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Post-Hearing Written Comments of BSA | The Software Alliance

Promoting Supply Chain Resilience (Docket Number USTR–2024–0002)

BSA | The Software Data Alliance (BSA)[1] appreciates the opportunity to participate in the public comment and hearing process relating to supply chain resilience being advanced by the Office of the US Trade Representative (USTR). BSA urges the USTR to take into account the importance of supporting US company adoption of enterprise software tools that can drive US supply chain resilience. A key factor in the adoption of those tools is to ensure that US companies maintain cross-border access to information necessary to use such enterprise software tools and to identify export opportunities to sell goods and services produced by American workers.

Enterprise software—or business-to-business (B2B) software—enables the operations of other companies promoting supply chain resilience that can benefit US manufacturing, nearshoring, and friendshoring efforts. B2B tools also promote economic inclusion for small businesses. Notably, 38 percent of small businesses in the United States cited increased sales and revenue as a benefit associated with using digital enterprise tools. These enterprise software tools help organizations of all sizes and across all industries operate more safely, enhance product and service development, and increase opportunities to innovate and grow. The enterprise software industry supports a wide range of organizations across the world, including SMEs and large companies; state and local governments; hospitals, schools, and universities; and non-profits.

Organizations in every sector of the US economy build their resilience across the supply chain by having access to cutting-edge software to run, facilitate, improve, and optimize their operations. For example, enterprise software underpins human resources and payroll operations; billing and financial transactions;

[1] BSA | The Software Alliance (www.bsa.org) is the leading advocate for the global software industry. Its members are among the world's most innovative companies, creating software solutions that help businesses of all sizes in every part of the economy to modernize and grow. With headquarters in Washington, DC, and operations in more than 30 countries, BSA pioneers compliance programs that promote legal software use and advocates for public policies that foster technology innovation and drive growth in the digital economy.BSA's members include: Adobe, Alteryx, Asana, Atlassian, Autodesk, Bentley Systems, Box, Cisco, CNC/Mastercam, Databricks, DocuSign, Dropbox, Elastic, Graphisoft, Hubspot, IBM, Informatica, Kyndryl, MathWorks, Microsoft, Okta, Oracle, PagerDuty, Palo Alto Networks, Prokon, Rubrik, Salesforce, SAP, ServiceNow, Shopify Inc., Siemens Industry Software Inc., Splunk, Trend Micro, Trimble Solutions Corporation, TriNet, Twilio, Workday, Zendesk, and Zoom Video Communications, Inc.

research and development; product design; workforce collaboration, communication, and messaging; customer relations; and logistics and supply-chain management, among many other business services.

Enterprise software can also promote domestic manufacturing through cutting-edge technologies such as "digital twins" software. In the same way manufacturers previously used blueprints to build their factories, experts today may use digital twin technology to build, simulate, and measure performance of factories, products and even processes before they start to build something. This dramatically increases the possibility to expanding US production and speed to market, while decreasing the risk of issues later in the process. A digital twin is made up of many different software solutions, some keep lists of each nut and bolt in operation and where they come from, some use advanced physics-based algorithms to predict performance, some simply are used to design new products in a digital environment. The digital twin then aggregates all that data to give manufacturers the ability to see and interact with their factories digitally and test out any changes to the facilities without having to stop production.

Enterprise software solutions are uniquely suited to increase competitiveness and productivity in the United States and allied economies, which often rely on knowledge and high-technology skills - rather than low labor costs - as a competitive differentiator. Importantly, to promote domestic manufacturing in the ways envisioned in the USTR's Federal Register notice, it is critical to maintain cross-border access to information from overseas, including information about export market opportunities.

Finally, enterprise software solutions also typically promote supply chain resilience because they are engineered to reduce operational risks for business customers who can be confident they are using tried and tested software products, with appropriate remedies and support, without having to develop their own software in-house. Enterprise software companies also often provide tools to facilitate their customers' compliance, for instance on privacy, consumer protection, cybersecurity, anti-money laundering, or energy efficiency.

Thank you for the opportunity to submit these comments.

Annexures:

- Annex A: BSA Jobs-Centric Digital Trade Policy
- Annex B: BSA Foundation Jobs Report – Supporting US Through COVID
- Annex C: Every Sector is a Software Sector – Manufacturing
- Annex D: Every Sector is a Software Sector – Smart Energy
- Annex E: Every Sector is a Software Sector – Agriculture

Annex A

Advancing a Jobs-Centric Digital Trade Policy

What is a Jobs-Centric Digital Trade Policy?

BSA | The Software Alliance supports a digital trade policy that benefits communities and workers through good jobs with good wages. A jobs-centric digital trade policy can focus resources on strategic export sectors that offer well-paid jobs in today's digitized economy – where there is room for further job growth.

One such sector is software. The US software industry supports a large US trade surplus, $103 billion in annual US R&D investments, and 16 million jobs nationwide, including 12.5 million jobs outside of the technology sector. These jobs pay more than twice the average US wage and that are often accessible with a vocational or technical degree.

A jobs-centric digital trade policy that protects overseas market access for US digitally enabled exports will open doors to America's future as a global leader in trade, technology, and innovation. US exports of digital services exceed $500 billion, and US exports of aircraft, automobiles, machinery, and other increasingly connected devices also exceed $500 billion, for a total of roughly $1 trillion in digitally enabled exports. Digital trade supports commerce in all sectors, with over 75 percent of the value of cross-border data transfers accruing to industries like agriculture, manufacturing, and logistics.

Addressing Digital Trade Barriers Threaten Jobs

This economic activity is under increasing threat as a growing list of countries erect digital barriers that undermine market access for US digitally enabled goods and services, and the workers that design, produce, and deliver them. By some reports, digital trade barriers have increased by over 800% since the late 1990s – especially in countries that have adopted restrictions modeled on the 2017 China Cybersecurity Law and related measures. Such barriers hurt workers and impede foreign market access for US exports of aircraft, vehicles and other connected devices, as well as services, that depend upon Internet-, wireless-, and satellite-based communications and other IoT functionality for their sales, operation and support.

According to USTR's National Trade Estimate, a growing number of trading partners are adopting digitally restrictive measures following digitally authoritarian models that undermine US democratic values and strategic interests. These measures undermine our security; our innovative edge; and our workers' livelihoods.

Supporting Digital Skills For an Advanced Manufacturing and Services Workforce

As USTR has stated, "the key to our global competitiveness and creating shared prosperity begins at home." A jobs-centric digital trade policy begins with support in skills development to support US advanced manufacturing and services jobs in a global digital economy. This means upfront investments in computer programming, software coding, and other digital skills – the skills that are needed to design and build the advanced, connected goods and services demanded in today's economy, and to compete in connected agriculture and other core industries.

A proactive public-private 21st century workforce development initiative – effectuated through national, regional, and sectoral digital upskilling efforts – can help workers build export competitiveness, acquiring the software-related skills needed to compete globally. Greater coordination among unions, private enterprises, and local, state, and federal authorities can help bring greater focus and resources to these efforts.

A four-year degree is often not necessary to acquire the coding and other skills necessary for software jobs. Transform Your Trade and similar programs connect workers with software training opportunities in the manufacturing and service sectors across all 50 US states, the private sector, community colleges, vocational schools, and apprenticeship programs. And there is room for further growth, as an estimated 1 to 2 million ICT- and software-related jobs continue to go unfilled in America, especially in the manufacturing sector, where 40 percent of manufacturers urge greater investment in skills for advanced manufacturing, including software engineering, computer-aided design and manufacturing (CAD/CAM), industrial machinery mechanics, and Computer Numerical Control (CNC) machinery operations.

Government and private sector representatives should work to create new pathways to increase opportunity among communities whose access to these digital job training opportunities has been limited to date. Easing access to digital upskilling programs is also a priority, whether through tax credits; public or private grants, scholarships, loans, or matching funds; apprenticeship programs, and so forth. Finally, expanding access to broadband Internet and to computers and other ICT equipment is also a key aspect of building US export competitiveness.

The US government and private sector should adopt a more robust and coordinated *ex ante* approach to developing the skills needed to benefit from job opportunities relating to digitally-enabled exports.

Negotiating an Indo-Pacific Economic Framework that Benefits Workers

A jobs-centric digital trade policy will benefit from expedited negotiation of new Indo-Pacific Economic Framework that can create new market opportunities and support jobs in fast growing, knowledge-intensive sectors, such as digitally enabled manufacturing and services, where the US economy is primed for further growth. This Framework can help focus efforts on the world's fastest growing economic region and a key market for US exports.

If done right, an Indo-Pacific Economic Framework would help level the playing field by lowering digital trade barriers that impede exports of goods and services produced by workers at home. This is particularly true in the Indo-Pacific region, as reflected in growing acceptance of cross-border data restrictions, efforts by the most digitally restrictive economy to accede to the CPTPP and the Digital Economy Partnership Agreement, and the lack of meaningful digital and cross-border data disciplines in the Regional and Comprehensive Economic Partnership Agreement (RCEP).

Ensuring that Workers and Citizens Get the "Benefit of the Bargain"

A jobs-centric digital trade policy depends upon workers and citizens deriving the "benefit of the bargain" from US digital trade policy. It is critical to ensure that US digital trade policy prioritize enforcement of existing commitments and that any future framework contain an effective enforcement mechanism. In addition to building out the roster of negotiators to draft and conclude strong digital disciplines, it is also important to retain lawyers with the requisite knowledge and to analyze and combat unfair and discriminatory practices that threaten US jobs and exports in digitally-enabled goods and services.

A Jobs-Centric Digital Trade Policy Requires:

1. Supporting Digital Skills For the Advanced Manufacturing and Service Workforce
2. Negotiating an Indo-Pacific Economic Framework that Benefits Workers
3. Ensuring that Workers and Citizens Enjoy the "Benefit of the Bargain"
4. Building Public Trust From the Start

Building Public Trust From the Start

The US government is right to seek a "durable trade policy that benefits a broad range of stakeholders by rebuilding trust with our workers and aligning our domestic and foreign policies." From the start, it is incumbent to build public support for a jobs-centric digital trade policy, including for any Indo-Pacific Economic Framework. This means showing, up front, what the benefits are, and how workers, citizens, and small businesses can secure them. Ongoing and transparent consultations with legislative representatives, and proactive public messaging from the Administration, are critical to building this confidence. For this economic framework to be seen as an opportunity, and not as a threat, Americans need the confidence that they can secure the information, training, and tools needed to unlock its benefits.

Annex B

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Software: Supporting US Through COVID

EXECUTIVE SUMMARY

The coronavirus pandemic presented challenges all across the US economy and Americans' lives in recent months. The response to the pandemic has featured tremendous tales of strength and agility, and, in many cases, those tales demonstrate what software makes possible in both the professional and personal lives of us all:

- By providing the infrastructure and services that enable remote work for many Americans, enterprise software firms have provided the backbone for much of the US economy in the past year.
- Healthcare providers and medical researchers leveraged software tools to improve patient care and help speed the development and distribution of new vaccines.
- Many workers have set themselves up at new desks in their homes, using software to remain connected and productive from outside the office.
- Businesses like restaurants and small retailers that can't go entirely virtual increasingly have turned to software platforms for ordering, sales, and other services that help minimize health risks.
- Shuttered schools have operated remote classrooms with students and teachers connecting from across their communities to advance their classwork.
- Software even fills our lives outside work by enabling entertainment options and social platforms that allow personal connections in our physically distanced world.

SOFTWARE SUPPORTING US

All across the United States in 2020, the COVID-19 pandemic transformed how Americans went about their daily lives—how we worked, how we learned, how we maintained connections with those most dear to us. The stories are all around us.

Connecting Students on Tribal Lands

When the pandemic closed the Casa Blanca school inside Arizona's Gila River Indian Reservation, school leaders turned to Intel and other firms for help. The Creating Learning Connections Initiative got every Casa Blanca student a new device and a broadband hotspot to allow distance learning—among the 17,000 devices, 7,500 education kits, and $200,000 for broadband the group distributed across the US.

Just as software has supported businesses and individuals through the pandemic, it has played a key role in supporting the US economy. Software jobs and the industry's impact on US GDP have grown since 2018—even in the face of the tremendous challenges facing the overall US economy. In 2020, the software industry supported more than 15 million jobs nationwide in a broad range of sectors, an increase of nearly 6 percent since 2018. Direct software employment increased by 7.2 percent in the past two years, and the software industry's total contribution to US value-added GDP in 2020 grew by 17.1 percent in two years.

Looking more closely at software jobs: While the largest concentrations of the software workforce remain centered in the traditional tech hubs of California and Washington, software jobs for years have been growing fastest in other states. The growth of software jobs is surging in states from New Mexico (direct jobs up 18.7 percent) to New York (12.9 percent), and Texas (10.9 percent) to Florida (10.1 percent).

And looking ahead, given the trajectory of software's spread through the overall economy and the pandemic-inspired spread of remote work, software jobs are poised for continued strong growth all across the country.

Consider: Much of the growth of software jobs comes as businesses outside the "technology sector" increasingly leverage the benefits of data and software to grow their businesses. Manufacturers, for example, are coding new solutions to optimize production, speed time-to-market, and deliver innovative products and services. Farmers are using software to maximize outputs and better manage their herds, utterly transforming

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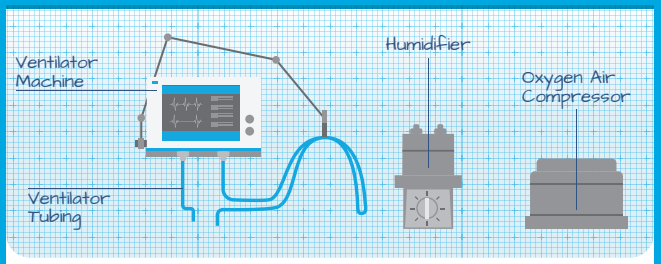
Providing Comfort for Patients

With patients looking for answers even as many doctors were forced to limit office access, Mercy Health in Missouri turned to Adobe to add a COVID-19 resource page to its website in a matter of hours. Patients could learn how to access in-person care even as Mercy protected patients and staff. The system also allowed Mercy to immediately contact patients experiencing coronavirus symptoms.



Addressing Ventilator Shortages

When a robotics startup company was put on hold in spring 2020 and the nation was facing a ventilator shortage, the company's founder and a global team of volunteers turned to Autodesk Fusion 360 to collaborate on a design for a new device in less than two weeks—and at a price that was a fraction of the cost of typical hospital ventilators.

KEY FINDINGS

The software industry continued to be a key driver of the US economy through the coronavirus pandemic, supporting jobs all across the country. In 2020, **software supported more than 15.8 million jobs in total**—an increase of 5.9 percent since 2018.

Software supports jobs all across the economy—in industries far beyond just the technology sector. In 2020, **software supported more than 12.5 million non-software jobs**—up 5.5 percent since 2018.

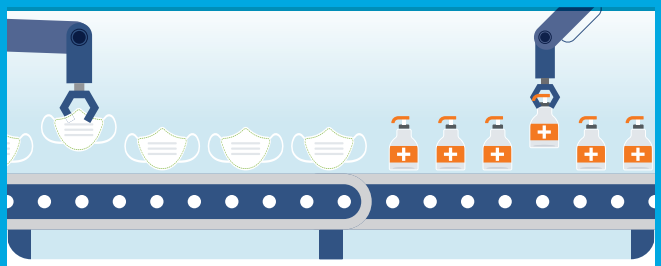
In 2020, **3.3 million people worked directly in software jobs in the United States**—up 7.2 percent over 2018.

Software contributed **$1.9 trillion to total US value-added GDP in 2020**—a 17.1 percent increase in two years.

The software industry directly contributed $933 billion to the US economy in 2020—a 15.1 percent increase since 2018.

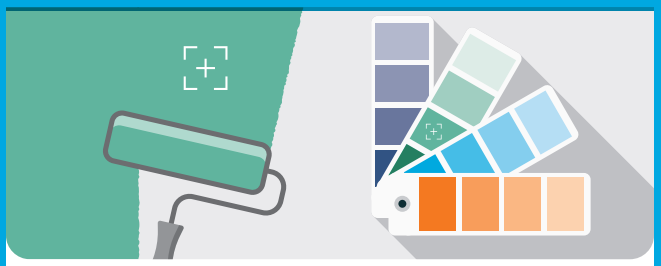
Software drives economic growth all across the country. Between 2018 and 2020, the software industry's economic impact grew by double digits in more than half of US states and the District of Columbia. In three states—Idaho, Nevada, and Washington—growth was up by more than 25 percent.

By investing strongly in research and development the software industry supports continued future growth. The **software industry invested more than $103 billion in R&D in 2018**—more than 27 percent of all domestic business R&D in the United States.



Pivoting to PPE Production

Mountain Productions, which normally builds elaborate stage designs for concerts and events, retooled its business to design modular medical structures and produce PPE by using Autodesk software. With concerts and public events canceled, the business set up a new division, redeployed its workers, and modified its structures to meet medical standards in a matter of days.



Transforming Customer Service

Pandemic shutdowns left many homeowners with lots of time for home improvement—but few chances to shop for supplies or get guidance on their projects. The makers of Behr Paint handled a surge in customer requests by leveraging IBM's artificial intelligence solutions to enable real-time, personalized dialogue with consumers and deliver a unique paint color recommendation for each user.

Helping Libraries Continue Lending

In an ironic twist for book lovers, the pandemic left many with lots of time for reading but no access to books. Many libraries ensured that patrons still had access to lending services by moving them online with Oracle software. The Library Corporation system gives readers the ability to search for "hands-free holds" or "library-to-go" catalogs and make appointments to pick up books.

Shifting to New Sales Models

With outdoor activities ramping up as many retailers were shutting down, Kent Water Sports in Washington turned to Microsoft's tools to transform their operations and sell directly to consumers. The changes allowed employees to easily access, manage, and share data and keep up with their customer needs. Even better, the company experienced a record sales year in 2020 and is set for future growth.

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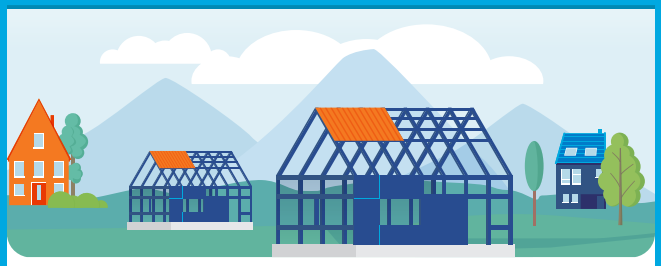
agriculture. In healthcare, electronic records and other innovations are improving medical administration and helping deliver a higher level of patient care. Those sectors—and the software workers who support them—are necessarily spread all across the United States.

In addition to this expansion of a wide range of new software jobs, businesses and policymakers must consider the newly discovered possibilities of remote work. The ability of traditional coders to take their skillsets out of high-cost tech hubs and work from far-flung home offices will dramatically alter the spread of the software workforce all across the country, a trend that will only increase as the pandemic recedes.

The numbers behind these and other trends are detailed in our fourth report working with researchers at The Economist Intelligence Unit (EIU) seeking to quantify software's economic impact on the US economy. In each of our previous reports—in 2014, 2016, and 2018—the EIU explored the state of the industry and demonstrated the enormous impact the software industry was generating throughout the country in both scale and scope. In this year's update, the EIU builds upon its earlier work with an analysis of the most recent data (from 2020) to quantify the breadth and depth of software's impact, and to show the rate at which these software opportunities are growing over time.



Growing to Meet a Building Demand

With families turning bedrooms into offices and dining rooms into schools, remodeling firms like Pennsylvania-based West Shore Home faced a huge increase in demand. That spike meant West Shore needed more salespeople, more designers, and more builders. Using Salesforce, the company could quickly pivot and scale up operations—from recruiting to sales—and grow revenue more than 100 percent.

Delivering Superior Care With Data

To quickly respond to COVID-19 outbreaks, New York-based Northwell Health turned to Oracle to help give patients the best care possible. Software helped Northwell better understand where and when their nurses are working, predict staffing needs, and care for a continually shifting number of patients. The secure system combines different datasets, enabling employees to better focus on patient care.

METHODOLOGY

In 2020, the Bureau of Economic Analysis, the official source of US economic data, made minor revisions to its 2015–2019 estimates for GDP. These updates are primarily due to improvements in underlying source data provided by various government agencies such as the US Census and Bureau of Labor Statistics (BLS). The BLS updates included similar revisions to employment and wage data for the same period.

To ensure comparability of results over time, The EIU has also revised the previous 2018 data/estimates to reflect these official updates. This has resulted in minor adjustments to the results of the 2018 study.

To estimate the total contributions of the software industry to the US economy, The EIU analyzed the direct contributions and estimated indirect and induced impacts using various economic multipliers:

- Direct contributions: the levels of output or employment of the industry in question;
- Indirect impacts: the inter-industry economic activity resulting from the direct contributions (e.g., purchases of inputs); and
- Induced impacts: the additional economic activity supported by spending on goods and services by households whose income were affected by the direct contributions and indirect impacts.

For more information on the report and a full discussion of the methodology, please visit **software.org/softwarejobs**

STATE ECONOMIC IMPACT

State	EMPLOYMENT		GDP	SOFTWARE R&D	
	Direct (Jobs)	Total (Jobs)	Direct Value Added GDP ($million)	Investments ($million)	Percentage of Total Business R&D
United States	**3,337,009**	**15,843,318**	**$933,240**	**$103,357**	**27.4%**
Alabama	30,446	61,953	$4,568	$270	21%
Alaska	1,583	3,213	$291	$6	30%
Arizona	57,355	136,493	$10,426	$409	8.8%
Arkansas	12,680	17,304	$2,044	$105	24.8%
California	618,968	2,187,298	$269,475	$53,650	41.4%
Colorado	100,101	203,711	$23,078	$1,130	26.4%
Connecticut	31,892	114,917	$7,728	$185	3%
Delaware	5,673	13,654	$1,133	$39	2.7%
District of Columbia	31,063	70,469	$7,762	$159	57.2%
Florida	150,497	302,119	$31,097	$1,071	23.8%
Georgia	113,425	212,334	$23,268	$1,158	28.3%
Hawaii	5,071	16,499	$989	$24	27%
Idaho	8,183	24,623	$1,539	$36	1.5%
Illinois	117,417	404,184	$29,289	$1,224	10%
Indiana	35,987	73,130	$5,891	$191	3.2%
Iowa	17,557	37,146	$3,793	$212	8.3%
Kansas	21,240	43,855	$3,812	$325	19.8%
Kentucky	20,437	30,735	$2,947	$72	6.1%
Louisiana	14,599	29,345	$2,217	$45	12.5%
Maine	6,961	19,520	$1,399	$40	15%
Maryland	90,684	182,867	$17,775	$513	12.1%
Massachusetts	140,006	477,131	$40,292	$3,509	15.5%
Michigan	62,933	165,215	$13,573	$608	3%
Minnesota	50,814	87,024	$12,463	$840	12%
Mississippi	6,901	9,141	$1,041	$15	6%

STATE ECONOMIC IMPACT

State	EMPLOYMENT		GDP	SOFTWARE R&D	
	Direct (Jobs)	Total (Jobs)	Direct Value Added GDP ($million)	Investments ($million)	Percentage of Total Business R&D
Missouri	60,839	155,611	$11,423	$707	17.8%
Montana	5,510	10,176	$889	$42	26.8%
Nebraska	20,642	27,951	$3,749	$246	48%
Nevada	13,020	32,991	$2,875	$68	10.7%
New Hampshire	17,411	42,678	$4,005	$189	19.1%
New Jersey	91,646	306,605	$26,223	$805	4.8%
New Mexico	7,169	15,445	$1,230	$75	20.1%
New York	210,168	964,764	$82,209	$6,314	41.1%
North Carolina	90,772	218,283	$20,118	$2,068	26.5%
North Dakota	4,940	6,093	$923	$113	39.8%
Ohio	86,159	218,210	$16,271	$684	10%
Oklahoma	12,386	31,353	$2,879	$112	13.6%
Oregon	36,736	118,439	$9,836	$1,071	12.7%
Pennsylvania	98,099	303,441	$21,316	$1,144	10.8%
Rhode Island	8,805	18,427	$1,473	$19	2.9%
South Carolina	25,403	48,970	$4,368	$196	13.4%
South Dakota	3,298	5,434	$594	$16	8.9%
Tennessee	34,544	78,640	$7,053	$88	7.4%
Texas	277,988	526,167	$52,840	$2,845	15.6%
Utah	50,576	138,096	$9,948	$951	36%
Vermont	5,508	13,020	$1,117	$71	30.5%
Virginia	192,540	558,086	$38,446	$1,409	34.4%
Washington	175,796	610,149	$83,548	$16,758	56.8%
West Virginia	5,567	11,638	$980	$29	13.9%
Wisconsin	47,938	80,627	$10,675	$970	18.2%
Wyoming	1,077	4,024	$362	$7	20.6%

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Software: Supporting US Through COVID

UNITED STATES[1]

EMPLOYMENT

In addition to providing the digital infrastructure that enabled our personal and professional lives during the pandemic, the software industry helped create jobs all across the economy and all across the country. In fact, the software industry supports 12.5 million jobs in industries outside software—jobs in every economic sector. The total number of jobs supported by the software industry has increased nearly 6 percent since 2018. This report, from Software.org: the BSA Foundation and conducted in 2021 by The Economist Intelligence Unit (EIU), captures the positive economic impact of the software industry in the United States at the state and national level.

Total

15.8 million jobs

Direct

3.3 million jobs

GDP

Software played a crucial role in enabling our lives through the pandemic, allowing us to connect socially with friends and family. At the same time, software helped businesses of all sizes to continue their work, underpinning innovation and driving growth in nearly every economic sector. Overall, software's contribution to total US value-added GDP has grown more than 17 percent since 2018.

Total Value-Added GDP

$1.9 trillion

(includes indirect and induced impacts)[2]

Direct Value-Added GDP

$933 billion

WAGES

Average Annual Wage for Software Developers

$114,270[3]

R&D

R&D Investment by Software Companies

$103 billion[4]

27.4% of All Domestic Business R&D in US[5]

[1] All data is from 2020 unless otherwise indicated.
[2] For definitions of "indirect" and "induced," see www.software.org/softwarejobs.
[3] US Department of Labor, Bureau of National Statistics, Occupational Employment Statistics.
[4] National Science Foundation/National Center for Science and Engineering Statistics and US Census Bureau, Business R&D and Innovation Survey. 2018 Industry breakdown.
[5] Ibid.

www.software.org

The Economist INTELLIGENCE UNIT

Annex C

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Every Sector Is a Software Sector: **Manufacturing**

How Software Is Turbocharging Manufacturing Opportunities for All

June 2018

www.software.org

Manufacturing has long been the backbone of the American economy. Today we stand on the verge of a major manufacturing renaissance powering more jobs, with economic impacts as transformative as those sparked by the first industrial revolution. Powerful and new software-driven technologies are helping expand a manufacturer's strategic options — enabling companies to create new kinds of jobs, boost efficiency, drive quality, and improve output.

Software has transformed manufacturing and manufacturing jobs. At the heart of this renaissance is a powerful set of revolutionary new software tools that enable manufacturers to radically rethink the way they make almost everything with digital precision and data-driven insights. These game-changing software advances are expanding possibilities throughout the manufacturing life cycle — generating designs never before possible, creating new types of manufacturing workers, fueling entirely new classes of software-enhanced machines, and transforming products from the ordinary into the extraordinary by infusing them directly with software.

At the beginning of the manufacturing life cycle, manufacturers are now able to design smarter prototypes more quickly and test more effectively using 3D design software infused with artificial intelligence. Workers can then feed these digital designs directly into a new class of software-enabled machines like 3D printers, laser cutters, water jet cutters, CNC machines, computer-controlled welders, and multi-axis robots that workers use to make things with digital precision. These changes not only allow manufacturers to make things previously impossible to make, but to expand the materials they make things with and the very ways they fuse, bond, extrude, cut, bend, and combine things.

> Together these software-enabled tools are helping manufacturers imagine the unimaginable, make the unmakeable, and create the unbelievable.

> The test of strength for tomorrow's manufacturing economy isn't whether things are built with gears, pulleys, and levers, but whether our manufacturing future is built with software, the cloud, and data.

Together these software-enabled design and fabrication tools are helping manufacturers imagine the unimaginable, make the unmakeable, and create the unbelievable.[1] These tools reduce the cost of complexity, allowing the consumers of things to also become the creators of things, and enabling the industry to move from mass production to a world of mass customization. Some are finding that it enables entirely new business models by radically improving time to market, lowering startup costs, increasing the speed of innovation, and eliminating the need for costly inventory. And with online marketplaces that enable anyone to upload 3D models for remote 3D printing, these tools democratize manufacturing as anyone with a good idea and an Internet connection can become the machine shop for the entire planet.

Factories are taking advantage of smarter software too. Factories are boosting output by harnessing data from production lines fitted with hundreds of actuators and thousands of sensors to provide a more immediate, dynamic, and comprehensive view for improving control of the manufacturing process. By combining this sensor data with predictive analytics software, managers can better predict costly equipment failures before they occur, enabling time-sensitive adjustments to maintain an uninterrupted factory flow and high-quality output. Software also is improving how the manufacturing process can be integrated and managed. For example, new software advances enable manufacturers to see across separate processes in an interconnected supply chain system so that they can boost orders, reduce errors, and speed delivery.

But the greatest improvement may be in the way that smarter factories now produce smarter products, too — products that are themselves infused with software to magnify and multiply what the product can do. This means that the key differentiators among products are increasingly the software lines in a product's code because software is increasingly incorporated directly into products themselves.

As a result, the test of strength for tomorrow's manufacturing economy isn't how things are built, but whether our manufacturing future is built with software, the cloud, and data.

Manufacturing is already the leading data-driven industry. Manufacturers don't just produce goods, today they produce data, and lots of it. The manufacturing sector generates nearly 2,000 petabytes of data every year — more data than any other sector of the economy, and twice as much as the next largest sector.[2] And yet, because modern software tools have yet to be fully implemented, an estimated 99 percent of manufacturing data gets discarded before decision-makers can take advantage of it.[3] It signals an enormous opportunity, and represents one of the key reasons manufacturers are now turning to software to change data into insights and open vast new opportunities to improve the way they do business.

Amazingly, to take advantage of these opportunities, manufacturers are now hiring more software developers than production line workers.

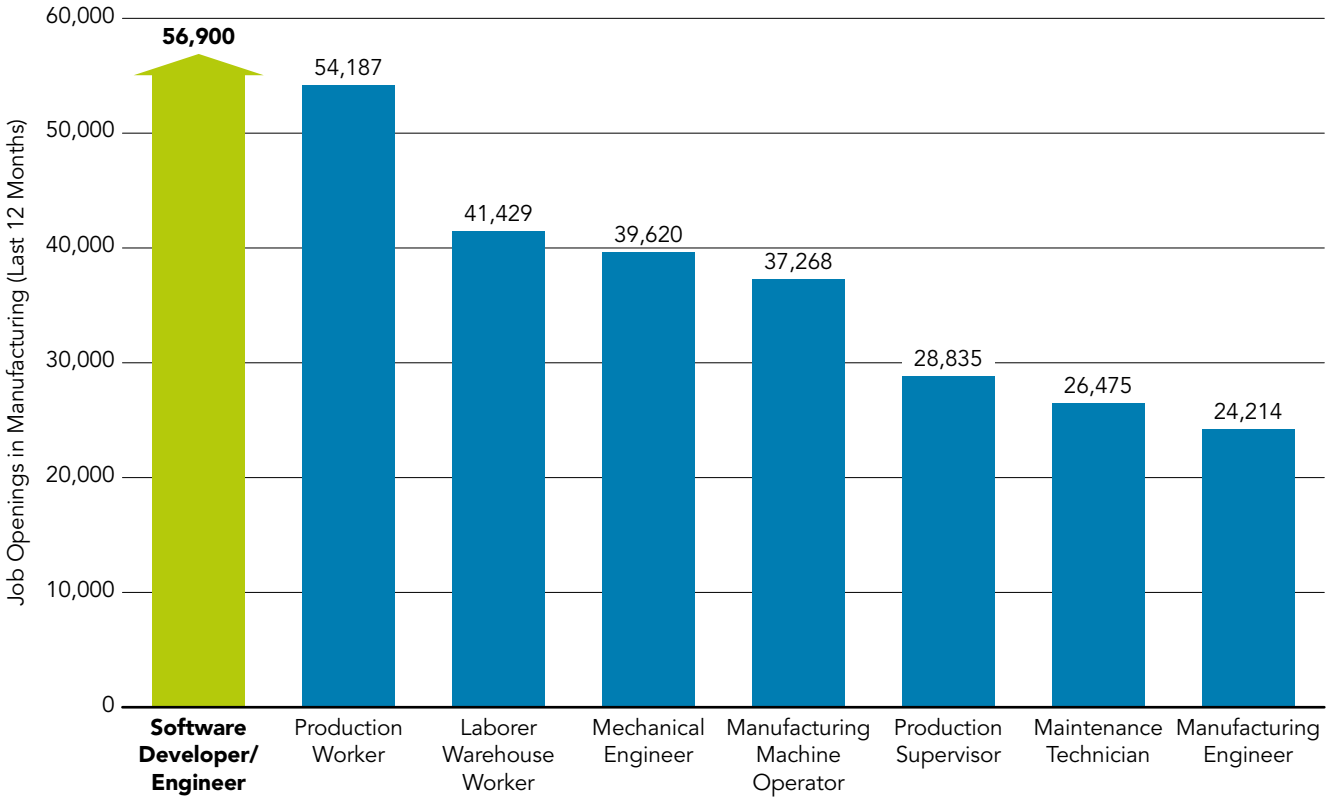
To take advantage of the software opportunity, the average manufacturing site today already uses more than 150 software programs to operate.[4] Now a new generation of cloud-based software capable of integrating systems is taking advantage of the abundance of data as a central focus for improving the way products are designed, built, and distributed.

These software advancements are not just improving the production line, they are also boosting the bottom line. Already, nearly two-thirds of US manufacturers expect digital manufacturing technologies to lower operating costs by at least 11 percent (with nearly a quarter expecting cost-savings exceeding 30 percent).[5]

To achieve these gains, manufacturers have been hiring software programmers in droves. There are already more than 150,000 software programmers who work in the manufacturing industry.[6] In fact, demand for software developers among auto manufacturers alone has grown an astounding 200 percent over just four years.[7] These are signs that what's being made and how it's being made increasingly depend on software.

Together these tools promise to make jobs more plentiful and America more prosperous. It is why some believe this manufacturing renaissance can create entirely new industries, supporting thousands of good paying jobs, and boosting US competitiveness.

Software Is Leading Manufacturing Job Openings



Source: Burning Glass Technologies

The Numbers Show Software Is Turbocharging Manufacturing Opportunity

Manufacturers are quickly adopting a wide range of software-enabled disruptive technologies like 3D design, additive manufacturing, the cloud, and the Internet of Things (IoT) to transform the way they design, build, and deliver new products — and the benefits are enormous.

Cutting Development Time

Up to **50 percent reduction** in development time, and elimination of defects prior to production through software-based design, simulation and testing.[a]

Optimizing the Factory Floor

10 to 25 percent increase in manufacturing productivity using sensors to bring intelligence to production equipment and optimizing their collective use.[b]

Boosting Energy Efficiency

25 percent improvement in energy efficiency by implementing smart manufacturing technologies.[c]

Improving Time to Market

10 times improvement in time to market in target industries by implementing smart manufacturing.[d]

Boosting Output

47 percent more goods are being produced today than 20 years ago through the development of automation, robotics, and advanced manufacturing.[e]

Reducing Safety Incidents

25 percent reduction in safety incidents by implementing smart manufacturing technologies.[f]

Driving Shop Floor Efficiency

67 percent of manufacturers are making investments in disruptive technologies to drive efficiencies in production.[g]

Cutting Downtime

40 percent reduction in maintenance costs, and **50 percent reduction** in downtime by connecting IoT sensors with predictive analytics.[h]

Enabling New Business Models

1 out of every 2 manufacturers are using disruptive technologies to enable new business models/ new revenue streams.[i]

[a] James Manyika, Michael Chui, Brad Brown, Jacques Bughin, Richard Dobbs, Charles Roxburgh, and Angela Hung Byers, "Big Data: The Next Frontier for Innovation, Competition, and Productivity," McKinsey Global Institute Report (June 2011), available at https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Big%20data%20The%20next%20frontier%20for%20innovation/MGI_big_data_full_report.ashx.

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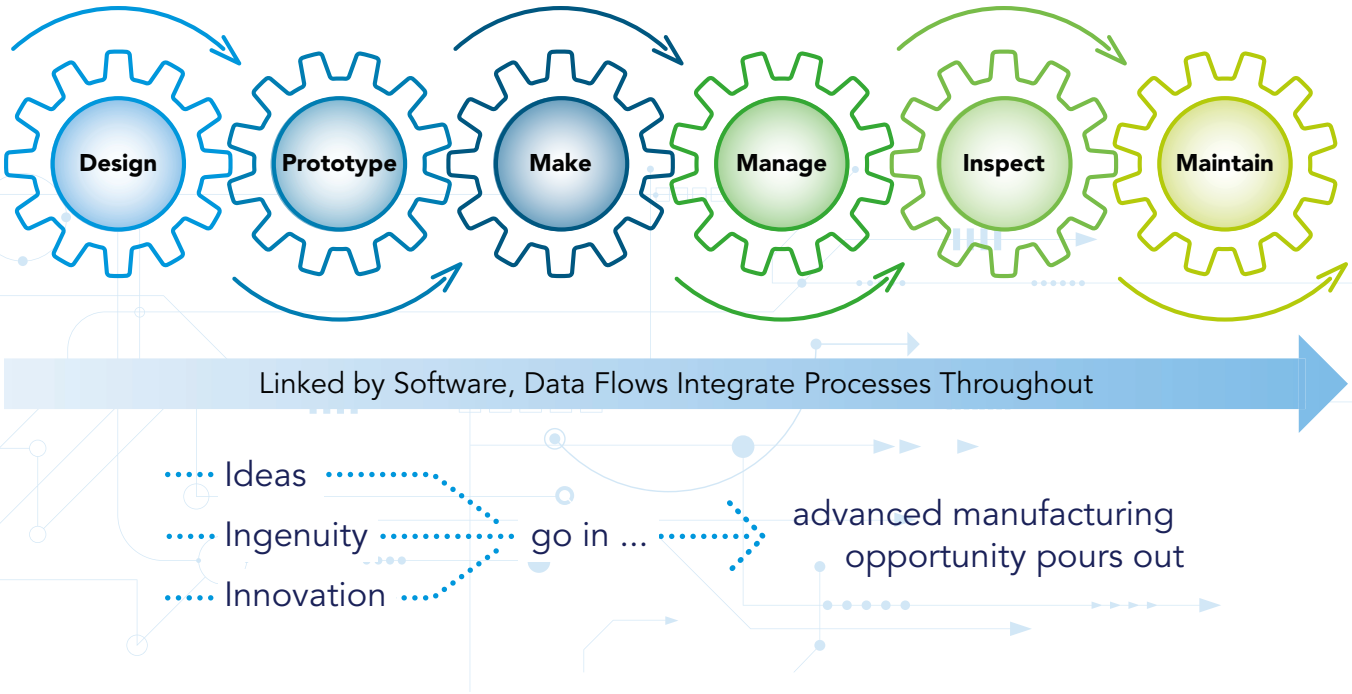
Software and Data: Innovation of the Entire Manufacturing Life Cycle



Making Smarter Designs

3D is the new shape of industrial manufacturing. Long before a product takes form on the factory floor, it takes shape on a computer screen where cutting-edge 3D software is used to generate new types of designs, prototype quicker, and test more effectively. These tools are so powerful that McKinsey found better use of software design and data in manufacturing can cut product development time by 20 to 50 percent by eliminating defects prior to production through simulation and testing.[8]

Generating new types of design. One of the amazing new opportunities now being enabled is the use of artificial intelligence algorithms to assist the design process. Called generative design, designers can now use cloud-based AI infused design tools to rapidly design and test countless computer-generated design options that meet specific design objectives (like cost, size, strength, and materials) to more quickly produce more robust and often unexpected solutions.

- ***Helping engineers create part design improvements.*** Generative design software is being used by GM as part of its ongoing efforts to reduce weight and increase the strength of its car parts. Using innovative new generative design software from Autodesk, GM was able to, for example, consolidate eight different parts into one 3D-printed seat bracket that is 40 percent lighter and 20 percent stronger using a new design whose organic structure no human could have conceived on their own.[9] Making each part lighter is critical because the lighter the part, the lighter the car, the less fuel it uses, the less carbon it emits, and the more money the driver saves.

Making prototypes faster. Today as product cycles shrink, development of the next generation product begins almost as soon as the last one reaches market. To accelerate the new product development cycle, companies are now taking advantage of advanced software that enables them to simulate design performance, test physical attributes in a virtual environment, and reduce the need for costly physical prototypes.

- ***Blowing other designs away.*** In the 1980s, Boeing had to test 77 different prototypes using physical wind tunnels. By 2005 it only needed to run 11 tests for its 787 prototypes using a virtual wind tunnel that took advantage of supercomputer speeds that could run complex computational fluid dynamic (CFD) models. But now, software like Flow Design puts the power of a supercomputer and a virtual wind tunnel on anyone's desktop.[10] For a company like Boeing, the ability to combine virtually tested 3D models with 3D printing has enabled it to produce more than 20,000 3D printed parts used on military platforms today.

- ***Smoothing out design simulations.*** American Axle & Manufacturing (AA&M) produces drivetrain systems for a range of cars and trucks, with the aim of doing it so smoothly that drivers cannot hear or feel vibrations from the driveline's transfer of power from the engine to the wheels. By using Siemens PLM Software for computer-aided engineering, AA&M's designers are able to produce simulated new models and predict product performance before any metal is cut.[11]

Enabling new forms of collaboration. Cloud-based design tools also have the advantage of enabling new kinds of collaboration among often disparate design teams who can work in real-time to improve project decision-making, and to virtually integrate individual parts into a broader assembly to ensure they work together as seamlessly as expected. One team in one location might work on designing a car door handle, and another the overall door assembly. But their designs can be integrated, tested, and modified together regardless of their location. It used to take as long as five years to design a new car. But Toyota, Fiat, and Nissan have all cut new-model development time by 30 to 50 percent through the collaborative use of data and software modelling techniques.[12,13]

Making Things in Entirely New Ways

With a 3D design in hand, a new generation of software-controlled fabrication machines is enabling these digital designs to be directly uploaded and turned into real-world things. By transferring complex 3D designs to a growing variety of digitally controlled fabrication machines, manufacturers can infinitely expand the art of the possible by changing how they fuse, bond, extrude, cut, bend, combine, and make things with digital precision.

3D printing, or additive manufacturing, is especially revolutionary — enabling manufacturers to print components directly from a computer file. It creates new opportunities for designers to create parts that are customized, stronger, lighter, and that frankly can't be manufactured in any other way. Importantly, according to the Department of Energy, using 3D printing to manufacture something can also reduce energy costs by 50 percent and material costs by 90 percent.[14]

As 3D printers have become less expensive, more functional, and able to print an increasing multitude of materials simultaneously, they have become increasingly important in industrial manufacturing. Today they can already print with a range of materials including titanium, glass, rubber, plastic, porcelain, color sandstone, and carbon fiber.

For example, rocket manufacturers are using software to design and 3D print rocket engines that use 100 times fewer parts, to help them fly better rockets.[15] NASA's rocket scientists found that their 3D printed metal rocket engine parts are reducing costs by nearly 35 percent and production time by more than 80 percent.[16]

Moving from mass production to mass customization. One of the most impactful implications of this software revolution is the ability to move manufacturing beyond mere mass production to a world of mass customization — personalizing products at unparalleled scale. Using clever software, digital factories can now mass produce individualized things. For example, today, three-quarters of a million people are smiling with 3D printed custom dental implants, an estimated 10 million people are hearing better with customized 3D printed hearing aids, and an estimated 2 million people are walking around with custom built 3D printed prosthetic devices.[17]

Making Smarter Factories That Run More Efficiently

Software is also creating smarter factories of the future in two distinct ways: (1) using software to improve factory layout and efficiency, and (2) by infusing sensors directly into factory machines to radically improve the way they operate.

Smarter factory layouts. Companies are now discovering huge gains by optimizing the layout of their factories with software that enables them to create a digital version of their factory to find the optimal layout that reduces handling costs, improves throughput, minimizes space requirements, and reduces energy needs. Software can identify ways to streamline everything from assembly lines to conveyor belts to production performance.[18]

Smarter factories using the Internet of Things (IoT). Factories are also making themselves more efficient by infusing sensors and actuators directly into the machines that make things. These IoT technologies enable sensors to produce data that can be used to improve the manufacturing process, monitor quality control, and alert managers to potential failures before they happen.

Because every moment a line is down is lost revenue, poor maintenance strategies can reduce a plant's overall productive capacity by an estimated 5 to 20 percent.[19] In auto manufacturing, downtime is estimated to cost as much as $1.3 million per hour.[20]

To overcome these challenges, companies are combining IoT sensors with predictive analytics software to prevent factory downtime and reduce unplanned maintenance. These software tools analyze real-time performance data from sensors, measuring things like vibration, heat, and energy use to better understand what is going on deep inside machinery and identify potential imminent equipment failures. These insights enable staff to schedule corrective maintenance steps before failures lead to costly downtime. According to McKinsey, companies that are connecting IoT sensors with predictive analytics are seeing a 40 percent reduction in maintenance costs, and 50 percent reduction in downtime.[21]

- To understand the opportunity, one GE manufacturing plant that makes batteries has already incorporated more than 10,000 IoT-enabled sensors spread across 180,000 square feet of manufacturing space to collect temperature, humidity, air pressure, and machine operating data in real time.[22] They use the real-time data to maintain quality control and lead the charge on factory efficiency.

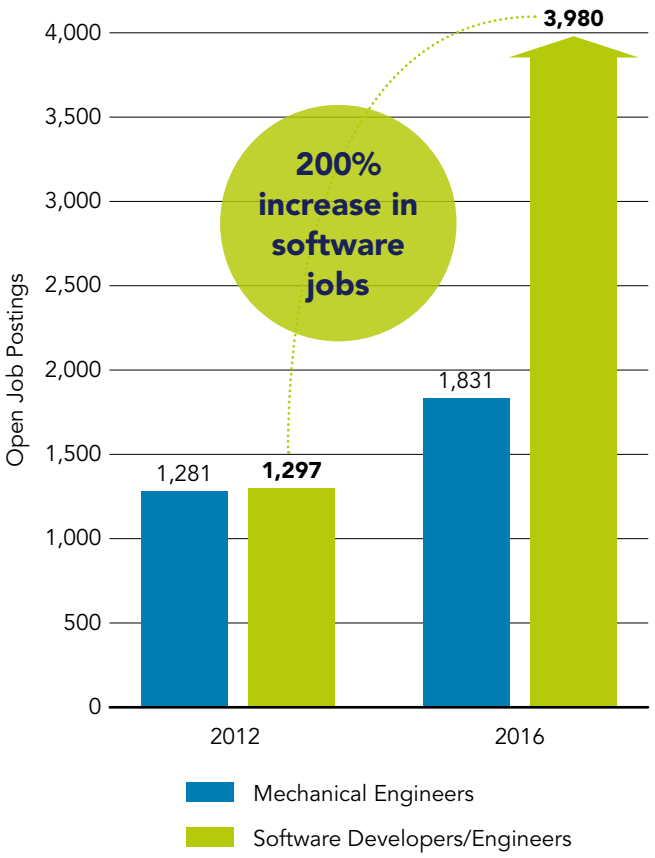
- Similarly in Florida, Jabil, a design and manufacturing solution provider, is using Microsoft's machine learning, predictive analytics, and the cloud to learn ahead of time when a piece of equipment might fail, instead of waiting for it to fail and dealing with the consequences and downtime.[23] By harnessing the cloud to analyze millions of data points from machines running dozens of steps through the manufacturing process, they've had an 80 percent success rate in identifying machine process failures in advance, cut scrap by 17 percent, and reduced energy by 10 percent. As a result, yield has gone up, the amount of re-work has gone down, and they have improved their ability to meet customers' demands for increasingly faster, more customized solutions.

Making the Products Themselves Smarter

Software isn't just spurring innovation of manufactured products, it is also changing what the products themselves can do, too. Software is increasingly being incorporated directly into manufactured goods meaning that manufacturers aren't just users of code, they are also writers of code.

- **Cars are software enabled.** When today's high-end cars are manufactured, they are built with 100 times more lines of code then the Space Shuttle had when it launched.[24] Most of the vital functions in a car are now software controlled, and as a result they have become more reliable, fuel efficient, and safe. Software has become so essential that up to 40 percent of the value of a new vehicle is now determined by its electronics and software content.[25] It's one of the reasons why demand for software developers among car and car part manufacturers has grown an astounding

Demand for Software Developers in Manufacturing Is Growing Like Crazy



Source: Burning Glass Technologies

200 percent over just four years because they continue to build software directly into the products they make to dramatically improve what they are capable of doing.[26]

- **Airlines are software enabled.** Software is not just modifying how airplanes are designed, but what they can do, too. A Boeing 777 is manufactured with 1,280 onboard processors that use more than four million lines of code.[27] In fact, modern jets are so packed with connected sensors on their engines, flaps, and landing gear that they can generate half a terabyte of data per flight to improve flight performance, cut turbulence, improve safety, and identify possible engine defects 2,000 times faster than before.[28, 29]

- **Appliances are software enabled.** Software is also taking ordinary things and making them extraordinary. With each generation, appliances are being manufactured with more and more software and sensor capabilities to enable them to do things never before possible by connecting with the cloud — improving what they can do, and how they can be controlled. It's astounding when you consider that today's newest refrigerators already contain more lines of code than a desktop computer had 20 years ago.[30]

- **Even ball bearings spin smarter with software.** Schaeffler Group, a leader making of ball bearings, envisions a world where even the humble ball bearing has built-in intelligence and sensory capabilities, using cognitive intelligence from IBM Watson.[31] By integrating sensor data with bearings, and integrating the bearings into everything from cars, planes, trains, and wind turbines, it can help reduce failures and make the world smarter, cleaner, and safer.

All of these benefits and opportunities, however, cannot happen without properly skilled workers. These innovations are not replacing workers; on the contrary, they require more and more workers with the right skills. Our country's economic competitiveness depends upon addressing the current talent shortage and skills gap. The renaissance of manufacturing lies in the hands of workers across America.

With innovation-enabled manufacturing opportunities expanding every day, tomorrow's benefits can be more easily maximized when leaders (1) take concrete steps to overcome a looming skills gap by filling the talent pipeline, (2) ensure that everyone is aware of the pathways of the manufacturing sector, and (3) address the talent shortage.

(1) Overcome the Looming Skills Gaps

US manufacturing leadership is rooted in having a well-trained workforce. As home to the world's leading software innovators, the US has a geographic leg up in the global advanced manufacturing race. However, there are twin skill gaps that could impede this opportunity with too few software developers and too few skilled manufacturers available in the pipeline.

Already today almost 40 percent of manufacturers say a skills mismatch is the chief barrier to taking full advantage of advanced manufacturing opportunity.[32] Manufacturers often can't hire enough software developers or the workers with skills necessary to run analytics software, create 3D models, or program 3D printers. Experts now project that the manufacturing sector is facing a shortage of two million workers due to the skills gap over the next decade.[33]

Further exacerbating the problem, demand for coding skills is stronger than ever, too. Today there are more than 500,000 unfilled programming-related positions across the country, and the US Bureau of Labor Statistics predicts that by 2020 there will be 1.4 million more software development jobs than applicants qualified to fill them.[34]

That may be why some studies suggest that a manufacturer's success or failure is increasingly tied to how geographically close they are to a ready supply of software talent.[35]

Because of this shortage and the strategic advantage access to coders provides, the German auto parts giant Bosch for example set up a research facility in the Pittsburgh area and another near Stanford — principally motivated by the desire to tap into the university's software engineering expertise and acquire future talent.[36]

> If we are to meet our manufacturing challenges for the future, we need to seize upon what may be software's greatest untapped potential — its ability to fundamentally expand what manufacturers can achieve.

To ensure every manufacturer has the opportunity to be successful, it's clear that we will need more workers with the skills to design and build the blockbuster products of the future. It's one key reason why leading software companies have stepped forward with ground-breaking commitments to STEM and manufacturing education.[37]

But as software is incorporated into almost everything we make and every connected thing around us suddenly runs on code, we simply aren't preparing enough workers to meet these future needs. It's for this reason that parents and teachers increasingly want computer science taught in K–12 classrooms. To advance a workforce with the skills to meet our 21st century manufacturing opportunities, policymakers need to make investments in computer science education to help prepare the next generation of tech workers.

(2) Highlight the New Career Paths of Manufacturing

Mapping out career pathways and highlighting the new paths available in the manufacturing sector is also key to addressing the skills gap. For those preparing to enter the workforce or those looking to make a career change, a career path is a guidebook on how to proceed. The manufacturing of today does not look like the assembly and production lines of yesterday. The fast pace of innovation in manufacturing has created opportunities in many emerging sectors and technologies. Career pathways are not just in production and assembly; the roadmap can take workers to research and development, engineering and design, programing, user experience research, and many other paths. Showcasing this reality will be crucial to attracting, retaining, and developing the manufacturing workforce of the present and the future.

A PRODUCTION CAREER PATHWAY USED TO LOOK LIKE THIS:

Entry-level

- Industrial Truck and Tractor Operators (Forklift Operators)
- Hand Packers
- Inspectors and Testers

Intermediate-level

- Single Trades
  - Machinists
  - Welder
  - Heavy Tractor-Trailer Drivers
  - Maintenance and Repair Workers
- Machine Operators
  - Printing Press Operators
  - Print Binding and Finishing Workers
  - Food Batchmakers
  - Packaging Machine Operators

Upper-level

- Industrial Machinery Mechanics
- Mechatronics Engineering Technologists
- Supervisors of Production Workers

Source: NIST Manufacturing Workforce Development Playbook

TODAY, IT CAN LOOK JUST LIKE AND INCLUDE THESE OCCUPATIONS ACROSS ALL LEVELS:

Maintenance Pathway

- Mechanical Engineer
- Mechanical Technician
- Front Line Supervisor
- Mechatronics Technician
- Maintenance and Repair Workers

Engineering Pathway

- Engineering Manager
- Project Engineer
- Electrical Engineer
- Electrical Technician Engineer
- Computer Hardware Engineering
- Industrial Machinery Mechanic

Production Pathway

- CAD/CAM Programmer
- Production Supervisor
- CNC Machine Programmer Supervisor
- CNC Machine Programmer
- Machinist
- Machine Set- Up Operator
- CNC Machine Operator
- Machine Operator

Logistics Pathway

- Director, Supply Chain Logistics
- General Operations Manager
- Purchasing Agent
- Logistics Technician
- Shipping and Receiving Clerk
- Forklift Driver

Source: Colorado Manufacturing Careers

(3) Foster Strategic Partnerships and Planning

The manufacturing workforce of the 21st century comes in many shapes and forms, different roles and occupations, skillsets and trades; what stands true and unchanged is that the development of the workforce will require collaboration across companies, government, and educational institutions. These major stakeholders hold the key to solving the talent shortage and fostering America's economic competitiveness and innovation leadership. Forming strategic partnerships to solve our most pressing workforce issues should be accompanied by strategic planning and an outline of what the technological and workforce future looks like and what would it take to bring everyone to a level playing field.

It is and will be possible for everyone to reap the economic benefits of software in industry, but this will require an active role among educators, employers, and policymakers. It will be as important to have a pipeline in place for those new to the workforce to gain the right skills that will secure them a job that will foster innovation in manufacturing, as it is to have a plan for those who need to re-skill and re-train to perform their duties in new ways. On-the-job training, ongoing credentials, certifications, tech skills development programs, and many more opportunities should be available across the board for the workers of today and tomorrow.

Conclusion

Throughout history, key moments have emerged when technology enables great leaps that fundamentally expands the kinds of things we can achieve. Today software is enabling such a manufacturing moment as it catalyzes innovation in what and how we make things — leading to breakthroughs as incredible as the first industrial revolution itself. But critical policy choices lay on the horizon that will determine whether America leads this revolution and benefits from its many economic opportunities. If we are to meet our manufacturing challenges for the future, we need to seize upon what may be software's greatest untapped potential — its ability to fundamentally expand what manufacturers can achieve.

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[28] The 787 uses data sensors to reduce fuel, monitor systems, and even uses accelerometers in the nose of the plane to counteract turbulence. If the sensors register a sudden drop, they immediately tell the wing flaps to adjust (in a matter of nanoseconds) and in so doing, what used to be a nine-foot drop in an older plane can be reduced to just three feet in the 787, making for a much smoother flight. Matthew Humphries, "The Boeing 787 Produces Over 500GB of Data During Every Flight," Geek.com, available at http://www.geek.com/news/the-boeing-787-produces-over-500gb-of-data-during-every-flight-1542105/; Kevin Gosling, E-Enabled Capabilities of the 787 Dreamliner," Boeing.com, available at http://www.boeing.com/commercial/aeromagazine/articles/qtr_01_09/pdfs/AERO_Q109_article05.pdf.

[29] Jet engine maker GE says the engine data allows it to figure out things like possible defects 2,000 times as fast as it could before. Quentin Hardy, "What Cars Did for Today's World, Data May Do for Tomorrow's," *New York Times* (August 10, 2014), available at http://bits.blogs.nytimes.com/2014/08/10/g-e-creates-a-data-lake-for-new-industrial-ecosystem/?_php=true&_type=blogs&_php=true&_type=blogs&module=BlogPost-Title&version=Blogpercent20Main&contentCollection=Bigpercent20Data&action=Click&pgtype=Blogs&region=Body&_r=1&.

[30] Mark Muro, Jonathan Rothwell, Scott Andes, Kenan Fikri, and Siddharth Kulkarni, "America's Advanced Industries: What They Are, Where They Are, And Why They Matter," Brookings Institution (February 2015), available at https://www.brookings.edu/wp-content/uploads/2015/02/AdvancedIndustry_FinalFeb2lores.pdf.

[31] IBM IoT Manufacturing, available at https://www.ibm.com/internet-of-things/industries/iot-manufacturing.

[32] The National Association of Manufacturing asked its members what effect new technologies like the cloud, additive manufacturing, and IoT were having on their businesses. They found out that technology-driven disruption in the manufacturing sector is having a positive effect on their business and products. "Competing to Win: Research, Innovation and Technology in Focus," Policy White Paper, National Association of Manufacturing, available at http://www.nam.org/Data-and-Reports/Competing-to-Win/Policy-White-Paper-Research/.

[33] "Top 20 Facts About Manufacturing," National Association of Manufacturers, available at http://www.nam.org/Newsroom/Top-20-Facts-About-Manufacturing/.

[34] According to code.org, there are currently 526,393 open computing jobs nationwide as of this writing.

[35] Lee G. Branstetter, Matej Drev, and Namho Kwon, "Get With the Program: Software-Driven Innovation in Traditional Manufacturing," Working Paper 21752, National Bureau of Economic Research (November 2015), available at http://www.nber.org/papers/w21752.pdf.

[36] "Get With the Program: Software-Driven Innovation in Traditional Manufacturing."

[37] Autodesk, for example, is providing every secondary school in America with free access to its cutting-edge software to teach the tools of the trade; help train the next generation of designers, engineers, and architects; and help students create a better world with better designs for the future. This Design the Future initiative makes available $250 million of 3D design software, project-based curricula, training, and certification to every middle and high school in the United States as part of the ConnectED initiative. "Autodesk Education's Design the Future program, Today," Autodesk (September 17, 2013), available at http://blogs.autodesk.com/inthefold/autodesk-educations-design-the-future-program-today/. Likewise, to empower more young women to pursue careers in technology, Software.org is supporting the Girls Who Code program. "BSA, Lockheed Martin, and Georgetown University Join Forces to Sponsor Inaugural Washington, DC, Girls Who Code Summer Immersion Program," Press Release, BSA | The Software Alliance (June 24, 2015), available at http://www.bsa.org/news-and-events/news/2015/june/enus06242015girlswhocode.

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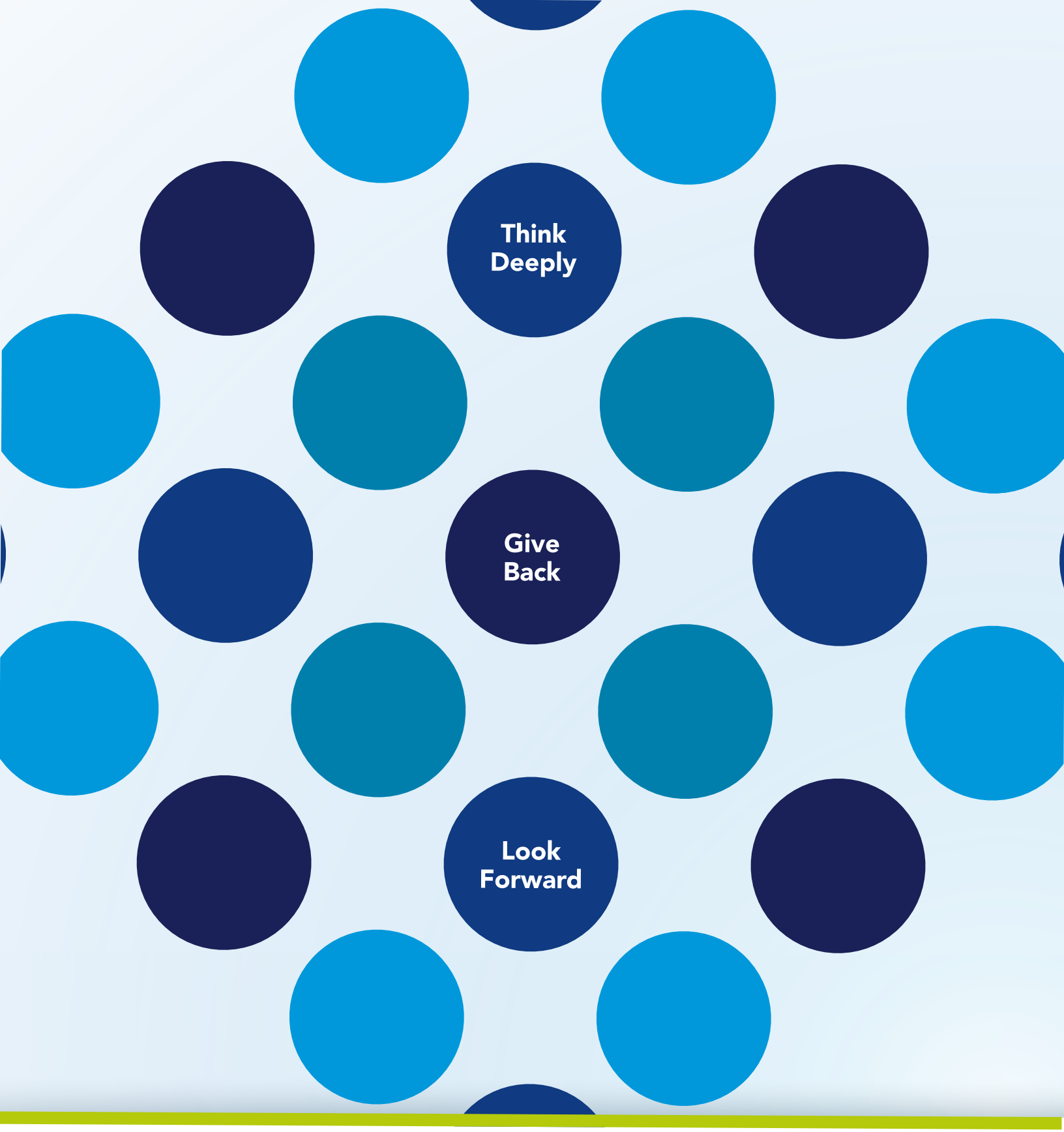

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Annex D

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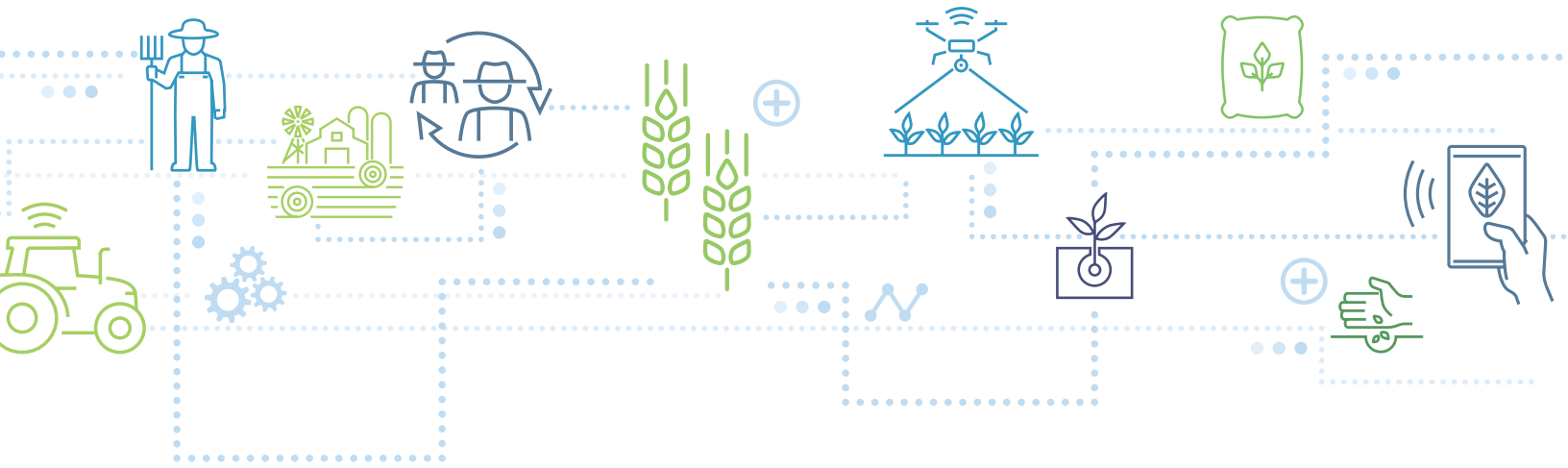
Every Sector Is a Software Sector: **Agriculture**

Agricultural Opportunity Is Growing With Software

May 2019

www.software.org



Agricultural opportunity today is rooted in software. Software innovations have quickly become essential tools for the day-to-day operations of the agricultural sector — improving the way everything from farms to tractors are run. Farmers have rapidly adopted breakthrough software advances that are enabling them to solve problems in ways previously unimaginable, thereby maximizing agricultural opportunity.

With enormous potential at hand, we are just at the beginning of what digitalization, data, and software innovation can deliver. Software developers are forging ahead with tremendous improvements in the way farmers grow, feed, harvest, and distribute food — boosting yields and cutting costs. Thanks to new advancements, software is now harvesting data from seeds, satellites, and sensors to help farmers make better decisions about what to grow, how to grow it, and when to grow it. It enables them to fine tune their operations with digital precision for maximum results. By being more precise, they can reduce the amount of fuel, water, and fertilizer they use; make better decisions about exactly when to harvest for maximal yield; and track food freshness from their farm to your fork. The effects are profound: when widely deployed, precision farming technologies can increase global crop yields as much as 67 percent and cut food prices in half.[1]

Software is delivering critical intelligence to enable farmers to do more with less:

- Soil sensors planted throughout a farm constantly feed data to cloud-based systems that track the soil's moisture, nutrients, and needs.
- Self-driving tractors and autonomous machines are becoming increasingly common — planting seeds with digital precision, killing weeds with a zap, and reducing overspray by delivering fertilizer precisely where it's needed.
- Data from satellites whizzing across the sky is combined with data from sensors in the ground and hyper-local artificial intelligence (AI)-based weather models to predict a plant's water needs — creating a customized irrigation plan that can go to automatic watering systems that deliver the right drops for each crop.

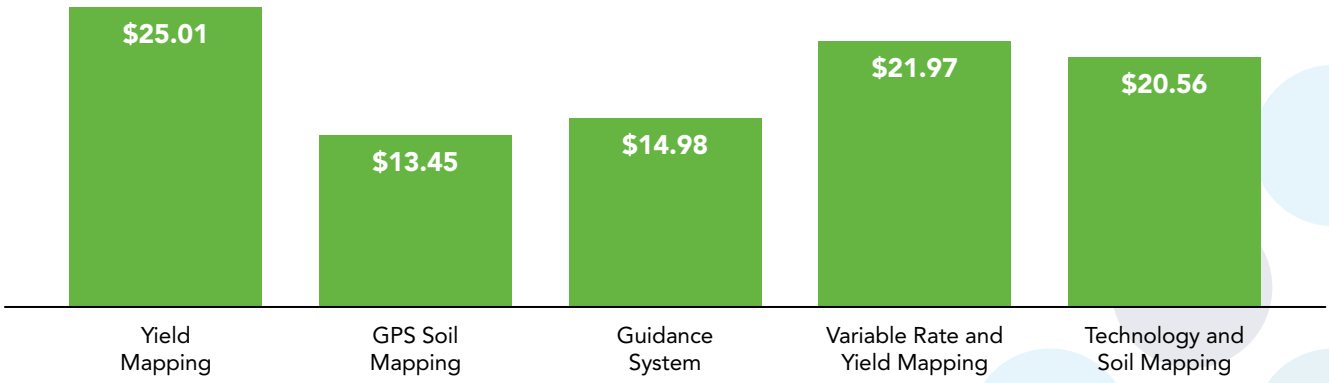
- Drones are taking opportunity to new heights as they buzz overhead with multi-spectral cameras to spot fungi earlier and in ways beyond what a human eye can see — avoiding costly disease outbreaks.
- Fences are being replaced with GPS, as connected livestock collars tell ranchers which animals may have wandered off, may be ready to breed, are potentially getting sick, or need special attention.
- To maximize yields, cloud servers check the weather, market prices, and growing conditions to tell farmers the precise moment to harvest to maximize results.

Software not only pulls all this data together, it puts the information at the farmer's fingertips — giving them more control over their livestock's and crop's progress from any device, anytime, anywhere with broadband. It enables almost everything to be done with greater efficiency, precision, and effect. Software is able to manage the vital supply chain process of getting fresh food distributed, processed, and delivered to your table in a safe and traceable manner — to reduce spoilage, ensure food safety, and cut food waste.

Software innovation has now reached a point where it provides the ability to solve some of the agricultural sector's greatest challenges. Software is helping farmers and ranchers tackle major challenges like producing more food to feed the world's next billion people, making foods that are more nutritious, ensuring crops can be more resistant to drought and diseases, and ensuring robust food safety all the way to your table. These innovations are helping the agricultural community be better stewards of the earth with technologies that can improve sustainability, reduce the use of harmful chemicals, cut greenhouse gas emissions while still boosting yields, and ultimately put more money in farmers' pockets. For example, when software-enabled precision technologies are widely deployed, experts predict they can cut water use by up to 30 percent,[2] reduce herbicide use by 99.99 percent,[3] reduce fuel use by 10 percent, boost crop yields by 70 percent, and cut food prices in half.[4]

Software is helping farmers harvest economic savings. These precision technologies don't just boost yields, they boost the bottom line, too. For example, according to the United States Department of Agriculture (USDA), a typical small family-owned corn farm in Ohio that implements precision farming technologies can save about $2,000 per seasonal corn crop.[5] Large farms can save nearly $40,000 per year with a return on investment of less than two years. More specifically, farms that deploy yield mapping can save $25 per acre, GPS soil mapping $13 per acre, software guidance systems $15 per acre, and software controlled variable rate application technology $22 per acre. Add it all up: software delivers big savings.

Savings Are Sprouting up Everywhere
Average cost savings by adopting software-enabled technologies
($ per acre saved)



Source: USDA Economic Research Service

Recovering Precision Farming Technology Investments

Farm Size	Annual Savings	Years for Return on Investment
Small (800 acres)	$11,000	6+
Average (1,600 acres)	$26,000	2+
Large (2,400 acres)	$39,000	~2

Source: National Geographic, *Farming: There's an App for That*

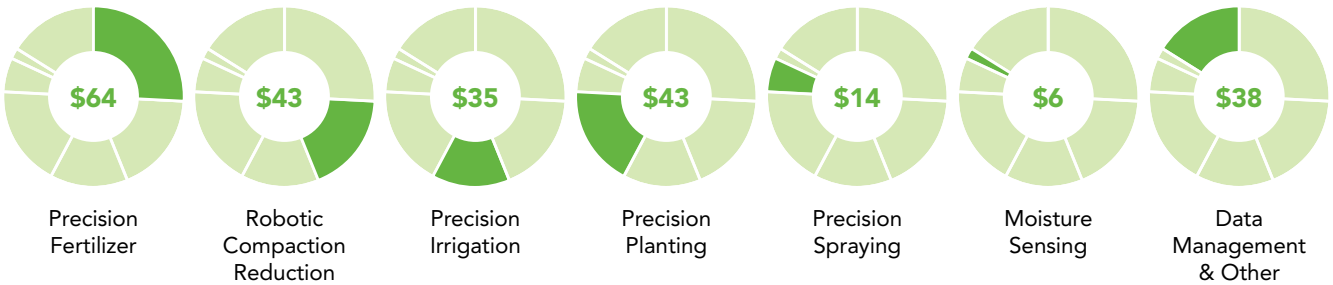
Software doesn't just help grow more crops more cost effectively, it can help grow rural economies, too. As farmers expand what technology enables them to do, technology expands what rural economies can achieve. Technology innovation is a proven engine for rural economic growth. For example, from 2007 to 2016 in Iowa alone, tech and tech-related jobs grew by 83 percent, accounting for almost one quarter of private-sector nonfarm job growth.[6] Already, the top 12 agricultural producing states, representing more than half of all US farm income, employ more than 1.3 million people in software-related jobs.[7] By 2026, these top 12 agricultural producing states are poised to create almost 200,000 new software-related jobs — jobs that often pay more than twice other private sector jobs, in many cases with annual salaries of more than $100,000.[8] And as broadband extends further and faster into rural communities, internet access won't just expand the types of precision technologies farmers can deploy; high-speed internet will expand rural economic diversity and access to the jobs and industries of the future.

But farmers must overcome key barriers to take full advantage of software-enabled progress. Although precision agriculture use is growing rapidly, in 2015 precision agriculture technology was used on less than 20 percent of all farmed land.[9] Too often, farmers may not be able to take full advantage of these software-enabled opportunities because 29 percent of US farms have no access to the internet.[10] Likewise while 200,000 new software jobs are projected to be created in the top 12 farm states alone, there are too few people with the skills needed to take these jobs, leaving many opportunities unfulfilled. Big gains can be made as these barriers are overcome and as more farmers begin taking advantage of software-driven technologies.

The opportunity is so big, studies estimate the addressable size of the precision agriculture market will grow into a $240 billion economic opportunity by 2050.[11] But these opportunities can only be achieved with pragmatic policies that remove precision agriculture barriers by closing the rural broadband gap, overcoming the rural skills gap, and nurturing the growing software innovation ecosystem with pragmatic policies that help it grow and thrive.

$240 Billion Digital Agriculture Opportunity

Billions of dollars addressable market by technology



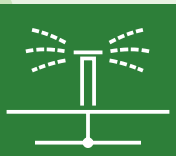
Source: Goldman Sachs Global Investment Research

Software Helps Solve Agriculture's Most Intractable Challenges

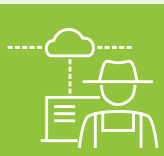
Feeding future generations by boosting yields and cutting costs. By 2050, to meet population growth, we need to produce 70 percent more food than we do today.[12] To help meet this challenge, software-enabled precision technologies can help boost global crop yields as much as 67 percent.[13]

Reducing greenhouse gasses by tackling the largest contributor. Food production is responsible for the largest share of CO^2 emission in the world. Livestock in particular is responsible for nearly half of all greenhouse gas emissions — three times that of all transportation combined.[14] Connected sensors are helping farmers identify ways to cut livestock emissions by monitoring feeding and digestion to optimize their diet in ways that reduce emissions.

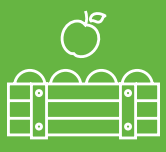
Reducing environmental impact by applying chemicals more accurately. Chemical runoff from over-application of chemicals can affect rivers, streams, and ocean life.[15] Using software-enabled computer vision and micro-dosing technology to deliver the precise doses to meet actual plant needs, herbicide use can be cut by 99.99 percent.[16]



Overcoming a growing clean water crisis by cutting water use. Agriculture uses 70 percent of global fresh water supplies[17] at a time when roughly two-thirds of the world's population live with severe water shortages.[18] Using software-enabled moisture sensors, better weather predictions, and smart irrigation technologies can reduce water consumption by 20 to 30 percent.[19]



Reducing food waste and improving security through better management. Up to 40 percent of food is wasted in the United States, costing approximately $165 billion each year — 50 percent happens during distribution. Sophisticated software is helping manage food distribution more efficiently, improving traceability, and cutting the cost of resolving a food recall in half.[20]



Increasing access to healthier diets with more nutritious foods. Unhealthy diets contribute to 678,000 deaths each year in the United States — including from obesity-related diseases like heart disease and diabetes.[21] Globally, 1.7 million (2.8 percent) of deaths are attributable to low fruit and vegetable consumption.[22] Software is helping scientists develop new plant breeds that grow more delicious and nutritious foods, while also helping get them to the markets that need them most.

Reducing weather-related crop damage with AI-powered hyper-local predictions. Although 90 percent of crop losses are due to weather,[23] crop damage can be reduced by 25 percent using predictive weather modeling and precision agriculture techniques.[24]

Making Smarter Decisions to Feed Future Generations

By the middle of the century the global population is expected to reach 10 billion, requiring the world's farmers to produce significantly more food with about the same amount of land. To meet the needs of future generations, farmers are turning to technology to produce more food with fewer resources.

They are combining soil sensors, imagery from satellites and drones, GPS guided computer-controlled farm equipment, and cloud-based analytics to customize the care that plants receive. For example, a camera equipped precision-guided farm vehicle might use infrared analysis and computer vision technology to assess individual plant health — like leaf shape, stem size, and soil moisture content — to target sprayers and spreaders with the specific resources for healthier plants.

Farmers also want insights into whether a certain seed performs better than others, why a part of the field ended up yielding less, or the exact right time for harvesting to maximize yield. Farmers, for example, can estimate yield improvement by 10 to 15 percent if they are able to find a data management software system that optimizes where to plant "aggressive" vs. "defensive" hybrids.[25]

- **Connecting precision opportunities together.** At the Dancing Crow Farm in Carnation, Washington, they use algorithms to deliver water, fertilizer, and pesticides only to the crops that actually need them. The farm combined Microsoft's cloud-based machine learning algorithms, low-cost sensors, and aerial drones to improve agricultural yield, lower overall costs, and reduce the environmental impact of agricultural production.[26] The drone, for example, uses software to make it easy for a farmer to survey the field using 25 percent less time.[27] One of the keys to this progress is the internet connectivity enabled by using an unoccupied slice of spectrum called "TV White Spaces," which enable sensors to be seamlessly connected and integrated with AI systems in the cloud.
- **Helping farmers focus on success.** Often today, farmers need to consolidate information from multiple inputs to give them a more complete picture of the farm's operations. Trimble's agriculture software, for example, brings together data from different farm equipment manufacturers so farmers can sort through data from different systems for a real-time overview of operations from any location. The systems help farmers focus on success by creating estimates of the cost-per-acre for better decisions throughout the growing season.

> To meet the needs of future generations, farmers are turning to technology to produce more food with fewer resources.

Growing More Crops Per Drop

Agriculture consumes more than 70 percent of the world's fresh water supplies.[28] And an estimated 60 percent of that water is wasted due to overwatering, runoff, contamination, and other issues.[29] To improve efficiency, software advancements like better weather analytics, new satellite imagery, and smarter soil sensors are being combined to help farmers get to the root of their water problems. These technologies are helping farmers grow more crops per drop by reducing water consumption by 20 to 30 percent.[30]

Software is helping farmers use water more efficiently:

- **Putting precision into irrigation.** Farmers are turning to Trimble's Irrigate-IQ water management solution to enable GPS-guided irrigation systems that precisely control every nozzle for highly targeted water application.[31] When implemented, they can reduce water consumption by 30 percent.[32]

- **Using sensor data to precisely deliver the right amount of water.** In California, a state continuously hit by drought, agriculture consumes about 80 percent of the state's water. California's thirstiest crops are almonds. Growing a single almond consumes around a gallon of water.[33] But now, by connecting wireless sensors across a farm, data can be collected, crunched in the cloud, and used to control an irrigation system that drips in water at just the right amount — using 20 percent less water than traditional irrigation techniques.[34]

- **Saving an aquifer by using water with digital precision.** In Kansas, the aquifer is dropping by as much as two feet per year in some counties.[35] Studies suggest that if existing trends continue, 70 percent of their water will be depleted by 2060. As a result, the Kansas Water Office partnered with forward-thinking farmers who are taking advantage of new technologies to identify ways to more efficiently use scarce water resources. T&O Farms combined soil sensors, precision weather predictions, and a drip irrigation system to cuts its water use by 33 percent without sacrificing yield. Across the whole season, the savings translated into about three inches of water saved for the entire crop — water savings that can be readily replicated throughout Kansas.

- **Delivering water just to the vine, to improve the quality of California's wine.** California is also home to a $35 billion wine industry, which is rooted in its ability to consistently produce quality grapes. To maximize the quality of its grapes, E. & J. Gallo Winery turned to IBM's Watson to develop an intelligent irrigation system that uses weather reports and remote sensor data to deliver precise amounts of water to each vine to increase the quality of its grapes. Because of this tailored watering, the winery reduced its water use by 25 percent, while also improving the quality of its wine.[36]

- **Improving the quality and quantity of crops in the developing world.** These technologies can be especially powerful when used abroad. For example, the millions of small-scale farmers in Kenya traditionally don't irrigate for their crops. IBM has stepped up to help Kenyan farmers optimize crop growth and improve food security by managing their water more effectively using Internet of Things (IoT) technologies. The IBM project EZ Farm uses sensors to help farmers understand how much water is in the soil and measure the amount of water in local water tanks. This data is then combined with weather data to plan irrigation times to optimize crop growth, extend the crop cycle, and improve the quality and quantity of crops.[37]

Fighting Pests and Protecting Crops While Reducing Harmful Chemical Use

Each year, as much as 40 percent of the world's potential harvests are lost to damaging insects, weeds, and plant diseases.[38] At the same time, chemical runoff from the overapplication of pesticides, herbicides, and fertilizers can affect the health of our oceans, rivers, and streams.[39] In fact, farmers who don't yet use precision fertilizer technology are estimated to be overfertilizing 40 percent of their fields, and still seeing yield loss on 10 percent of their fields.[40] That's in part because an estimated 95 percent of chemicals sprayed miss their intended target, wasting the expensive agricultural chemicals and raising the toxicity risk for both people and wildlife.[41] To solve the problem, farmers are turning to software-enabled precision technologies to reduce waste by delivering just the right amount of chemical precisely where it's needed.

- **Applying fertilizer in calibrated doses.** Software-enabled technologies now help apply fertilizers in more calibrated doses to meet specific soil and plant nutrient needs, dramatically cutting fertilizer and other chemical use. For example, Trimble's Field-IQ software is a fertilization control system that helps control variable rate sprayers aimed at precisely managing a grower's inputs. Using an integrated system of hardware (precision nozzles, boom adjusters, and spinner speed controls) and its innovative software, the system provides a more accurate seeding and fertilization system to the grower.[42]

- **Using soil sensors to improve nutrient uptake.** Software is also helping improve crop health by optimizing soil pH levels, which is essential for nutrient uptake that can reduce the amount of fertilizer needed and directly impact yields. The growers at Costa Farms in Florida partnered with Microsoft to create a better way to measure and regulate pH throughout the day and across the lifecycle of its plants.[43] Based on the Azure IoT system with pH sensor devices, Costa Farms is now able to not only automatically measure pH levels, but dramatically increase its yield using fewer chemicals.

- **Advancing weed-whackers to spot and zap weeds more efficiently.** New technologies also create opportunities to kill weeds more accurately. Robotic weed-whackers with image recognition software can recognize weeds and zap them with a laser or apply a micro-dose of herbicide directly to a weed's leaf. These devices can cut herbicide use by as much as 99.99 percent.[44]

- **Crowdsourcing caustic critter solutions.** Software also enables new ways to tackle infestation problems. When some local farmers had lost up to 90 percent of their crops to fruit flies, Greenwood Orchards turned to Microsoft's cloud technology to fight the critters.[45] Using traps tied to GPS coordinates, they developed a crowdsourced application that created a community-wide infestation monitoring system to detect the early warning signs and enable early action to prevent devastating consequences.

> Each year, as much as 40 percent of the world's potential harvests are lost to damaging insects, weeds, and plant diseases.

Improving Food Safety and Logistics From Their Farm to Your Fork

Software is also vital to the process of getting fresh food to your table in a safe and traceable manner. Being able to monitor and track the food production process not only helps ensure food safety, but also can cut food waste. According to McKinsey, about a third of food produced is lost or wasted every year at a cost of $940 billion globally.[46] About 50 percent is wasted in the food distribution process alone.[47]

To get the freshest food to the right place at the right time, produce needs to be routed as efficiently as possible because every minute food is ripening, microbial populations may be growing. Software not only helps speed distribution and management of the entire supply chain, it also can play a critical role in the unfortunate event that contaminated food needs to be traced back to its source. By improving traceability, sophisticated software can now cut the costs of resolving a food recall in half[48] while building a level of trust in the food supply chain that was previously unattainable.

- **Tracking tomatoes from the field to your ketchup bottle.** Kagome, one of the largest tomato processors, uses IoT sensors and Microsoft's cloud to manage the entirety of its supply chain process — from field harvesting, to factory delivery, to in-plant processing and shipment to its customers. To improve food security, the software enables them to figure out where a tomato comes from, and where it ends up. The company calculated a return on investment of about 500 percent in the first season alone.[49]
- **Getting the right food to the right place at the right time.** Cargill, responsible for 25 percent of all US grain exports, turned to software from SAP to create a digital supply chain.[50] It not only helped Cargill improve transportation logistics and on-time delivery, it also helped reduce the cost of integrating plant systems by 70 percent.
- **Ensuring high-quality rice in every single bite.** And any time you thrust a fork into a pile of Uncle Ben's rice, you are looking at rice kernels that can be traced back through an entire global supply chain thanks to Microsoft's Azure cloud software.[51] Because Mars Food uses Transparency-One supply chain software to monitor its global food supply chain from the cloud, they are able to ensure quality products. The software not only tracks food supplies but also helps them ensure their rice comes from sustainable farms that use resources responsibly, pay farmers well, and have good working conditions on every farm.
- **Improving trust and transparency in the food you eat with a blockchain ecosystem.** Today, consumers often want to know everything possible about their food, like where it's from, how it was produced, and whether it's organic or sustainably grown. Similarly, food processors and sellers increasingly need to know everything about the food they use and have trust in the entirety of its food supply chain. To advance a global trusted holistic food supply chain, IBM has developed an innovative Food Trust, powered by their blockchain platform.[52] This network directly connects growers, processors, wholesalers, distributors, manufacturers, retailers, and others to enhance visibility and accountability in each step of the food supply. Importantly, it allows companies like Walmart to trace food throughout its entire journey in seconds, not weeks.

Improving the Vitality of Livestock

Livestock management is often a 24/7 endeavor. When livestock are fitted with sensors, farmers and ranchers can remotely monitor and manage the vitality of their livestock around the clock and across the farm — watching over the health, location, and well-being of every animal wearing a connected sensor. The data derived can lead to insights that produce better yields, increase survival rates, and improve milk output.

- **Supporting livestock vitality through real-time sensor monitoring.** Connected sensors enable ranchers to more quickly identify sick cattle that need to be pulled from the herd to prevent the spread of disease. Acoustic sensors that can recognize coughing are giving pig farmers an early warning for possible respiratory sickness. Accelerometers on a cow's tail can help predict when it is ready to breed, or send a farmer a text message when it goes into labor to give birth — helping improve chances of a live birth.[53] A pH sensor in a cow's stomach that only activates when it detects high acidity levels can be an early warning sign for SARA — a digestive disorder that reduces milk yields by three liters per cow per day and costs the US dairy industry as much as $1 billion a year.[54] A trial of these connected pH sensors showed an increase in production in 60 percent of farms, which could translate into a 10 percent increase in milk yield overall.[55]
- **Ensuring every cow counts.** SCR Dairy developed HealthyCow24, which combines Microsoft's Windows embedded software, with connected devices and its Azure cloud, to help farmers monitor their cows to help boost milk production, smooth the calving process, and ensure healthier cows.[56] The technology now connects about four million cows, enabling farmers to get real-time alerts on their smartphones.[57]

> When livestock are fitted with sensors, farmers and ranchers can remotely monitor and manage the vitality of their livestock around the clock and across the farm — watching over the health, location, and well-being of every animal wearing a connected sensor.

Improving the Environment and Reducing Greenhouse Gas Emissions

Food production is responsible for the largest share of CO^2 emissions worldwide. A large part of this is caused by livestock, which are responsible for half of all greenhouse gas emissions — three times that of all transportation sources worldwide combined.[58] Reducing these emissions is a big challenge. Methane from livestock accounts for nearly 40 percent of all greenhouse gas emissions from agriculture.[59] Fortunately, farmers are breathing a little easier thanks to software and connected sensors that help cut livestock emissions by monitoring feeding and digestion to optimize their diet and potentially reduce emissions.

- **Cutting greenhouse gasses by minimizing its largest source.** New "clean cow" technologies like the wireless sensors from WellCow can help optimize the diet for cattle by remotely monitoring what they eat and how well they digest it to identify opportunities to reduce methane emissions.[60] USDA also has developed software called the Dairy Gas Emissions Model (DairyGEM) for estimating and reducing the emissions from these gas-passing cows.[61]

- **Reducing farm fuel use with digitally directed farm equipment.** Agricultural greenhouse gas emissions also emanate from using farm equipment. Using conventional methods, farmers use more than six gallons of diesel fuel per acre each year.[62] But now, with the advent of software-enabled GPS-guided farm equipment, farmers are able to cultivate the land more uniformly without passing over the same point multiple times. These tractors use 40 percent less fuel than conventional methods — meaning lower fuel costs and fewer greenhouse gas emissions.[63]

Growing Foods That Are More Nutritious and Sustainable

Americans face critical challenges related to the health of the food they eat, from diabetes, gluten intolerance, high cholesterol, and a growing obesity epidemic. When we can grow more nutritious foods and increase every American's access to fresh fruits and vegetables, it can save thousands of lives and billions of health care dollars in the process.

Cloud biology is a new field that combines AI, DNA data, machine learning, and analytics to reduce the time needed to identify new crop breeds that are more nutritious and sustainable. By moving tests from the lab to the cloud, it shrinks the time it takes to identify ideal genetic signatures from years to weeks which in turn can enable huge breakthroughs. For example, scientists use software to identify the genes necessary to help develop wheats and nuts that don't cause allergic reactions, soybeans that don't contain the unhealthy trans-fats that contribute to high cholesterol and heart disease, and biofortified foods that help prevent malnutrition in low-income communities. With the help of software, machines can drop bits of DNA into tubes that use enzymes — like a pair of tiny genetic scissors — to turn certain food traits on and off almost as easily as we turn on and off the lights. In other cases, scientists can use cloud software to model a plant's metabolism and identify the genes that could improve photosynthesis and crop growth. These software innovations could help increase plant diversity and empower farmers with fresh approaches for expanding what they can produce.

- **Developing more nutritious, delicious, and sustainable foods.** Startup Ginko BioWorks is a Boston-based organism design foundry that uses software, banks of robotic DNA synthesizers, and software-controlled molecular analysis robots to create a vast decisional database. The resulting data helps the company's software make increasingly accurate predictions about which biological parts work together to create certain compounds. These results in turn help scientists design better food for livestock, create better enzymes for turning milk into cheese, produce new yeasts for better beer, and identify new options for food sweeteners that may be healthier for consumers.[64]

- **Moving plant research to the cloud.** Emerald Cloud Lab's web-based life sciences laboratory is cutting the cost and improving the efficiency of lab work by enabling researchers to run experiments in a centralized computer-controlled

> Cloud biology is a new field that combines AI, DNA data, machine learning, and analytics to reduce the time needed to identify new crop breeds that are more nutritious and sustainable.

lab from anywhere in the world. Using machines that look like 3D printers but work more like a remote army of lab technicians pipetting drops of DNA, the service enables researchers to remotely order tests so they can focus on their research, without the grunt work of washing test tubes.[65] It's a lab in the cloud.

- **Opening the door to entirely new kinds of agriculturally based products and solutions.** Autodesk developed software that makes it easier for scientists to design, visualize, and simulate proteins in the cloud.[66] Its Genetic Constructor software helps with everything from high-level genome sketches to base-pair editing. Its Molecular Simulation software enables scientists at all levels to simulate molecular design, while its Wet Lab Accelerator software enables cloud biology as a sort of robotic lab assistant. It could open the door to entirely new kinds of agriculturally based products and solutions — like new kinds of biofuels and new ways to make insulin from plants.

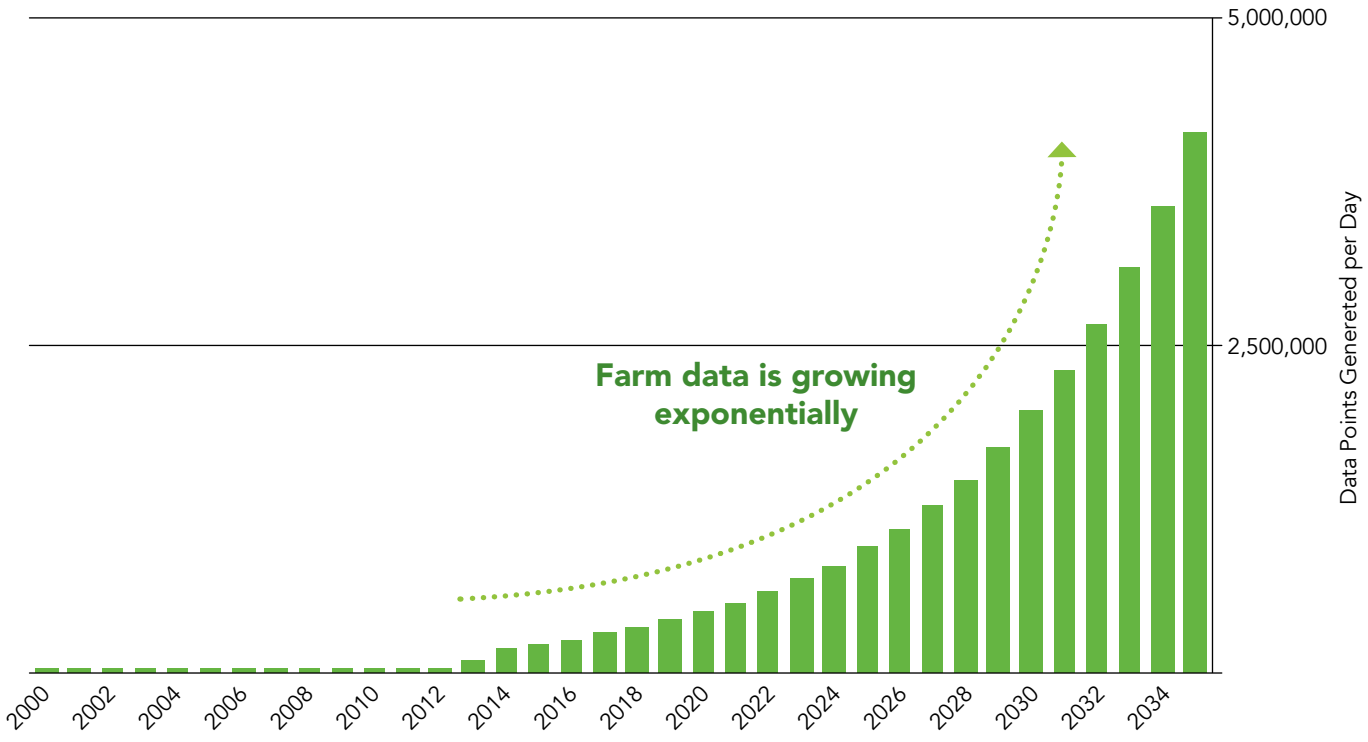
Technologies Fueling the Promise of Precision Agriculture

Farming Data: The Bigger the Data, the Greater the Yield

Today's farms generate lots of rich and varied data that must be harvested before it becomes useful. In 2014, the average farm produced just 190,000 data points per day. By 2050, a connected farm will be generating more than four million data points per day. As data grows exponentially, so does opportunity. The key challenge for data analysts is turning this deluge of information into actionable insights for farmers.

Farmers used to store their most precious resource in silos. Now they are storing their most precious data in the cloud. But when new farm equipment is introduced, the data might be siloed and stored for only one purpose. To enable precision opportunities, data needs to be stored in the cloud where it can be acted upon by software solutions to enable new insights, and accessed from the farmhouse, the office, or even a combine's cab.

Estimated Amount of Data Generated by the Average Connected Farm Per Day

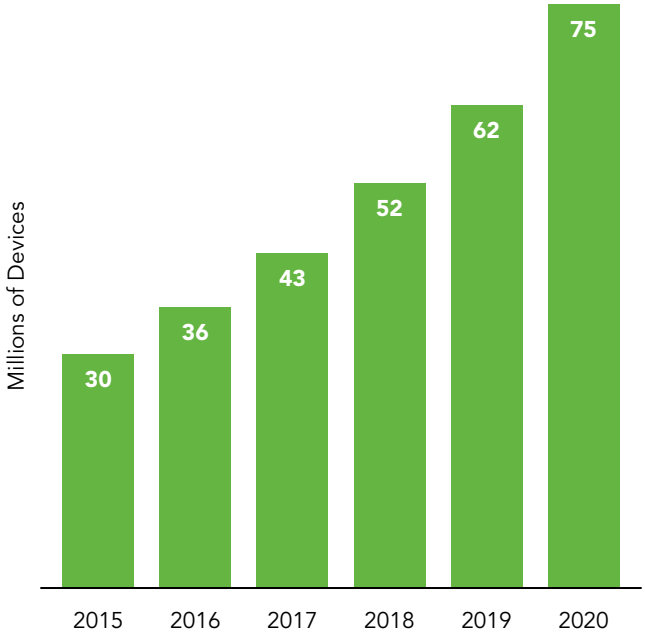


Source: Onfarm, BI Intelligence Estimates

Internet of Things: Sensing New Agricultural Opportunities

Some of the most powerful technologies enabling precision farming techniques today are software connected sensors that are transforming almost every aspect of farming operations. Wireless sensors can detect 26 different soil health parameters — from moisture, temperature, pH levels, aeration, and nutrient levels like nitrogen phosphate and potassium.[67] Other types of sensors are used with livestock to monitor key information that helps farmers improve healthy outcomes. These connected sensors are proving to be such a game changer that the number of connected agricultural devices is expected to grow orders of magnitude bigger — from 13 million at the end of 2014 to 225 million by 2024, and up to 2 billion by 2050.[68]

Connected Agriculture Devices Are Doubling



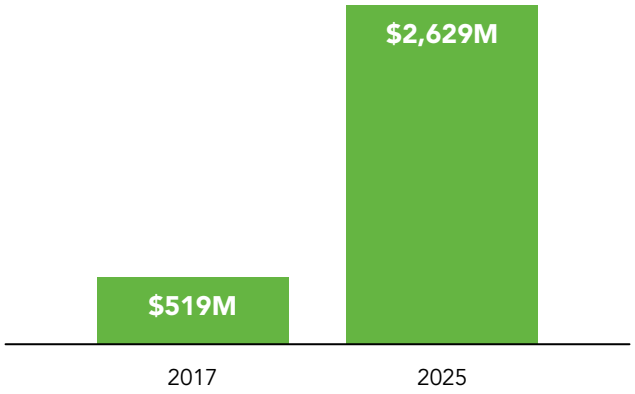
Source: Business Insider Intelligence Estimates

Artificial Intelligence: Creating Smarter Farming Solutions

To grow robust crops, farmers must constantly juggle a set of variables — soil moisture levels, looming weather, plant nutrition, and pest outbreaks — to calculate the exact cost of steps that can boost their bottom line. Now AI tools are performing calculations for the farmer with insights that simply could never have been calculated before.

One of the biggest AI applications that is helping farmers is hyper-local weather predictions. According to USDA, 90 percent of crop losses are caused by weather.[69] This crop damage can be reduced by an estimated 25 percent using predictive weather modeling and other precision agriculture techniques.[70] It helps ensure fewer crops are wasted and more food makes it to the table.

Artificial Intelligence in Agriculture
Growing 5 times larger by 2025



Source: Markets and Markets

AI in agriculture is turning out to be so powerful that market forecasters project the AI in the agriculture market to grow from $519 million in 2017 to $2.6 billion by 2025 — growing 22.5 percent per year.

These AI tools are being put to work today. For example, IBM's self-learning weather models are enabling farmers to take advantage of new kinds of hyper-local weather forecasts. When combined with IBM Watson's IoT platform, the system can analyze a variety of data like temperature, soil pH and other agricultural and environmental factors to give farmers insights that can help them make better decisions — and harvest greater yields.[71]

AI in agriculture is turning out to be so powerful that market forecasters project the AI in the agriculture market to grow from $519 million in 2017 to $2.6 billion by 2025 — growing 22.5 percent per year.[72]

Precision-Controlled Farm Equipment: Driving Efficiency in the Field

Forget self-driving cars; autonomous tractors are gaining traction and can already drive themselves through crop fields using GPS with less than an inch of error. These machines are enabled by Trimble, whose software allows highly accurate GPS-controlled navigation and steering systems for tractors.

Agricultural equipment manufacturers are embedding autonomous GPS navigation right into new farm equipment. John Deere estimates about two-thirds of large US farmers already use self-driving technology.[73] These tractors can be fitted with sensors that collect crop and soil data and can use variable-rate spreaders and sprayers that make sure fertilizers, herbicides, and pesticides are used in exactly the right amounts. They have found that software-enabled precision agriculture technology raises profitability per acre by $5 to $100 and increases overall productivity by 15 percent.[74]

Much of this machinery innovation has been made possible by software that has sped up agricultural machine design. For example, John Deere turned to Siemens software to enable faster design and virtual testing to improve the performance of new agricultural equipment.[75]

Agricultural Robots: Getting Precision Ag Rolling

Innovators are developing specialized AI-enabled robots that help farmers work more efficiently. These autonomous robots tend to the crops by seeding, weeding, fertilizing, and harvesting. Soil experts estimate large tractors and combines reduce field yield by up to 13 percent due to soil compaction, but a shift to smaller more autonomous robots can help boost yield and enable new precision.

- For example, the Lettuce Bot — a sort of Roomba for crops — uses a 3D camera mounted on a tractor and clever software processing to analyze real time images of lettuce crops to improve yields by precisely feeding each plant with the nutrients it needs to maximize output.[76]
- Similarly, Switzerland-based Ecorobotix has developed an ultra-light, solar-powered autonomous weeder that uses an AI-assisted camera to apply micro-doses of herbicide directly to a weed's leaves — cutting herbicide usage by 20 percent.[77]
- However, when some crops get tall, like corn, it can become a challenge to apply the right amounts of nutrients like nitrogen to the soil. Enter the cleverly named RowBot, which can navigate between rows of corn to keep nitrogen levels in sync with corn needs.[78]

> Innovators are developing specialized AI-enabled robots that help farmers work more efficiently.

Drones: Helping Farmers See Things More Clearly

With the help of autonomous drones, agricultural opportunity is looking up. For years, farmers have had to survey fields by foot. But now software-controlled drones are taking on tasks like field surveys to give farmers a more comprehensive vision of farming needs. With just a tap on a smartphone app, drones can create HD imagery, 3D maps, and multi-spectral imagery — allowing farmers to see their fields in ways beyond what a human eye can see. These drones can map weeds, yield, and soil variations from above to spot problems sooner. They produce a ton of data. In just one 160-acre field, a drone can take more than 150 high-resolution pictures, generating huge amounts of data that needs to be transmitted, processed, and correlated to identify new actionable insights.[79] As overhead imagery is fed into an AI engine, it can identify troubles like fungus growth in corn and soybean crops weeks before the naked eye detects it.[80] Being able to treat diseases early saves money and helps ensure greater yields.

Food for Thought: Four Key Recommendations to Enable Precision Farming Opportunities at Every Farm

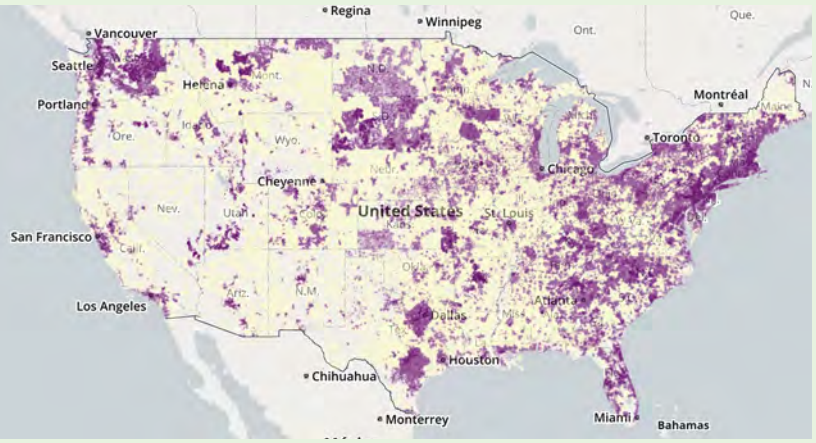
1. **Extend Precision Agricultural Opportunity Everywhere by Closing the Rural Broadband Gap**
2. **Enable Thousands of New Ag State Software Jobs by Closing the Farm State Software Skills Gap**
3. **Remove Barriers to Adoption by Fostering Farmer Trust by Modernizing Federal Data Policies**
4. **Enable Even Smarter and Bigger Agricultural Opportunities by Advancing a National AI Framework**

Although precision agriculture usage is growing rapidly, in 2015 precision agriculture technology was used on less than 20 percent of farmland.[81] Farmers may be unable to take advantage of the opportunities enabled by these technologies because they lack reliable broadband, don't have access to programmers who can customize solutions, want assurances that their data is private, and need access to continuously advancing smart AI technologies.

Extending precision agricultural opportunity everywhere by closing the rural broadband gap.

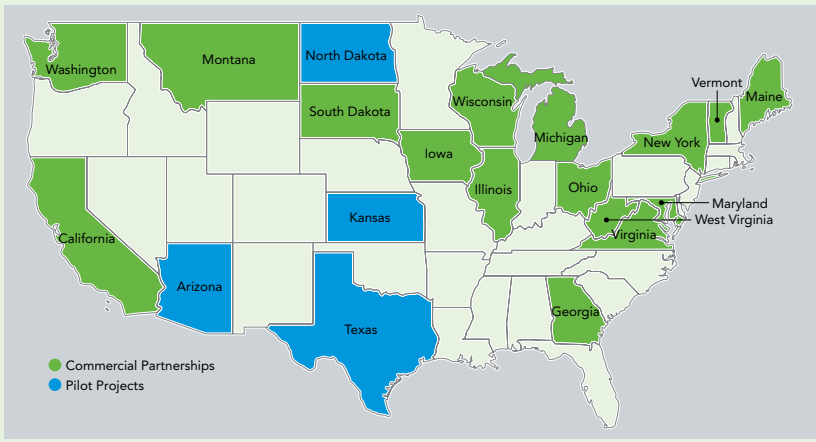
For farmers and ranchers, ubiquitous rural internet access has now become an agricultural accelerator and economic imperative. Broadband is not only essential for connecting the sensors, software, and clouds that enable precision farming techniques, but it also is vital for enabling farmers to search for new customers, find buyers, and identify the most affordable sources of seeds, fertilizers, and farm equipment.

Rural Broadband and the Digital Divide



This FCC map shows whether there are providers of fixed residential services of at least 25 Mbps/3 Mbps in a specific area. Yellow areas indicated areas that have no providers at 25Mbps/3Mbps.

TV White Spaces Pilot Project



An effort to use TV white spaces to close the rural broadband gap, the Microsoft Airband Initiative has projects in 16 states, and that number is expected to grow to 25 in 2019.

Unfortunately, rural Americans have been left behind in the broadband revolution where an estimated 19.4 million Americans live without access to high-speed broadband.[82] Making matters worse, the USDA reports that 29 percent of US farms have no access to the internet at all.[83] Without rural broadband, this digital divide means farmers lack the tools they need to take advantage of software-enabled precision farming technologies, and rural communities lack the tools they need to grow in a global economy.

Given the lack of farm access and the size of the precision agricultural opportunity, congressional leaders already have set a critical goal of achieving reliable internet service on 95 percent of farmland by 2025.[84] To address this, software innovators are advancing new rural broadband solutions using something called "TV White Spaces" that overcome the economics of distance that have long left rural communities digitally disconnected. The technology takes advantage of underused television spectrum to transmit data to places that have been left behind for too long.

The opportunity for rural America is one of the reasons why the Farm Bureaus in Montana, Oregon, South Dakota, and Wisconsin have all come together to support the deployment of this new wireless broadband technology.[85] Together with a group of more than 100 organizations, leaders are working with the Federal Communications Commission (FCC) and other policymakers to allocate enough unlicensed, low-band spectrum in every market to expand broadband connectivity via TV White Spaces — enabling broader precision agricultural opportunity everywhere.[86]

Enabling thousands of new ag state software jobs by closing the farm state software skills gap.

Software developers are the force multipliers when it comes to creating the breakthrough applications that will propel major agricultural advances in the years ahead. But many executives have come to understand that lack of access to software developer talent is one of the biggest potential threats to growth — bigger than even access to capital.[87] With nearly 200,000 software jobs expected to be created in the top 12 agriculture producing states by 2026, it's critical that these farm states have the developer skills necessary to fill these jobs.[88] Unfortunately, today there are already more than 500,000 unfilled computing jobs nationwide,[89] and the US Bureau of Labor Statistics

estimates that one million computer programming jobs in the United States will go unfilled by 2020.[90] To overcome this rural skills gap, we need to cultivate skilled coders who work in rural areas and can design and run the transformative software-enabled tools of tomorrow. That is why policymakers throughout the country need to make investments in computer science education to help prepare the next generation of software-literate workers by ensuring that computer science is taught in every high school.

Removing barriers to adoption by fostering farmer trust by modernizing federal data policies.

In order to advance precision farming adoption, it's critical that farmers have assurance that their data can be appropriately protected.[91] That's why modernizing federal data policies to ensure they are clear, effective, and predictable for farmers, innovators, and governments alike is critical to unlocking agricultural opportunity. Given that 9 out of 10 farmers use a smartphone in their combine,[92] they also need to trust that the information in their personal devices can be appropriately secured.

Enabling even smarter and bigger agricultural opportunities by advancing a national AI framework.

The smartest farming solutions today rely on AI to improve agricultural opportunity — from autonomously driving precision farm equipment, to hyper-localized weather forecasts, to systems that spot crop diseases in advance, to software that can project the perfect moment to maximize a harvest. Artificial intelligence is so critical that market forecasters project that AI solutions in agriculture will grow at a rate of 22.5 percent per year.[93] Despite that AI opportunities are growing at such a high rate, the United States has no federal policy toward AI or a strategy for advancing its trusted use. To address this, congressional leaders are looking to advance AI opportunities by setting up a process to develop forward-looking recommendations that can spur investment, empower the workforce, protect privacy, and ensure ethical behavior, among others.[94]

Conclusion

Today's precision agriculture advancements aren't just improving the way farmers grow, feed, harvest, and distribute food, they have the potential to boost yields, cut costs, and dramatically expand what the agricultural sector can achieve. With software innovations now firmly planted at the forefront of future farming opportunity, the key question is how quickly we can remove the barriers that prevent farmers from taking full advantage of these opportunities to accelerate agricultural opportunity all the way from the farm to the dinner table.

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[87] *The Developer Coefficient: Software Engineering Efficiency and Its $3 Trillion Impact on Global GDP* (September 2018), available at https://stripe.com/files/reports/the-developer-coefficient.pdf. Collectively, developers have the ability to raise global GDP by $3 trillion over the next 10 years. Access to developers is a bigger constraint than access to capital.

[88] ERS/USDA and BLS long-term occupational projections (2016–2026) for software-related occupations. The job categories included here include the following OCC codes: 15-1121 Computer Systems Analysts; 15-1122 Information Security Analysts; 15-1131 Computer Programmers; 15-1132 Software Developers, Applications; 15-1133 Software Developers, Systems Software; 15-1134 Web Developers; 15-1141 Database Administrators; 15-1142 Network and Computer Systems Administrators; 15-1143 Computer Network Architects; 15-1151 Computer User Support Specialists; 15-1152 Computer Network Support Specialists; and 15-1199 Computer Occupations, All Other.

[89] According to https://code.org/.

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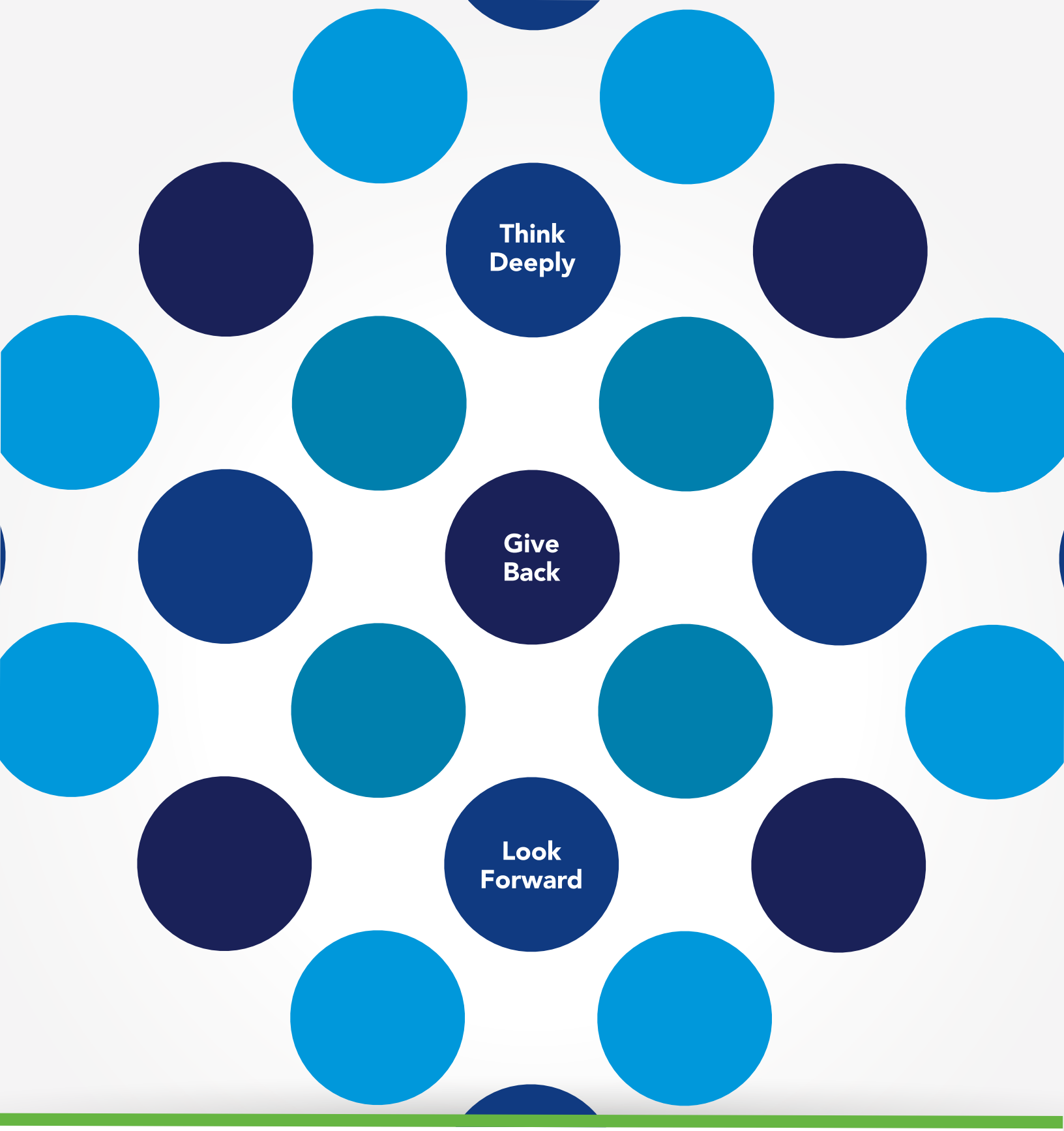

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Every Sector Is a Software Sector:
Smart Energy

Software Powers Energy Sector Transformation

June 2019

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Since the days of Thomas Edison, our country's economic opportunity often has been based on our ability to produce an increasing number of megawatts. But today, energy opportunity is increasingly being fueled not by the number of megawatts we produce, but the number of megabytes we harness.

That's because data opportunities now run through our electric grids, wind farms, and factories because software innovations radically improve our ability to solve energy challenges in previously impossible ways. The energy sector uses an estimated 1.8 billion software-connected devices and 4,500 petabytes of data to power today's economy.[1]

Looking ahead, software can improve the energy sector in several important ways — and throughout the process:

- By boosting energy production, helping access untapped domestic reserves and increasing the generation of renewable energy;
- By improving electric grid transmission, making the system more reliable and more secure; and
- By reducing energy use, leading to financial savings, and reduced environmental impact.

Given the power of innovation, the energy sector has begun transformative efforts to maximize its use of software to fuel a cleaner, greener energy sector that is more distributed, resilient, and affordable. Software is being deployed in energy to process underused data, unlock previously scarce resources, rethink the ways we do things, and make our energy use more efficient. It is fueling a huge revolution throughout the entire energy life cycle with the potential to transform how we generate, distribute, use, and save energy.

We are at the beginning of the energy transformation that digital data and software can deliver. The power behind this transformation comes not just from smarter grids, smarter thermostats, smarter buildings, and smarter vehicles, it comes from the breakthroughs that are allowing us to be smarter energy users, too. As innovative software is increasingly incorporated into everyday physical

The energy sector uses an estimated 1.8 billion software-connected devices and 4,500 petabytes of data to power today's economy.

devices, connected to the cloud, and infused with artificial intelligence (AI), it drives powerful new opportunities throughout every sector of the economy — increasing the size of our energy opportunities, while decreasing the size of our energy footprint. And because energy is often expensive, saving even a little amount of wasted energy can help us save lots of money, while concurrently cutting greenhouse gas emissions.

Energy innovation is happening everywhere. Data bits are helping drill bits see through rocks to reach vast reserves of untapped energy resources. The cloud is helping solar power shine by increasing its predictability. Drones are taking powerline, pipeline, and wind turbine inspections to new heights. Better weather analytics are taking the renewable energy industry by storm. Three-dimensional design software enables buildings capable of making more energy than they consume. And smarter software in connected devices helps save energy in our homes, cars, and factories by enabling almost everything to perform more efficiently.

When deployed pervasively, these technologies have the potential to make the smart grid even smarter, renewable power more prevalent, everyday devices more efficient, and energy more affordable. It means the scale of our energy opportunity is not measured just by the number of our pipelines and powerlines, but also the software that will encode our energy future with energized opportunities and electrified outcomes.

Critically, software innovation has advanced to the point where it now puts within reach the ability to help solve some of the energy sector's greatest challenges. Leaders have long struggled to find ways to solve some of our most intractable energy challenges — reducing dependence on foreign energy, boosting renewable energy use, cutting greenhouse gas emissions, making the outdated electric grid more resilient, and slashing energy costs, to name a few. These are the same challenges that software innovation now is helping to address in ways both big and small.

To achieve ambitious energy goals, our energy sector needs a software upgrade. Software has quickly emerged as the operating system that tomorrow's cleaner greener energy economy will run on, but too often, data goes underused, devices remain disconnected, renewable resources go unexplored, and our grid remains costly, outdated, and unreliable. Addressing these critical energy challenges requires taking advantage of the innovative potential of software-enabled technologies like artificial intelligence, predictive analytics, 3D modeling, the cloud, and the Internet of Things (IoT).

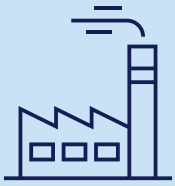
The software opportunities are immense. For example, when software-enabled technologies are deployed pragmatically and widely, experts predict, they can help us reduce overall net electricity demand by more than 25 percent,[2] cut greenhouse gas emissions by 19 percent,[3] save billions on our energy bills, help make us more energy independent, and enable a smarter electric grid that is more efficient, reliable, and resilient. They not only help advance solutions that can make systems cleaner, greener, and more efficient, but can enable a more secure, smart, and sustainable energy future.

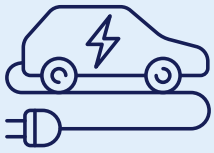
The software industry is at the forefront of accelerating these energy opportunities. Many companies have invested heavily in time, talent, and research to unlock software innovations with the potential to expand opportunities, and they also have been leading by example by working toward the goal of using only renewable energy to power their own progress.

To take full advantage of the software innovations behind this energy transformation, leaders need to help address as set of emerging challenges, including closing a looming software skills gap, ensuring robust cybersecurity measures are appropriately infused throughout connected energy operations, and accelerating cloud adoption throughout the energy sector.

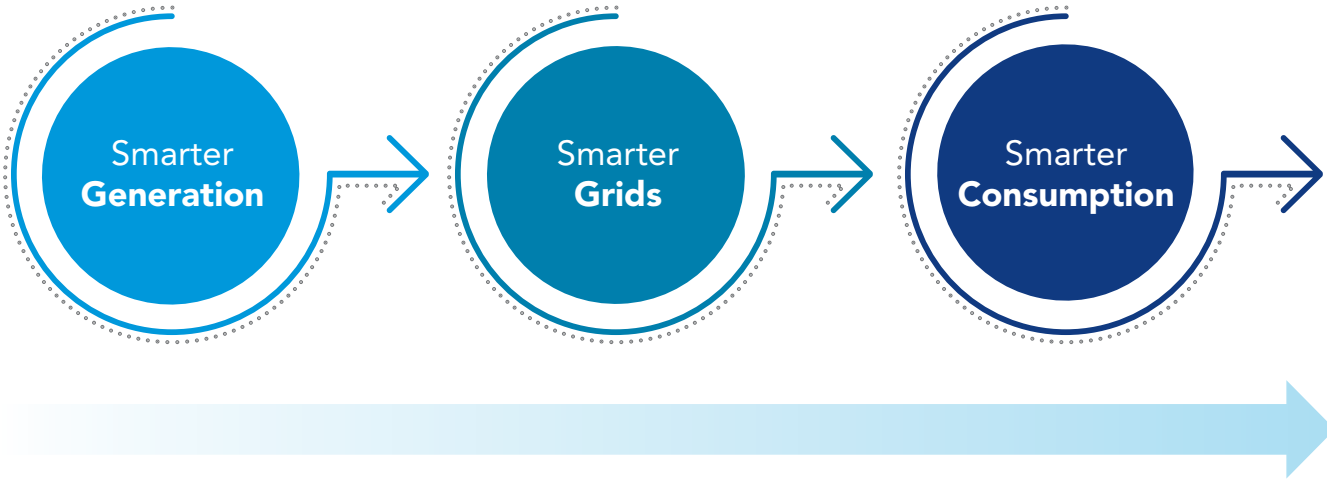
Energy Opportunities Are Immense

If widely deployed, software-enabled advances can help achieve important energy goals.

Goal	Societal Challenge	Opportunity if Digital Technologies Are Widely Deployed
Reducing Energy Use 	**Growing Energy Use** **28 percent increase in overall energy use by 2040,** under current scenarios.[4]	**25 percent reduction in overall electricity demand by 2050,** by maximizing the use of data and software.[5]
Reducing Greenhouse Gas Emissions 	**Unchecked Greenhouse Gas Emissions** **6,800 million metric tons of CO_2 annually** — the amount of US greenhouse gas emissions released into the atmosphere each year.[6]	**19 percent reduction in global greenhouse gas emissions** by widely adopting software enabled IoT technologies.[7]
Cutting Energy Costs 	**Growing Energy Costs** **$1,300 a year** — the average American's annual electricity bill.[8]	**10 percent reduction in home energy use,**[9] a 20 to 30 percent reduction in factory energy use,[10] $30 billion saved in transportation through widespread use of software technologies.[11]
Achieving Energy Independence 	**Foreign Energy Reliance** **5.6 million barrels of oil imported per day** — the difference between how much more oil America consumes than it produces.[12]	**10 to 20 percent reduction in production costs** through digitalization, including advanced processing of seismic data, the use of sensors, and enhanced resource modeling.[13]

Goal	Societal Challenge	Opportunity if Digital Technologies Are Widely Deployed
Boosting Solar 	**Slow Solar Uptake** **Uncertainties in predictions affect up to 70 percent of daytime solar** capacity due to passing clouds.[14]	**30 percent improvement in solar energy forecasts** by harnessing artificial intelligence software and improving our ability to incorporate renewable energy into the grid.[15]
Advancing Wind 	**Wind Not at Full Potential** An estimated **2.4 terawatts per hour of untapped wind energy is being wasted** within our already installed wind farms.[16]	**20 percent increase in wind farm power output** by digitizing new wind farms to harness untapped resources — adding value of $100 million per wind farm.[17]
More Efficient Transportation 	**Inefficient Transportation** **28 percent of global energy demand** comes from the transportation sector and **23 percent of global CO_2 emissions** are generated from fuel combustion.[18]	**20 percent reduction in vehicle energy consumption, 25 percent reduction in trucking energy use, $90 billion in fuel savings for freight rail** — by maximizing the use of software, data, and sensors.
Cutting Building Energy Usage 	**Wasted Buildings Energy** **More than 30 percent of energy in buildings is wasted,**[19] costing American businesses an estimated $60 billion per year.[20]	**21 percent reduction in a building's total energy costs** by using software to design smarter buildings.[21] **Savings of $20–$25 billion a year** by connecting sensors and HVAC to create smarter buildings.[22]

Software enables us to manage and save energy in smarter ways throughout **the entire energy life cycle**.



Enabled by widely deployed cutting-edge software:

- **Robust cybersecurity** that can improve the resiliency of our vulnerable grid
- **Connected IoT devices** than can make everything smarter
- **Super smart AI** that enables unprecedented opportunities
- **Capable clouds** that reduce onsite energy and enable IOT opportunity
- **Nimble drones** that can inspect pipelines, powerlines, and wind turbines
- **Predictive analytics** that reduce failures and predict weather energy impacts
- **3D design software** — that can make things more energy efficient by design

Throughout the entire energy life cycle — from generation to transmission to consumption — software, data, and digital devices are transforming the energy industry, and expanding what it can achieve. Increasingly data enables energy opportunity. When that data can be processed and acted upon by software, it can become the driver for tomorrow's energy economy.

Using Data and Digital Devices Is Powering Energy Transformation

	Digital Devices (installed in millions)			**Data** (Petabytes of storage on-premises and in the cloud)		
	2014	2020	CAGR* (percent)	2014	2020	CAGR (percent)
Power **Generation** (fossil, nuclear, renewables, etc.)	169	577	23	2,296	10,839	30
Power **Grid** (transmission and distribution)	1,327	5,008	25	805	3,445	27
Power **Consumption** (non-residential lighting power distribution and management, HVAC and climate control)	316	1,817	34	1,403	9,875	38
Total	**1,812**	**7,402**	**26**	**4,503**	**24,159**	**32**

*Compound annual growth rate

50 percent of the 24 exabytes of data generated across the energy sector by 2020 will reside in the cloud (public, private, or hybrid)

Source: Harbor Research estimates and General Electric, Powering the Future Leading the Digital Transformation of the Power Industry, available at https://www.ge.com/content/dam/gepower-pw/global/en_US/documents/industrial%20internet%20and%20big%20data/powering-the-future-whitepaper.pdf.

Boosting Energy Generation and Production

Software is expanding our opportunities to generate cleaner and greener renewable energy, such as solar and wind energy, while also helping companies find untapped oil and gas reserves to reduce our dependence on foreign energy and reduce our dependence on coal.

Eliminating Dependence on Foreign Oil by Tapping into Torrents of New Data

Reducing our dependence on foreign oil has been a long-standing US policy challenge. But as recently as 10 years ago, the United States remained heavily dependent on Middle East oil, paying $100 a barrel for crude, leading to ever-increasing prices at the gas pump. Then intrepid innovators decided to combine software, big data, seismic sensors, the cloud, and 3D imaging to create high-resolution 3D seismic maps of underground resources from the flood of data produced from underground seismic activity. Like seeing a 3D MRI scan of the underground world, the imaging software allowed drillers, for the first time, to see through underground rocks and tap into hard-to-reach underground reserves. When combined with digital drill sensors that connect the data with software to recognize different layers of rock in real-time, operators can precisely drill horizontally through previously unreachable resources. By combining data bits and drill bits, they can unlock new energy reserves and natural gas deposits from the gushers of data that can now be refined.

New technologies fueled the growth of cheap, cleaner-burning natural gas and boosted the productivity of oil and gas rigs by 200 to 300 percent almost overnight.[23] Use of these previously untapped unconventional reservoirs now accounts for about half of all U.S. production and has quickly reduced our dependence on foreign energy sources.[24]

Despite this digital progress, the global oil and gas industry still trails other industries in using software and data.[25] Whereas oilfield sensors generate petabytes of production data,[26] oil and gas companies are still often using only 1 percent of the data they generate.[27] To make better use of this untapped data and improve security, Chevron, for example, partnered with Microsoft to take advantage of the innovations built into its cloud. Together they are accelerating work by tapping into up to a million sensors in just one oil field and estimate the data it handles is doubling every 12 to 18 months.[28] Microsoft's cloud platform processes real-time data coming from the sensors and marries it with Chevron's 6,000-plus software applications.[29] It enables Chevron to apply Microsoft's AI tools and optimize its drilling, production, and costs.[30]

For offshore oil platforms, McKinsey estimates they are running at only 77 percent of maximum production potential — and that software data analytics could help them close this $200 billion performance gap.[31] This is the kind of work IBM Watson enables 70 miles off the Australian coast where a drilling platform now capitalizes on more than 30 years' worth of operations data to save time, drive efficiency, and reduce costs.[32] For hard-to-reach offshore platforms, Siemens software enables remote monitoring with the potential to make platforms 20 percent more efficient than they are today, predict potential failures before they occur, reduce costs, and improve safety.[33]

When used extensively, these technologies offer enormous opportunity. The International Energy Agency predicts that more widespread use of digital technologies would further decrease oil and gas production costs between 10 percent and 20 percent, including through advanced processing of seismic data, the use of sensors, and enhanced reservoir modelling.[34] But as software becomes more pervasive and essential to energy output, the oil and gas industry faces a software skills shortage in the quest to unlock the data insights necessary for expanding energy reserves.[35]

Boosting Cleaner and Greener Renewable Energy Resources

Software also is helping increase the use of renewable energy sources like wind and solar. One of the key challenges to maximizing the use of renewable power generation is the often unpredictability of solar and wind generation given their dependence on minute-by-minute weather changes. Utilities are tackling these problems by turning to AI, machine learning, and analytics to transform solar panels and wind farms into more predictable power assets.

For example, utilities are turning to IBM's Hybrid Renewable Energy Forecasting (HyRef) software to help forecast renewable generation capacity. By continuously improving the accuracy of its forecasting, the software enables more dependable planning and creates opportunities for utilities to incorporate more renewable energy into the grid. The system is increasing renewable power generation integrated in the grid by 10 percent, where the energy would be otherwise lost. It's enough energy to power more than 14,000 homes.[36]

Enabling Solar Options to Shine Brighter

There are several ways software enables new solar opportunities: better siting, design, integration, and sun tracking. For example, software is:

- **Improving siting.** To maximize output, it's also important to optimize the location of a solar farm. Under the US Department of Energy's SunShot initiative, an effort that seeks to make solar cost-competitive with other forms of electricity, a team of National Lab experts and university researchers turned to Microsoft's open source framework to create PVMapper. The 3D mapping software uses site location, time zone, sun path, nearby weather station data, and social preference data to optimize solar siting decisions.[37]
- **Boosting predictability.** In the sky, cloud formations hinder solar farm performance, but with software, cloud computing unlocks solar opportunities. For example, the solar power producing company renewables. AI used Microsoft's Azure cloud platform and AI tools to increase its productivity by 50 percent and propel them toward their goal of generating 50 gigawatts of solar power.[38]
- **Reducing uncertainty.** California leaders joined with experts from our National Labs to integrate Siemens software into its grid operations to reduce the uncertainty in solar power forecasting, thus reducing the costs of integrating solar generation into the bulk power system.[39] Likewise, the Hawaiian Electric Power Company is using Siemens software in its Energy Management System to better predict and incorporate rooftop solar into their forecasting and decision-making abilities.
- **Maximizing solar farm design and operation.** Improving design and operation of solar farms is important, too. To maximize solar output, designers can turn to Autodesk's design software and associated Solar Farm Planner plug-in to rapidly create and collaborate on solar farm designs. And to maximize solar collection and energy output, Autodesk also makes software that helps solar panels stay pointed at the sun regardless of season.[40]

> Utilities are turning to AI, machine learning, and analytics to transform solar panels and wind farms into more predictable power assets.

Enabling Wind Energy Options

Software innovation is helping make wind energy an even more promising energy resource by improving operations, siting, and cost-effectiveness.

Software is helping drive wind power opportunity:

- **Improving siting.** To maximize the use of wind, software like WindSim uses computational fluid dynamics that combines advanced processing with 3D visualization to help identify locations with the highest wind speeds, design the most optimal layout, and operate the wind farm in the most efficient way possible.[41]
- **Enabling wind generation everywhere.** Software is helping make wind turbine design a breeze. For SAFE-T Wind Systems, Autodesk's design software aids in designing small, safe, and inexpensive wind turbines that could be installed on any rooftop.[42]
- **Eliminating noise impediments.** In some instances, one of the impediments to adopting wind turbines is the noise they make. Renewable Energy Solutions Australia used Autodesk's design software to create whisper-quiet wind turbines that are silent, sustainable, efficient — and capable of generating 30 percent more power than conventional turbine designs.[43]
- **Boosting wind operational efficiency.** It's estimated that the operations and maintenance of a windfarm can contribute between a quarter and a third to total lifetime costs of energy.[44] To help maximize wind cost-effectiveness and support the day-to-day operations and logistics of wind farm management, IBM developed its Maximo Accelerator for Wind Energy software.[45] Showing great promise, IBM is also partnering on an EU project called ROMEO to reduce the maintenance costs of wind turbines using predictive machine learning algorithms, the IoT, and cloud computing.[46]

In part because software is helping improve renewable energy prospects, solar and wind jobs are now projected to explode, growing twice as fast as any other occupation in the United States.[47]

Improving Electric Grid Transmission

Creating a Cleaner, More Resilient, and Smarter Grid That Can Cut Our Energy Bills

Our electric grid needs a software upgrade. Our electric grid is made up of an antiquated patchwork of facilities, some of which date to the 1880s, leaving it vulnerable to outages and cyber-attacks.[48] The World Economic Forum ranks our electric grid at 24th in the world in terms of reliability, just behind Barbados.[49] As a result, we lack the capacity to meet America's growing needs, lack the sensors that tell operators when power goes out, and are unable to transform the way power is produced, stored, and sold.

By infusing the electric grid with software and sensors, and enabling it to connect to circuit breakers, meters, and appliances, the smart grid is poised to change the way electricity is generated, distributed, managed, and consumed — providing up to **$2 trillion in customer benefits** during the next 20 years, while creating millions of new jobs.[50] In the United States alone, the Electric Power Research Institute (EPRI) estimates that the transition to a digitally controlled smart grid will enable us to save as much as 200 billion kWh of electricity and avoid between as much as 200 million tons of CO_2 emissions. That is roughly equivalent to taking one to two million cars off the road for a year.[51]

> The energy sector is one of the fastest growing IoT segments, with projections of nearly one billion smart meters installed by 2020.

So how does a regular grid become a smart grid? Software. Software is what puts the smart in the smart grid by connecting everything with connected devices and infusing it with intelligence. The smart grid enables both power and information to flow in multiple directions, which boosts the overall efficiency, cost-effectiveness, resilience, and sustainability of the system. AI software, for example, can help providers generate and distribute energy more efficiently. Software analytics helps predict outages and maintenance requirements in advance to reduce downtime. Ultra-accurate demand prediction helps operators better manage the grid. And by connecting various sensors, software can help transform the grid to reduce energy, reduce the need for new power plants, and improve the environment.[52]

Smart grid benefits are already apparent. Because of these opportunities, installations of smart meters have more than doubled since 2010 — nearly of all US electricity customer accounts now have them.[53] They are producing results: smart grids have reduced customer interruptions by 55 percent, avoided 197,000 truck rolls, 3.4 million vehicle miles traveled, and reduced an estimated 2,350 metric tons of CO_2 — the same amount produced to power 214 homes for a year.[54] It's one of the reasons why the energy sector is one of the fastest growing IoT segments, with projections of nearly one billion smart meters installed by 2020.[55]

Software innovators are helping drive this opportunity.

- **Siemens, whose power generation technology produces enough electricity to meet one-third of US power needs, has been at the forefront of fostering smart grid improvements.** For example, they are helping advance future grid technologies by infusing them with decentralized intelligence to maximize autonomy.[56] They developed an Energy Management System that runs on Microsoft's Azure cloud to integrate energy data and information from sensors to manage smart buildings, electric vehicles and public lighting with renewable energy generation and storage.[57]

- **Smart grids often need smart clouds.** Using Microsoft's Cortana Analytics suite, utilities are now able to tap into easy-to-use cloud-based machine learning tools that can connect distributed data sources, forecast energy demand, and make it easier for utilities to adopt cleaner and greener energy sources.[58] And by using its Azure IoT hub with the cloud, utilities are now able to better predict demand and engage distributed resources, like rooftop solar panels, electric vehicles, and smart homes, when they are needed.[59]

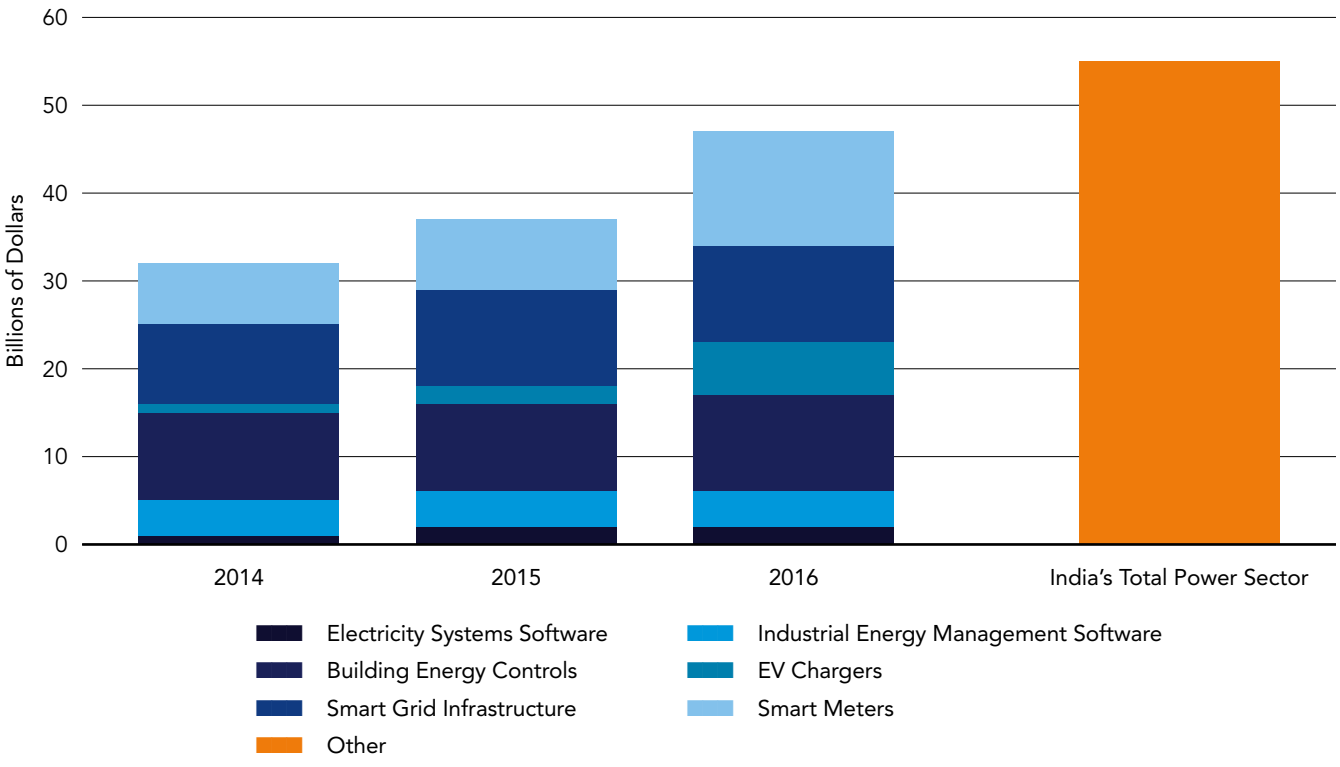
- **Using the cloud to predict cloudy skies and keep the lights on.** With 70 percent of power outages related to weather, better long-term weather forecasts can help utilities predict outages as much as five days in advance, which allows them to prepare and avoid costly outages. The Weather Company (an IBM business formerly known as the Weather Channel), uses IBM's Watson to produce highly accurate hyper-local weather predictions that help utilities keep your lights on by better predicting peak power demand periods, better predicting storm outages in advance, and better predicting real-time wind and solar output.[60] One US utility was able to save $1 million during a recent severe weather episode because it was able to predict outages in advance.[61]

- **Software can coordinate thousands of sensors simultaneously to avoid outages.** The New York Power Authority, for example, turned to advanced software to implement a continuous protection system that tracks the overall health of transmission assets in order to help the utility avoid unnecessary maintenance and proactively identify equipment that is in need of repair before it fails.[62] It uses the same software for its power generation system and has so far saved up to $3 million in maintenance costs. Overall, the utility uses more than 400 software applications that analyze 24,000 sensors to monitor every step of the production and transmission of electricity.

Given the amazing results, the pace of energy digitalization is accelerating. For example, global investment in digital electricity software and infrastructure is growing more than 20 percent per year. To get a sense of the magnitude of the bet companies are placing on this digitalization, in 2016 the digital investments energy companies were making around the globe ($47 billion) were nearly 40 percent higher than investment in gas-fired power generation worldwide ($34 billion) and almost equal to the total investment in India's electricity sector ($55 billion).[63]

Investments in Software and Digital Electricity Infrastructure Is Surging — Growing 20% a Year

Nearly equivalent to India's total electricity sector investments



Sources: International Energy Agency analysis based on MarketsandMarkets (2016), Internet of Things in Utility Market; BNEF (2016), Digital Energy Market Outlook.

Reducing Energy Use

Buildings: Transforming the Way Buildings Are Designed and Used

Many are unaware that buildings use almost 40 percent of all energy, 70 percent of electricity, and account for 30 percent of greenhouse gas emissions.[64] To make them more efficient, smart building software is helping design buildings in ways to use less energy. Buildings are also becoming smarter as they are infused with sensors and software control systems that make buildings operate dramatically more efficiently. These software technologies have shown so much promise, Accenture estimates that smart buildings could save businesses $25 billion a year in energy costs.

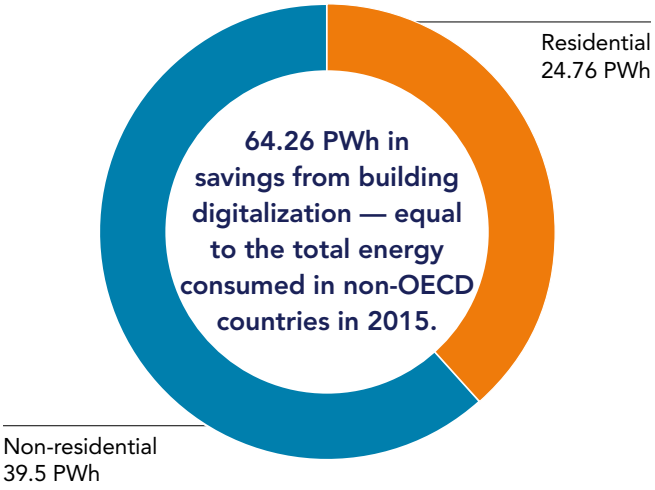
It all starts with better designed buildings. Today, cloud-based 3D design software can take advantage of AI and a technology called Building Information Modeling (BIM) to create more intelligent design options that cut costs and save energy. Studies have found that the energy tools built into BIM software can save as much as 21 percent in total energy use over a 10-year period.[65] With the click of a mouse, designers can now maximize energy efficiency with algorithms that help orient a building to maximize daylighting, ensure appropriate internal airflow for energy efficient HVAC systems, and identify design options that can improve overall life cycle energy use.

With the help of AI in the cloud, BIM software can now automatically generate the most effective design options for meeting specific design objectives like energy efficiency. These algorithms rapidly and systematically test countless computer-generated design options that meet, for example, specific energy targets, often producing unexpected solutions.

These are powerful design tools.

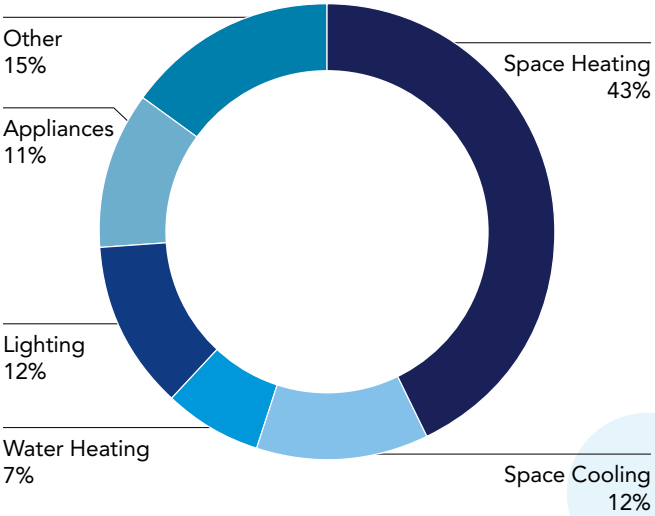
Building Digitalization Energy Savings

Perawatt hours (PWh) saved between 2017 and 2040



Source: International Energy Agency.

Building Digitalization Energy Savings by Source



Source: International Energy Agency.

> Digital smart building control systems can cut commercial building energy usage by 10 percent, which globally would amount to 65 petawatt hours of energy saved by 2040 — equal to the total energy consumed in non-OECD countries in 2015.

- BIM is able to wring energy savings even out of the most complex projects. For example, by using BIM software instead of traditional tools, the San Diego International Airport saved an estimated $800 million in the largest improvement project in the airport's history.[66] The project served as an economic stimulus for the region, created 1,000 jobs at peak construction, and was designed using "green" design principles leading to decreased water usage and reduced energy consumption.[67] Because of its pioneering design and energy efficiency gains, it was awarded the Leadership in Energy and Environmental Design (LEED) Platinum certification — making it the first LEED Platinum certified commercial airport terminal in the world.
- In the United Arab Emirates, these same kinds of tools were used to design the world's first positive-energy building that actually produces more energy than it consumes.[68] As others implement the software worldwide, it could have a dramatic effect on our global carbon footprint.

Once a building is designed and built, building energy management systems (BEMS) software plays a critical role in managing building operations in energy efficient ways. By controlling smart thermostats, and smart lighting, these digital smart building control systems can cut commercial building energy usage by 10 percent, which globally would amount to a whopping 65 petawatt hours of energy saved by 2040 — equal to the total energy consumed in non-OECD countries in 2015.[69]

Transportation: Software Is Driving a New Era in Transportation Efficiency

Software is on the move in the transportation sector. Today, the transportation sector accounts for about 28 percent of global energy demand and generates 23 percent of global CO_2 emissions from fuel combustion.[70] To cut fuel use and thus costs, the transportation sector is mobilizing the power of software innovation to dramatically boost the efficiency of the energy they use.

- **Truckers are achieving truckloads of fuel savings from software.** By using ingenious software to route trucks in more efficient ways (like eliminating time-consuming left turns), UPS has been able to save millions of gallons of gas and reduce emissions by the equivalent of taking thousands of cars off the road for a year.[71] Because of software's potential, the International Energy Agency found that applying digital solutions to truck operations and logistics could reduce road freight's energy use by 20 to 25 percent.[72] Driverless trucks that can autonomously form pelotons to cut wind resistance offer even greater promise.
- **Car efficiency now runs on software.** Since 2010, as the number of software lines of code in a car have expanded by a factor of 15 to roughly 150 million lines, the opportunities to cut fuel use have expanded even faster.[73] Software code runs onboard diagnostic systems that monitor oxygen sensors to tell us whether our cars are burning fuel cleanly, provides real time fuel

economy updates to help us drive more fuel efficiently, and calculates the most efficient route to our destinations. Studies show eco-routing software can cut fuel consumption by as much as 9.3 percent, eco-cruise control software can cut fuel consumption by 9.7 percent, and control software can reduce a Hybrid vehicle's energy consumption by 56 percent.[74] To achieve even greater fuel savings and emissions reductions, the US Department of Energy's ARPA-E is turning to software innovation through its NEXTCAR initiative aimed at reducing vehicle energy consumption another 20 percent by catalyzing software and sensor development that can perform real-time powertrain control to minimize energy consumption.[75]

- **Software is giving consumers smarter ways to drive energy savings.** Consumers can be one of the biggest determinants in how much fuel is used or saved. Increasingly, consumers are turning to AI fueled software apps to route them more efficiently, reducing trip miles and fuel. Software in the dashboard of hybrid cars displaying real-time fuel economy feedback is transforming "lead foot" drivers into so-called "hyper-milers" — people who use their dashboard display like a videogame to maximize fuel efficiency and beat their best score. These on-board displays coaxing us to become better drivers can cut fuel consumption by 30 percent.[76] Employers are turning to apps that encourage us to ride share in order to help reduce congestion, cut pollution, and reduce the number of cars on the road by 75 percent.[77] And as more cities deploy software infused smart traffic lights, they are reducing time at red lights by 40 percent and travel times by 26 percent.[78]

- **Software is creating the brains in trains that keeps fuel savings on track.** The freight rail industry has been investing in new software, sensors, and analytics to make them more efficient.[79] As a result, trains can now move a ton of freight using just half the fuel it used in 1980.[80] For example, fuel management software that analyzes train length, weight, route topology, and wind can improve fuel efficiency by up to 14 percent. These transformations are being achieved with software like SAP's IoT platform, which is being used to analyze terabytes of real-time data from thousands of train sensors to improve fuel efficiency and reduce maintenance costs by 8 to 10 percent.[81] But some of the biggest gains come from some of the latest trains. The most advanced locomotives today leverage thousands of readings from hundreds of sensors to assess performance every minute and help them achieve a 90 percent reduction in particulate emissions and 80 percent reduction in nitrogen oxide emissions.[82] GE estimates that even just a 1 percent improvement in system efficiency from better use of software and devices would result in freight fuel-savings of as much as $27 billion over 15 years.[83]

Software Efficiencies Cut Energy and Create Massive Savings

Industry	Segment	Type of Savings	Estimated Value Over 15 Years (Billions nominal US$)
Aviation	Commercial	1% Fuel Savings	$30
Power	Gas-fired Generation	1% Fuel Savings	$66
Rail	Freight	1% Fuel Savings	$27
Oil & Gas	Exploration & Development	1% Reduction in Capital Expenditures	$90

Source: Peter C. Evans and Marco Annunziata, *Industrial Internet: Pushing the Boundaries of Minds and Machines*, General Electric (November 26, 2012), available at https://www.ge.com/docs/chapters/Industrial_Internet.pdf.

> Even just a 1 percent data driven productivity improvement in aviation could save $30 billion in fuel savings worldwide over 15 years.

- **Software is lifting airline fuel savings.** Fuel accounts for more than 24 percent of the average airline's operating expenses and is the fastest-rising cost facing airlines.[84] To reduce fuel, the airline industry is talking advantage of software, sensors, and data. Modern airlines can now generate up to half a terabyte of data per flight from sensors throughout the plane that is used to improve flight performance, cut turbulence, improve safety, and identify engine defects 2,000 times faster than before.[85] Data helps improve flight path planning and lets crews know when a part may be degrading performance — all of which help cut fuel. These gains add up. By using data and software to optimize flight altitude, decide how much fuel to carry on board, and determine how long planes idle on tarmacs, GE estimates cloud software and analytics can reduce fuel costs by 2 percent, saving Southwest Airlines, as an example, an estimated $100 million a year. Even just a 1 percent data driven productivity improvement in aviation could save $30 billion in fuel savings worldwide over 15 years.[86]

Consumers: Empowering Consumers With Tools to Make Smarter Energy Choices

Today we waste significant amounts of home energy by leaving lights on in rooms that we aren't in and leaving air conditioning on in homes when we are away. This wasted energy costs consumers around $40 billion a year for energy that doesn't contribute to our well-being but does contribute to climate change. It's one of the reasons why smart thermostats, smart lights, and smart apps that put new power in the hands of consumers are so popular.

- **Connected devices don't just help people save more on their energy bills, they can help people who want to save the planet, too.** Already, software connected thermostats are helping us cut our home heating and cooling costs by as much as 20 percent simply by letting our homes to turn down the thermostats when we are away.[87] We can achieve even more when we use software to shut off lights and put appliances to sleep when we leave. When IoT devices are widely deployed in homes with automation software to control temperature, lighting, and appliances, we could collectively help reduce total residential energy consumption by as much as 10 percent,[88] while radically cutting reduce greenhouse gas emissions by as much as 19 percent.[89]

- **Smarter appliances can maximize renewable energy usage, too.** To help make the transition to smarter appliances, Microsoft has created an open source tool that enables developers and users to access real time carbon emissions data for their region, which can be used to enable water heaters and air conditioners to optimize their usage for times when renewable energy is at a peak. The Rocky Mountain Institute estimates that smarter water heaters and air conditioners that adjust their timing just slightly could reduce carbon emissions in the United States by more than six million metric tons per year — the equivalent of taking one million cars off the road.[90] Adding smart water heaters and air conditioners could triple the emission reduction potential.

- **Better energy information to improve consumption behavior.** Another way software is empowering consumers to save energy involves providing strategic pieces of information that can influence their behavior. For example, just knowing how your neighbors are doing on their energy usage compared to your own has been shown to be a powerful incentive that encourage people to reduce energy usage on average by about 7 percent.[91] And when even small reductions in peak electricity demand on hot days can have major economic and operational benefits for the stability of the power grid, with added incentives people can cut their electricity use during peak demand by 15 percent or more.[92] To empower people with this information, one software company has used a cloud based platform that analyzes more than 600 billion meter reads and 60 million utility customers to create personalized energy reports that more than 100 utilities use to allow consumer to compare their own usage to that of their neighbors. It has resulted in homeowners saving $250 million collectively on their home energy bills.[93]

Harnessing Software to Cut Carbon and Improve the Environment

At a time when the concentration of CO_2 in Earth's atmosphere has reached a level not seen in 800,000 years and is continuing to rise,[94] many leaders are looking for solutions that can simultaneously cut greenhouse gas emissions while growing the economy. Software has become a powerful tool that not only enables companies to save money by doing things more efficiently, but at the same time to cut their carbon footprint. The opportunities to cut greenhouse emissions are massive. For example, the widespread adoption of software connected IoT devices throughout the energy, transportation, building, and agriculture sectors could help to reduce global greenhouse gas emissions by a whopping 9.1 billion metric tons by 2020, or about 19 percent.[95] On a global scale, that is equivalent to eliminating all the United States' and India's total greenhouse gas emissions combined.

To accelerate these opportunities, software innovators are stepping up to the plate. For example, Microsoft's newly created AI for Earth Innovation Grants seek to advance ways to use AI to help us better understand, engage, and protect the planet. Grants are being given to novel projects that will be able to use Microsoft cloud and AI tools to improve the way we monitor, model, and ultimately manage Earth's natural systems.[96]

The widespread adoption of software connected IoT devices throughout the energy, transportation, building, and agriculture sectors could help to reduce global greenhouse gas emissions by a whopping 9.1 billion metric tons by 2020, or about 19 percent.

Software Companies Are Leading by Example

Autodesk

In 2015, Autodesk made a commitment to power its facilities and cloud services with 100 percent renewable energy by fiscal year 2021. The company achieved this milestone several years early.[97] Since 2009, the company has decreased its greenhouse emissions by 44 percent, exceeding its goal of a 35 percent reduction.

"At Autodesk we are all in. Our employees are in. Our customers are in. We are more committed than ever to enlist our customers to design, build and manufacture net positive climate solutions. We will help our customers design buildings that generate more energy than they use, make products without mining or extracting raw materials, and design cities that restore ecosystems."

~ Lynelle Cameron, president and CEO of the Autodesk Foundation[98]

IBM

Since 2005, IBM has reduced CO_2 emissions at its managed locations by 42.9 percent as of 2017, exceeding its goal of 35 percent by 2020.[99] IBM has procured electricity from renewable sources for 22.9 percent of its global electricity consumption, exceeding its goal to procure 20 percent by 2020.

"We know that businesses must play a leadership role in the fight against climate change, and we continue to lead by reducing our own operational impact and by developing innovative solutions to help our clients do the same."

~ Wayne Balta, IBM vice president of Corporate Environmental Affairs and Product Safety[100]

Microsoft

Microsoft has been powered by 100 percent renewable electricity since 2014.[101] In July 2012, Microsoft made a companywide commitment to carbon neutrality. They have purchased more than 10 billion kilowatt-hours (kWh) of green power and reduced their emissions by 7.5 million metric tons of carbon dioxide equivalent (mtCO2e.) In 2016, Microsoft set further ambitious targets to source clean electricity for its datacenters directly from local sources of energy; 50 percent by the end of 2018 and 60 percent by early 2020.[102] In 2017, Microsoft pledged to reduce its operational carbon emissions 75 percent by 2030 and is on target to achieve this goal.[103] Microsoft is testing next-gen technologies to nearly double the efficiency of datacenters.

"At Microsoft, we believe technology has tremendous potential to address environmental challenges and attain a clean energy future. We seek to serve as a model in our commitment to environmental sustainability by delivering on our carbon neutrality commitment and uncovering new ways technology can help us better understand our planet."

~ Satya Nadella, CEO, Microsoft

Salesforce

Salesforce has announced a goal to power all its data centers with renewable energy. It has already achieved three significant milestones — achieving net-zero greenhouse gas emissions, delivering a carbon neutral cloud for all customers, and powering its two office towers at the heart of its global headquarters in San Francisco with 100 percent renewable energy.[104]

"The planet needs immediate action, our customers expect us to take a leadership role, and we're proud to provide them a carbon neutral cloud. Committing to work toward 100 percent renewable energy is an important step on our ongoing sustainability journey."

~ Patrick Flynn, senior director Sustainability[105]

Siemens

Siemens has committed to cut its global carbon footprint in half by 2020 and become carbon neutral by 2030. From FY14 to FY16, Siemens cut its global CO_2 emissions by 20 percent.[106]

Steps to Accelerate 21st Century Energy Opportunities

The transformative energy opportunities on the horizon made possible by software innovation are immense, but so too are the barriers that could stifle software innovation. To overcome these challenges, the software industry is investing heavily in time, talent, and research to unlock unprecedented new energy opportunities. But key challenges must still be overcome to maximize the potential of these energy-saving, greenhouse gas reducing, cost saving cutting technologies, including:

1. **Ensuring energy resilience through continuously improving cybersecurity.** With the energy grid becoming more connected and connected devices becoming increasingly vital for energy efficiency, it is now more important than ever that we have appropriate cybersecurity efforts in place to defend the integrity, privacy, and utility of the entire internet ecosystem. Taking steps to use the most up-to-date secure technologies is especially important as malicious cyberattacks on the North American electric grid continue to grow in frequency and sophistication — with one analysis finding that power companies and utilities reported a six-fold increase in the number of detected cyber incidents in just one year.[107] Robust cybersecurity is especially important given reports that sophisticated nation-state hackers have turned their attention to infiltrating the US power grid.[108] Experts now warn that a sophisticated cyberattack on the US power grid could cause nearly $250 billion in economic losses and, under the most severe circumstances, cost more than $1 trillion to the US economy.[109] But industry leaders and policymakers alike must meet this growing challenge with a commensurate commitment to improving cybersecurity in the connected age.

2. **Accelerate the transition to secure and energy efficient cloud services.** To achieve the most transformative technology benefits from energy digitalization, organizations must first move to the cloud. The cloud is important because it provides both greater security and a platform for advancing the opportunities from digitalization. It's why 50 percent of the 24 exabytes of data generated across the energy sector by 2020 are projected to reside in the cloud.[110]

   The cloud provides inherent security advantages. The cloud provides inherent security advantage over traditional models because providers are able to see across a broader threat landscape to identify risks earlier and deploy more sophisticated security technologies than individual customers could afford to do on their own. Cloud providers are able to maximize security by deploying advanced threat protection technologies, encrypting data at rest and in transit, and automating updates to more quickly protect systems form newly discovered threats. Together these capabilities can improve the resiliency of data and strengthen an organization's security.

> BSA developed "Security in the Connected Age," a comprehensive cybersecurity agenda that defines the key elements necessary for ensuring a robust, agile, and effective U.S cybersecurity policy. It calls for (1) advancing innovative partnerships between industry and government for a secure software ecosystem, (2) strengthening the government's approach to cybersecurity and supporting international standards, (3) advancing a 21st century cybersecurity workforce, and (4) embracing digital transformation.

The cloud is a natural born energy saver. One of the ways businesses are saving energy is by choosing to move their data to the cloud, instead of using an onsite data center. When researchers at Lawrence Berkeley National Laboratory looked at the problem, they found that moving software from a local data center to the cloud would enable companies to shrink their computing energy footprints by 87 percent, saving 23 billion kilowatt-hours annually — enough to power the city of Los Angeles.[111] In some cases, cloud services can be up to 93 percent more energy efficient than traditional on-premise enterprise datacenters, and 98 percent more carbon efficient.[112]

3. **Maximize cleaner and greener energy opportunities by accelerating energy digitalization and transitioning to a smarter grid.** We need to upgrade our outdated electric grid with smarter technologies that can better accommodate renewables, become more secure, and boost resiliency. Our current grid wastes too much energy, costs us too much money to maintain, and is too susceptible to outages and failures. But to achieve the full promise of the benefits that energy digitalization can drive, we need to not only invest in the smart grid technologies that make them smart, we also need to invest in the foundational technologies that can make everything smart. When we can make our thermostats smarter, our buildings smarter, our cars smarter, our cities smarter, only then will we be able to reap the smarter opportunities for reducing energy, cutting greenhouse gas emissions, and putting more money back into consumer pockets.

Energy Jobs of the Future

As our energy opportunity becomes increasingly digital, we face a looming shortage of the people with skills to help us take full advantage of these opportunities. To address this, we will need more workers trained to design and run the transformative software-enabled tools of tomorrow.

Jobs for coders. By 2020, experts expect the deployment of more than seven billion devices in the energy sector, generating more than 24,000 petabytes of data. But the software necessary to maximize their use can't be written if there aren't enough coders to do so. Whereas today there are already more than 500,000 unfilled computing jobs nationwide, the US Bureau of Labor Statistics estimates there will be 1.4 million open computing jobs by 2020, but only 400,000 computer science graduates with the skills to fill them.[113]

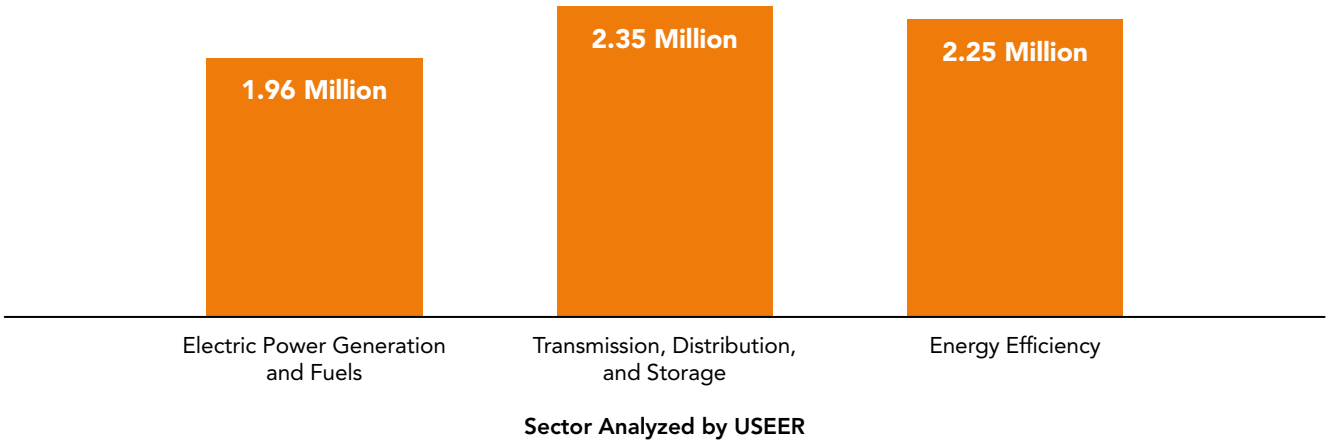
Tech-enabled jobs. Technologists and energy experts continuously seek ways to manage resources more efficiently and develop and discover new sources of energy. With progress in the energy field, roles that bridge various disciplines have emerged quickly and in large numbers. In addition to closing the software skills gap, stakeholders who want to see the energy sector thrive will have to showcase these new kinds of jobs. Options for a job in the energy sector are not limited to a traditional or limited scope of the field and can include roles in utility infrastructure, transportation, waste, and wastewater, among many others.

According to the Department of Energy, the five fastest growing green jobs[114] are:

- Energy efficiency specialist
- Wind turbine technician
- Solar installer
- Clean car engineer
- Sustainable builder

According to the International Renewable Energy Agency *2018 Annual Review*, the renewable energy sector globally created more than 500,000 jobs in 2017.[115] The report highlights that jobs in the sector increased 5.3 percent that year, totaling 10.3 million jobs. Looking domestically, the 2018 United States Energy and Employment Report (USEER), an annual study on energy employment data, found that traditional and renewable energy sectors employ approximately 6.5 million Americans.[116] The USEER determines the jobs created by the energy sector by adding jobs created by the electric power generation and fuels production sector; the transmission, distribution, and storage sector; and the energy efficiency sector.

2018 US Energy and Employment Report by Sector, 2017 Jobs



Source: The 2018 U.S. Energy and Employment Report, available at https://www.usenergyjobs.org/.

Conclusion

Today's digital energy revolution won't just improve our energy independence, improve our ability to use renewable energy sources, and drastically cut greenhouse gas emissions; it can save us billions and become an economic accelerant for creating the new jobs, industries, and opportunities for a more prosperous future. At a time when software is quickly becoming the most transformative technology of our time, enabling broader use of software solutions throughout the economy has not only become an energy opportunity accelerator, but a critical climate change imperative.

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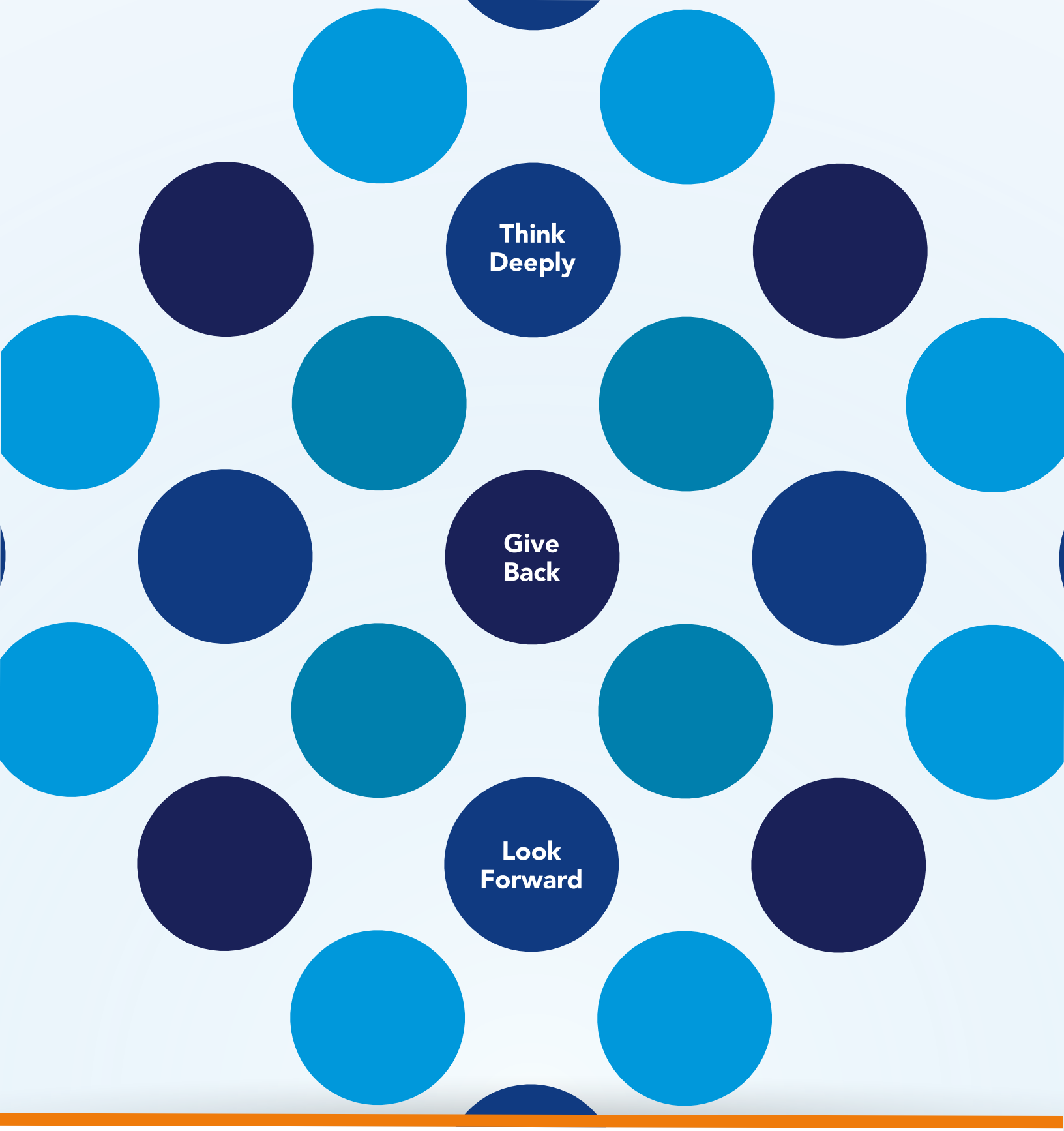

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