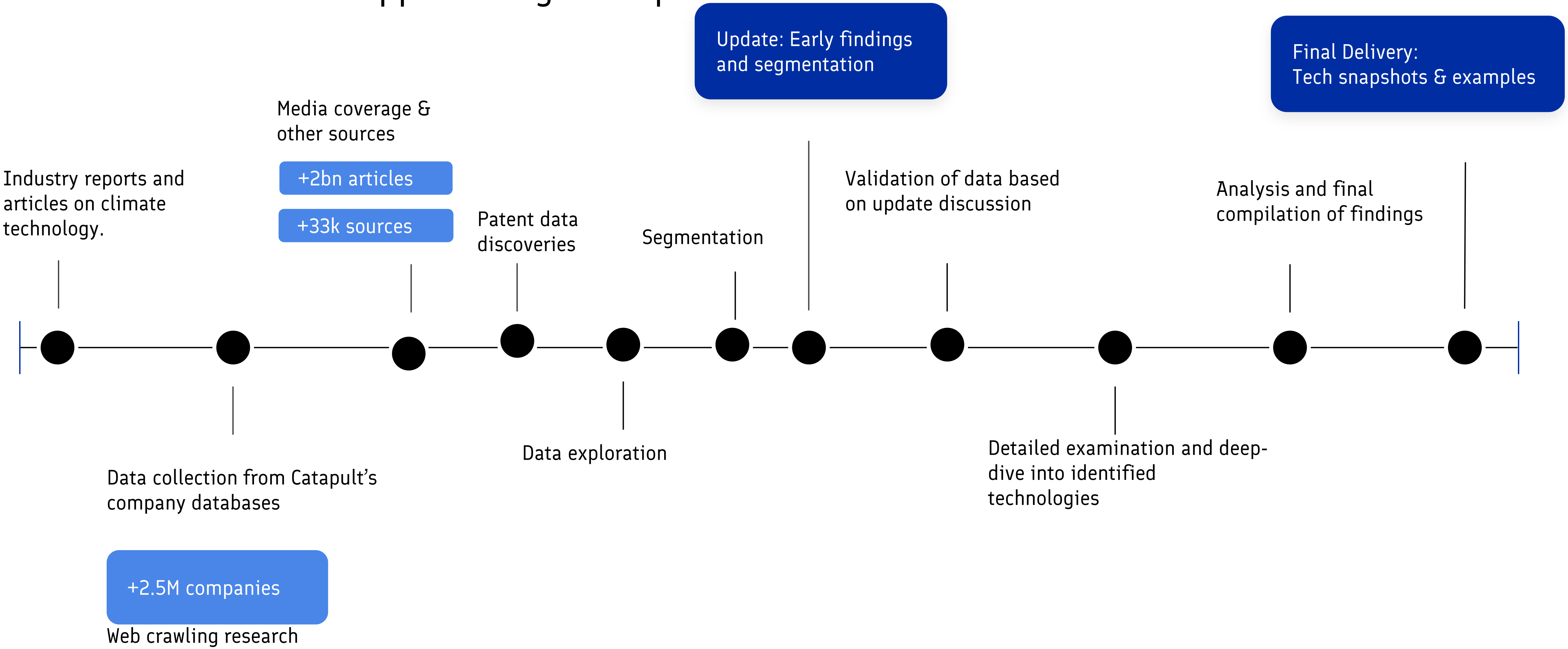
Examples of areas that are of special interest to Business Finland include:

- Regenerative and mitigative technologies
- Material innovations
- Novel use of buildings in energy storage and generation.

Business Finland is also interested in understanding technology dependencies required to bring these detected innovations to market.

Research Roadmap

How research team is approaching the topic?



Industry reports and articles on climate technology.

Data collection from Catapult’s company databases

+2.5M companies

Web crawling research

Media coverage & other sources

+2bn articles

+33k sources

Patent data discoveries

Data exploration

Segmentation

Update: Early findings and segmentation

Validation of data based on update discussion

Detailed examination and deep-dive into identified technologies

Analysis and final compilation of findings

Final Delivery:
Tech snapshots & examples

Catapult’s research is a combination of quality sources and hands-on work by the analyst team.

Part 2

Big Picture & Early Findings

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Big Picture Insights

Introduction

Next up

We'll start going through the early insights by looking at the key drivers of innovation and evolution of the climate technology sector at a general level.

This will enable us to paint the picture and understand which regions have been active and what types of technologies have been gaining attention in recent years.

Climate Technology Drivers

What is driving future innovation?

Regulation and policy

Compliance-based drivers, such as the EU ETS, tend to focus on the outcome rather than specific technologies making them suitable for a wide-range of climate tech.

Public funding

Incentive-based drivers, such as USA's IRA, are costly but offer open-ended support that can lead to faster adoption and accelerated development.

Consumer interest

Consumers are increasingly aware and interested in sustainability, expecting companies adhere to CSR guidelines.

Corporate net zero targets

Net-zero targets set by companies, either as single entities or in groups (e.g. FMC) drive the search for and adoption of low-carbon technologies.

Technological advances

New technologies like affordable IoT, AI, and ML are helping organisations to make informed decisions based on data resulting in improved operational efficiency.

Investor pressure

Investors are increasingly advocating companies to disclose their emissions, establish emissions targets and implement emission reduction plans.

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Investment Activities

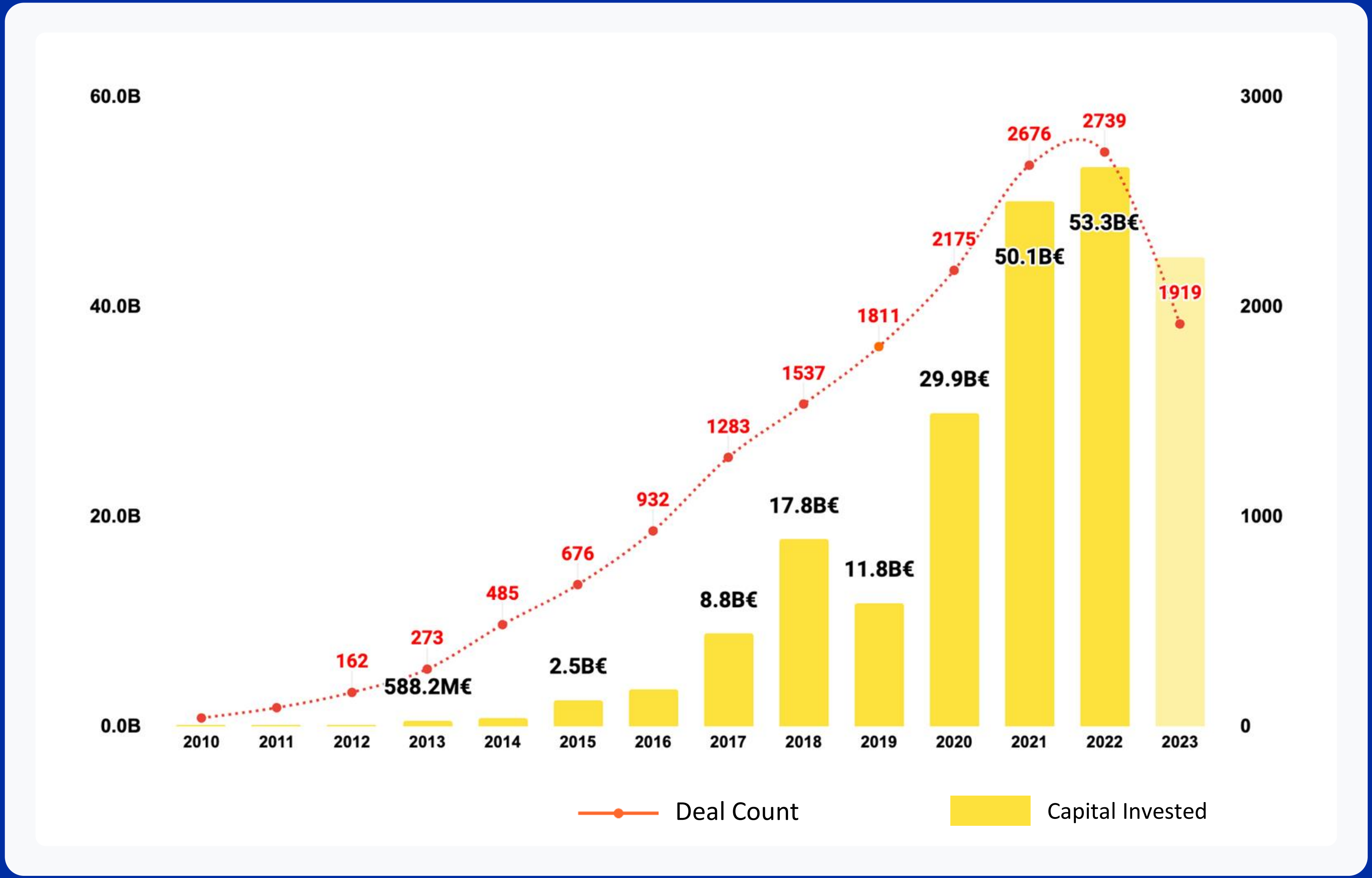
Quick overview of the investment going into climate technology

Insights

In 2023, funding for climate tech start-ups decreased to levels last seen two years ago.

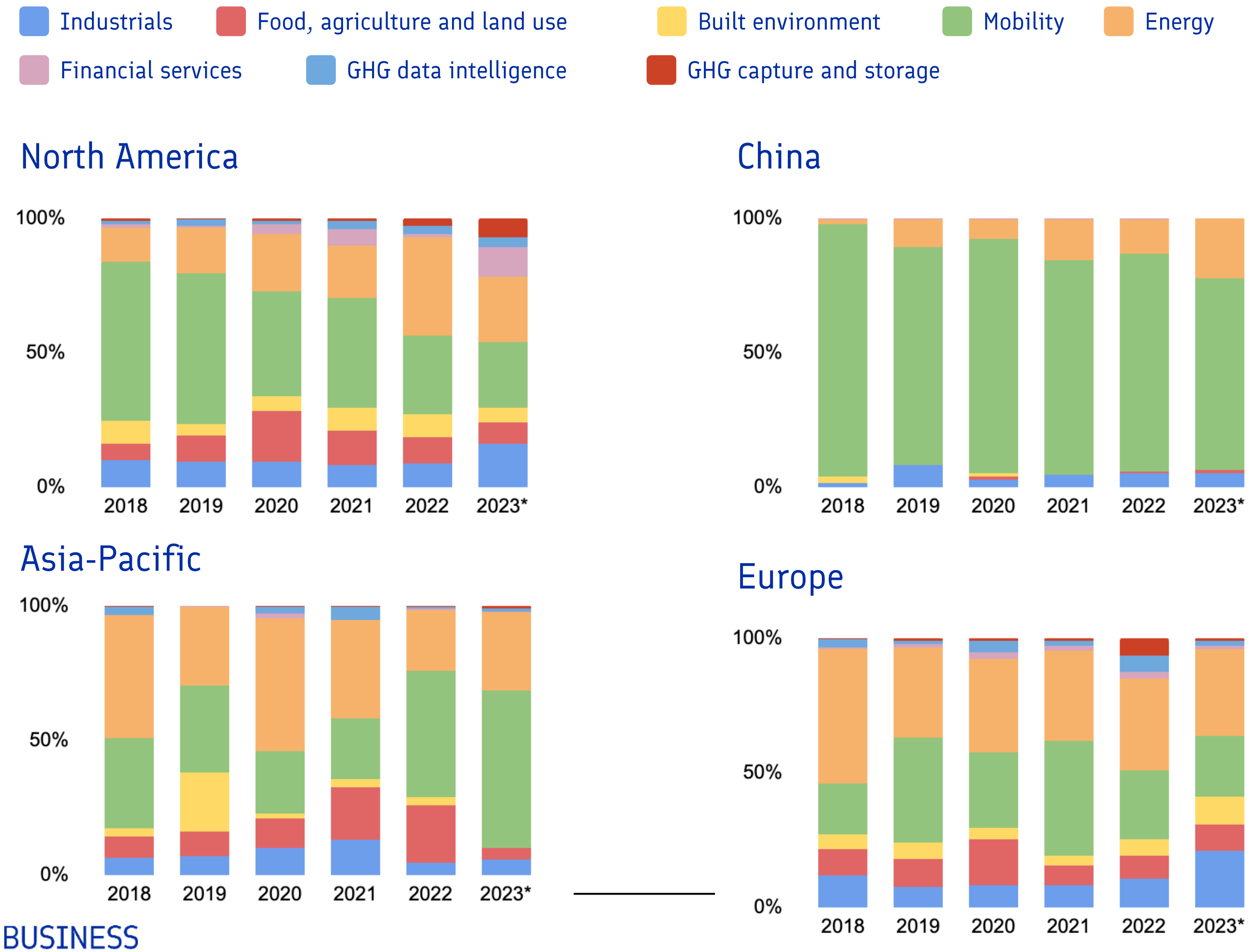
The change and decline in climate tech investment is due to economic uncertainties, less capital availability.

Investments into climate technologies, however, did not decrease as much as the total venture and private equity investment over the same period of time (50.2% vs. 40.5%). This can be seen as a positive indication.



*Data from the capital invested into companies founded after 2010

Investment Trends Across Regions



Insights

Funding relative to emissions reduction potential (ERP) is evolving. Five years ago, lower-ERP technologies like light-duty battery EVs and micromobility received more funding.

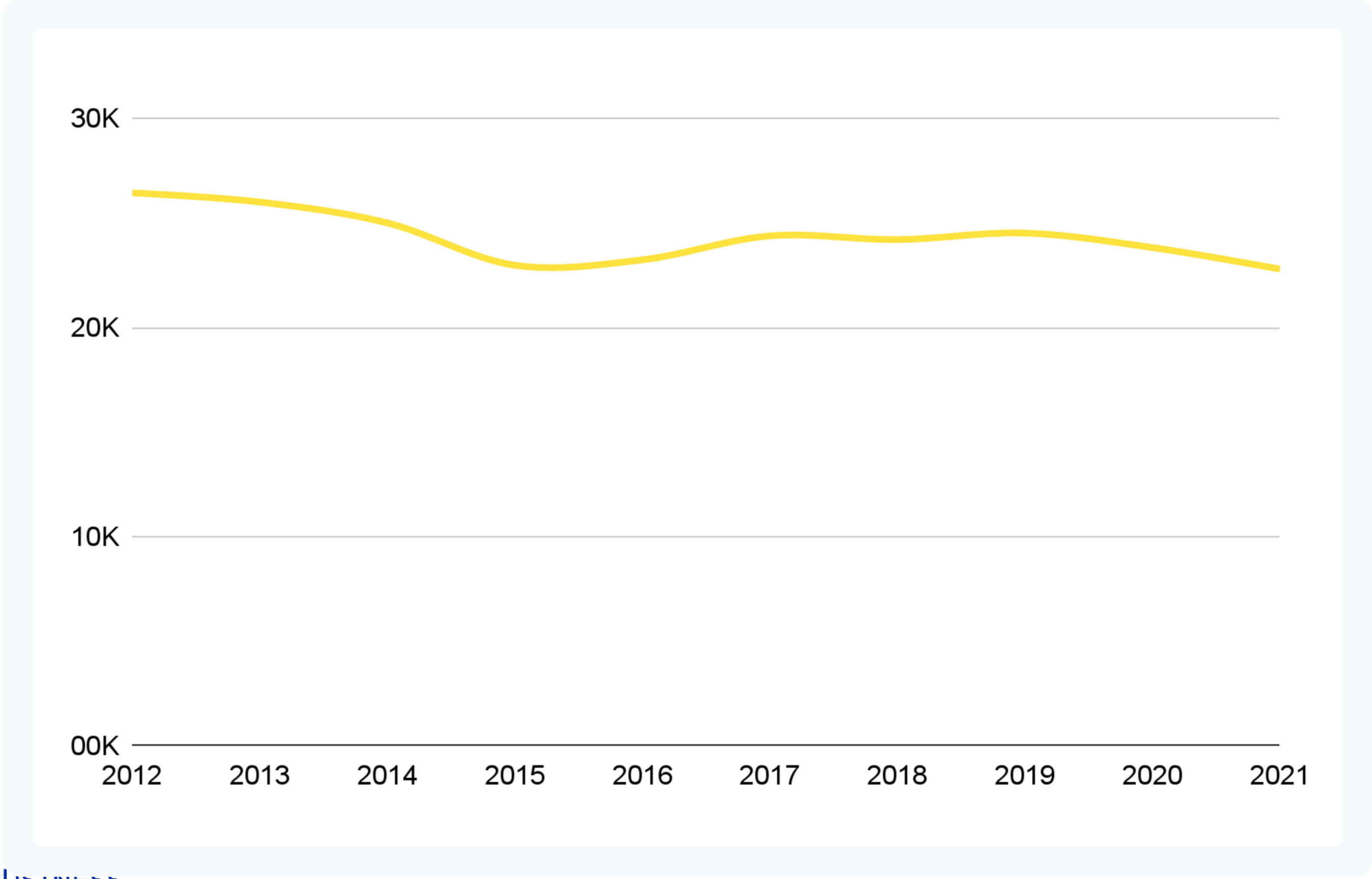
Solar and wind startups now get less investment due to technology maturity and investor interest in other climate solutions.

Currently, investors are prioritising investments focusing on higher-ERP technologies e.g. CCUS, hydrogen, and alternative fuels and foods.

*Data for 2023 is current through the third quarter of the year
Source: Data from Pitchbook, PwC analysis

Climate Technology Patents

2012-2021 showing a downward trend.



Insights

The number of patents filed in key countries over the past 10 years shows a slight downward trend.

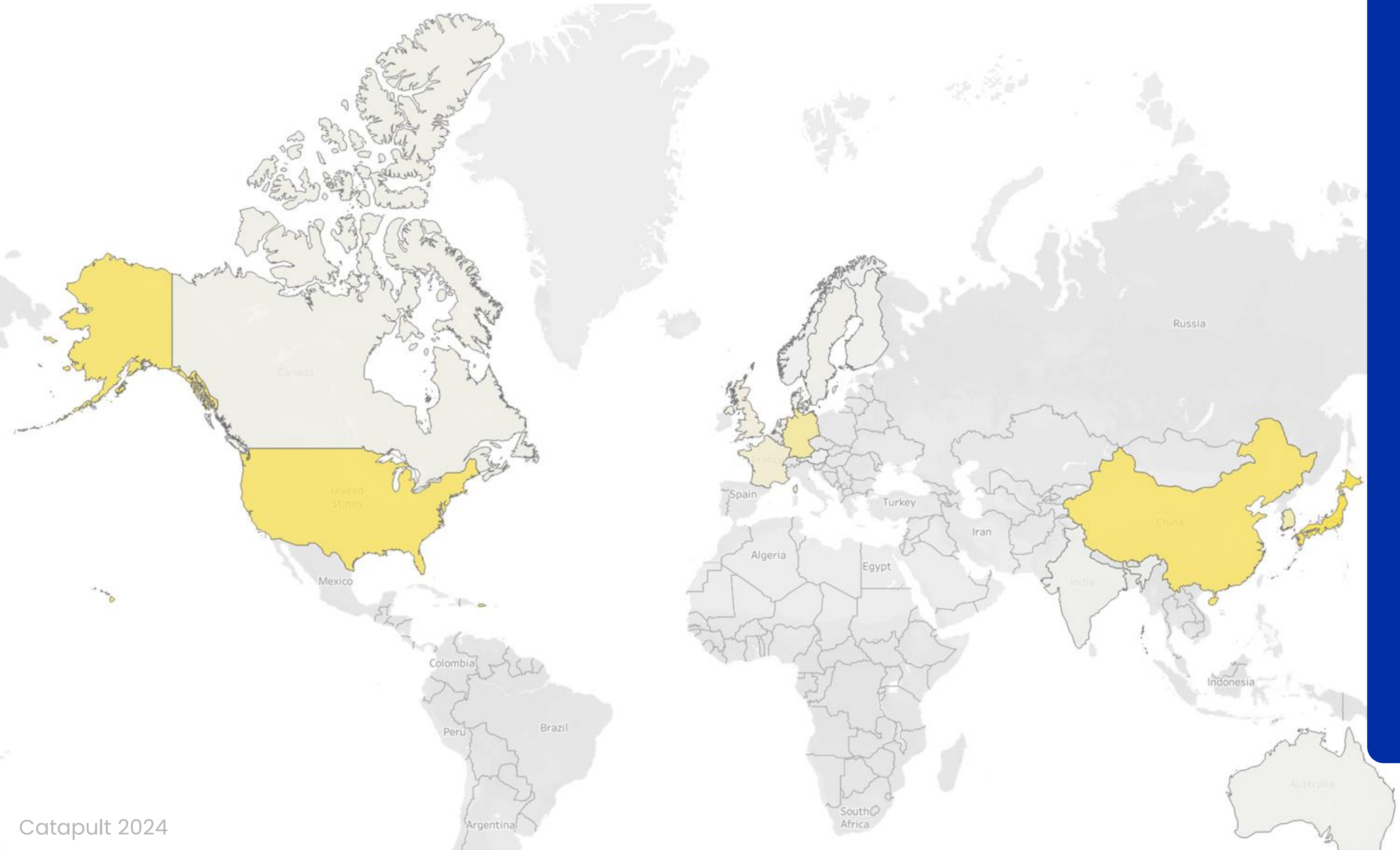
In the beginning of the observed period (2012) the total number of filed applications for patents related to climate technologies stood at 26,444. In 2021 the number of filed patents stood at 22,798.

The list of countries includes: United States, China, Japan, South Korea, Germany, France and United Kingdom.

Source: OECDFinl

Climate Technology Patents

Focusing in 2017-2021



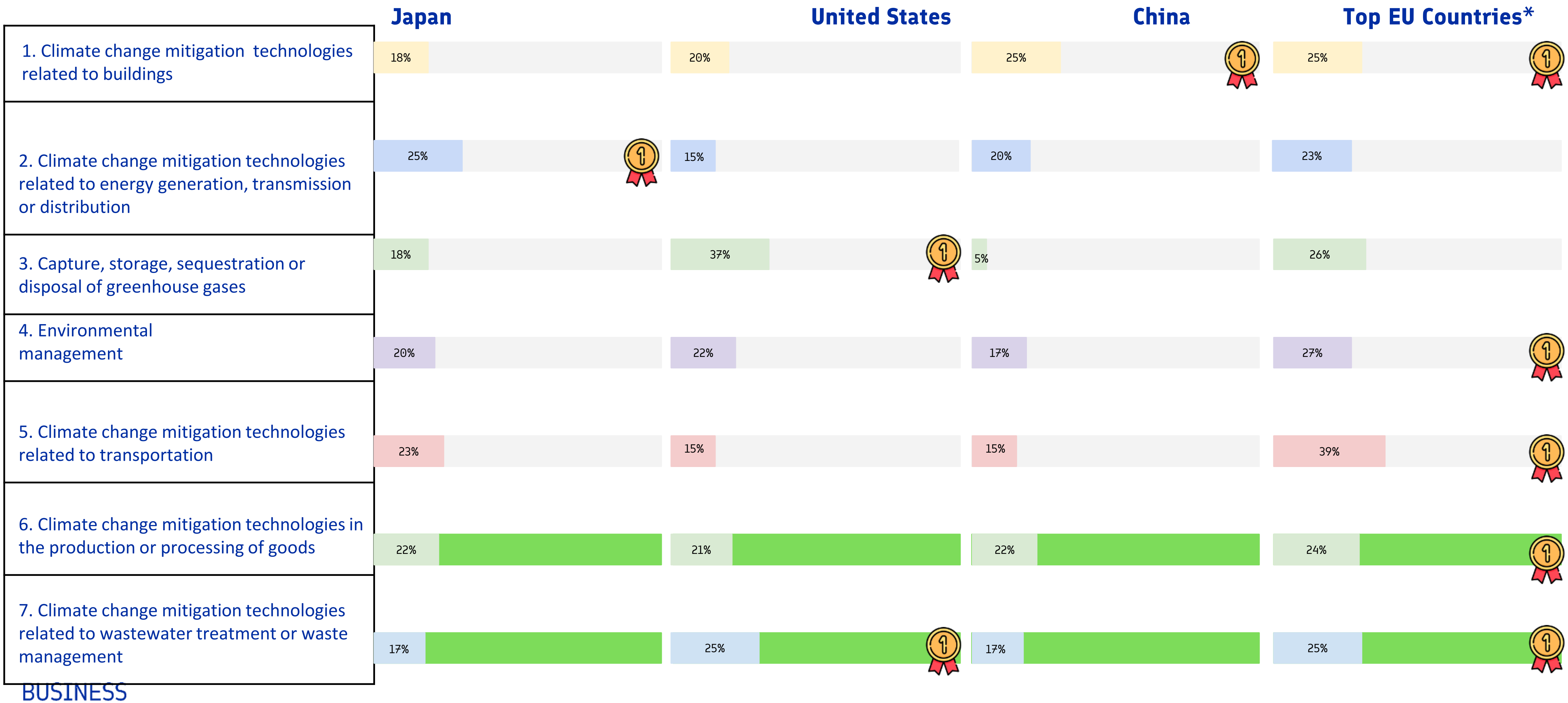
Countries

Japan	30,337
United States	25,042
China	24,640
Germany	15,927
South Korea	13,395
France	6,395
United Kingdom	4,003
Canada	2,315
Denmark	2,036
Netherlands	2,103
Sweden	1,950
India	1,703
Australia	1,454
Austria	1,428
Finland	1,178
Norway	627

Source: OECD

Climate Technology Patents

Patents Breakdown 2017-2021



	Japan	United States	China	Top EU Countries*
1. Climate change mitigation technologies related to buildings	18%	20%	25% 🥇	25% 🥇
2. Climate change mitigation technologies related to energy generation, transmission or distribution	25% 🥇	15%	20%	23%
3. Capture, storage, sequestration or disposal of greenhouse gases	18%	37% 🥇	5%	26%
4. Environmental management	20%	22%	17%	27% 🥇
5. Climate change mitigation technologies related to transportation	23%	15%	15%	39% 🥇
6. Climate change mitigation technologies in the production or processing of goods	22%	21%	22%	24% 🥇
7. Climate change mitigation technologies related to wastewater treatment or waste management	17%	25% 🥇	17%	25% 🥇

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*Top EU Countries include: Germany, France, United Kingdom, Austria, Netherlands, Finland, Denmark. Sweden, and Norway.

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Patent Analysis

A closer look at recent climate technology patent themes and trends

Carbon Capture

In carbon capture patenting, the US leads in application numbers, followed by China, Japan, the EPO, and Germany. Solvent and membrane technologies dominate patents, with the US, China, Korea, and Japan at the forefront of global grants. For more information, see the Global CCS Institute's report.

Hydrogen

In hydrogen technology patents, the EU (28%) and Japan (24%) lead, with the US experiencing a decline.

Germany, France, and the Netherlands spearhead Europe's growing leadership in electrolyser production. Data is based on EPO findings.

Battery and clean energy

Based on EPO data from 2022, electrical machinery, apparatus and energy (+18.2%), a field that includes clean energy inventions and battery technology, grew fastest. In 2023, Asian applicants filed over two-thirds of energy storage patents at the EPO, while EPO member states contributed only 21% to battery-related applications.

Insights

The patent analysis reveals that advanced economies lead in green innovation, while developing nations are significantly behind.

The next wave of climate technology patenting is likely to involve higher ERP and enabling technologies technologies such as carbon capture, smart grids, hydrogen ecosystem or value chain, and fuel cells that can complement readily available clean technologies.

Next up

In the next section we'll take a look at the three technology segments identified from the data and look at what themes, technologies, and geographic areas are trending within each of the segments.

Based on the discussions on these initial observations, we'll target the research into more concrete emerging technologies for the final research delivery.

Market Segmentation

Introduction

1. Energy

Focus on energy management and storage, clean energy sources and electrification.

2. Carbon

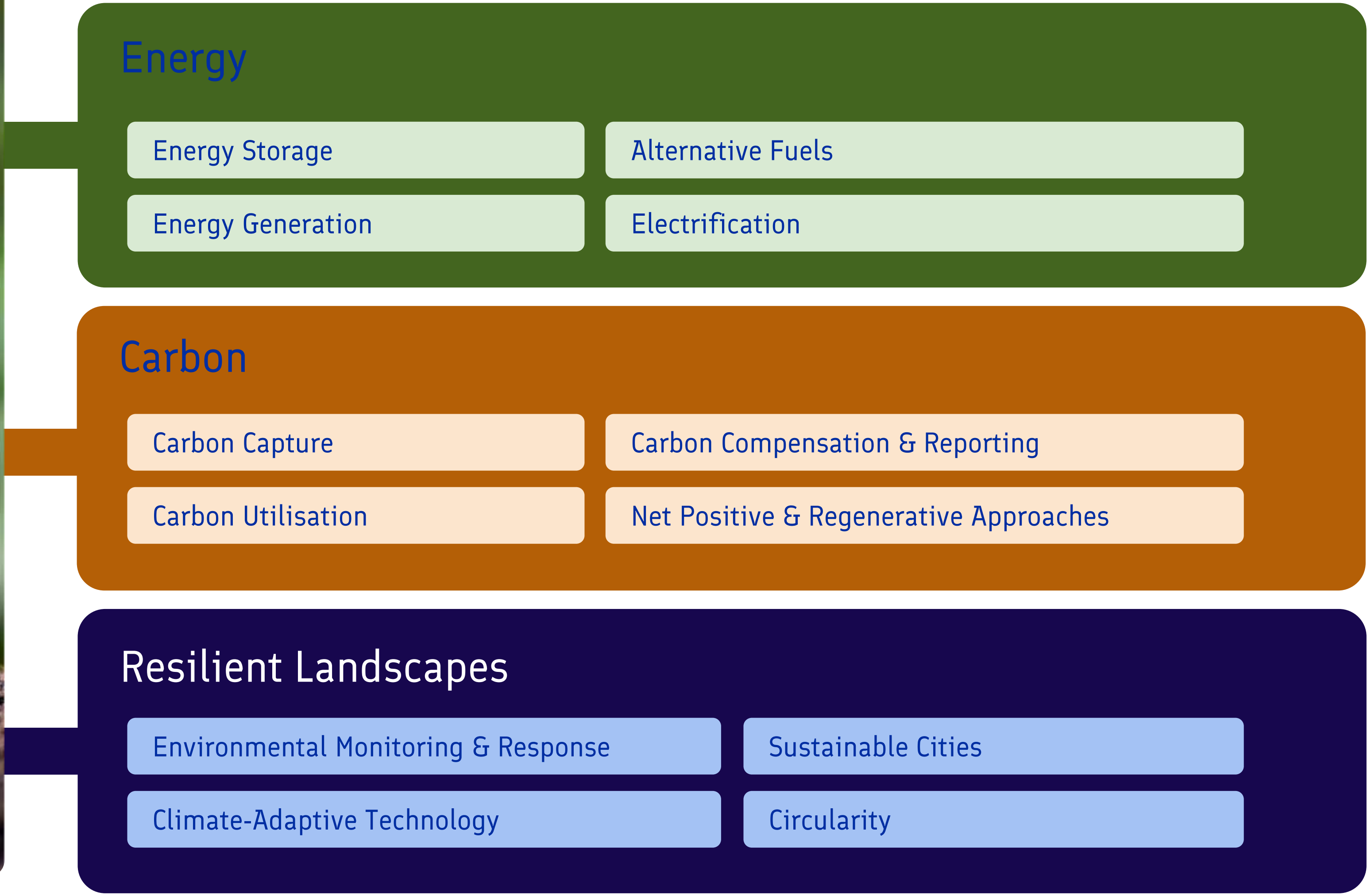
Focus on opportunities enabled by carbon technologies and software solutions.

3. Resilient Landscapes

Focus on creating secure, responsive and adaptable environments.

Emerging Climate Tech Snapshot

Themes and technologies that stand out



Energy

- Energy Storage
- Alternative Fuels
- Energy Generation
- Electrification

Carbon

- Carbon Capture
- Carbon Compensation & Reporting
- Carbon Utilisation
- Net Positive & Regenerative Approaches

Resilient Landscapes

- Environmental Monitoring & Response
- Sustainable Cities
- Climate-Adaptive Technology
- Circularity

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Energy

Introduction

DETECTED THEMES

This segment highlights solutions targeting the decarbonisation of the energy sector. Technologies focus on reducing global dependence on fossil fuels by innovating alternative energy sources and storages. Major theme influencing the speed of the energy transition is digitalisation and developments enabled by it, especially in energy management and optimisation.

The early findings linked with energy have been divided into the following categories:

- Energy Generation
- Energy Storage
- Alternative Fuels
- Electrification

Energy Generation

A look at recent developments

Observations

In the aftermath of COP28's call to phase out fossil fuels, the energy generation industry is expecting an increased growth of solar and wind capacity creating both energy independence but also hardware dependencies. Innovative developments in geothermal, nuclear and hydrogen are expected to further expedite this transition. Challenges can be anticipated to rise from permitting and supply chain issues.

Geographic focus

Development activities appear to be most active in China, U.S., Japan, and European countries including UK, Germany and France.

Technologies

- Concentrated solar power
- Advanced SMRs
- Energy harvesting
- Fuel cells
- Airborne wind energy
- Renewable energy optimisation

Energy Storage

A look at recent developments

Observations

The increase in renewable energy utilisation drives the production of long-duration energy storage. Simultaneously, the ever-growing EV infrastructure requires also short-term solutions. While the current focus lies on enhancing energy consumption capacities to secure stable power system operations, the focus in the near future appears to be on the development of portable energy storage. Also, research into improving battery performance and lifespan by finding alternatives to lithium batteries is gaining attention.

Geographic focus

Research indicates the majority of developments taking place in the U.S., China, and the UK.

Technologies

- Alternative battery materials
- Alternative storages
- Hydrogen storage
- Distributed energy storage
- Solid-state batteries
- Second life batteries

Alternative Fuels

A look at recent developments

Observations

Development of clean, alternative fuels has been on the development map for relatively long but challenges in scalability and high production costs have hindered large-scale adoption. Green hydrogen-based fuels represent one of the leading alternatives while other more recent developments in low-carbon hydrocarbon fuels such as biofuels and synthetics fuels are also emerging as viable options. Benefits of these include drop-in replacements without major hardware modifications.

Geographic focus

Much of the developments in alternatives are taking place in North America, Brazil, and Asian countries including China and India.

Technologies

- Green methanol
- Biofuels
- Green hydrogen
- Waste to fuel
- Synthetic fuels
- Air to fuel

Electrification

A look at recent developments

Observations

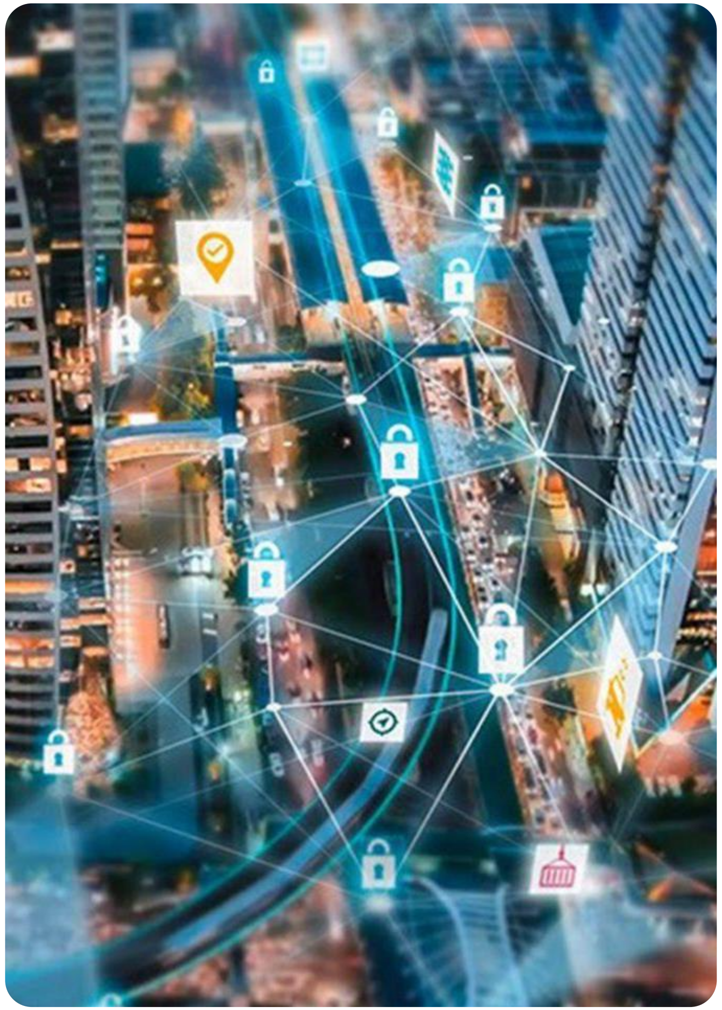
Demand for clean electricity is set to grow significantly with major sectors such as transportation, building, and industrial segments undergoing rapid electrification. The ongoing “electrification of everything” is further driven by developments in energy management and optimisation supported by AI and smart grids. Along with digitalisation, decentralisation is a key theme under electrification.

Geographic focus

Innovation activities are particularly active in UK and Germany as well as the U.S.

Technologies

- Smart Grid
- VPP
- V2X
- AI & Blockchain
- Contactless charging
- Fleet management



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Carbon

Introduction

DETECTED THEMES

This segment consists of technologies and pathways to remove, store and/or utilisation carbon emissions from industrial processes or the environment.

The findings linked with carbon emissions have been divided into the following categories:

- Carbon Capture
- Carbon Utilisation
- Carbon Compensation & Reporting
- Net Positive & Regenerative Approaches

Carbon Capture

A look at recent developments

Observations

The buzz around the carbon capture at COP28 climate talks has brought renewed focus to carbon capture strategies. CCS faces challenges in terms of cost, scalability, and achieving complete carbon capture efficiency. Many are now promoting innovative carbon sequestration technologies, focusing on enhancing nature's carbon-absorbing capacity or nature-based capture approaches e.g. restorative agriculture, soil and plant enhancement.

Geographic focus

USA, Japan, China and the EU are leading with the development of capture technologies.

Technologies

- Direct air capture
- Modularisation
- Biochar / bio-CCS
- Membrane
- Microbial carbon capture
- Cryogenic
- Solid sorbents /MOF
- Photochemical

Carbon Utilisation

A look at recent developments

Observations

Overall progress in development is gradual but accelerating, hinging on joint advancements in cross-cutting technologies including transport or storage. While CO2 use offers climate and economic benefits, its small market size makes dedicated storage a key focus in carbon strategies. There is increased policy and support for research and development for scalable, competitive CO2-based products and services, with a primary focus on reducing energy required for converting CO2 into fuels and chemicals.

Geographic focus

The US and UK are increasing funding for CCU projects, while the EU sets a Co2 storage goal to encourage investment in the sector.

Technologies

- Electrocatalytic
- Mineralisation
- Biotechnology
- Photochemical
- Catalytic conversation
- Electrolysis & plasmolysis

Carbon Compensation and Reporting

A look at recent developments

Observations

Facing a credibility crisis, the carbon offset industry is turning to emerging technologies for a solution. Innovations like high-resolution imagery, AI, machine learning, and blockchain are being deployed to improve the accuracy and transparency of measurement, reporting, and verification. Software providers have developed more sophisticated LCA and carbon accounting platforms featuring automation and the complete digitalisation of the reporting process.

Geographic focus

A lot of the private sector technology development is coming out of North America and the EU.

Technologies

- LCA /dMRV
- Imagery-based indicators
- Blockchain
- Data ecosystems
- AI/ML
- Advanced sensors

Net Positive & Regenerative Approaches

A look at recent developments

Observations

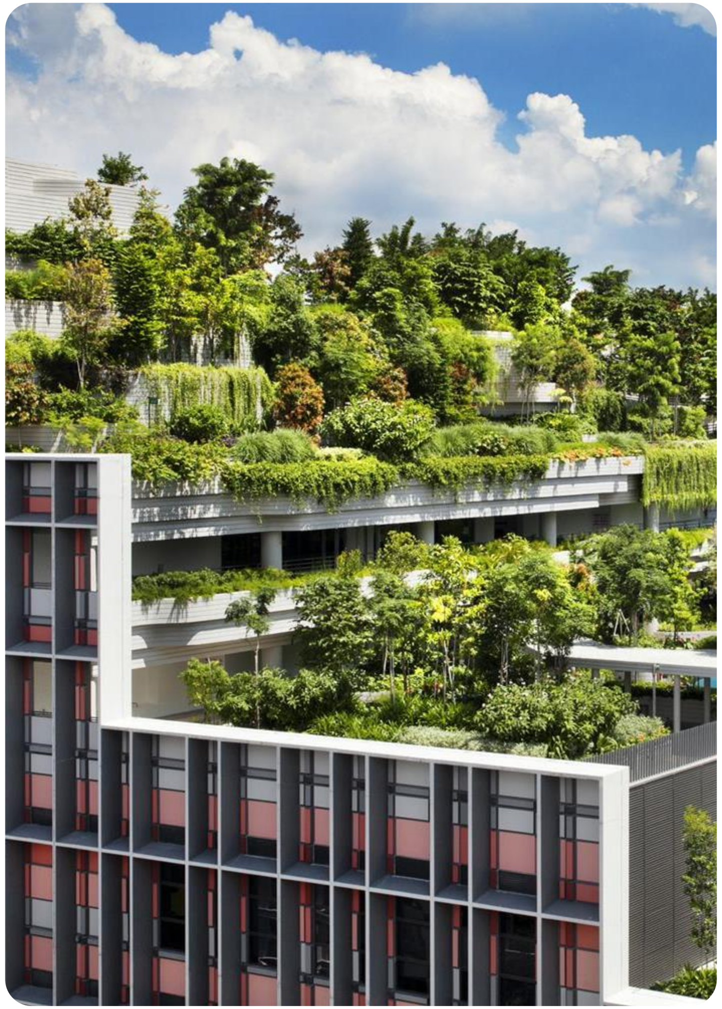
As the general discussion has been shifting from carbon neutrality to more ambitious strategies, the terms net positivity, regenerative approaches and carbon handprint have started to take the limelight. So far the main focus has been on theories and frameworks for regenerative and net positive practices, and a lot of emphasis has been placed on the agricultural sector. However, new innovations are being developed for industries and the built environment.

Geographic focus

Europe is a thought leader for net positive and regenerative practices, offering emerging also in North America.

Technologies

- Waste-based raw materials
- Regenerative buildings
- Regenerative fibres
- Quantification & monitoring
- Data sharing
- Supply chain management



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Resilient Landscapes

Introduction

DETECTED THEMES

This segment consists of technologies that aim to create and conserve secure, responsive and adaptable environments in the era of climate change and extreme weather. Optimised built environments and mobility, availability of critical resources, circularity and self- sustaining buildings are core themes in this segment.

The early findings have been divided into the following categories:

- Environmental Monitoring & Response
- Climate-Adaptive Technology
- Sustainable Cities
- Circularity

Environmental Monitoring and Response

A look at recent developments

Observations

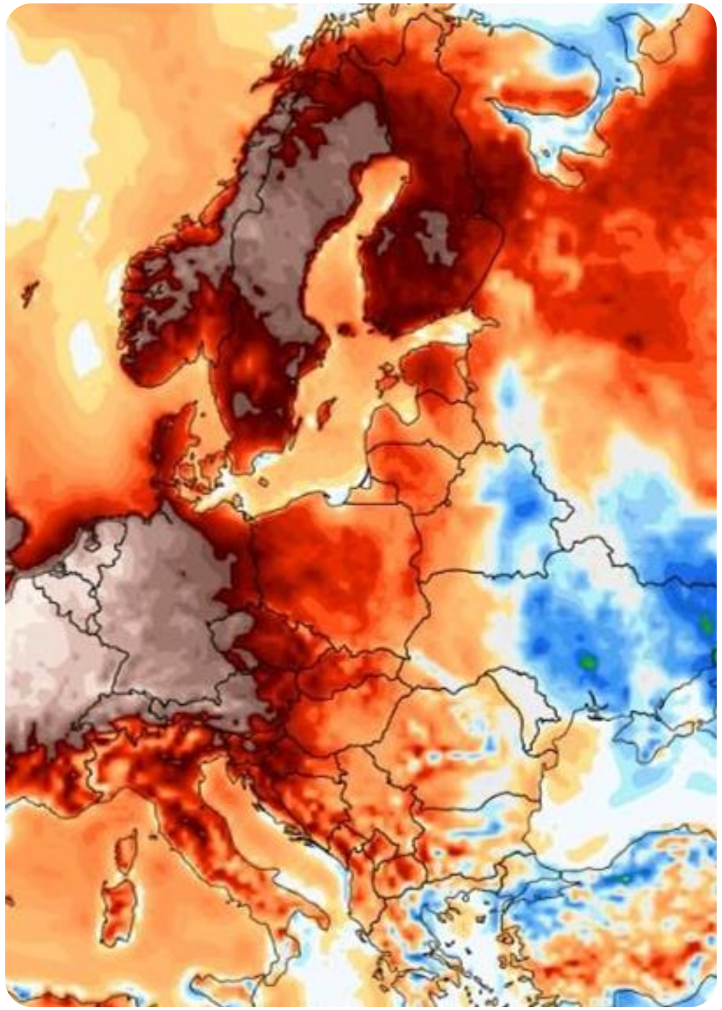
Advancements in IoT technology and remote sensing, including space satellite technologies and drones, have opened a range of opportunities from real-time emission data capture to grid surveillance and illegal logging detection. Paired with advanced AI algorithms and ML the data can be utilised in predictive analytics and climate modeling. In addition, disruptive solutions altering or reversing climate conditions are under development and gaining increasing attention.

Geographic focus

Early research indicates that majority of environmental monitoring technology developments is taking place in the U.S.

Technologies

- Geo-engineering
- AI-based climate change modeling
- Remote sensing
- Data ecosystems
- Satellite data and imaging
- Climate risk modeling



Climate-Adaptive Technologies

A look at recent developments

Observations

With the advancing climate change, societies are faced with more adverse weather patterns that put existing infrastructures under pressure. Adaptive technologies try to mitigate the effects of draughts, floods and extreme storms and ensure resource security even under the new conditions, while even driving benefits from phenomena such as extreme heat.

Geographic focus

Data shows offering mainly from United States, China, Japan, South Korea and the EU with activity also in India and Singapore.

Technologies

- Desalination tech
- Biomimicry
- Flood & drought resistant materials
- Vertical farming
- Water capture & treatment
- Heat capture

Sustainable Cities

A look at recent developments

Observations

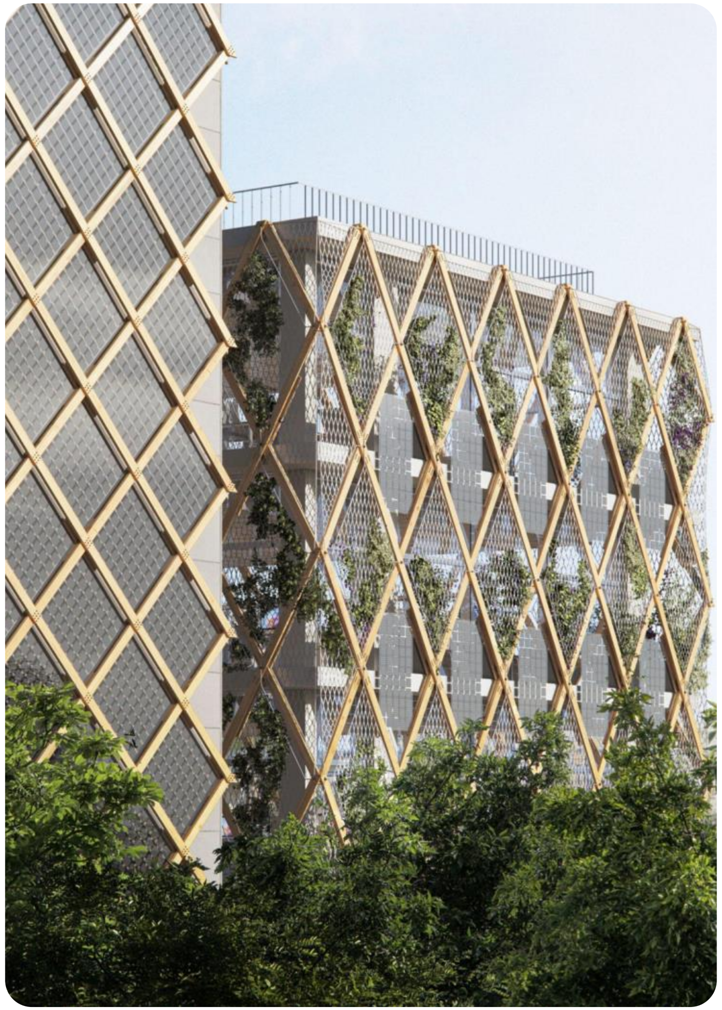
Developments in advanced connectivity technologies including 5G, IoT and AI are emerging as key components in climate resilient urban planning. Additionally, nature-based solutions and intelligent infrastructure including smart buildings and mobility, are expected to play an increasing role in climate change response. Currently smart cities are at the forefront of adapting and responding to climate change induced hazards.

Geographic focus

Majority of developments appear to be made in China, Japan and South Korea, followed by Germany and the U.S.

Technologies

- IoT & AI
- Green roofs
- Electrochromic windows
- V2B
- CO2 absorbing infrastructure
- Self-sustaining energy



Circularity

A look at recent developments

Observations

The data shows that circularity is most visible in industrial settings where production side streams are being utilised in new applications. In addition to converting waste to energy and fuels, circular materials are being used increasingly in 3D printing. More attention is put on end-of-life services that feed raw materials to the value chain, and especially battery recycling is trending to decrease dependency in China to source critical raw materials.

Geographic focus

EU countries and Japan are leading the way in circular economy.

Technologies

- Process optimisation
- Battery recycling
- Alternative materials
- Closed-loop water systems
- Membrane technology
- End-of-life service concepts

Part 3

Emerging Climate Technology

Emerging Climate Technology

The themes, topics and prioritised areas

Energy

- Power-to-X and conversation pathways
- Active role of buildings in the energy systems
- Decentralised energy production and flexible energy systems

Carbon

- Carbon utilisation
- Data-driven emissions compensation and reporting

Resilient Landscapes

- Climate-adaptive technology
- Circularity & regenerative technologies
- Alternative materials specifically related to e-waste/EV batteries

Regenerative Climate Technologies

The transition from sustainable to regenerative approaches

Regenerative agriculture

The primary focus is on regenerative agriculture, which aims to improve soil health, biodiversity, and restore degraded land.

Environmentally, regenerative agriculture helps limit deforestation and grassland conversion by making existing farmland more productive and restoring unproductive lands. Companies like Seqana are supporting the transition to regenerative agriculture.

Some supporting technologies include:

- Automation
- SynBio
- Soil monitoring & measuring
- Robotics

Regenerative carbon capture

Emerging

Regenerative approaches to carbon capture are emerging that go beyond reversing the negative, and directly provide value to ecosystems.

Restoring pre-industrial systems, like the carbon cycle, is crucial. Nature-based solutions can efficiently and affordably remove carbon, enhancing permanence.

Regenerative materials

Emerging

Regenerative materials seem to be gaining increasing attention in multiple industries from textiles and leather to industrial pigments and alternative building materials. One such example is Green Charcoal , a brick that allows plants and insects to thrive on its surface.

In addition to the end products, also production processes are cultivated to adhere to regenerative principles. As an example Interface's Factory as a Forest concept utilises biomimicry in designing the production facilities as forest ecosystems.

Soil Carbon Sequestration

Harnessing carbon dioxide and boosting agricultural production

Microbial Carbon Storage

Emerging microbial biotechnologies for cropping systems can enhance drought resilience, boost productivity, and sequester carbon by enhancing plants' natural carbon storage in soil.

One example of a recent development is CarbonBuilder, a microbial seed inoculum designed to enhance carbon sequestration in agricultural soils. The technology enhances carbon accumulation in soil structures known as micro-aggregates, leading to increased long-term CO2 storage.

Tech dependencies

Technology is commercially available but needs to be adjusted per seed making growth slow. Challenges may also arise from regulation.

Active players

- Loam Bio
- Rhizocore
- Groundwork BioAg

Impact

Building soil carbon brings productivity and climate resilience benefits to farmers and can reduce the amount of nitrogenous fertiliser used in agricultural production, further reducing emissions.

Stage

○ Vision ○ Research & validation ○ Commercialisation ● Concept Building

Power-to-X and Conversion Pathways

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Power-to-X

Integrating renewables and supporting decarbonisation

P2X

The increased introduction of renewable energy and their nature of intermittency has pushed for new developments in the conversion of energy.

Such technologies are improving the uptake of RES and are expected to play a key role in the decarbonization of several industries.

Here we have looked beyond the production and storage of hydrogen and electrolysis, and have identified the following as key developments in the power-to-x scene:

- Power-to-ammonia
- Power-to-methanol
- Power-to-gas

Power-to-Ammonia

Green Ammonia

Water, air & electricity

Green ammonia is becoming an attractive solution compared to hydrogen because of its higher volumetric energy density, making it easier to store and transport. Since ammonia can also be split back to hydrogen and nitrogen after being transported, green ammonia serves as a very good hydrogen and energy carrier. Ammonia is already well traded around the world creating a very good case for green ammonia.

Tech dependencies
Water electrolysis, re-configured and electrified Haber-Bosch process.

Active players

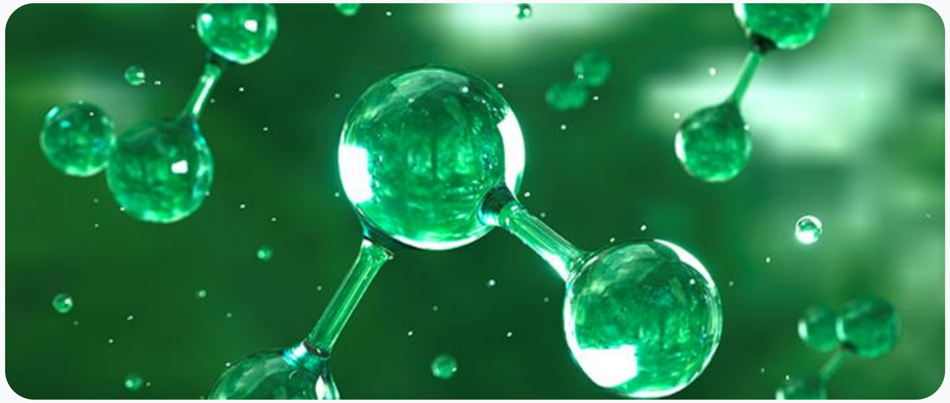
- University of Oxford
- Oxford Green Ammonia Technology
- Ammonia Energy Association
- Thyssenkrupp
- Siemens Energy
- Nel Hydrogen
- Høst

Impact

Green ammonia presents a great potential in decarbonizing the agricultural sector and the shipping industry as it has a mere 10 % carbon footprint of conventional ammonia.

Stage

○ Vision ○ Research & concept ● Validation ○ Commercialisation



Green Ammonia

A closer look at the methods for green ammonia synthesis

Haber-Bosch with green hydrogen

This common method modifies the Haber-Bosch process by replacing grey hydrogen (from fossil fuels) with green hydrogen (from water electrolysis using renewable energy).

Its full viability hinges on green hydrogen's availability and cost, affected by water electrolysis efficiency and renewable energy prices.

Emerging players have refined the Haber-Bosch process to work under milder conditions, significantly reducing engineering risks and simplifying the scale-up for industrial applications.

Active players

- Liquium
- PlasmaLeap

Direct electrolysis & photocatalytic

Direct electrolysis approach seeks to create green ammonia from water and nitrogen, eliminating hydrogen production. However, direct electrolysis struggles with slow ammonia production and high energy needs due to nitrogen's strong triple bond.

Photocatalysis uses solar energy and semiconductors to catalyse ammonia and oxygen production, but faces low conversion efficiencies and challenges in light use and catalyst effectiveness.

Stage

○ Vision
● Research & Concept Building
○ Validation
○ Commercialisation

Power-to-Methanol

e-Methanol

Catalyst technologies

Decarbonising the production of methanol, which is widely used in chemical, construction and plastics industries, by synthesising hydrogen and carbon dioxide.

Research is focusing on advancing catalyst technologies, so that the price of producing methanol decreases. Examples of that are Synspire, a new catalyst developed by BASF, or the latest generation of MegaMax by Clariant.

Tech dependencies

Carbon capture technologies
Water electrolysis
Materials innovation

Active players

- Methanol Institute
- BASF
- Clariant
- Europe Energy

Impact

What makes e-methanol an attractive alternative is the fact that it is compatible with existing liquid fuel infrastructure. An alternative fuel cutting down carbon emissions by 95%. Besides being an alternative fuel (specifically shipping industry), e-methanol finds applications also in paints, carpeting, and plastics.

Stage

○ Vision ○ Research & Concept Building ○ Validation ● Commercialisation

Power-to-Gas

Microbiological Methanation

Microbia

Microbiological methanation is the process of capturing CO2 from various sources, mixing it with water in a bioelectric chemical reactor, where micro-organism obtain the hydrogen, dissolve CO2 and produce methane.

There are several pilot projects taking place, especially at steel plants where the emission of CO2 is very intense, so that the process will be as efficient as possible.

Tech dependencies

Carbon capture technologies and water electrolysis.

Active players

- E-fuels Tech
- Q-Power
- European Biogas Association
- Wageningen University and Research

Impact

92% reduction of CO2 emission compared to fossil fuel, easier transportation even in cases of long distance. It has the potential to become a source for heating homes, powering different industries, trucks or even personal vehicles.

Stage

○ Vision — ○ Research & Concept Building — ● Validation — ○ Commercialisation

Conversion Pathways

Sustainable conversion technologies

Conversion

Multiple technologies are emerging that utilise various inputs and convert those into alternative fuels or products. The research on alternative fuels is focused on moving away from food related products as they have a negative impact on the environment and the food supply chain. Hence, woody feedstocks, emissions or waste are being considered as a sustainable solution to obtain alternative fuels and products.

More specifically we have chosen to highlight the following emerging technologies:

- Woody biomass to Ethanol
- Emissions-to-syngas
- Waste-to-products

Biomass-Based Fuels

Woody biomass to ethanol

Woody biomass to Ethanol

Innovation in biofuels is geared towards finding solutions that are non-food based and a promising feedstock is woody biomass. Recently, Berkeley Lab successfully used non-toxic chemicals, commercially available enzymes, and a specially engineered strain of yeast to convert wood into ethanol in a single reactor.

Tech dependencies

Work is underway to launch a pilot project that would convert one ton of biomass per day to ethanol. Berkeley Lab is cooperating with Aemetis, a renewable fuels company, to commercialise the technology.

Active players

- Berkeley Lab
- Aemetis
- VTT
- SINTEF

Impact

The new method claims to reduce costs in production of biofuels and its wider adoption will have a direct impact in avoiding wildfires from the overgrown biomass.

Stage

○ Vision ○ Research & Concept Building ● Validation ○ Commercialisation

Synthetic Biology

Biotechnological pathways to turn various waste streams into products

Waste into High-Value Products

Synthetic biology (SynBio), focusing on creating new biological entities and redesigning existing ones, is emerging as a key technology in the creation of chemicals and materials.

Innovative methods are underway, such as using waste methane and oceanic microbes to produce biopolymers, replacing plastics and curbing greenhouse gases. Another approach is gas fermentation, converting industrial waste into sustainable chemicals like aviation fuel and ethanol.

Tech dependencies

Safety and environmental concerns, AI/ML, gene-editing technology like CRISPr to make these organisms more efficient, as well as cost optimisation and policy challenges.

Active players

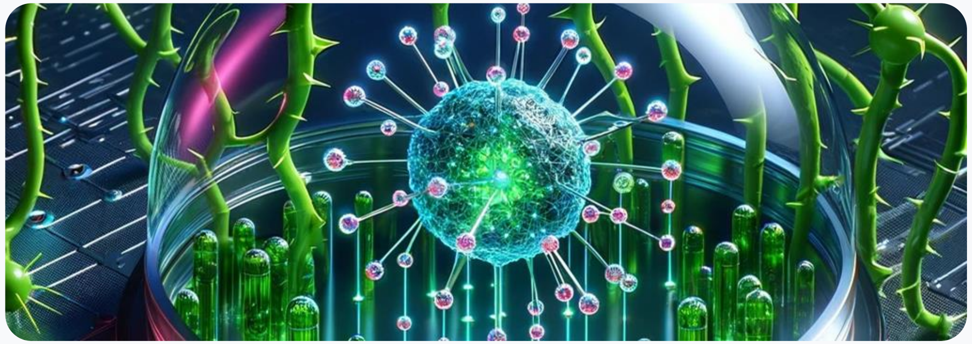
- Newlight
- LanzaTech
- SynBioBlox

Impact

Enhancing natural carbon capture and utilisation processes offers more sustainable alternatives to traditional practices: contributes to circular carbon economy, higher yields, renewable characteristics, and may even have reduced environmental impact.

Stage

- ○ Vision
- ○ Research & Concept Building
- ○ Validation
- ● Commercialisation



Plasma Carbon Conversion

Turning CO2 and CH4 into syngas and hydrogen

Emissions to syngas

The plasma carbon conversion transforms CO2 and methane (CH4) into hydrogen and syngas, which are further used in products such as chemicals, fuels, and energy.

A novel technology which has gained attention for being an energy efficient method to capture and utilise carbon emissions. It leverages floating microwave plasma technology to break the bonds of greenhouse gases to make clean fuels and products.

Tech dependencies

The efficiency and sustainability of plasma-based conversion heavily depends on the source of electrical energy used to generate plasma.

Active players

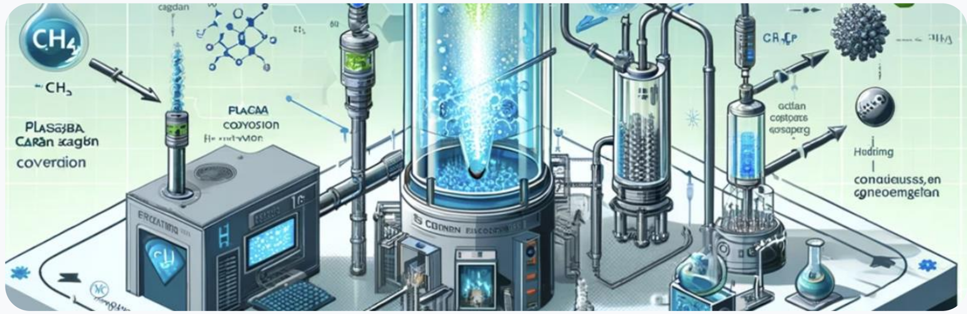
Recarbon Inc.

Impact

Plasma carbon conversion can contribute to the development of a circular carbon economy, where two of the world’s most harmful greenhouse gases
are captured and converted into hydrogen and synthetic gas, creating value from waste. The technology is expected to help decarbonize industries such as steel, chemicals, and cement.

Stage

○ Vision
○ Research & Concept Building
○ Validation
● Commercialisation



Built Environment and Energy

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Built Environment and Energy

Creating flexible energy infrastructures

Active role of infrastructure

The nexus between the built environment and the energy market is undergoing transformative changes characterised by decentralized energy systems coupled with advancements in energy storage and smart grid.

Technologies are emerging that promise a future where buildings not only consume less energy but can also produce and manage it.

These developments drive innovation in this field:

- Distributed Energy Resources / VPPs
- Radiative cooling
- Alternative energy harvesting
- Built materials as an energy source or storage

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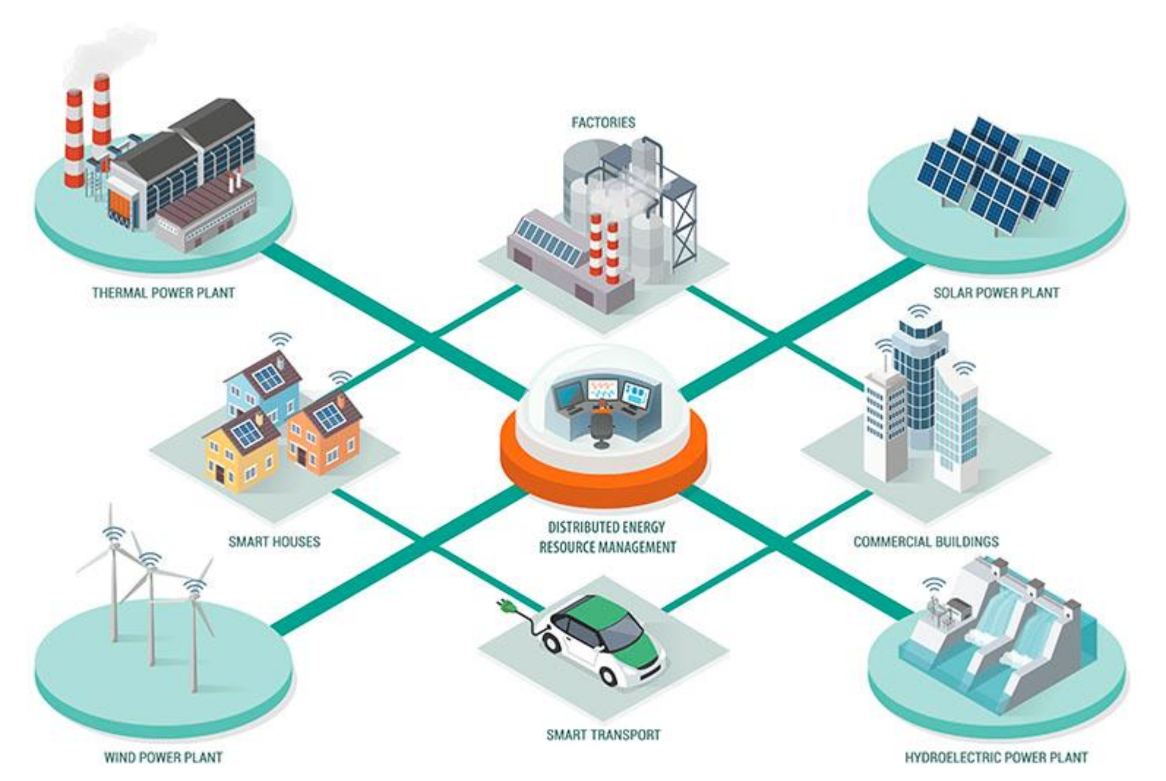
Distributed Energy Resources

Decentralising Power Generation



Revolutionising the Energy Landscape

Major developments are taking place in boosting local energy production at residential and commercial level towards increasing consumers' independence and at the same time supporting grid management. Introduction of DERs is transforming how energy is produced, traded, distributed and consumed.

Some of the key developments in this field include:

- Smart meters
- Peer-to-peer trading
- Integration & control
- Residential energy storage
- Grid modernization
- Microgrids
- Local flexibility markets
- Demand response
- Virtual power plants
- Energy analytics

Distributed Energy Resources

Virtual Power Plants

Cloud-software Solution

Virtual Power Plants are software solutions that orchestrate energy technologies and optimise operations by using AI & ML. They enable integration and management of distributed energy generation, storage, EVs, and heat pumps - regardless of the location of the resources.

For example, Sonnen is deploying thousands of residential batteries and utilising those as a source of flexibility through their VPP software.

Tech dependencies

Smart metres
IoT - smart devices
AI and ML models

Active players

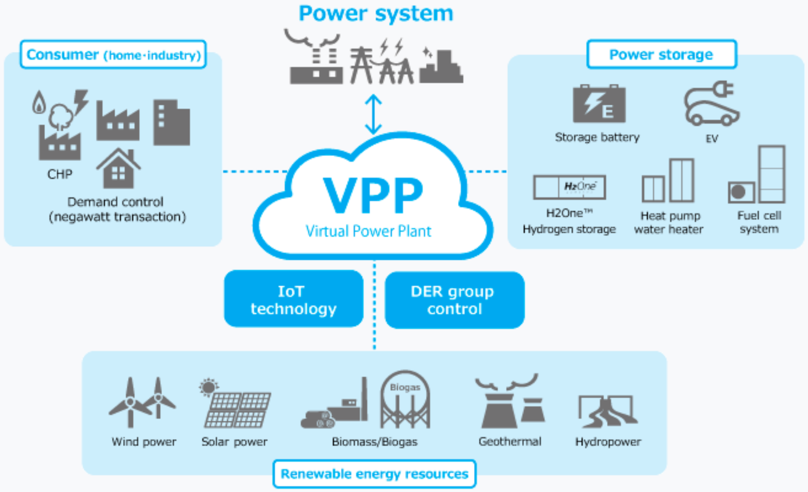
- OhmConnect
- Statkraft
- Next Kraftwerke
- Sonnen

Impact

VPPs have a wide impact in the energy sectors such as capitalising on any size of generation or storage, opening up the market to individual consumers, providing demand flexibility, and optimising operations.

Stage

○ Vision ○ Research & Concept Building ○ Validation ● Commercialisation



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Catapult 2024

Molecular Solar Thermal Energy Storage

Storing energy in the chemical bonds of molecules

MOST

MOST is an innovative technology storing solar based energy in the chemical bonds of molecules. An ongoing EU project has identified molecular photoswitches that can absorb and store solar energy at room temperature. Utilising quantum computing, the researchers were able to analyse a large database (400,000 molecules) to find molecules best suited for MOST. The technology presents a promising way to harness and store solar energy due to its high density and long duration storage (18 years).

Tech dependencies

Molecular systems, catalysts, heat release devices and specialised hybrid solar collectors, which will all be developed as part of the project.

Active players

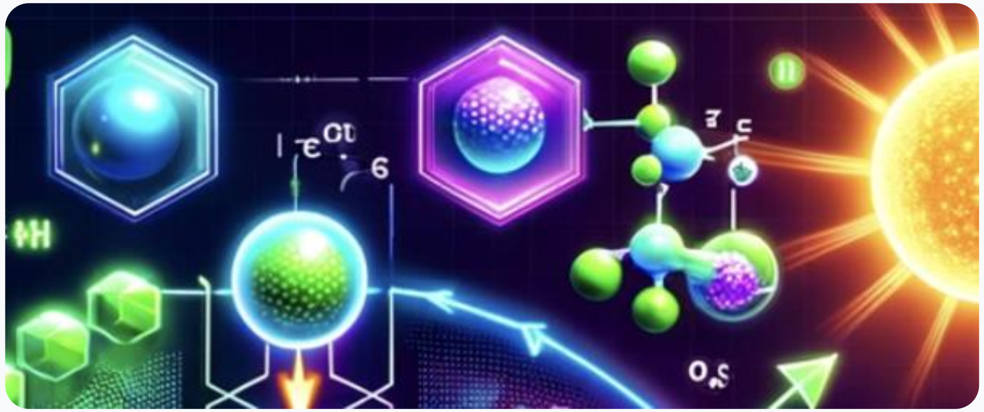
- Technical Uni. of Catalonia
- Uni. of Copenhagen
- MOST EU Project

Impact

A zero-emission solar energy system based on benign, all renewable materials. The first prototype devices have been developed.

Stage

○ Vision — ● Research & Concept Building — ○ Validation — ○ Commercialisation



Carbon-Cement Supercapacitors

Electrified cement

Electrifying Buildings & Infrastructure

MIT engineers have created a promising supercapacitor technology for renewable energy storage. This innovative method uses cement and black carbon, readily available materials that, when combined with water, form a supercapacitor, providing a new energy solution.

The technology could eventually be integrated into structures like building foundations or roads, allowing for energy storage and usage as needed. Tradeoffs between storage capacity and strength have been researched and the material can be altered based on use case needs.

Tech dependencies

The principle has been proven, next steps include increasing the size of the block to validate theoretical assumptions.

Active players

MIT

Impact

Claimed to be easily scalable and if successful could provide an alternative to battery storages. Initial use cases could include isolated houses or buildings far from grid power. Other applications could include roads that can wirelessly charge electric vehicles.

Stage

○ Vision

● Research & Concept Building

○ Validation

○ Commercialisation

Thermal Energy Storage

Waste-heat recycling and net-zero heat and power

Integration of TES into Buildings

A significant area of exploration is the use of common building materials as energy storage solutions, specifically through Thermal Energy Storage (TES) systems. These utilise inexpensive, mineral-based construction materials like bricks, stone, and sand, to store heat and release it over time. One emerging approach is using volcanic rock to store heat, employing water to transfer the stored heat as steam for utility and industrial applications.

This concept is reimagining building systems, transforming them into dual-purpose solutions to support energy capture, with the bonus of heating and cooling capabilities.

Tech dependencies

Industrial process and grid utility integration, dependent on advances in thermal engineering.

Active players

- Rondo Energy
- Brenmiller
- Antora

Impact

Cost-effective alternative to electricity storage, avoiding the issues related to Li-ion batteries and playing a crucial role in achieving a clean energy economy. These TES systems leverage materials readily available in construction, thereby presenting a viable and scalable solution to energy storage and use.

Stage

○ Vision
○ Research & Concept Building
○ Validation
● Commercialisation

Eco-Active Building Envelopes

Passive cooling mechanisms for buildings

Radiating heat into space

Developers of passive cooling and heating systems are tapping into the concept of radiative cooling. Innovations are evolving around coatings that can be directly applied to building walls, panels or vehicles. The reflective technologies integrated into surfaces emit longwave infrared radiation back into space preventing the building from absorbing the heat.

One promising technology is cooling glass, a microporous glass coating reflecting 99% of solar radiation back to space. Possible to apply to multiple surfaces including bricks, tiles and metal.

Because multiple new innovations arise within this theme, challenges appear to arise in understanding and comparing the actual cooling effects.

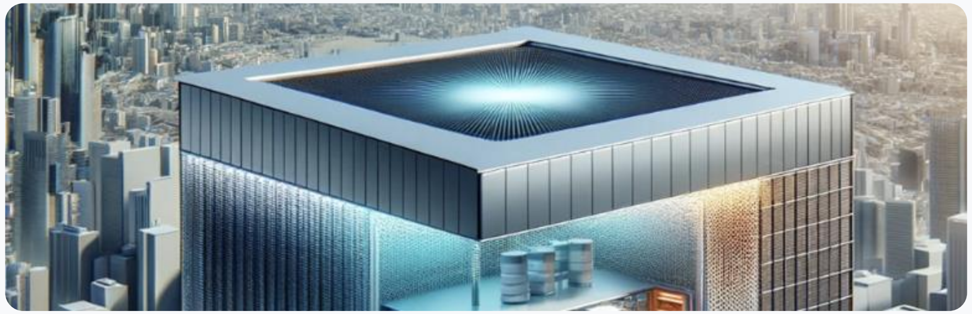
Active players

- University of Maryland
- SkyCool Systems

Impact

These coating technologies have the potential to reduce carbon emissions by offering a way to provide electricity-free cooling. They can positively contribute to mitigating urban heat island effects by providing passive cooling.

Stage



Alternative Energy Harvesting

Mechanical energy harvesting from rain

Triboelectric Nanogenerator (TENG)

Rain panels capture electrical power from falling rain, utilizing a new "bridge array generators" design to enhance efficiency by overcoming previous technical constraints. This innovation significantly boosts power output, positioning rain panels as a feasible renewable energy source alongside or as an alternative to solar panels.

The technology shows promise for widespread raindrop energy harvesting, potentially transforming renewable energy landscapes.

Tech dependencies

Not tested at scale. Future integrations into energy systems.

Active players

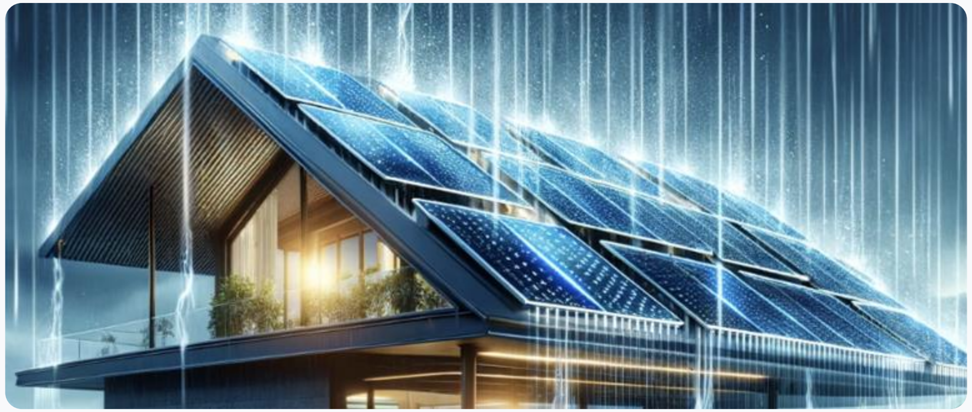
Tsinghua University

Impact

Substitute and complement solar panels. Potential to be integrated into buildings, enabling energy production also in cloudy or rainy conditions.

Stage

○ Vision
● Research & Concept Building
○ Validation
○ Commercialisation



Alternative Materials and Processes

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Reducing Dependencies

Emerging technologies and approaches for battery materials and processes

Expanding alternatives

As the demand for critical raw minerals escalates concern arises over their finite supply and reliance on a handful of nations for procurement.

Consequently, recent innovations have focused on confronting this issue by pioneering alternative material development and spearheading the advancement of low-carbon recycling methodologies. Research suggests that particularly alternatives to REE are developed in the U.S., South Korea, and Japan.

Some technologies and developments include:

- Iron-nitride magnets
- Aqueous rechargeable batteries
- Microbial battery recycling

Alternative Battery Materials

What is the current status of alternative battery materials and chemistries?

Overall status

A lot of early research is underway for high-performance substitutes to rare earth elements (REE) used in batteries. Northeastern University engineers have patented a method to produce an alternative to rare earth magnets using tetrataenite, a mineral from meteorites, aiming to mitigate the global rare earth crisis and lessen reliance on China.

Japanese companies are leading the charge, enhancing their development of alternative technologies to reduce dependence on rare earths. Some alternatives being developed:

Iron-nickel

Iron nitride

Samarium-iron isotropic

Iron-nickel superlattice magnet in the spotlight

Emerging

Denso, a top global automotive parts manufacturer, has developed an alternative magnet called the "iron-nickel superlattice magnet." Made solely from iron and nickel, it matches or exceeds the performance of neodymium magnets. Denso aims to commercialize this innovative magnet in the near future.

Sustainable mining methods

Emerging

Biomining is also emerging as a promising green technology that could revolutionise the way we recover rare earth elements. The traditional process of extracting these elements is energy-intensive and environmentally damaging, involving high temperatures and harsh chemicals.

Researchers in the US have engineered bacterial strains that can biosorb up to 210% more rare earth elements, suggesting a potential to replace solvent extraction methods with a more environmentally friendly process.

Iron Nitride Magnets

Replacing rare earth elements

Industrial Permanent Magnets

The need to find alternatives to REE magnets is growing at a rapid pace. Companies are piloting on REE-free possibilities to replace the need for REE’s such as neodymium, praseodymium and dysprosium.

One promising option is seen in iron nitride magnets, currently in scale-up piloting phase. The technology utilizes nanomaterial engineering and mature metallurgical methods to produce high-strength, rare earth-free permanent magnets.

Tech dependencies

Large car manufacturers have pledged to move to REE-free magnets, making the industry attractive. Challenges may rise in funding industrial scale production facilities.

Active players

Niron Magnetics

Proterial

Impact

Reducing supply chain depencies on rare earth elements by replacing previous critical minerals with more available elements.

Stage

○ Vision
○ Research & Concept Building
○ Validation
● Commercialisation

Aqueous Rechargeable Batteries

An alternative to lithium-ion batteries

Zinc-ion batteries

Aqueous batteries have long shown promise as a viable alternative to lithium-ion batteries, but safety concerns have hindered their commercial success. Recently breakthroughs have been made in both the safety and durability of AZBs positioning them as a strong competitor in energy storage to conventional lithium-ion batteries.

Tech dependencies
While commercialisation and scaling of zinc-ion batteries is taking place, research into their characteristic and further enhancements of their energy capacity continue.

Active players

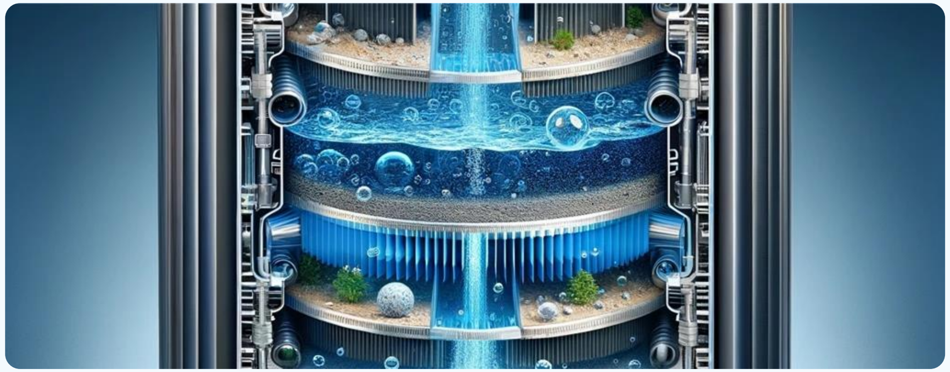
- KIST Energy Storage Research Center
- Salient Energy Inc.
- University of South Wales
- Enerpoly

Impact

Due to the materials used in AZB’s, they are less expensive, safer, and regarded as more environmentally friendly than lithium-ion batteries. Impact on the advancement of electrification seem promising.

Stage

○ Vision
○ Research & Concept Building
○ Validation
● Commercialisation



Microbial Battery Recycling

Biotechnology’s role in recycling e-waste

Engineered bacteria

Biotechnology has emerged as a viable, low-emission alternative for recycling precious metals from electronic waste and other waste streams, most recently from EV lithium-ion batteries. Newly tested engineered bacteria has been created to simulate natural reaction of fermentation that enables the break down of EV batteries into nano-sized metallic compounds of precious metals.

Tech dependencies

While microbial e-waste recycling is piloted by some companies, innovation is yet to find scalable business models. For each project, specific microbiomes need to be identified. If commercially viable could present a step towards more sustainable, low-emission battery recycling.

Active players

- University of Edinburgh
- BRAIN Biotech

Impact

Utilizing microbes to extract metals significantly reduces the CO2 footprint compared to traditional mining and recycling methods. This petrochemical free method of recycling and repurposing valuable materials such as cobalt, manganese, nickel, and lithium also has the potential to improve supply chain security and stability.

Stage

○ Vision
○ Research & Concept Building
● Validation
○ Commercialisation

Carbon Management

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Emission Management

Some emerging approaches for carbon validation and reporting

Tackling transparency and traceability

Sensors are increasingly crucial for gathering and transmitting real-time data, enabling organizations, for example, to optimize energy consumption instantly (scope 1-2). Digital twins are emerging technologies enabling organisations to model, analyze, and improve operations and resource consumption.

However, a major challenge is acquiring high-quality vendor data, especially on scope 3 carbon emissions, which form the bulk of an organization's carbon footprint but often lack adequate reporting.

Some emerging approaches and technologies in this field include:

- Centralised Data Platforms
- Distributed Ledger Technology

Centralised Data Platforms

Platforms for data sharing and value chain impact verification

Carbon Management Platforms

Some of challenges hindering Scope 3 reporting are limited data transparency and traceability.

New platforms are emerging to centralise data, enabling businesses and their suppliers to measure and share emissions data more easily. These platforms allow companies to directly obtain emissions data from suppliers, moving beyond conventional carbon surveys and providing more accurate tools for carbon accounting than traditional revenue-based estimates.

This also covers social data like working hours, labor practices, and worker demographics at supplier sites to refine emission estimates.

Active players

- Persefoni
- Plana
- SustainCERT
- Emitwise
- CO2 AI

Impact

As the demand for accurate and comprehensive climate reporting intensifies, these data platforms mark a significant step forward in driving sustainable practices and creating a more transparent value chain. As AI solutions evolve, they will enhance the precision, efficiency, and decision-making in managing emissions.

Stage

○ Vision ○ Research & Concept Building ○ Validation ● Commercialisation

Distributed Ledger Technology

Decentralised technology for emission reporting

Blockchain and dMRV

The emerging trend of utilising blockchain for collecting and reporting Scope 3 emissions is gaining momentum. By establishing a permanent and transparent data ledger, this approach ensures that all relevant users have access to the necessary information in a consistent format, enhancing both efficiency and supervision.

This approach ensures uniformity across technical frameworks while utilizing the strengths of distributed ledgers, such as auditability, discoverability, and liquidity, to improve emission offsetting and sustainability reporting.

Tech dependencies

Blockchain development and acceptance and, decentralised platforms, dMRV solutions

Active players

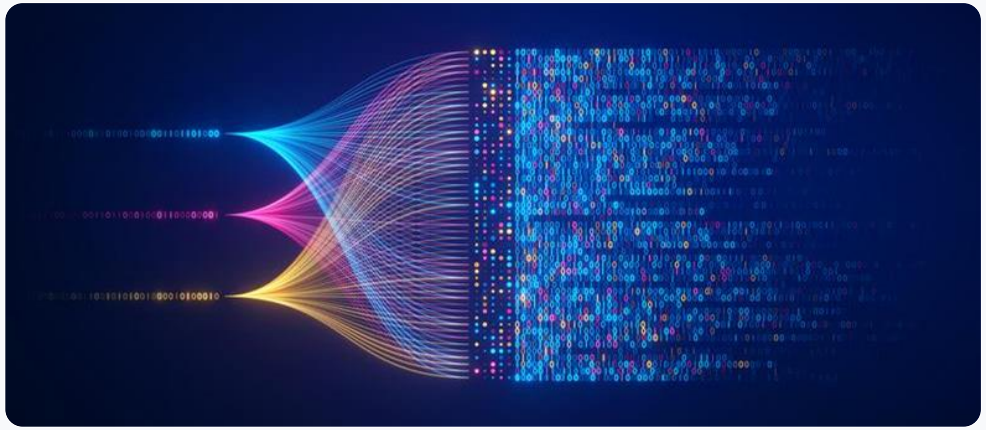
- The Hedera Guardian x Hyphen
- TraceX Technologies

Impact

These development set potential new standards for sustainability reporting to ensure credibility and accuracy from disparate data sources.

Stage

○ Vision
○ Research & Concept Building
● Validation
○ Commercialisation



Part 4

Concluding Notes

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Takeaways

Summarising thoughts and possible future collaboration opportunities

Energy and Power-to-X

Green ammonia, from green hydrogen, is becoming viable route to carbon neutrality in hard-to-electrify industries, benefiting from its existing market and transport ease. Overall, hydrogen ecosystems hold significant promise beyond energy considerations in transforming manufacturing and bringing in new raw materials for various industries.

Buildings are poised to evolve into energy storage hubs with the development of new thermal energy storage solutions.

Carbon

There is increased interest and development in microbial and biological technologies for carbon capture and utilisation.

The task of reporting and verifying Scope 3 emissions poses a considerable challenge. Significant efforts are being made to create cooperative data platforms that enable the transparent sharing of data and the verification of emissions reporting. Europe seems to be leading this initiative, with pioneering solutions originating from European startups.

Alternative Materials & Processes

The US, South Korea, and Japan, in particular, lead in creating commercial alternatives to rare earth battery materials. There's also a rising focus on more sustainable and effective recycling and mining.

Another emerging area is regenerative approaches to materials and the concept of biomimicry, which is gaining more attention in industries ranging from textiles to construction.

Further opportunities

Collaboration ideas

- A comprehensive solutions level research into energy storage solutions or power-to-x players
- Deeper research into regenerative climate technologies
- Alternative materials linked to specific industries
- A closer look at synthetic biology and its applications across different sectors

Research project was delivered for Business Finland by CATAPULT

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> “Catapult provides the means for corporations to implement their digitalization strategy on a practical level.”
>
> **Johannes Milén | Director, Pepsico**

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