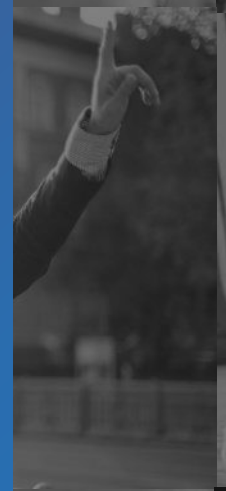
EXECUTIVE SUMMARY

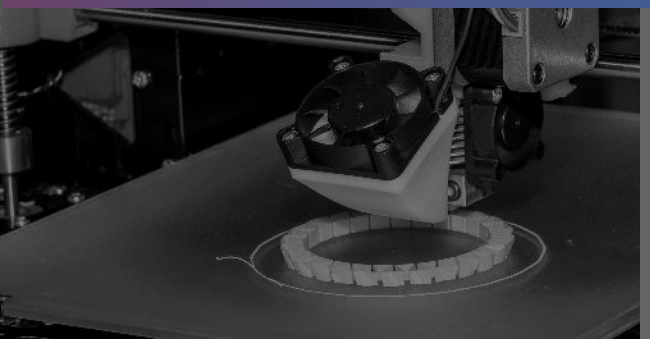
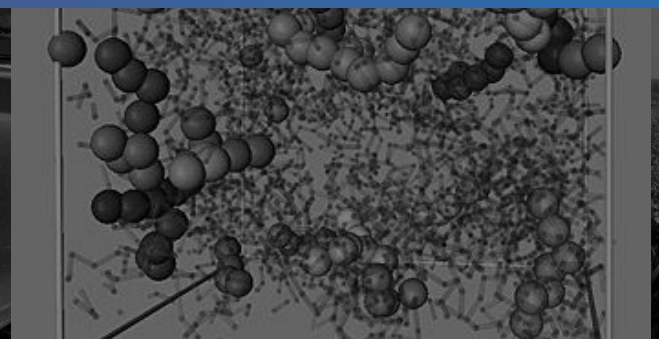
FORESIGHT 2021

Top Emerging Technologies to Watch







Lux Research

INTRODUCTION

What technologies will you be following this year that have the greatest potential to transform the world over the next decade?

Each year, we ask our analysts the above question. We also investigate the same question using data – including patents, academic papers, funding, and more. The full report highlights our findings and provides a jumping-off point into much more in-depth information on the Lux platform via dedicated Tech Pages and other research.

This year, we chose 12 key technologies, and we now include case studies for each, along with megatrend implications. In response to client feedback, we've now included an industry view as well, with the top five technologies for each of five key industries, to better connect these to your business.

We hope you enjoy!

Michael Holman, Ph.D.
VP, Research

Kevin See, Ph.D.
VP, Research

METHODOLOGY

Each of our 12 top emerging technologies features an overview, a case study, and a view into driving megatrends

RANKING
In the upper left, you'll find the ranking as well as an introduction to the technology.

LUX TAKE
What our research team's subject matter experts think of the technology – why it matters, and what to do about it.

MEGATRENDS
The key megatrends driving each technology, as well as innovations within each technology driving it forward.

LUX TECH SIGNAL
Our summary of data on patents, papers, funding, and more, compared to the average for all technologies we track.

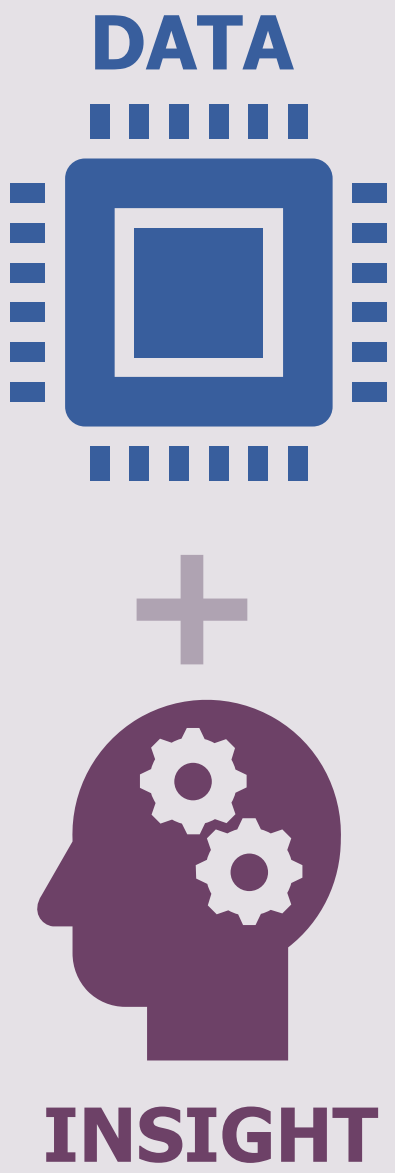
CASE STUDY
Highlights of how companies are using these technologies today to drive business results.

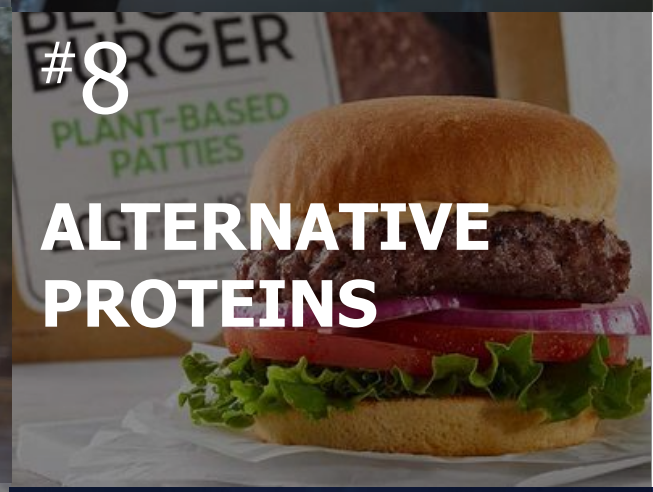
METHODOLOGY

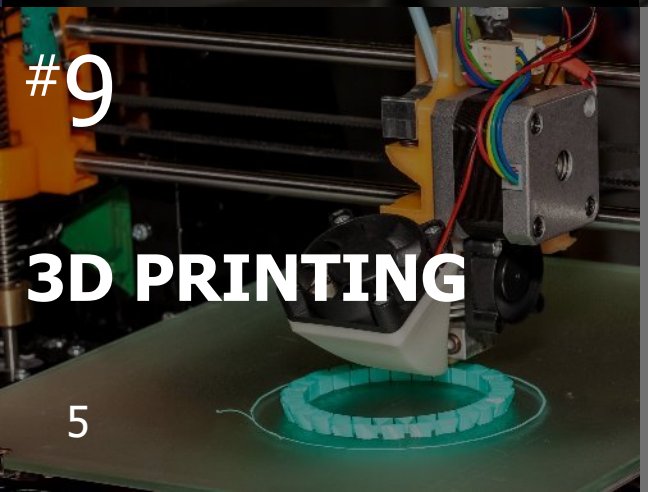
Technologies on our list are not just a function of Lux Tech Signal score

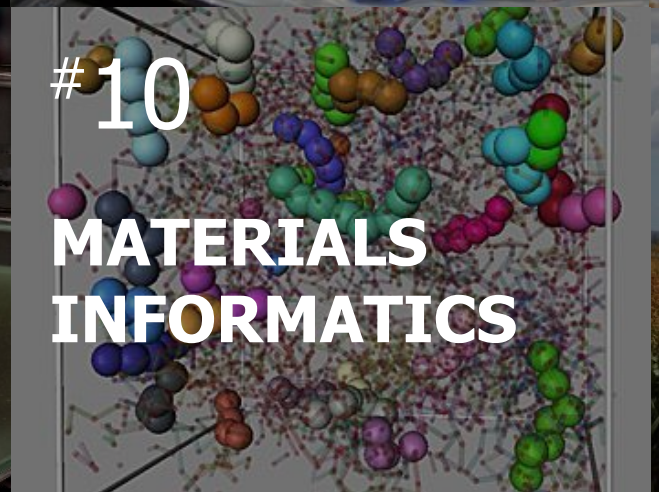
You may notice that the ranking on our list is not simply a function of that Lux Tech Signal score highlighted on each slide. So how did we choose these technologies, and put them in this order?

1. For one, when we rank technologies based on our data, we don't simply look at the current score but also at the rate of improvement, the innovation history, and other factors.
2. What's more, **these rankings are not simply a function of the innovation data – we also use the insight of domain experts on Lux's analyst team**. They flag technologies with high innovation scores that may still face market roadblocks that make them dubious bets – or technologies that have less impressive scores but fit a key unmet market need that will enable them to make a major impact.
3. Finally, we also calibrated the final choices to represent a breadth of innovation across energy, materials, health, and digital. Based on the Lux Tech Signal alone, digital innovations would dominate the list due to the world's intense recent focus on digital transformation.









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Source: Waymo

Returning to our leaderboard

#1 AUTONOMOUS VEHICLES

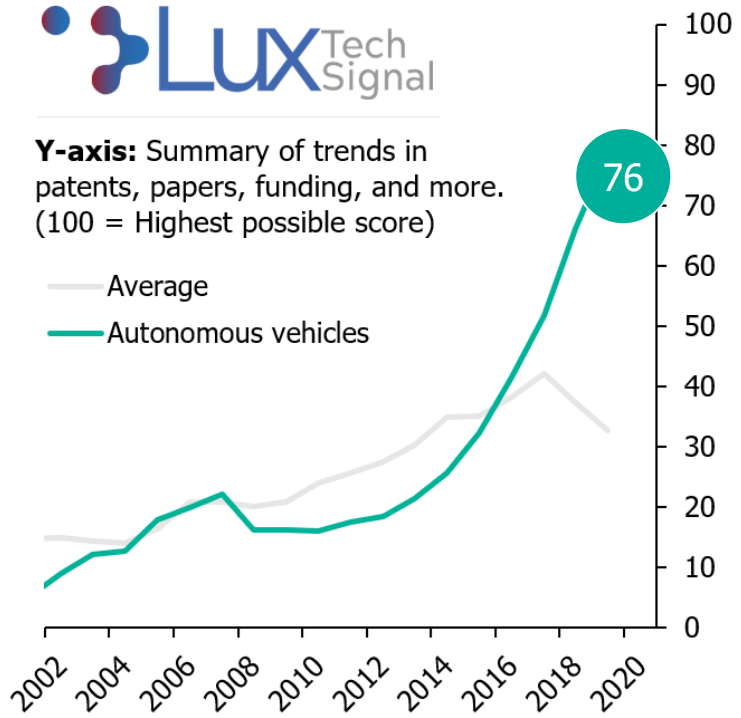
Increasing levels of vehicle automation, eventually resulting in removing the need for drivers in consumer and commercial vehicles.

LUX TAKE

Why it's important: Improvements in safety and efficiency are happening at all levels of vehicle automation, benefiting both consumer vehicles and commercial applications. Further out, Level 4 and 5 autonomous vehicles will open new mobility and logistics possibilities by removing the need for a driver in a vehicle.

Lewie Roberts

What you should do: Tap into emerging opportunities in areas like sensors and connectivity for autonomous vehicles while also planning for the impact on mobility businesses more broadly.



DATA HIGHLIGHTS

600

Number of self-driving cars in Waymo's fleet, some of which the company is now using for fully self-driving taxi rides in limited, geofenced areas.

DETAILS For key player analysis, full data, case studies, and more, see our **Autonomous Vehicles Tech Page.**

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MEGATRENDS

That are driving this technology's adoption

AI, analytics, & data

Improved data from both maps and sensors, along with advances in AI to translate into actions, help make autonomy possible

Workforce automation

Autonomy can help replace existing drivers or aid areas like trucking with labor shortages

Returning to our leaderboard

#1 **AUTONOMOUS VEHICLES**

Increasing levels of vehicle automation, eventually resulting in removing the need for drivers in consumer and commercial vehicles.

INNOVATIONS

What to watch in this technology going forward

DATA FUSION OF MULTIPLE SENSORS

Sensor data fusion and environmental modeling are increasingly offered as software components from specialty AV companies and startups

HIGH-DEFINITION MAPPING

Real-time and high-resolution 3D maps for autonomous vehicles as well as for advanced driver assistance systems

Returning to our leaderboard

#3 PLASTIC RECYCLING

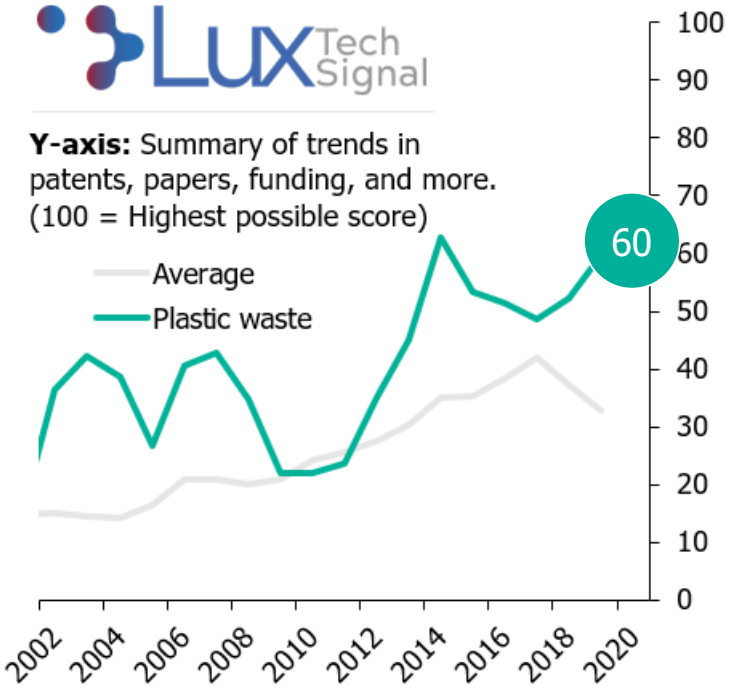
Innovations that can convert plastic waste into a variety of valuable products, enabling a circular economy and avoiding pollution.

LUX TAKE

Why it's important: Concerns about plastic waste from consumers and regulators have only grown, and major consumer product companies from food to apparel have made commitments to increase recycling rates and usage of recycled content. Innovations that can convert waste into higher-value products are in high demand to meet the challenge.

Charles Willard

What you should do: Engage with waste collection to secure inputs for recycling facilities – find opportunities to take advantage of plastic waste as a distributed feedstock source and to play in new stages of the value chain.



DATA HIGHLIGHTS

155

Startups addressing plastic waste founded in the past decade from Lux's company database.

DETAILS For key player analysis, full data, case studies, and more, see our **Plastic Recycling Tech Page**.

MEGATRENDS

That are driving this technology's adoption

Climate & sustainability

Recycling addresses plastic waste and can reduce emissions and other impacts

Globalization & inequality

Not all countries have fossil fuels, but all have plastic waste to use as a local resource

Returning to our leaderboard

#3 **PLASTIC RECYCLING**

Innovations that can convert plastic waste into a variety of valuable products, enabling a circular economy and avoiding pollution.

INNOVATIONS

What to watch in this technology going forward

Advances in tracking and sorting

Extended producer responsibility (EPR) requires validation of material collection

Design for recyclability

Multimaterial products can be hard to recycle; single-material or easy-to-separate designs are needed

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New to our leaderboard

#4 AI-ENABLED SENSORS

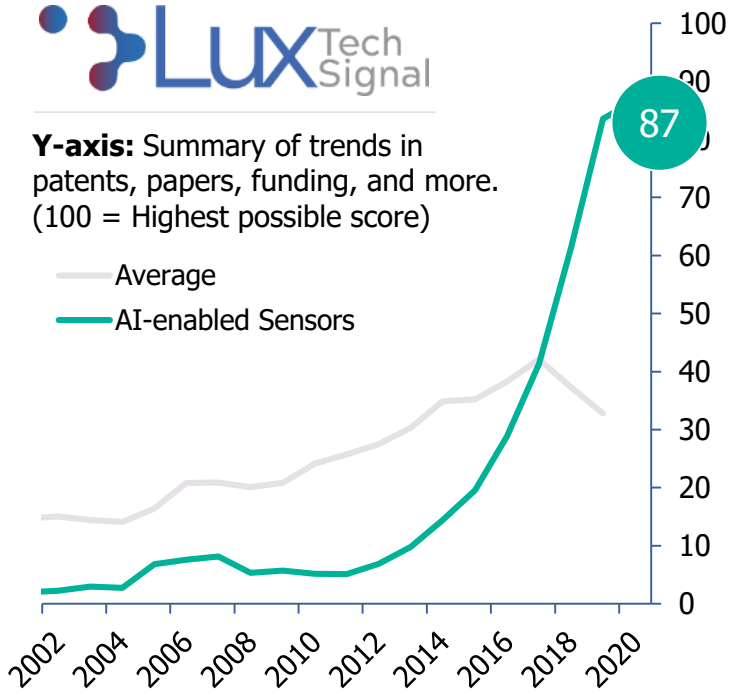
Sensors of all kinds now can provide more impactful insights when coupled with machine learning and AI.

LUX TAKE

Why it's important: Recent advancements in machine learning capabilities enable developers and operators to extract more value out of sensors; this is an opportunity to create new products and improve internal processes by generating deeper insights off existing hardware.

Cole McCollum

What you should do: Consider existing sensor deployments and examine how more value can be wrung out of the data. For new products and services, consider technologies like computer vision, which enable business models that increase stickiness with customers.



DATA HIGHLIGHTS

>$1.8 billion

Raised by companies developing or using AI-enabled sensors.

DETAILS For key player analysis, full data, case studies, and more, see our **AI-enabled Sensors Tech Page**.

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MEGATRENDS

That are driving this technology's adoption

AI, analytics, & data

While AI has made its mark in traditional tech, integration with physical sensors will benefit a huge variety of industries

Workforce automation

AI plus sensors enables automation of processes and enhancement of workers responsible for acting on that insight

New to our leaderboard

#4 **AI-ENABLED SENSORS**

Sensors of all kinds now can provide more impactful insights when coupled with machine learning and AI

INNOVATIONS

What to watch in this technology going forward

Leveraging low-cost sensors

Startups like Algorithmica are developing solutions that can generate data from lower-cost sensors

Integration with automation

AI-enabled sensors are powerful when coupled with automation, as in 3D printing and robotics

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Returning to our leaderboard

#6 GREEN HYDROGEN

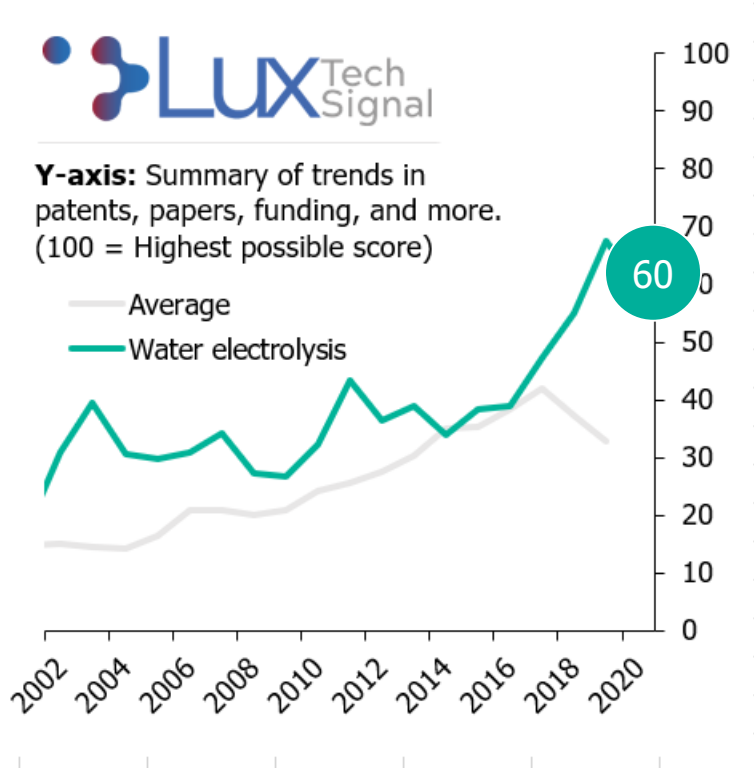
Producing clean hydrogen for energy, mobility, and industrial uses, plus applications in storing and transporting energy.

LUX TAKE

Why it's important: Vehicles powered by hydrogen fuel cells have been an unfulfilled dream, but green hydrogen can help clean up otherwise hard-to-decarbonize industrial processes. "Green" hydrogen produced from renewable electricity can enable storage and transportation of clean electricity for a more robust and flexible energy transition.

Runeel Daliah

What you should do: Look to industrial hydrogen uses in applications from cement and steel products to power-to-chemicals and explore the potential of hydrogen to enable new energy networks as renewables costs fall.



DATA HIGHLIGHTS

>10,000

Patent publications in water electrolysis for green hydrogen over the past decade, rising at a 14% compound annual growth rate (CAGR).

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MEGATRENDS

That are driving this technology's adoption

Climate & sustainability

Enabling coupling of renewable energy and helping decarbonize industrial processes

Globalization & inequality

Distributed hydrogen will create a global renewable energy trade and enable new clean energy leaders

Returning to our leaderboard

#6 **GREEN HYDROGEN**

Producing clean hydrogen for residential, mobility, and industrial energy, plus applications in storing and transporting energy.

INNOVATIONS

What to watch in this technology going forward

Hydrogen energy carriers

Solid- and chemical-based carriers will be critical to enabling a hydrogen economy for renewable energy globally

Power-to-chemicals

Hydrogen can be the basis for making chemicals from electricity and CO_2, as a path to distributed manufacturing.

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Returning to our leaderboard

#8 ALTERNATIVE PROTEINS

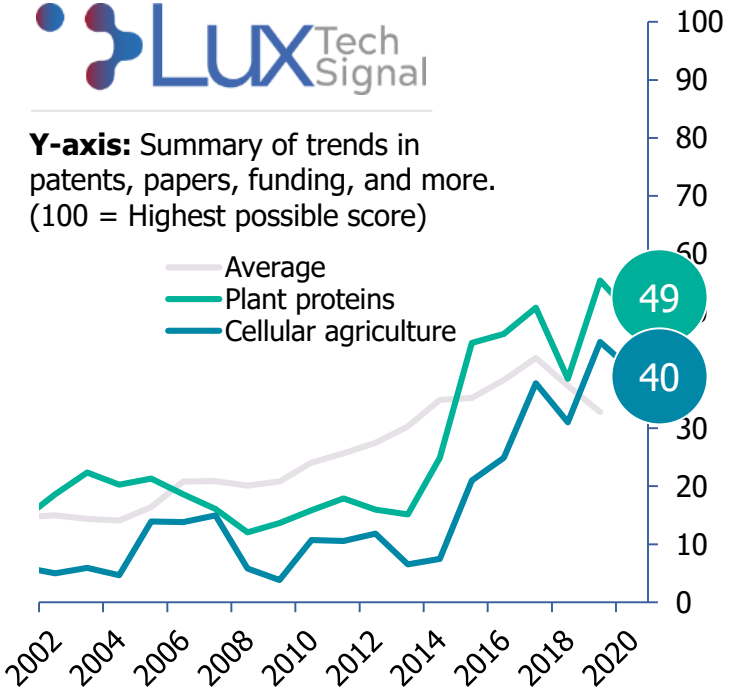
Alternatives to the resource-intensive traditional meat industry are emerging rapidly, with immediate impact from plant-based proteins.

LUX TAKE

Why it's important: Meeting the growing global demand for protein supply sustainably is an urgent concern. Impossible Foods and Beyond Meat are showing that there is a massive opportunity to cater to sustainability-minded consumers and to the demand for protein choice in general.

Harini Venkataraman *Thomas Hayes*

What you should do: Consider the technology capabilities required to further the impact of plant proteins in the near term and cellular agriculture in the long term. Increasing the inherent protein content in crops and improving the sensory/nutritional quality of plant proteins can generate major opportunity.



DATA HIGHLIGHTS

112% return

Change in stock price for Beyond Meat in 2020 (YTD 8/31/2020). This more than doubling of stock price far outpaced the general market.

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MEGATRENDS

That are driving this technology's adoption

Demographic shifts

Consumer consciousness regarding the origin and lifecycle of food has grown significantly in the past decade

Climate & sustainability

Animal meat is known for its resource-intensive nature; alternative proteins provide a pathway to similar but sustainable food experiences

Returning to our leaderboard

#8 **ALTERNATIVE PROTEINS**

Alternatives to the resource intensive traditional meat industry are emerging rapidly, with immediate impact from plant-based proteins.

INNOVATIONS

What to watch in this technology going forward

New tools to improve protein content

Tools like computational breeding or CRISPR will drive new heights in protein content and quality, particularly for staple crops like rice

Focus on the sensory

Consumers want familiarity with their sustainable food; novel processing tech and ingredients will continue to dictate broader adoption

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Where are they now? Technologies that dropped off from last year's list

All told, 23 different technologies are part of either our overall top 12 or one of our industry top fives. Still, that leaves off 10 technologies that were part of the Lux 20 for 20 technologies last year. These techs all remain important areas of innovation but just don't hit the top overall or industry lists.

#14 for 2020

The solutions for **last-mile delivery** are still represented on our list through options like autonomous vehicles and enablers like AI sensors.

See the Last-Mile Delivery Tech Page

#16 for 2020

Battery fast charging will still be a key enabler for BEVs, but for now, innovation momentum in battery swapping is higher.

See the Electric Vehicle Charging Tech Page

#15 for 2020

Perpetually controversial, **blockchain** continues to generate eye-popping innovation metrics, but tread cautiously due to the lack of use cases.

See the Blockchain Tech Page

#18 for 2020

Graphene and other **2D materials** continue to drive research and patenting, but integration and manufacturing challenges will slow adoption.

See the Graphene Tech Page

#20 for 2020

Vertical farming continues to gain traction, but economics remain unfavorable outside of certain high-value crops like leafy greens.

See the Vertical Farming Tech Page

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What to look for beyond the top technologies – and what to do going forward

1 **Have data-driven as well as expert-led monitoring in place.** As the annual changes and shifts on our lists show, tech innovation is highly dynamic. It's not enough to assess an area once: Ongoing monitoring is essential, and data science approaches can be particularly useful for areas where past disappointments might bias individuals against them.

2 **Align with your industry needs – but cast a wider net as well.** The top techs in each industry are essential to be on top of, but the next great innovation to impact your industry might come from well outside it as well. Most innovation organizations are fairly adept at monitoring innovations from within their own industry, but a wider view is critical as well.

3 **Have a plan for technologies outside the core focus as well.** Even when a tech area drops out of the top fields to monitor for a given industry, innovation doesn't stop – and can still be impactful. Whether shifting out of the innovation team's spotlight due to maturing into the execution phase, such as 5G, or being slower to market, such as quantum computing, it's still important to keep tabs on latest developments.

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