McKinsey & Company

The Next Digital Leap: Where's AI in ChE's Future?

Sam G. Samdani, PhD

June 24th, 2020

Agenda

What's top of mind among executives & engineers today?

When AI meets biology

AI-powered innovation as the catalyst

Closing thoughts & open questions

We recently asked chemco executives about their top-of-mind issues

Digitization

Price transparency through digital revolution

China becoming self-sufficient for more and more chemical products

China

Significant changing trade flows resulting from Trade Wars/ Increasing protectionism going on in the background

Possible macroeconomic developments: increasingly nationalist/protectionist policies? (Trade wars, Brexit, etc.) ... Downturns? More volatility? ...

Digitization/ecommerce platforms

Integrated supply chains

Energy policy change in Europe creating major disadvantage for Europe production

Artificial intelligence (e.g., in innovation, market intelligence)

Refinery and petrochemical integration

Energy transition nearing peak oil demand for transportation

The impact of wrong or right information arriving at consumers, voting citizens and legislating politicians. Science as a cheap commodity with very short shelf life and quality issues

Large scale entry of state-owned companies

Potential major economic slow down

Biotech

Climate change which impacts production processes

Big Data

Impact of low cost feedstock regions (shale NAM/ME)

Recycling

Sustainability

Conceptually I have difficulties to assume a disruption within the next 5 years. However, aspects related to Circular Economy, be it consumer perception or regulation might impact the industry heavily. Digital will gradually change the landscape, but not disrupt within five years. New competitors from China will heavily impact the industry, but not disrupt

Consolidation within specialty or semicommodity segments, leading to a greater number of "large" players in non-PE/PP space

The threat of politically motivated global and regional trade conflicts: disrupting global chemical supply chains; tempting governments to treat/discriminate companies based on short-term political agendas Europe/European companies face a difficult position sandwiched between the U.S. and China

Digitalization

Trade policies, environmental regulation enforcement throughout value chain, efficiency gains by automation/AI, digitalization of customer facing processes

Digital business models

The potential of digital disruption particularly in specialty businesses

Emerging markets

Circular economy

Reversal of globalization trend (e.g., trade restrictions, etc.)

China development (environmental, economic)

Upcoming trade tariffs and slow down of global economy

Environmental regulations Digitalization Economic downturn due to trade barriers and recession

Further industry consolidation

Emergence of USA as a production base for chemicals

Recycling/sustainability | Digitalisation/Big Data/AI | PetChem | Climate change | Trade conflicts/economical slow down

One engineer's monthly musings as a 'bloggerhead'

About Author

Sam Samdani

A full-time lateral thinker and part-time literal tinkerer with thinkertoys, i.e., powerful ideas worth playing with.

Newsium - Dispatches from a Bloggerhead

Newsium is a launch pad for elemental ideas - as mind-altering as lithium and as neuron-nourishing as potassium - designed to plant memetically modified "seeds" in the fertile minds of globe-trotting McKinsey colleagues and to propel ourselves with enough "escape velocity" to boldly go where no one has gone before. Care to join in the conversation?

Is AI about to evolve a bit of CI at scale? | Edit

27 October 2019
by Sam Samdani

Could artificial intelligence (AI) help us crack the creativity code and possibly scale up our creative intelligence (CI) beyond the human levels? The English mathematician and writer Ada Byron Lovelace (1815 – 1852) is famous for her work on another English polymath Charles Babbage's (1791 – 1871) proposed mechanical general-purpose computer, the Analytical Engine. She was the first to recognize that the machine had applications beyond pure calculation and published the first algorithm intended to be carried out by such a machine. Not surprisingly, she is sometimes regarded as the first to recognize the full potential of a "computing machine" and one of the world's first computer programmers.

Could AI automate leakage of more of the future into the present?

Is AI advanced enough to be indistinguishable from magic?

Aren't we already living in a matrix of superintelligences?

Is AI about to spark a 'Cambrian explosion' of alien intelligences?

What's a human to do at McKinsey and why?

Waiting for the Mendeleev – or better yet, Moseley – moment in AI?

Is AI yet to advance beyond its alchemical intelligence phase?

AI-powered esprit de escalier, anyone?

Does AI = DI + Hu?

Source:https://home.intranet.mckinsey.com/wiki/blog/12497

Ready to reset your intuition?

“I think there is a world market for maybe five computers.”

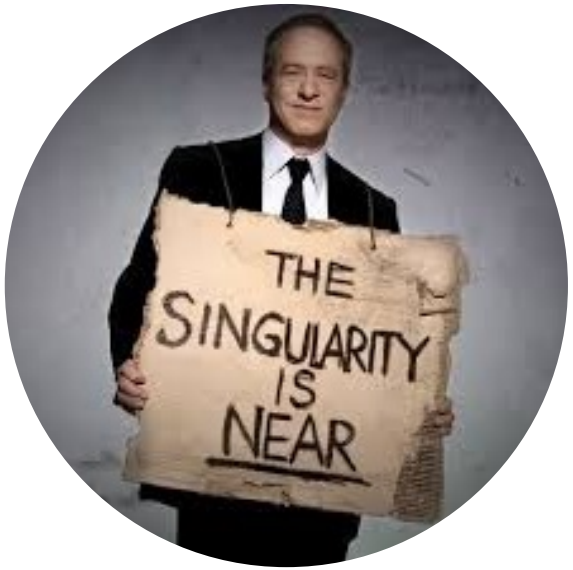
Thomas J. Watson

It’s always been hard to make predictions, especially about the future

> The cell phone penetration in the US by 2000 will be 900,000 subscribers.

McKinsey & Company

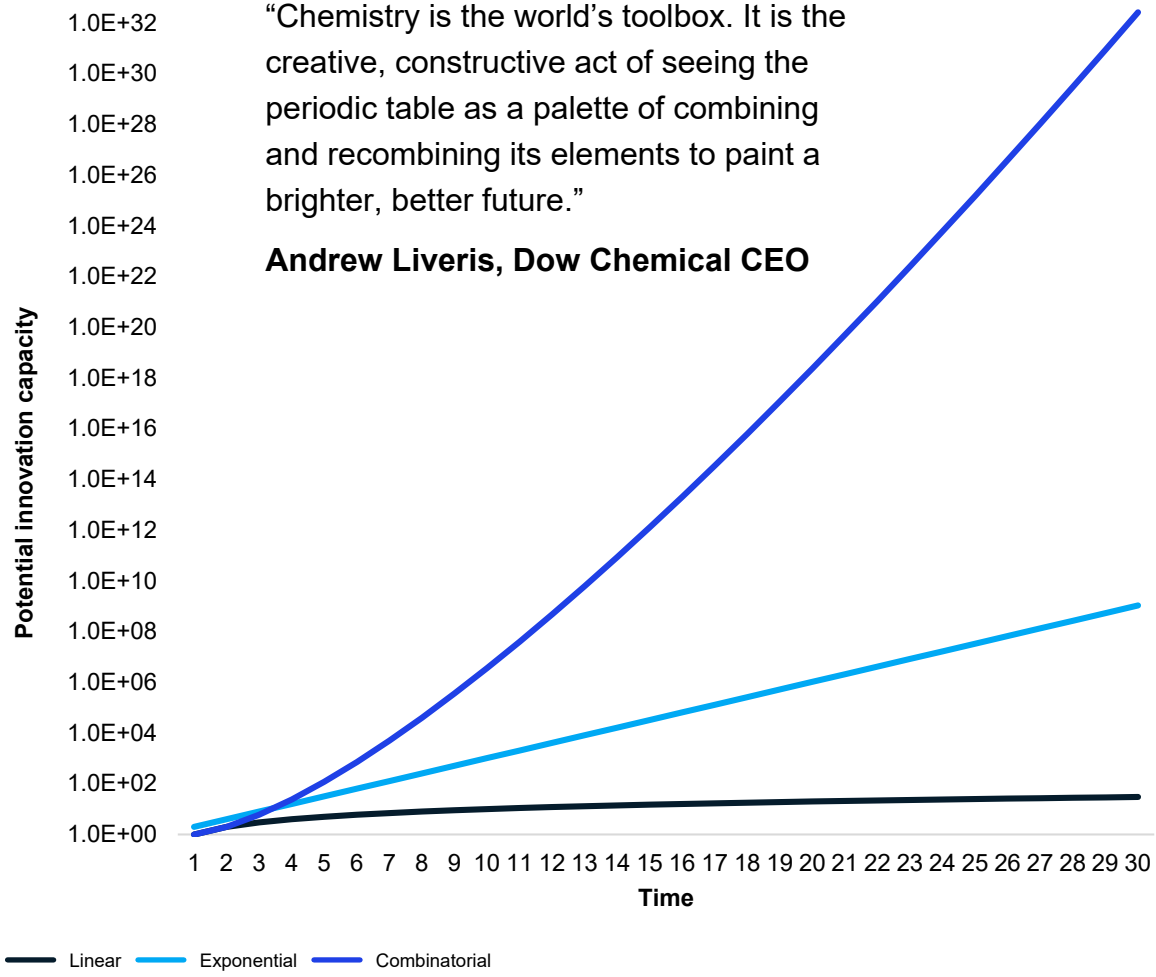
Why do we need an intuition reset?



"Thanks to the exponential growth trajectory of many disruptive technologies, we won't experience merely 100 years of progress in the 21st century; it will be more like 20,000 years of progress at year 2000 rate."

Ray Kurzweil

Value curation via combinatorial innovation should ensure the continuation of progress by other means beyond the Moore's Law



"Chemistry is the world's toolbox. It is the creative, constructive act of seeing the periodic table as a palette of combining and recombining its elements to paint a brighter, better future."

Andrew Liveris, Dow Chemical CEO

"Combinatorial explosion is one of the few mathematical functions [*sic*] that outgrows the exponential trend. That means that combinatorial innovation is the best way for human ingenuity to stay in the race with Moore's Law."

Erik Brynjolfsson & Andrew McAfee

"In the early stages of [combinatorial] development, growth is constrained by the number of potential new ideas, but later on it is constrained only by the ability to go through all the potential recombinations to find the truly valuable ones."

Martin Weitzman

"Compared with the past, we not only have greater expertise today, it's also more varied. We have to combine this expertise because together we will be able to make connections between things that at first glance seem to have nothing to do with each other. This is how innovations are created."

Kurt Bock, BASF Chairman

Source: Chemical Week, May 9, 2016; Erik Brynjolfsson & Andrew McAfee, The Second Machine Age (2014); Martin Weitzman, "Recombinant Growth," The Quarterly Journal of Economics, May 1998.

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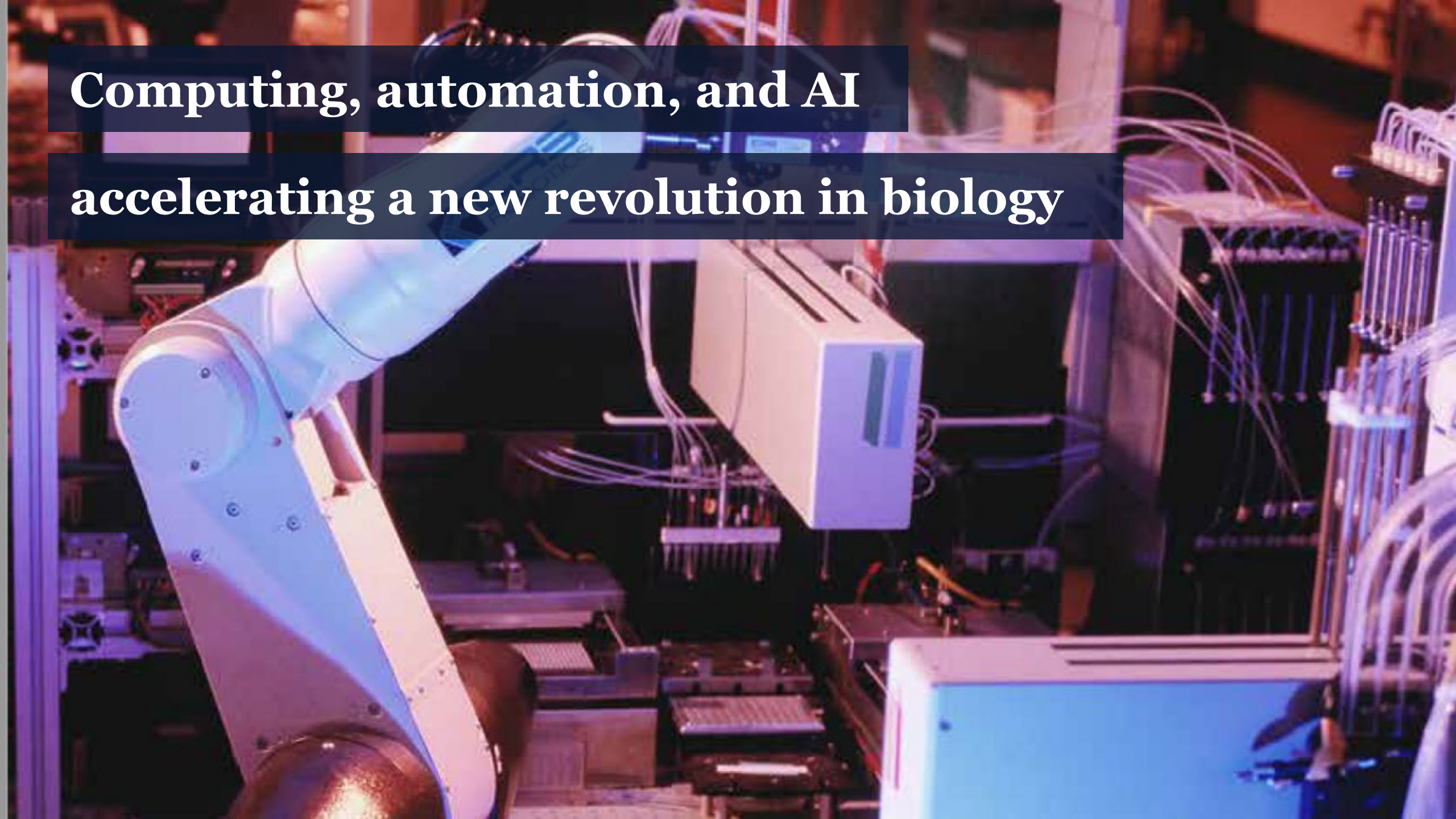
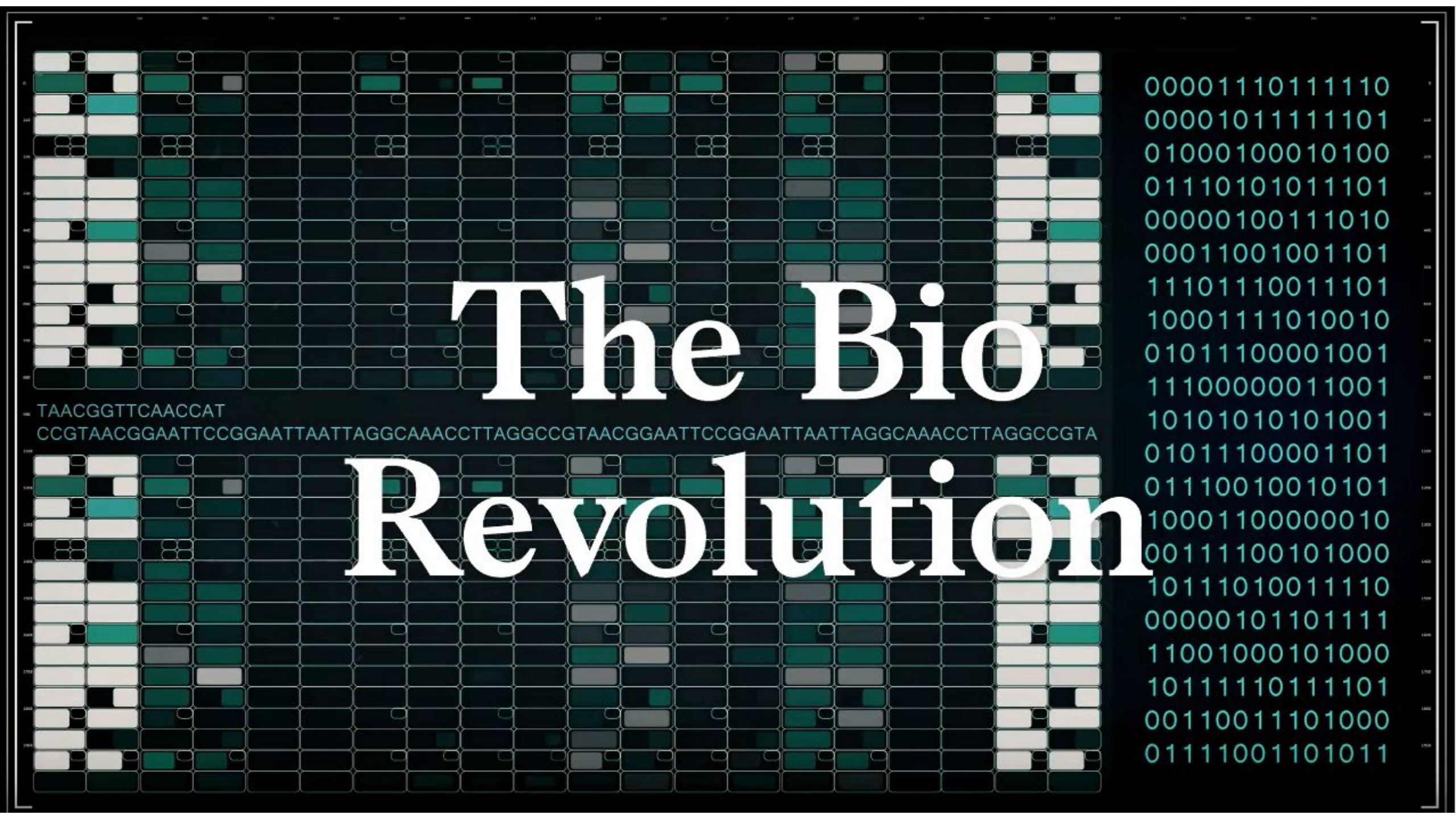

Computing, automation, and AI
accelerating a new revolution in biology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The Bio
Revolution

The science behind the Bio revolution: Innovations occurring in four key arenas, increasing our ability to understand and engineer biology

	Biomolecules	Biosystems	Biomachine interfaces	Biocomputing
				
Examples:	*Gene therapy for monogenic diseases*	*Cultured meat grown in a lab*	*Neuroprosthetics for motor control of a robotic limb*	*Data stored in strands of DNA*

Source: McKinsey Global Institute analysis

Our findings

Our ability to understand and engineer biology is increasing at a rapid pace

These advancements in biology are creating several transformational capabilities

Bio innovations will be broad, spanning domains beyond healthcare

The ~400 innovations we identified will create $2-4T of direct annual economic potential in 10-20 years

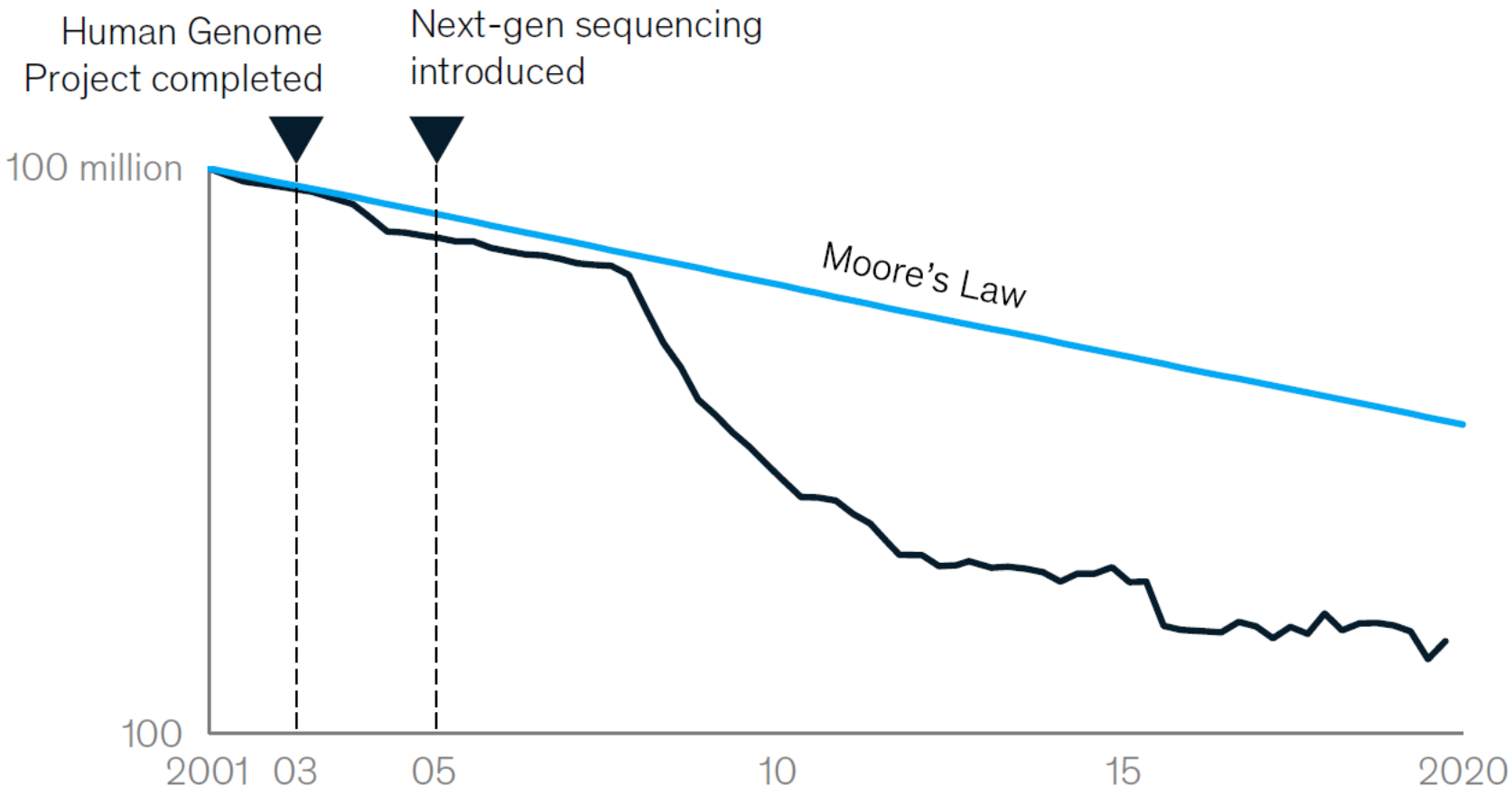
Bio innovations come with unique risks that require mitigation

Adoption of innovations hinges on factors around science, commercialization, and diffusion

The cost of sequencing is falling faster than Moore's law

Cost per human genome[1]

$ (log scale)



Source: McKinsey Global Institute analysis

Innovations are creating five new potentially transformative capabilities

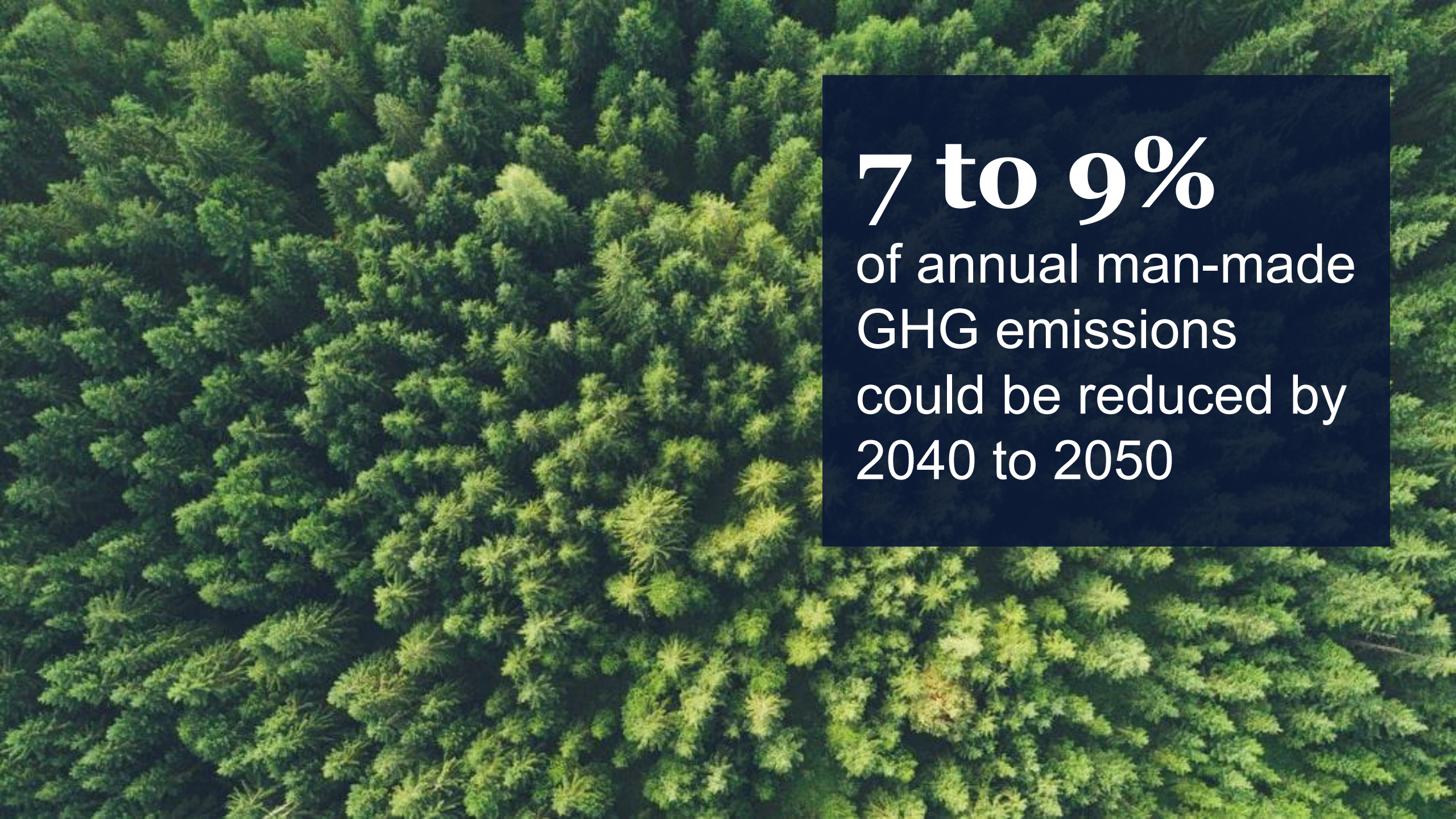
1. Biology-based production improving performance and sustainability
2. More control and precision to target actions
3. Increased ability to engineer and reprogram organisms
4. Higher R&D productivity enabled by automation and AI
5. Growing potential in biomachine interfaces and computing

Source: McKinsey Global Institute analysis


60%
of physical inputs to the global economy could be produced using biological means


45%
of world’s disease burden could be addressed with bio innovations


30%
of private sector R&D spend could be impacted by biology


7 to 9%
of annual man-made GHG emissions could be reduced by 2040 to 2050

The Bio Revolution has significant impact in human health…

Example applications XX Annual direct economic impact in 2030—40

Human health and performance

Health optimization in future generations

Gene drives to reduce vector-borne diseases

Gene therapies to prevent and treat diseases

Improvements in drug development and delivery

$0.5—1.3T

Note: Percentages based on the midpoint of annual direct economic potential for each domain

...and also directly impacts multiple domains outside of health

Example applications XX Annual direct economic impact in 2030—40

Human health and performance


Health optimization


Gene drives


Gene therapies


Drug development and delivery

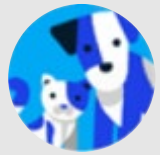
$0.5—1.3T

(35%)

Consumer products and services


DTC genetic testing


Microbiome beauty products


Genetically engineered pets

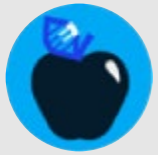

Personalized nutrition

$0.2—0.8T

(19%)

Agriculture, aquaculture, and food


Selective breeding


Genetic engineering


Plant-based protein


Soil microbiome data

$0.8—1.2T

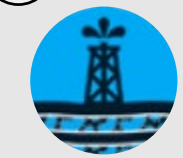
(36%)

Materials, chemicals, and energy


Bioroutes for fabrics


Fermentation processes


Biopolymers


Microbial resource extraction

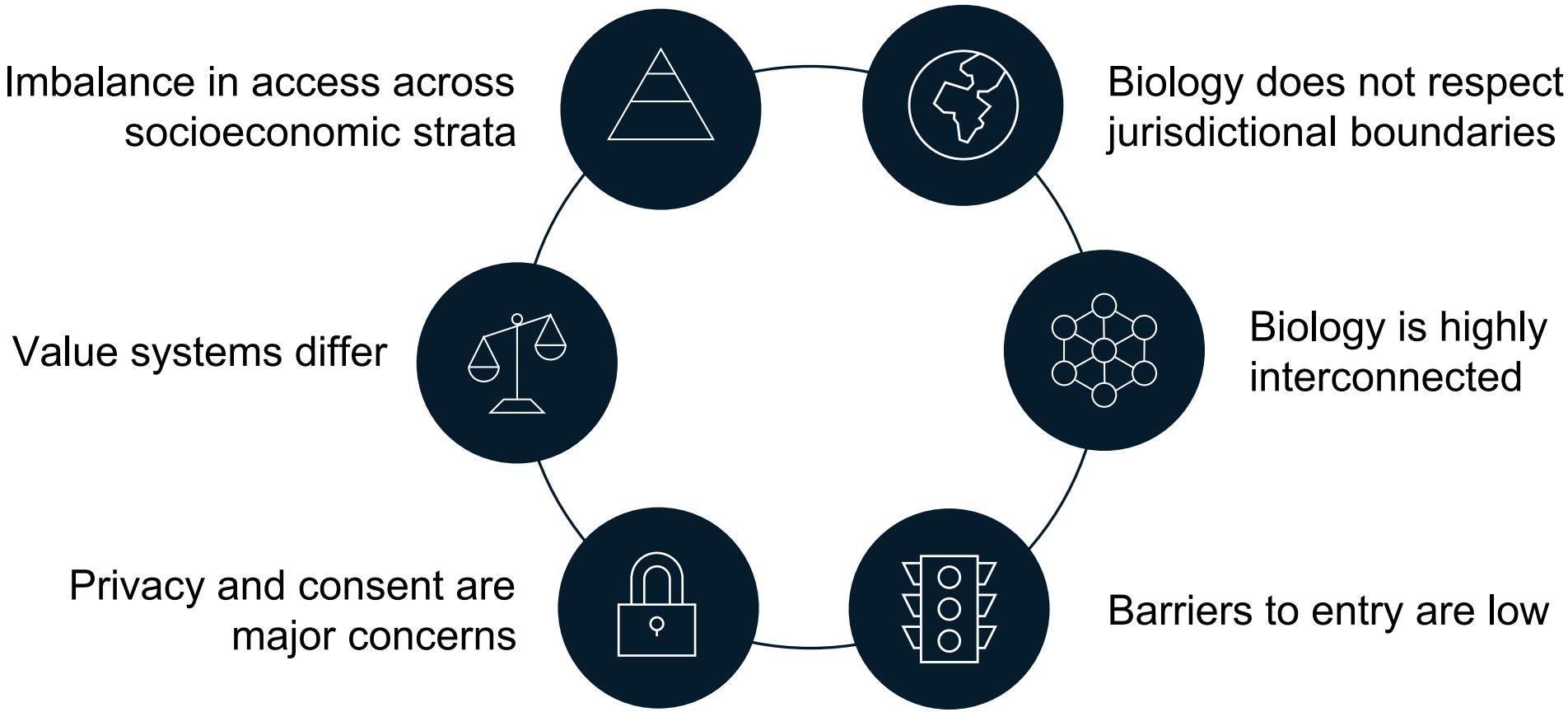
$0.2—0.3T

(8%)

We sized 400+ applications, which added up to $2-4T of annual direct economic potential within the next 10 to 20 years

Note: Percentages based on the midpoint of annual direct economic potential for each domain

Though rich with possibilities, biological advances are fraught with risks that need to be understood and mitigated



Live participants poll

What do you want us to discuss in the interactive section?

Agenda

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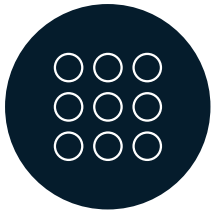
Your smartphone: a powerful case example of value disruption

Examples



Free apps available on your smartphone today worth

>900,000

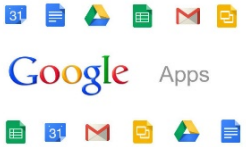
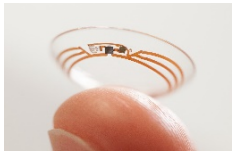
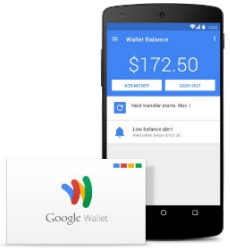
Application	Cost in 2011	Original device name	Year launched	MSRP[1], $	MSRP in 2011,$
Video conferencing	**Free**	Compression Labs VC	1982	250,000	**586,904**
GPS	**Free**	TI NAVSTAR	1982	119,900	**279,366**
Digital voice recorder	**Free**	SONY PCM	1978	2,500	**8,687**
Digital watch	**Free**	Seiko 35SQ Astron	1969	1,250	**7,716**
5 Mpixel camera	**Free**	Canon RC-701	1986	3,000	**6,201**
Medical library	**Free**	CONSULTANT	1987	2,000	**3,988**
Video player	**Free**	Toshiba V-8000	1981	1,245	**3,103**
Video camera	**Free**	RCA CC10	1981	1,050	**2,617**
Music player	**Free**	Sony CDP-101 CD player	1982	900	**2,113**
Encyclopedia	**Free**	Crompton's CD encyclopedia	1989	750	**1,370**
Videogame console	**Free**	Atari 2600	1977	199	**744**

1. Manufacturer's suggested retail price

Source: Peter Diamandis and Steven Kotler, Bold: How to go big, achieve success, and impact the world (2015)

Apple and Google have successfully disrupted multiple industries with their technologies

Disruptive technology – an innovation that can transform the way we live and work, enable new business models, and provide an opening for new players to upset the established order.

	Telecom	Entertainment	Healthcare	Banking
Apple				
Google				

Disruptive technologies are often **not confined to single area or industry**, and once their broader applicability is realized the **uptake becomes extremely quick**

Source: Value curation team research

The chemical industry is the custodian of the most comprehensive technology portfolio enabling technological progress

a Home button

b Capacitive touch screen

c Display module

Retina LED display

Silicone layer to enable high-resolution display

d Battery pack

Lithium ion battery

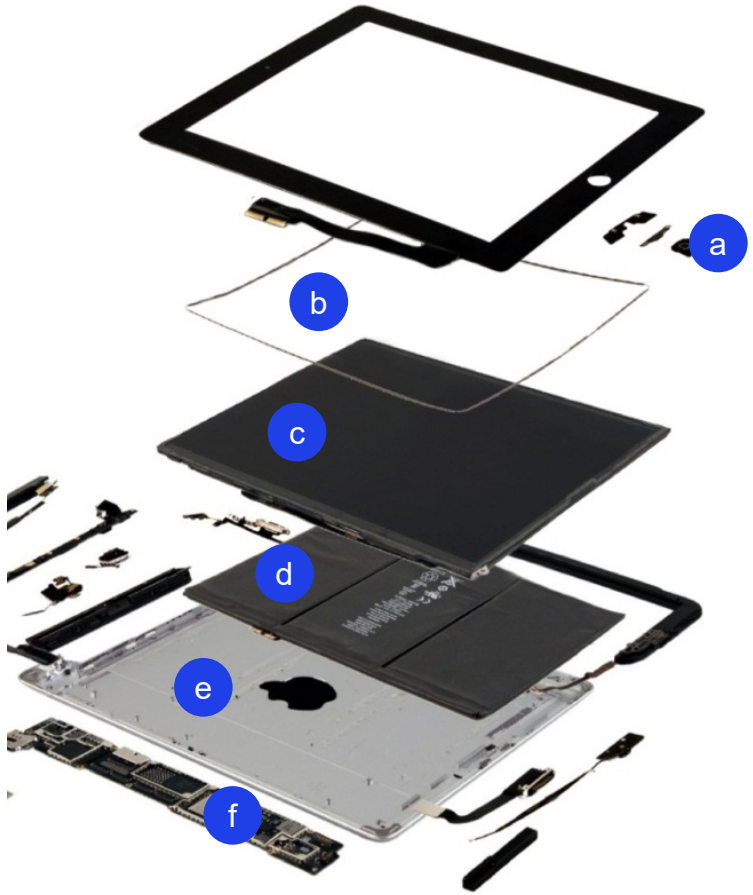
Silicone encasing

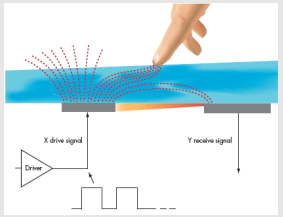
e Back cover

Anodized aluminum cover

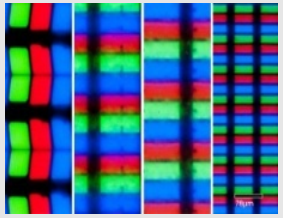
f Main PCB

Woven fiberglass re-inforced epoxy resin base





The **touch screen** features a **capacitive indium tin oxide (ITO) layer** which forms multiple vertical and horizontal electrodes



Advanced plasma-enhanced chemical vapor deposition process to allow ultra-densely applied LEDs for **retina display**

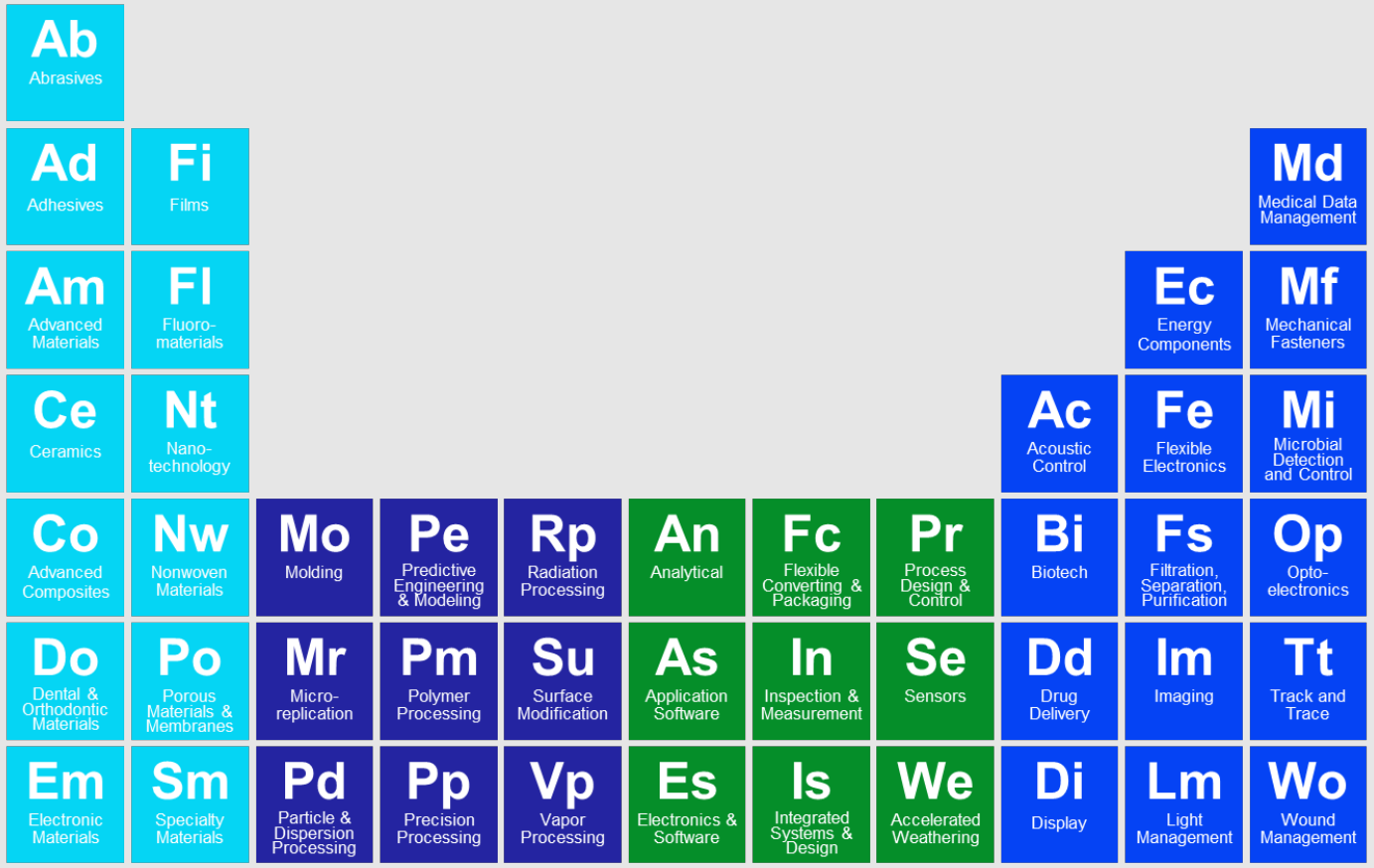
Lithium-ion polymer **battery,** where the **electrolyte is held in a polyethylene oxide composite,** enabling a battery in the exact shape of the iPad

Source: IHS iSuppli; Corning; howstuffworks.com

3M leverages its 'periodic table' of

46

core technology platforms…



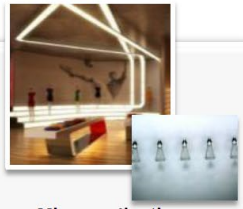
Source: Dr. Gayle Schueller, 3M Vice President (Global Sustainability presentation, July 16, 2015)

...to capture value-creating growth through innovative mixing and matching of technologies and markets...

Pressure-Sensitive Adhesives
75% of Company

Filtration
30% of Company

Films
40% of Company



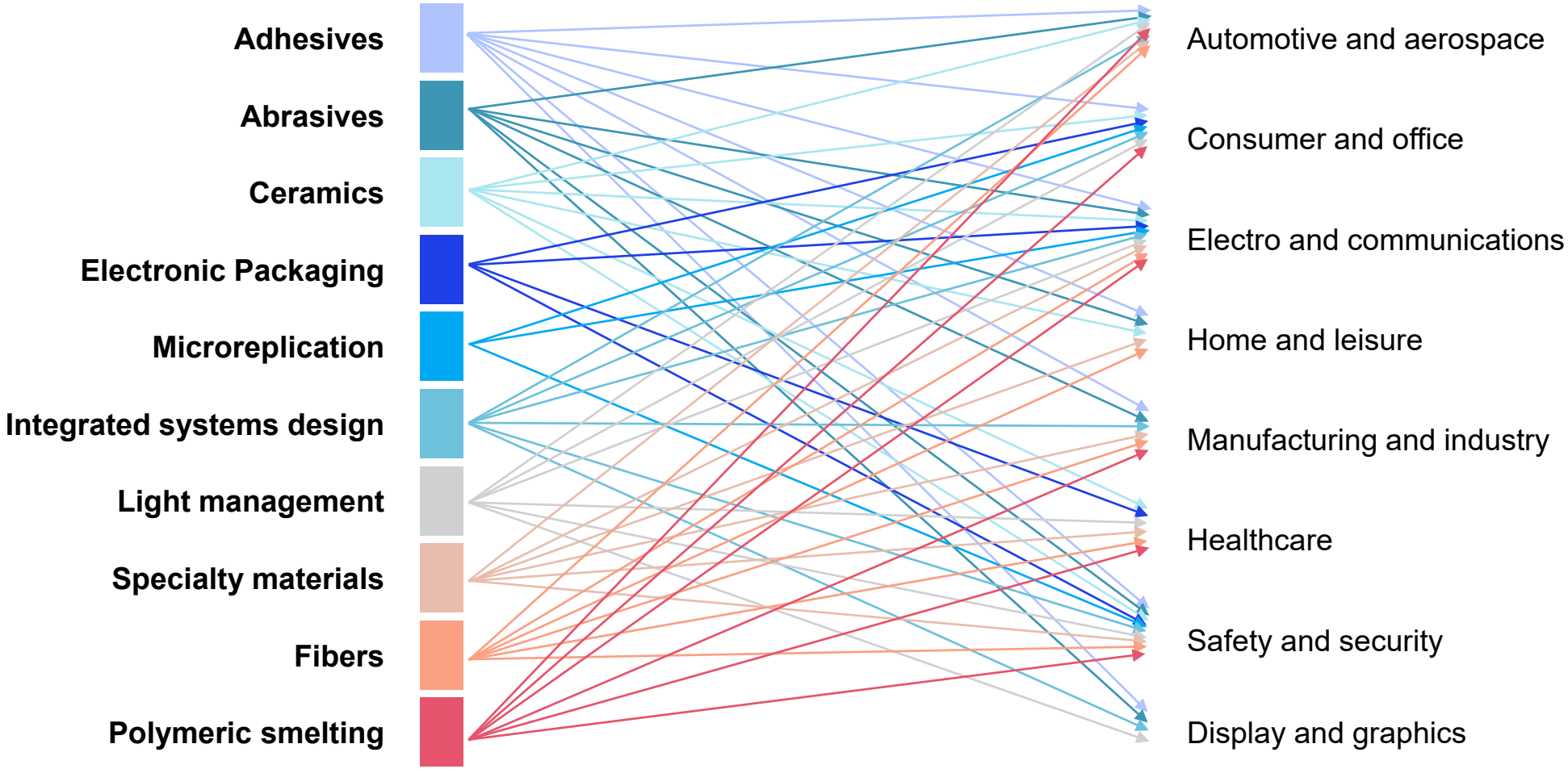
Microreplication
45% of Company

Non-wovens
70% of Company

Innovation model encourages sharing and combination of platforms

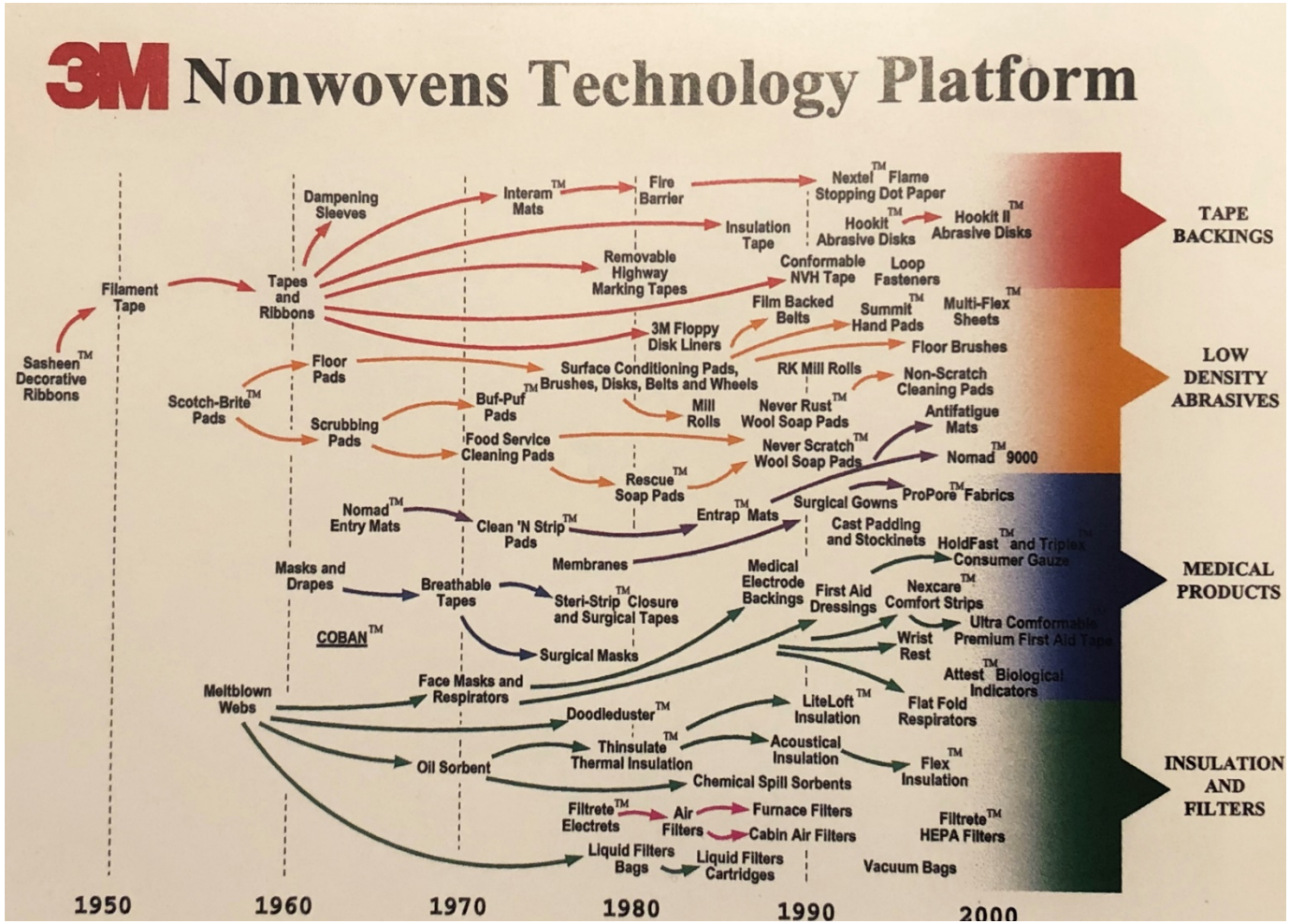
Source: Randy Frank, 3M presentation on "Uncommon Connections, Innovative Solutions" at IEEE meeting, November 2014

...and to build extraordinary market diversity into its portfolio...



Source: Dr. Gayle Schueller, 3M Vice President (Global Sustainability presentation, July 16, 2015)

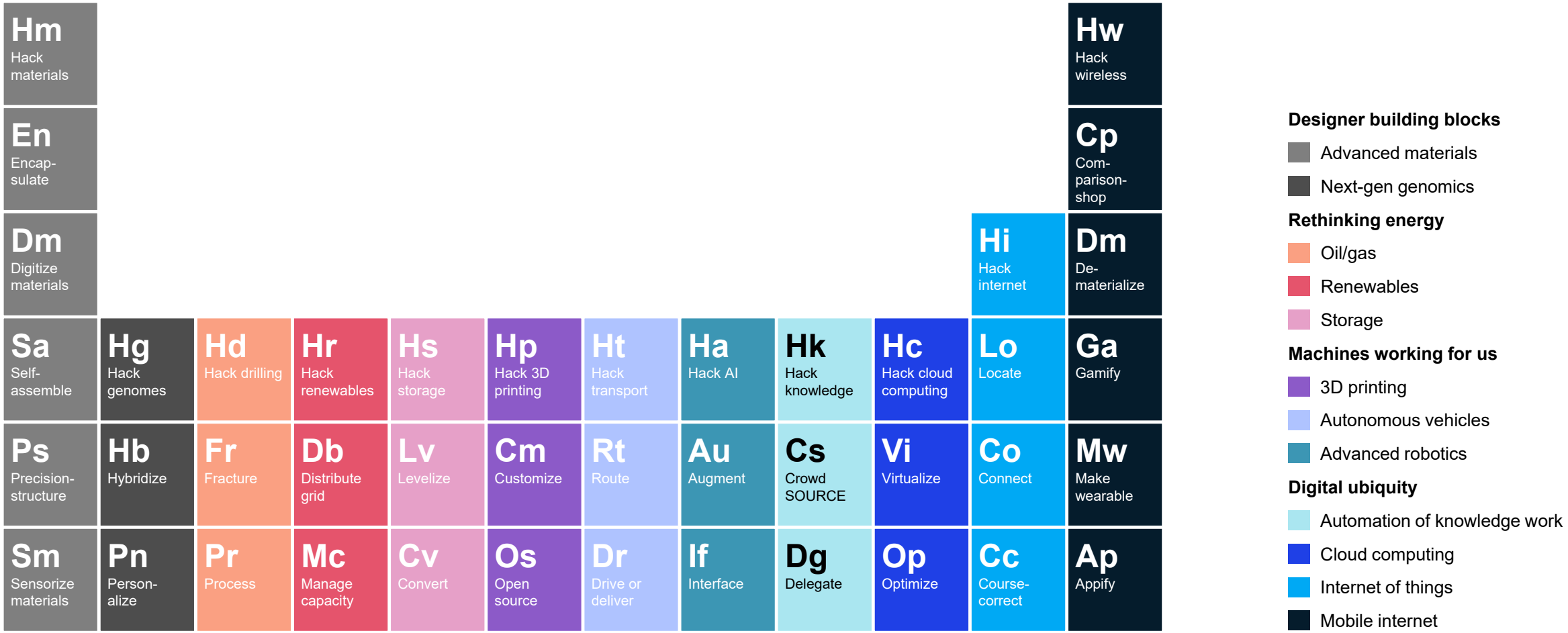
...over time, e.g., serving diverse markets with its nonwovens technology



Source: A Century of Innovation – The 3M Story

Think of McKinsey's 'disruptive dozen' technologies as a set of verbs that can be recombined to create game-changing business models...

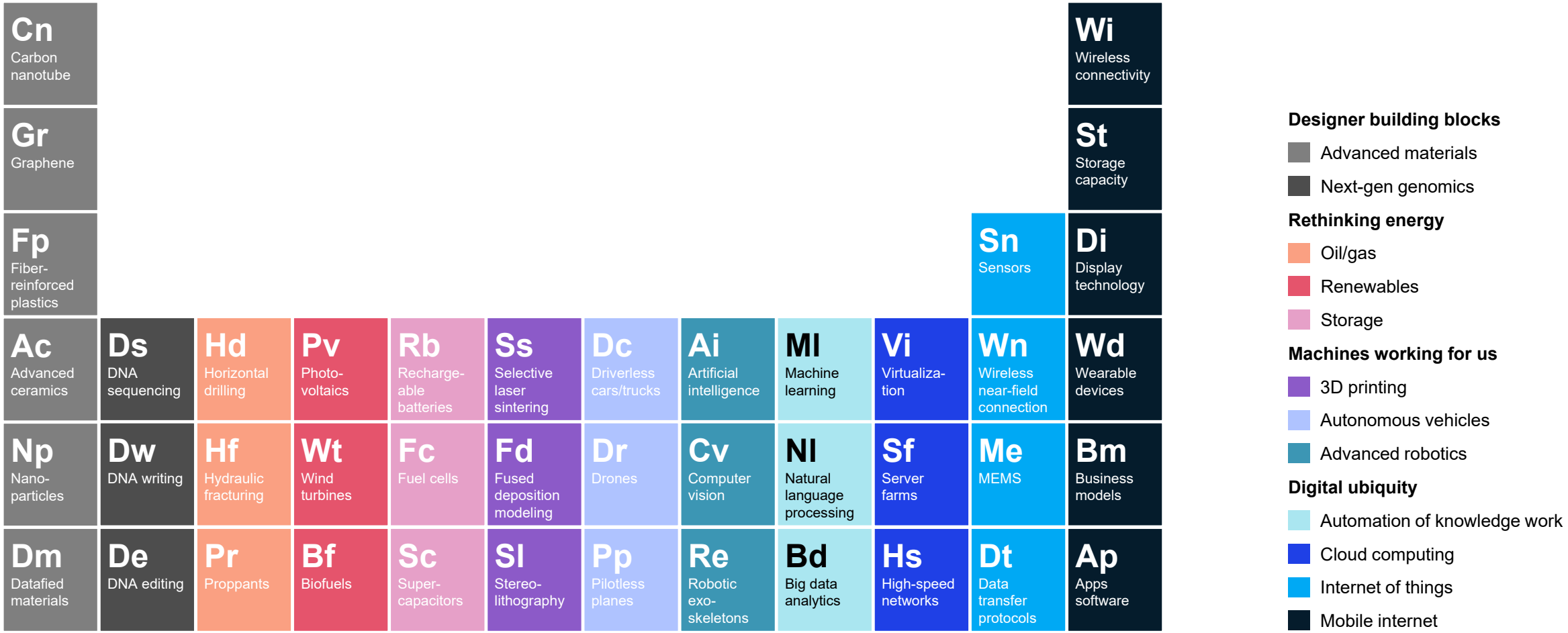
Entrepreneur's version



Source: McKinsey Global Institute; Sam G. Samdani

...or as discrete sets of engineering hacks that may be combined in unforeseen ways to create new capabilities

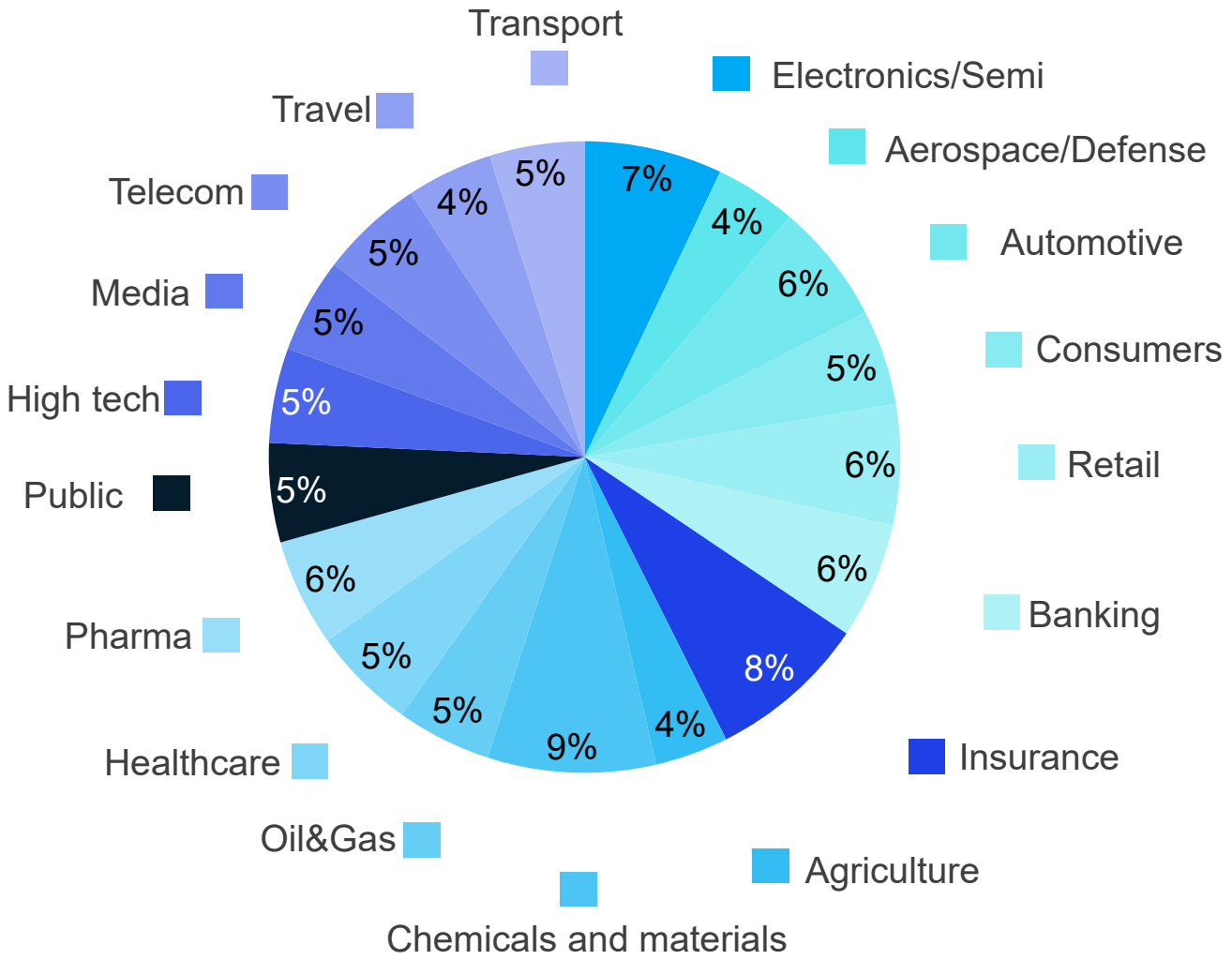
Engineer's version



Source: McKinsey Global Institute; Sam G. Samdani

We examined more than 600 actual use cases of application of AI

Breakdown of 600 real use cases



Advanced/AI techniques

Reinforcement learning

Transfer learning

Deep learning (e.g., feed forward neural networks, CNNs, RNNs, GANs)

Ensemble (e.g., random forest, gradient boosting)

Dimensionality (e.g., PCA, tSNE)

Instance based (e.g., KNN)

Decision tree learning

Monte Carlo methods

Linear classifiers (e.g., Fisher's discriminant, SVM)

Clustering (k-means, tree based, db scan)

Regression Analysis (linear, logistic, lasso)

Markov process (e.g., Markov chain)

Statistical inference (e.g., Bayesian inference, ANOVA)

Naive Bayes classifier

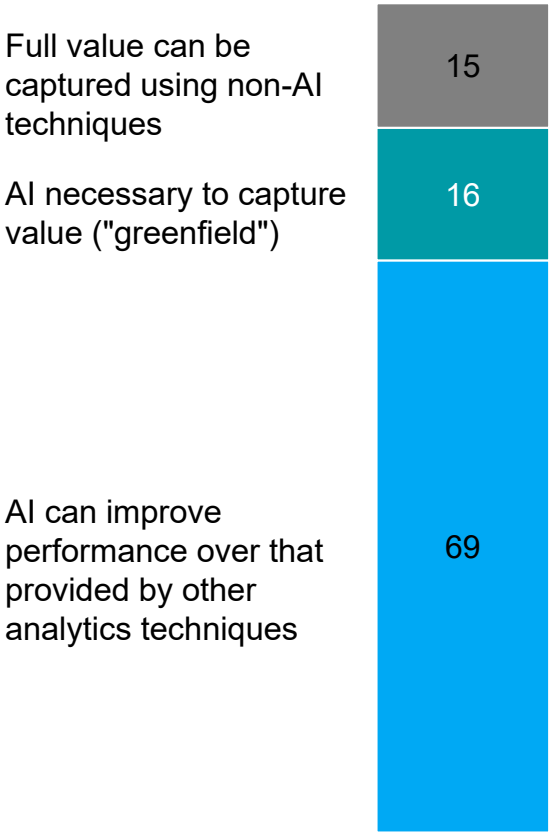
Traditional techniques

SOURCE: McKinsey research and expert interviews

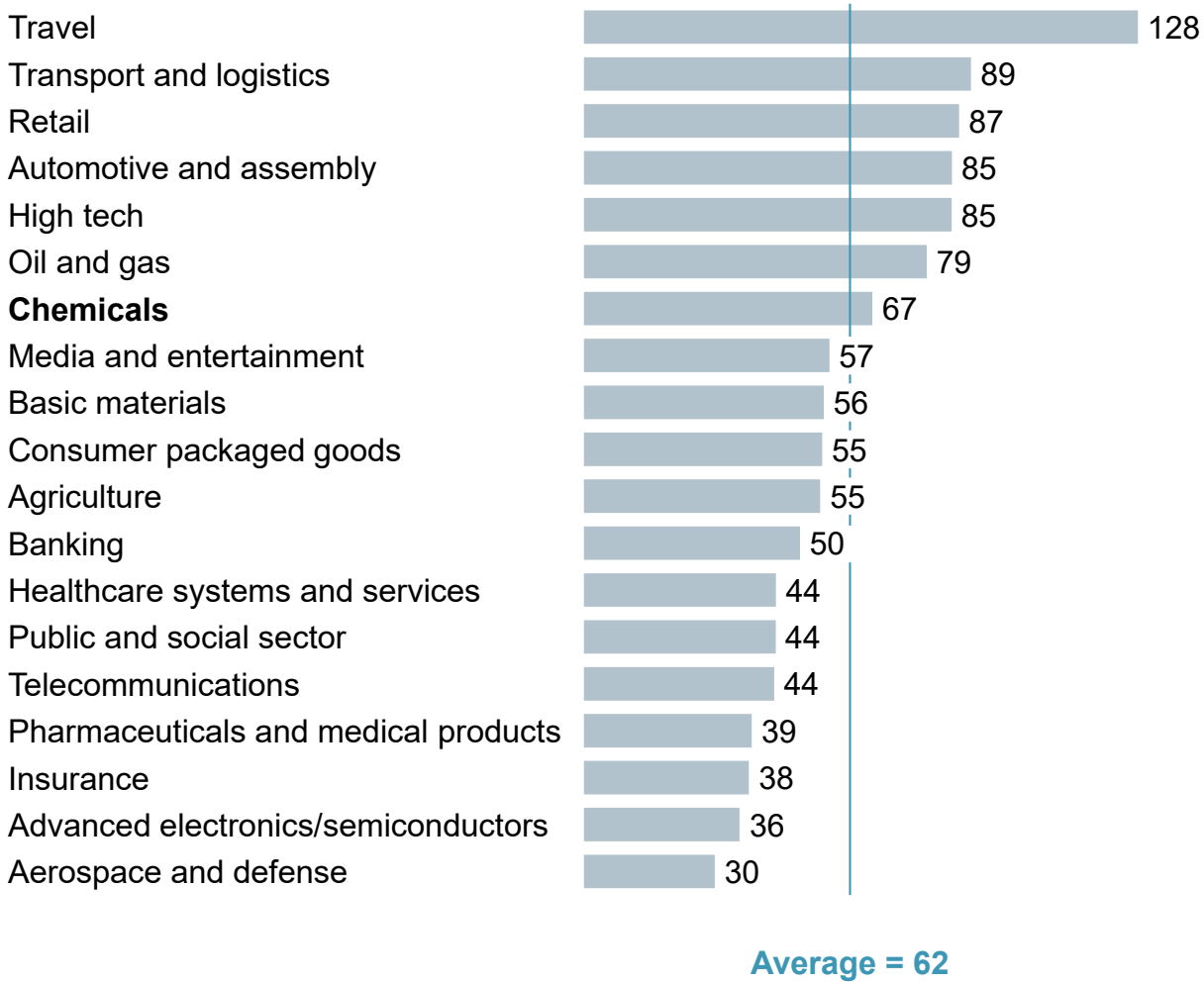
In more than two-thirds of our use cases, AI can improve performance beyond that provided by other analytics techniques

%

Breakdown of use cases by applicable techniques

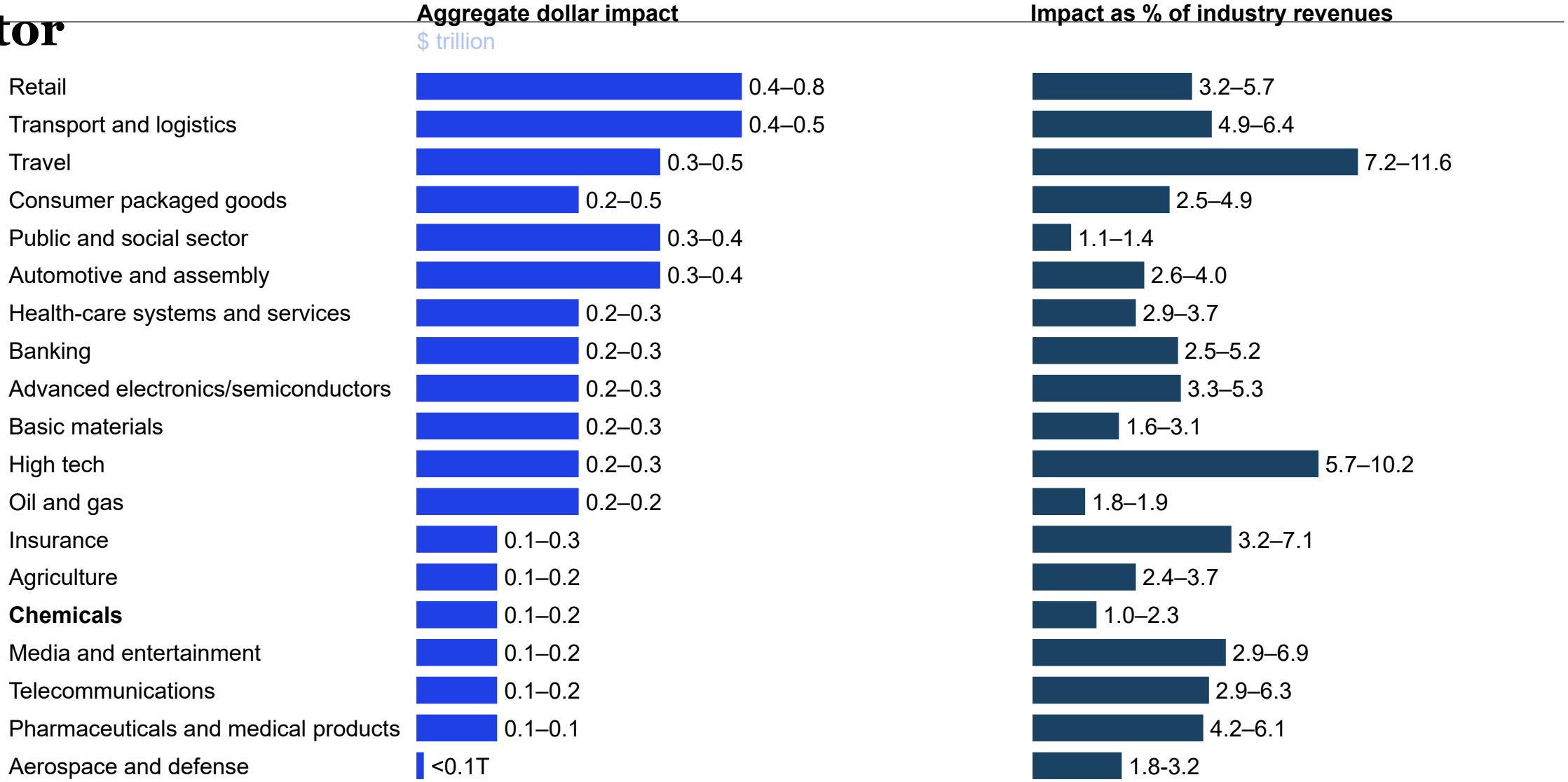


Potential incremental value from AI over other analytics techniques



NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey Global Institute analysis

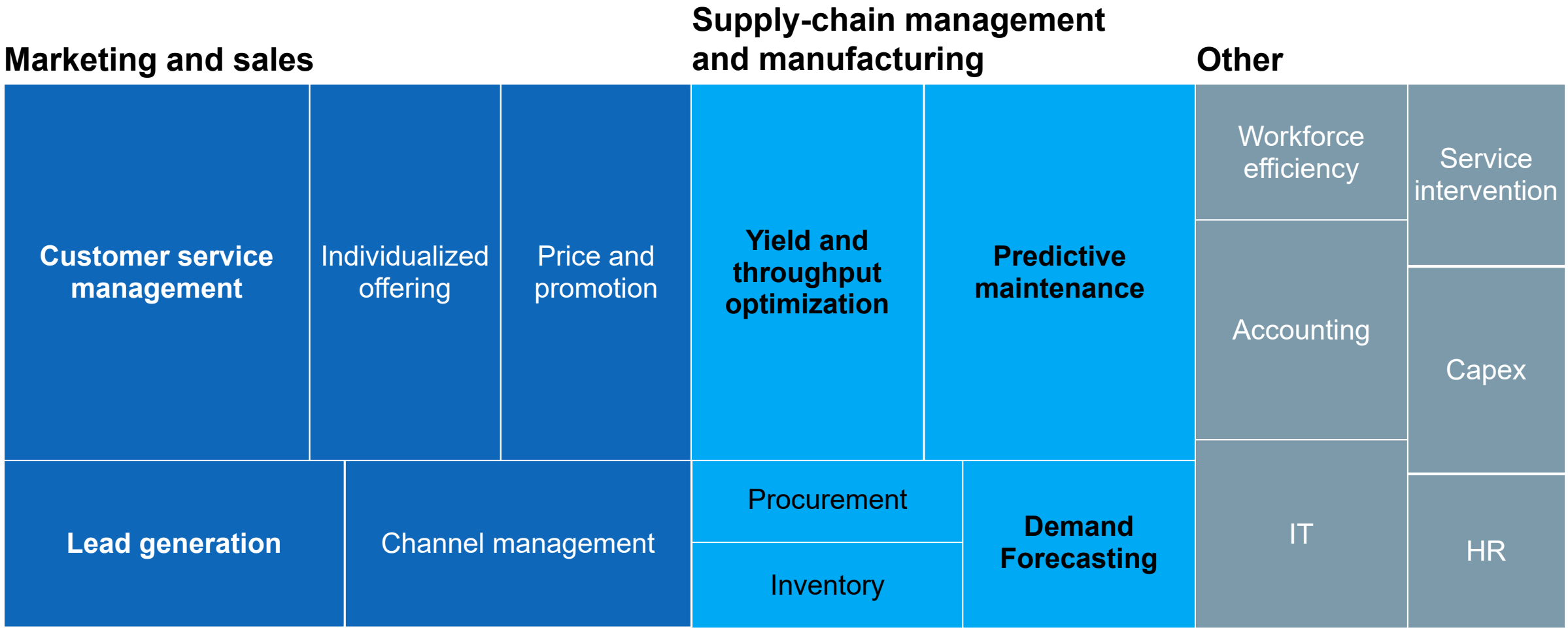
AI has the potential to create annual value across sectors totaling $3.5 trillion to $5.8 trillion but the potential varies significantly by sector



NOTE: Artificial Intelligence here includes neural networks only. Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

AI-powered marketing and sales, supply-chain management and manufacturing are among the largest drivers[1] of value in chemicals



1 Box sizes are indicative of value potential

SOURCE: McKinsey Global Institute analysis

McKinsey is working with the World Economic Forum to share best practices in “Industry 4.0” level automation through “lighthouse” sites

Objective Set up a global network of benchmark Fourth Industrial Revolution (aka Industry 4.0) production sites to support industrial companies and economies on their digital transformation journey

Global network of best-in-class Industry 4.0 technology assets

Lighthouse sites
Lighthouse sites have a mature implementation of multiple Industry 4.0 use cases and form the basis of the platform

Enablers
Best-practice on enablers such as change management, capability-building and agile use case development

Impact achieved
Significant financial and operational impact

Integrated use cases
Integrated Industry 4.0 use cases deployed at scale

Technology platforms
Scalable Industry 4.0 technology platforms to deploy multiple technologies

Structured visits for learning and exchange
Exclusive to C-suite of private and public organizations

Learn about Industry 4.0 technologies, use cases, and implementation in practice

Build new collaborations and partnerships

Explore new business models

Knowledge sharing platform for Industry 4.0 including:
Overview history, progress and scope of network

Key findings and insights from lighthouse case studies

Collection of ancillary Industry 4.0 related knowledge generated by community

Overview of Industry 4.0 use cases

The lighthouse project was launched in response to the struggle of many organizations to scale up Industry 4.0-level manufacturing technologies

Industry 4.0 manufacturing technologies are well-established

Connectivity

8.4bn Connected devices worldwide

700 IoT platforms

AI

90% % of humankind's data created in the last 3 years

5% Image & speech recognition error rate 2015 (2010: 27%)

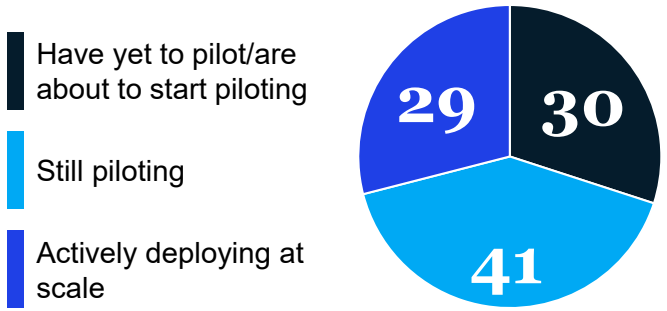
Flexible automation

60% Automation potential manufacturing with today's technology

100k Kiva robots used by Amazon across 26 DC's

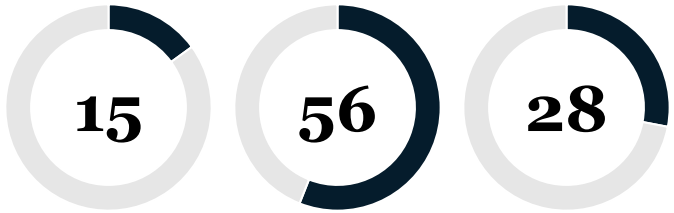
But the majority of companies are stuck at "pilot purgatory"

Companies piloting AI & IoT solutions
% respondents



Long pilots prevent testing of additional use cases

Pilot length
% respondents



Associated benefits are significant

Potential **$ 3.7 trillion**

for global economy through enhanced productivity in manufacturing

Improved business value drivers:

Agility and responsiveness

Resource productivity and efficiency

Speed to market

Customization to customer needs

An independent global Industry 4.0 expert group is responsible for evaluating the lighthouse sites

Private Sector

Sergey Chebotarev
VP of Energy
NLMK

Steffen Lang
Global Head Technical Operations
Novartis

Enno de Boer
Partner, Leader Manufacturing, McKinsey

Dr. Ravi Kumar
Associate Vice President & Head, Advanced Engineering Group at Infosys

Loic Regnier
Strategic Thought Leadership
Schneider Electric

Bart Talloen
VP Supply Chain Strategy & Deployment
J&J

Shwetha Shetty
Sr. Director Corporate Strategy
SAP

Jeffrey Wilcox
VP Digital Transformation, Lockheed Martin

Majid Gwaiz
General Sup., Advanced Process Solution
Saudi Aramco

Renee McKaskle
SVP and CIO, Hitachi

Christian Haecker
Head of Additive Manufacturing Industrialization.
Oerlikon AM

Aly Wahdan
PM Rakona, P&G

Academia

Prof. Jun Ni
Director Manufacturing Research Center,
U. of Michigan

Prof. Jeremy Edwards
Reader in Economics, University of Cambridge

Prof. Krystyn Van Vliet
Professor of Materials Science & Engineering,
MIT

Technology Pioneers

Ric Fulop
Founder and CEO
Desktop Metal

Natan Linder
CEO and co-founder Tulip

Andreas Kunze
CEO and Co-founder
Konux

Melonee Wise
CEO Fetch Robotics

Carl Vause
VP of Energy
NLMK

The Global Lighthouse Network includes 44 sites where Industry 4.0 technologies are successfully deployed at scale

1 **Zymergen**
Biotechnology, US

2 **Fast Radius with UPS**
Additive manufacturing, US

3 **Johnson & Johnson vision care**
Medical devices, US

4 **Groupe Renault**
Automotive, BR

5 **MODEC**
Oil and gas, BR

6 **Johnson & Johnson DePuy Synthes**
Medical devices, IR

7 **GSK**
Pharmaceuticals, UK

8 **Schneider Electric**
Electrical components, FR

9 **Groupe Renault**
Automotive, FR

10 **Tata Steel**
Steel products, NL

11 **Henkel**
Consumer goods, DE

12 **Phoenix Contact**
Industrial automation, DE

13 **AGCO**
Agricultural equipment, DE

14 **Rold**
Electrical components, IT

15 **Bayer**
Division pharmaceuticals, IT

16 **BMW Group**
Automotive, DE

17 **Procter & Gamble**
Consumer goods, CZ

18 **Sanvik Coromant**
Industrial tools, SE

19 **Nokia**
Electronics, FI

20 **Arcelik A.S.**
Home appliances, RO

21 **Petkim**
Chemicals, TR

22 **Ford Otosan**
Automotive, TR

23 **Saudi Aramco**
Gas treatment, SA

24 **Unilever**
Consumer goods, UAE

25 **Tata Steel**
Steel products, IN

26 **Siemens**
Industrial automation products, CN

27 **Infineon**
Semiconductors, SG

28 **Schneider Electric**
Electrical components, ID

29 **Micron**
Semiconductors, SG

30 **Petrosea**
Mining, ID

31 **Foxconn Industrial Internet**
Electronics, CN

32 **FOTON Cummins**
Automotive, CN

33 **Danfoss**
Industrial equipment, CN

34 **Weichai**
Industrial machinery, CN

35 **SAIC Maxus**
Automotive, CN

36 **Haier**
Home appliances, CN

37 **Johnson & Johnson DePuy Synthes**
Medical devices, CN

38 **Bosch**
Automotive, CN

39 **Procter & Gamble**
Consumer goods, CN

40 **Boashan Iron & Steel**
Steel products, CN

41 **Haier**
Appliances, CN

42 **POSCO**
Steel products, KOR

43 **GE Healthcare**
Healthcare, JP

44 **Hitachi**
Industrial equipment, JP

Source: World Economic Forum in collaboration with McKinsey and Company

Agenda

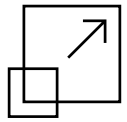
What's top of mind among executives & engineers today?

When AI meets biology

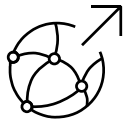
AI-powered innovation as the catalyst

Closing thoughts & open questions

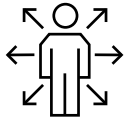
McKinsey & Company is a global management consulting firm, deeply committed to helping institutions in the private, public, and social sectors achieve lasting success. For over 90 years, our primary objective has been to serve as our clients' most trusted external advisor. With **consultants in over 100 cities in over 60 countries, across industries and functions**, we bring unparalleled expertise to clients anywhere in the world. We work closely with teams at all levels of an organization to **shape winning strategies, mobilize for change, build capabilities and drive successful execution.**



Transformation



Enabled by technology



Sustained through capabilities

In **Partnership** with individuals and institutions

When and where there's potential to **move the needle**

From **strategy to execution**

With the best **people and assets,** operating as one firm globally

We jointly create distinctive and lasting **performance, health and societal impact**

If AI is the answer, what are your questions?

- What does **success with AI-powered digital transformation** under the Industry 4.0 framework look like in your organization, say, 12 months from now? What about five years from now?
- What would the **CEO/President of your organization say if he/she were sitting here now**, listening to this session?
- **What would Steve Jobs do** if he were here today?

Extra slides

AI can help unlock circular economy (CE) opportunities by facilitating business models, and optimizing infrastructure to ensure circularity

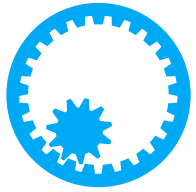
AI can enable the circular economy across industries

- AI capabilities can help build a circular economy, at a faster rate than would be possible without AI
- AI can boost development and design of completely new circular products and businesses
- AI can help traditional players in their transition to become more circular

Across industries, AI technologies can unlock three high potential circular economy opportunities

Design circular products, components, and materials

AI can enhance and accelerate the development of new products, components, and materials fit for a circular economy through iterative machine-learning-assisted design processes that allow for rapid prototyping and testing



Facilitating circular business models

AI can magnify the competitive strength of circular economy business models, such as product-as-a-service and leasing. By combining real-time and historical data from products and users, AI can help increase product circulation and asset utilization through pricing and demand prediction, predictive maintenance, and smart inventory management

Optimize infrastructure to ensure circular product and material flows

AI can help build and improve the reverse logistics infrastructure required to ‘close the loop’ on products and materials by improving the processes to sort and disassemble products, remanufacture components, and recycle materials

SOURCE: McKinsey, Artificial Intelligence and the Circular Economy - AI as a tool to accelerate the transition

AI is uniquely positioned to offer a suite of solutions to fundamental CE requirements

	Design circular products, components, and materials	Facilitate circular business models	Optimize infrastructure to ensure circular flows
CE requirements	Design innovation to **keep product, components and materials at their highest utility and value** Designs that can **empower cycles of reuse, repair, refurbishment, and recycling** of technical materials and the cascading and looping of biological nutrients	Organize **business functions** in a way that they **underpin circular economy principles** **Introduce circular business propositions** (e.g., asset sharing or product as a service) that compete with linear propositions	Materials and products are **reused, repaired, remanufactured and recycled** to keep the **materials in use** or to **recover nutrients** **Reverse logistics infrastructure** is required to facilitate effective collection, sorting, treatment, and redistribution
AI opportunities	AI can **generate design suggestions** that can **improve quality of design** and **speed of design delivery** AI does so by **navigating complexity and supporting decision making** - **Taking more features into consideration** (e.g., disassembly, upgradability, and recycled content) - **Taking more material and construction options into considerations** (e.g., full material data base, 3D printing, local available materials and by products - **Preventing use of potentially harmful materials** by leveraging broadest available knowledge base	AI can through **dynamic pricing and matching algorithms** has unlocked the potential for **sharing and access models** AI technology **facilitates reusing, recovering components and parts harvesting for remanufacturing or recycling** - **Assess usability of products** taking into consideration product condition and current market situation - **Enable reverse logistics** by asset tracking and understanding fluctuations in demand and supply	AI can help **sort post-consumer heterogeneous material and product flows** thereby enabling to recover products and by-products, and organic and technical materials AI helps to **control waste sorting robots** (up to a 98% level of accuracy)

SOURCE: McKinsey, Artificial Intelligence and the Circular Economy - AI as a tool to accelerate the transition

Case example: Accelerated Metallurgy uses AI to design new materials for a CE

About the project	Funded by the **European Space Agency**, the project **'Accelerated Metallurgy'** conducted research on rapid and systematic developing, producing, and testing of novel alloy combinations
Contributing to a circular economy…	The project aimed to develop new metals with the same performance in a more efficient way. Alloys designed with circular economy principles in mind: are non-toxic; are designed to be used and reused; have longer use periods; and could be made using additive manufacturing and processing methods that minimize waste. Additionally, improved material properties can implicitly reduce resource use through enhanced product performance
…by using AI	Accelerated Metallurgy uses AI algorithms to systematically analyze huge amounts of data on existing materials and their properties to design and test new alloy formulations. By capturing details of the chemical, physical, and mechanical properties of these unexplored alloys, the algorithms can map key trends in structure, process, and properties to improve alloy design using rapid feedback loops
Solving real business problems	Using AI to improve and accelerate the material design process can lead to the development of alloys that can circulate at high value in the economy and that support product and technology innovation (e.g. alloys that can convert waste heat to electricity), as well as other potential benefits such as increased performance and extended product life

With potential for system level impact

Accelerated Metallurgy has achieved for the metallurgy industry a drastically reduced time to market. Moreover, emphasis on environmentally friendly alloys at an early design phase, in combination with life-cycle analysis, will contribute to conserving natural resources and the move to low-carbon technologies

European Commission

SOURCE: McKinsey Analysis, Flightglobal, CORDIS

Case example: Stuffstr uses AI to operate a circular business model that keeps products longer in circulation

About the project	Founded in Seattle in 2014, Stuffstr offers consumers the opportunity to buy back used household items, with an initial focus on clothing and apparel, in exchange for vouchers, which can be spent at the original apparel retailer. As part of this process, Stuffstr collects the products and re-sells them through existing secondary markets
Contributing to a circular economy…	Stuffstr boosts re-use of apparel by giving it a second life. The service offers consumers a low hassle solution for getting rid of unused stuff, with a financial incentive. The concept increases awareness for the value of unused clothing and also encourages consumers to sell back items they no longer need or want so they can be circulated
…by using AI	Stuffstr uses AI algorithms for the pricing of both the products they buy from consumers and the products they sell in secondary markets. The backend of their service uses machine learning to ensure a consistent classification of all re-sale items. Finally, AI helps refine Stuffstr's sales strategy through constant experimentation and rapid feedback loops
Solving real business problems	For retailers, Stuffstr provides an additional revenue stream as well as an improvement in consumer loyalty. Stuffstr itself generates revenue by reselling used apparel and servicing fashion brands by ensuring that their products are only sold in certain secondary markets. For consumers, the company pays for used and/or unwanted apparel in a transparent and convenient manner

With potential for system level impact

The CO2 embedded in the household items we buy each year exceeds the emissions of the entire U.S. auto fleet. And almost 85% of U.S. textiles end up in the landfill—at about 70 pounds per person every year — yet most are eligible for recycling. Current circulation rates are incredibly low, for instance only 2% of apparel products enter a secondary market.

John Atcheson, CEO Stuffstr

SOURCE: McKinsey Analysis, Stuffstr

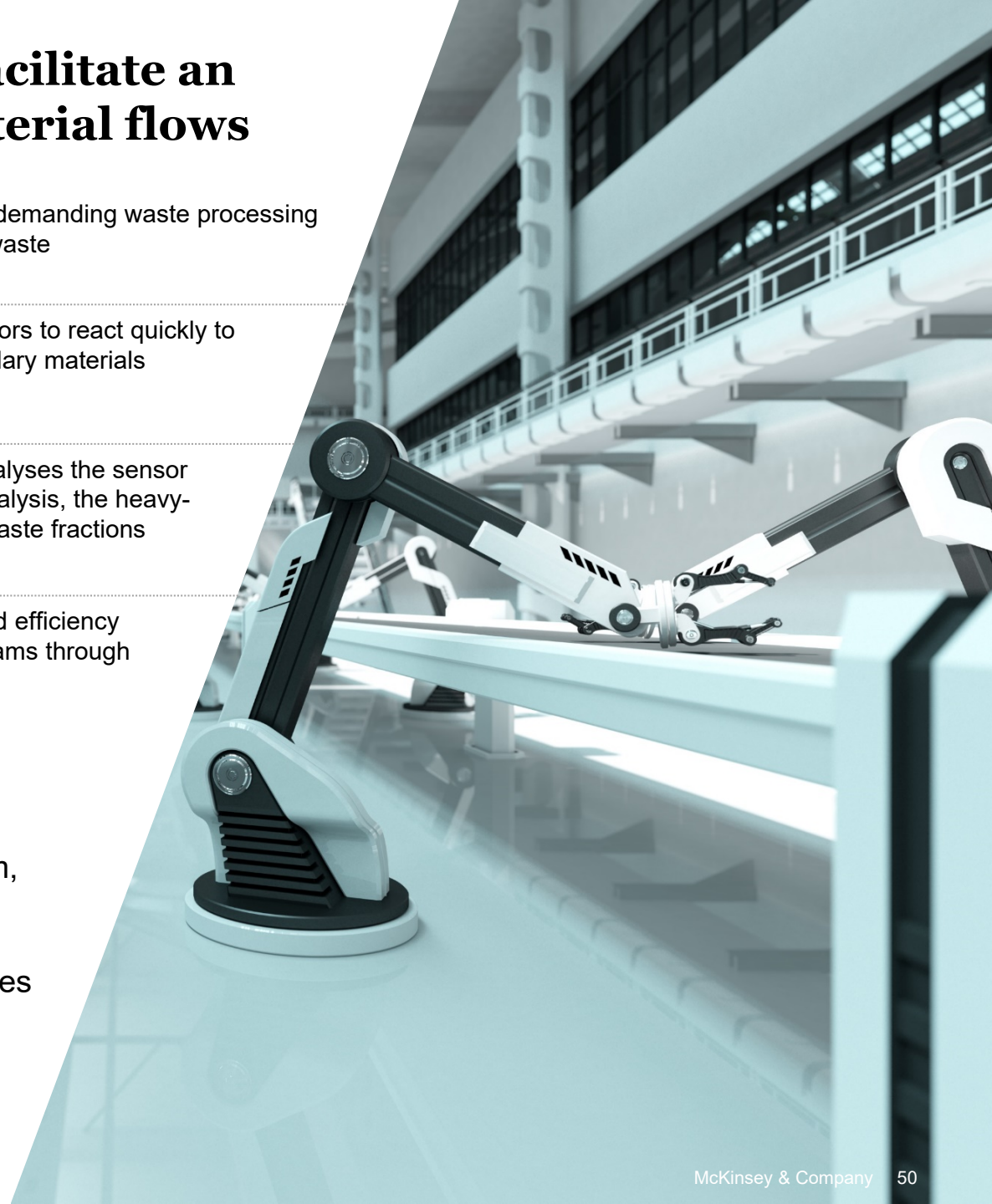
Case example: ZenRobotics uses AI to facilitate an infrastructure that ensures circular material flows

About the project	Founded in 2007, ZenRobotics was the first company to apply AI and robotics in a demanding waste processing environment. The company combines AI and robotics to recover recyclables from waste
Contributing to a circular economy…	ZenRobotics's technology allows greater flexibility in waste sorting, enabling operators to react quickly to changes in a waste stream and increasing the rate of recovery and purity of secondary materials
…by using AI	Waste is monitored by cameras and sensors. The AI software, called ZenBrain, analyses the sensor data, creating an accurate real-time analysis of the waste stream. Based on this analysis, the heavy-duty robots make autonomous decisions on which objects to pick, separating the waste fractions quickly with high precision
Solving real business problems	ZenRobotics waste sorting solutions offer opportunities to improve performance and efficiency of waste sorting. This increases the value that can be generated from material streams through improved recovery rates and overall quality of outputs

With potential for system level impact

Intelligent robotic systems can process almost any given waste stream, and sorting capabilities can be redefined for every new market situation—even on a daily basis. Furthermore, increased flexibility in recognition gives plant operators the possibility to explore new use cases

Waste Management World



SOURCE: McKinsey Analysis, ZenRobotics, Techcrunch

Case examples of two industries, namely Food & Agriculture and Consumer Electronics to assess AI enabled circular economy value

Sector	Estimated upper magnitude of the opportunity by 2030, USD Bn	Example applications of AI for CE levers	
1 Food & Agriculture	127	Use image recognition to determine when fruit is ready to pick Match food supply and demand more effectively Enhance the valorization of food by-products	
2 Consumer Electronics	90	Select and design specialist materials Extend the lifetime of electronics through predictive maintenance Automate and improve e-waste recycling infrastructure through the combination of image recognition and robotics	

Given the fundamental difference in the food & agriculture and consumer electronics industry, and the essential similarities between the opportunities in these industries, AI likely has the potential to unlock value across industries

SOURCE: McKinsey, Artificial Intelligence and the Circular Economy - AI as a tool to accelerate the transition