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FORESIGHT BRIEF

Innovations reshaping our society: Emerging technologies

Many of today's emerging technologies – that may soon be common worldwide – will have profound impacts on governments, industries, and people. While few technologies seem likely to disrupt the world the way Artificial Intelligence has over the last two years, some of today's emerging technologies have the potential to disrupt one or more important systems. This brief explores five such technologies.

Nanomaterials that catalyze chemical reactions or give familiar materials powerful new properties could advance sustainability efforts, improve food security, and reduce consumer and industrial waste.

Batteries are evolving rapidly and may soon enable greater use of renewables to generate power. This might accelerate the green energy transition but hurt the bottom lines of fossil fuels exporters.

Automated transportation is changing the way humans and goods move through the world. It may reduce carbon footprints and boost productivity but also generate regulatory challenges.

Geoengineering may be one of the few viable ways to tackle polar warming and sea level rise, but it poses significant environmental risks that could cause geopolitical complications in the absence of effective oversight.

Spatial computing could unlock new opportunities for creativity, efficiency, and connectivity, improving decision-making and service delivery in the public and private sectors.

We live in an era of unprecedented technological change that will shape our future. Foresight offers a powerful aid to responsible and successful navigation through such dynamic change.

Canada

Innovations reshaping our society: Emerging technologies

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Introduction

Imagine a world where everyone can afford transportation, and our devices never run out of power – all thanks to reliable, sustainable, renewable energy. Imagine self-healing construction materials that can repair cracks in buildings, making them more resilient to natural disasters. Imagine you could interact with digital content as if it were part of your physical environment. Imagine we could manage climate change by spraying reflective particles into the air.

This world is closer than you think.

Technologies are developing quickly. Many of today's emerging technologies – that may soon be common worldwide – will have profound impacts on governments, industries, and people. Artificial Intelligence (AI), in particular, Generative AI is the great contemporary example of a transformative technology. From the moment it went mainstream, the breadth and depth of its potential impact became clear. Now, less than two years later, it has brought massive disruption to a broad array of domains. No doubt its impact will continue to broaden and deepen in the years to come.

Very few technologies have this level of historical significance. But that is not to say that other technologies are unimportant. Today the pace of technological development is such that at any given moment several technologies are emerging that could have a major impact on one or more important systems.

This brief examines five rapidly evolving technologies that fall into this category: nanomaterials, batteries, automated transportation, geoengineering, and spatial computing. They were selected because their potential to shift the future in unexpected ways deserves more attention.

The purpose of this document is to support forward-looking thinking and inform decision making. It does not provide specific policy guidance and is not meant to predict the future.

I. Nanomaterials

Tiny materials, big impacts

From catalyzing chemical reactions to creating materials with new properties, tiny synthetic nanomaterials are at work in the world around us. They could advance sustainability efforts, improve food security, and reduce consumer and industrial waste.

Today

Nanomaterials have **at least one dimension less than 100 nanometers** – smaller than an HIV virus. Recent advances have led to more efficient methods for their synthesis, manipulation, and application. They are increasingly common in fields such as biomedicine, electronics, industrial chemistry, energy, consumer products, and environmental engineering[1].

Nanomechanics creates materials with unusual properties, such as increased strength, stiffness, or conductivity[2]. **Catalytic nanoparticles**—tiny, manufactured particles with relatively large surface areas—can enable faster or more efficient chemical reactions[3]. Other nanomaterials can self-assemble, change properties in response to stimuli, and even 'heal' themselves when damaged[4].

Futures

In the next 5 to 10 years, nanomaterials are likely to have increasingly significant impacts on our society and economy.

Catalytic nanoparticles could be used to **break down environmental pollutants** such as heavy metals, dyes, and chlorinated organic compounds in lakes and riverways. Nanoparticles may make solar power more efficient, enabling them to capture longer, low-energy wavelengths of light.

Nanomaterials could **also improve the quality and performance of products** such as coatings, composites, textiles, and cosmetics. Advances in **nanoelectronics** could lead to faster, smaller, or more efficient devices and systems, from mobile phones to laptops and smart watches. Electric vehicles could become more environmentally friendly by using more lightweight and conductive nanomaterials.

Smart materials that adapt to changing situations could enhance the resilience of infrastructure, such as power grids, communication networks, and transportation

systems. For example, regenerative concrete could naturally repair itself when it cracks.

Implications - “Future Impacts”

Research and development of nanomaterials can be costly, and additional challenges lie in producing them safely and at scale. Nonetheless, they present important strategic opportunities as well.

1. Supercharged chemical reactions and self-healing materials have the potential to **improve sustainability in many areas of life.**
2. Nano-catalysts that make fertilizer more efficient could make agriculture more sustainable and **improve food security.**
3. Self-healing objects that continuously mend and repair themselves could help to **reduce consumer and industrial waste.**
4. Some nanoparticles **may endanger human or environmental health** and could be very hard to find and remove in non-controlled environments.
5. Widespread use of nanomaterials could present **new challenges for regulators and safety agencies** and may inspire public fears about the safety of foods, consumer goods, and environments.

II. **Batteries**

Powering tomorrow

The future is electrifying. Advances in battery technology will enable greater use of renewables to generate power. Countries that export fossil fuels could see demand decrease. Strategic opportunities to invest in battery research and development could emerge.

Today

Batteries power portable electronic devices, from laptops to smartphones and medical equipment. They power vehicles and enable grid-scale energy storage. This makes intermittent renewable energy sources such as solar and wind more useful contributors to energy systems[5].

Researchers are improving the **lithium-ion batteries** that dominate the market despite certain limitations. **New lithium cells using less scarce materials** could reduce costs and environmental impact, while improving battery lifespan[6].

Solid-state batteries promise to be smaller, lighter, and faster charging. Sodium-ion, magnesium-ion, and organic batteries could become viable alternatives[7].

Futures

Battery technology has the potential to reshape several sectors over the next 5 to 10 years.

It could give **grids more flexibility to store energy** from solar and wind farms, for use at night, when the wind stops, or during peaks in energy demand. This would reduce the need to rely on coal and natural gas plants.

Households could also store energy using new battery technologies. This would help them to use more electricity at cheaper times and increase resilience against disruptions to the grid.

Emerging battery technologies could **shift priorities in the mining sector**, with potentially higher demand for materials such as sodium and magnesium and less need for cobalt, nickel, and manganese. This could impact ecosystems and local communities.

The development of battery technology might create more **demand for skilled workers**—engineers, technicians, and data analysts—to manufacture, install, and maintain batteries in sectors such as aerospace, defense, robotics, and biotechnology.

Implications - “Future Impacts”

Widespread adoption of **grid-scale battery technology** still faces barriers, such as capital costs, institutional commitment, and technical and safety issues. Going forward, key considerations include:

1. Demand for fossil fuels could decline, affecting **nations that produce and export fossil fuels.**
2. The battery transition presents **new opportunities in recycling, rather than consuming natural resources.**
3. Countries investing in **battery research and development** could lead the energy revolution.

III. Automated Transportation

Steering towards the future

Mobility is the basis of much economic activity. Automated transportation is changing the way humans and goods move through the world. It could reduce carbon footprints and boost productivity – but may also require new regulations so systems can work together.

Today

Automated transportation is becoming a reality in many places. AI systems, trained on vast amounts of data, use sensors and cameras to navigate vehicles through complex environments safely and efficiently without human intervention[8]. Automated systems are becoming the **main operators of industrial vehicles[9].**

Futures

Over the next 5 to 10 years, automation could transform supply chains and logistics systems.

Self-driving cars promise to reduce congestion, accidents, and emissions, as well as being more convenient for users. In industrial transportation systems, automation could improve productivity by optimizing routes and increasing capacity. We could see more automated drones, trains, and ships that deliver packages and cargo.

Self-driving trucks could transport cargo across long distances without driver fatigue or human error. **Cooperative truck platooning**—in which centralized control allows trucks to travel more closely together because they accelerate or brake simultaneously—could make cargo transport faster and more efficient.

This could incentivize **the development of smart highways** that integrate automated vehicles while monitoring and responding to environmental conditions. In the future, other vehicles equipped with AI could automatically join and leave platoons.

Automated construction vehicles such as pavers and excavators could build and maintain large-scale, modular structures. In agriculture, vehicles such as tractors and combines could soon work independently of direct human intervention thanks to GPS, laser guidance, obstacle detection, and performance optimization systems.

Implications - Future Impacts

Automated transportation has the potential to **impact the estimated 500,000 Canadian jobs** in the transportation sector. This could create both challenges and opportunities for workers, firms, and policymakers.

1. Widespread automation within transportation **could erode a range of traditional skills** associated with the handling and movement of goods, as well as the maintenance of infrastructure**.**
2. Automated transportation could lower greenhouse gas emissions, significantly **reducing carbon footprints.**
3. It could **boost economic productivity**, making logistics more efficient and creating new jobs in the technology and data analysis sectors.
4. It could make trucking much **safer, reducing accidents**, lawsuits and therefore insurance costs. However, novel factors, such as AI, could make existing systems of regulation and accountability obsolete.
5. Connected and/or AI powered vehicles and infrastructure could create **new vulnerabilities to cyberattacks or accidental failures** that cascade through systems critical to productivity, prosperity, and public safety.
6. The private sector may call on governments to **consider regulations that ease the deployment of automated systems.**

IV. **Geoengineering**

Geoengineering the future of our planet

Geoengineering is complex and controversial. It poses significant risks and will require international cooperation and oversight frameworks to be effective and safe. However, it may be one of the few options to tackle polar warming and rising sea levels.

Today

Geoengineering—**the deliberate modification of Earth's climate**—is no longer confined to science fiction. Some examples are uncontroversial, such as planting more trees to absorb more CO2 from the atmosphere[10].

More debate surrounds **solar engineering,** which aims to cool the planet by reducing the amount of solar radiation that reaches Earth. One approach, **stratospheric aerosol injection**, involves airplanes spraying tiny aerosols of sulfuric acid into the stratosphere. These particles reflect sunlight back into space, like large volcano eruptions. Experimentation is currently underway[11].

Marine cloud brightening is another form of solar engineering currently being studied. It involves spraying tiny aerosols of salt water into the air from ships to condense surface-level clouds. There has been an attempt to use it to cool the waters of the Great Barrier Reef[12].

Futures

Looking ahead 5 to 10 years, more research and experimentation with these and other geoengineering methods could produce practical interventions that affect global climate change mitigation efforts.

Solar engineering could help **lower global temperatures**. The UN estimates that a $20 billion per year investment in aerosol injection could offset 1 degree Celsius of planetary warming.

However, it could also have unwanted impacts. **Sulphate aerosol injection** may deplete the ozone layer, allowing more ultraviolet radiation to reach Earth and increasing acid rain. The benefits and harms of geoengineering projects may be **unevenly distributed**. For example, solar engineering could dry out parts of the planet where vulnerable communities exist, such as the Amazon rainforest and East Africa.

Crop yields and disease patterns may shift, altering living conditions and migration patterns. Such changes could also lead to conflicts over resources and land. Unilateral deployments of geoengineering projects may be met with counter-deployments by countries that have been negatively affected.

Implications “Future Impacts”

Turning to geoengineering to address the climate crisis could **risk undermining incentives to limit greenhouse gas emissions**. If so, geoengineering efforts might need to be continuously increased to offset increased emissions, with heightened risks for ecosystems and biodiversity.

Ultimately, geoengineering could disrupt sectors such as agriculture, real estate, and insurance. Despite these concerns, geoengineering could have significant upsides:

1. If the climate transition does not happen fast enough to stop the Greenland ice cap melting, geoengineering may be the only way to **stem the rise in global sea levels caused** by polar warming.
2. Geoengineering technologies could **create new industries and jobs**, such as developing cloud-brightening drones and managing large-scale forestation projects.
3. Unintended impacts on ecosystems, biodiversity, or natural spaces could make geoengineering **a catalyst for social unrest** and distrust.
4. Since geoengineering will have geopolitical implications, it may drive the emergence of **international oversight and cooperation frameworks**.

V. Spatial Computing

Unleashing new realities with spatial computing

Spatial computing could unlock new opportunities for creativity, efficiency, and connectivity across industries. It could improve the effectiveness of decision-making and collaboration, service delivery, and public trust in policy decisions and institutions.

Today

Spatial computing blends the virtual and physical worlds. It uses a range of technologies – such as headsets and smartphones – that support **augmented reality (AR), virtual reality (VR), and mixed reality (MR)**[13]**.**

Spatial computing enhances how we **visualize, simulate, and interact with digital data**. It can create fully immersive experiences (VR). It can overlay virtual digital information on real-world surroundings (AR). It can enable people to interact with virtual elements, for example by turning physical surfaces into touch interfaces (MR)[14]. By gathering and analyzing data about the world – such as light or soil conditions or flows of traffic – it can present information that helps users **make better real-time decisions**[15]**.**

Futures

In 5 to 10 years' time, the evolution of spatial computing could make it comparable in significance to the internet and smartphones. Today's relatively simple bridge between the digital and the physical could become a multi-level, multi-modal, and omnipresent portal.

Instead of clunky headsets, we could routinely wear smart glasses or even contact lenses that let us interact seamlessly with digital content in our environment. VR, AR and MR tools for engagement and remote collaboration could open new possibilities in areas from art to news, and from advocacy to public decision-making. The internet of things could equip more objects with sensors to collect physical data in real-time, enabling spatial computing to form part of more extensive and **powerful decision-making systems**.

Spatial computing could **transform training and education**. Instead of reading about a process in a textbook, trainees could learn by doing, using VR to simulate real-world scenarios. When the virtual environment includes AI-generated characters, this could include practice handling difficult interpersonal situations.

New technologies for capturing 3D images could make it easier to create "**digital twins**" of the real world. Digital twins could be used to simulate real-world scenarios – for example, of how a self-driving car approaches an intersection, or the best way to fight a forest fire.

Implications - “Future Impacts”

Realizing the potential of spatial computing may depend on addressing concerns about privacy and surveillance in smart environments, improving our understanding of risks associated with digital addiction, and nurturing expertise in spatial and user experience design. If these issues can be managed, spatial computing could have significant benefits as well as challenges:

1. The affordances of spatial computing could enable **new forms of harassment or contextual disinformation** that are harder to counter than current forms.
2. These same affordances could create **new opportunities for meaningful connections** between people that help offset current challenges around isolation, loneliness, and belonging.
3. By presenting users with real-time contextual information, it can improve the effectiveness of **decision-making and collaboration**.
4. By enabling people who are physically distant to interact more meaningfully, spatial computing can **improve service delivery** to people in Canada through remote consultations.
5. Improved access to better information and models could **enhance public trust in policy decisions and institutions.** On the other hand, trust may decline further if questions remain about the validity of online information and models, or the safety and security of spatial computing platforms.

Conclusion

While none of these five technologies seems likely to bring the same level of disruption as AI, the Internet, or electricity, their impact may still be profound. A game-changing breakthrough could accelerate their deployment or expand their scope of impact. They may combine with each another, or AI, or any other emergent technology in ways that bring even more surprising opportunities and challenges. We live in an era of unprecedented technological change that will shape our future.

Foresight offers a powerful aid to responsible and successful navigation through such dynamic change.

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