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Every Sector Is a Software Sector: **Smart Energy**

Software Powers Energy Sector Transformation

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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

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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).

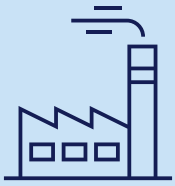
The software opportunities are immense. For example, when software-enabled technologies are deployed pragmatically and widely, experts predict, they can help us reduce overall net electricity demand by more than 25 percent,[2] cut greenhouse gas emissions by 19 percent,[3] save billions on our energy 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.

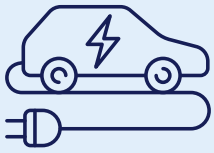
The software industry is at the forefront of accelerating these energy opportunities. Many companies have invested heavily in time, talent, and research to unlock software innovations with the potential to expand opportunities, and they also have been leading by example by working toward the goal of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

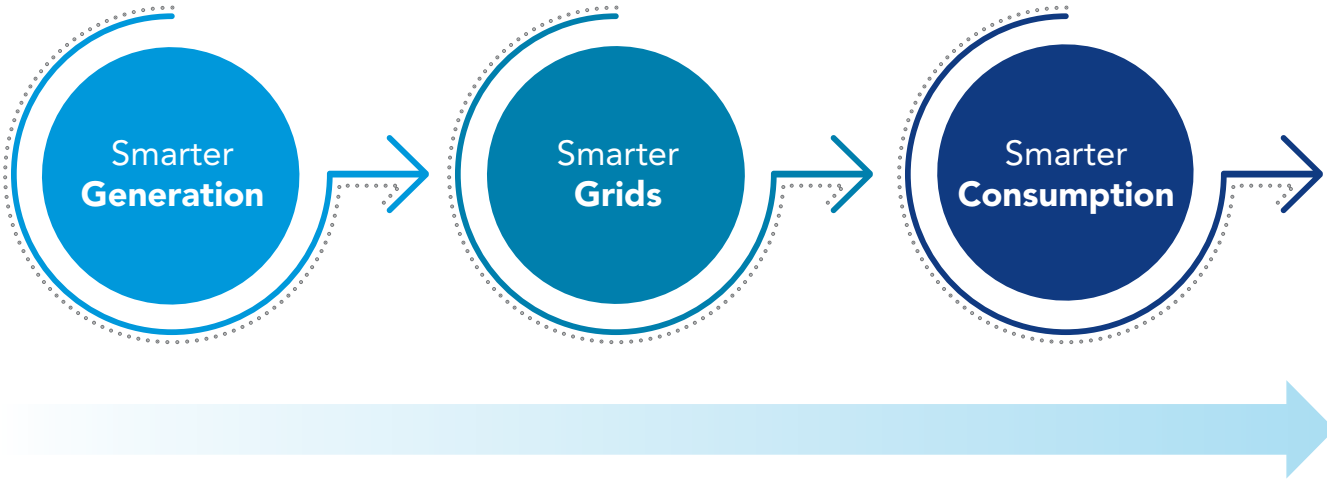
Energy Opportunities Are Immense

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]

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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]

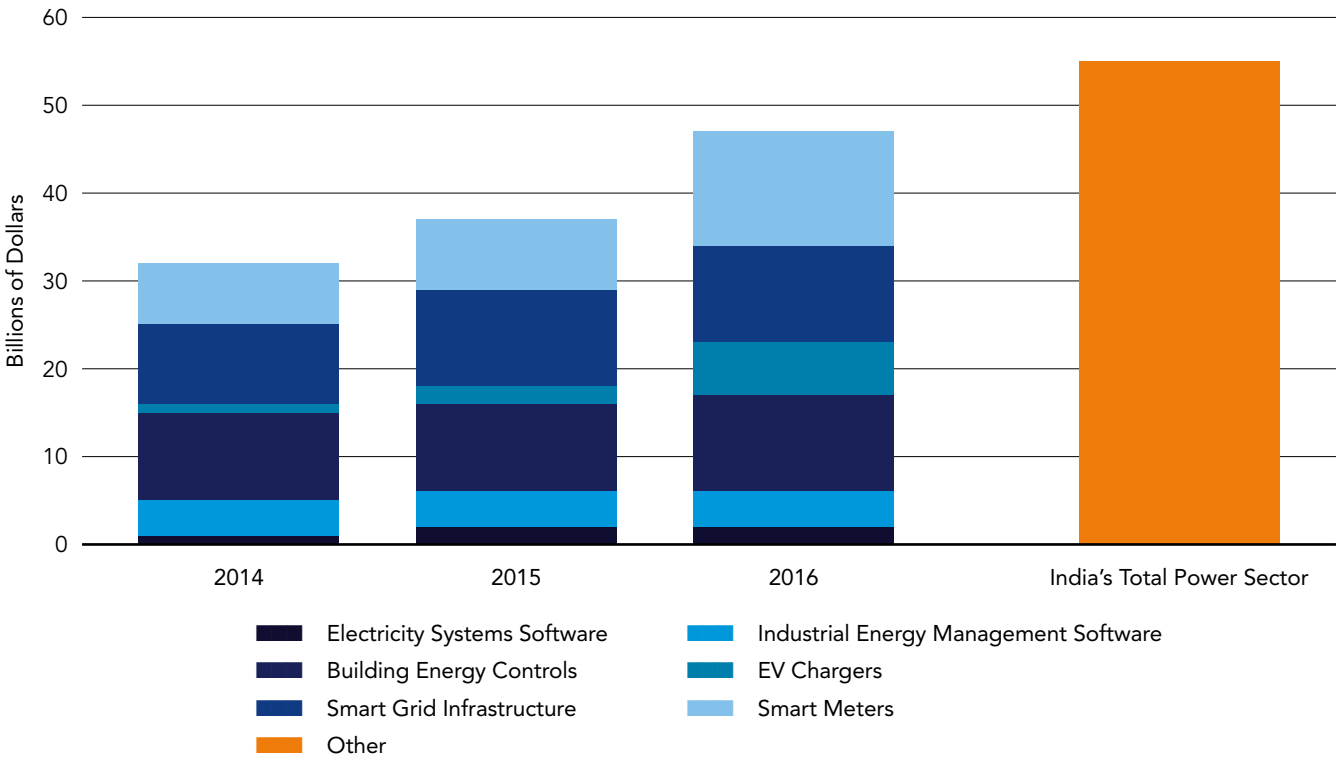
- **Using the cloud to predict cloudy skies and keep the lights on.** With 70 percent of power outages related to weather, better long-term weather forecasts can help utilities predict outages as much as five days in advance, which allows them to prepare and avoid costly outages. The Weather Company (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.

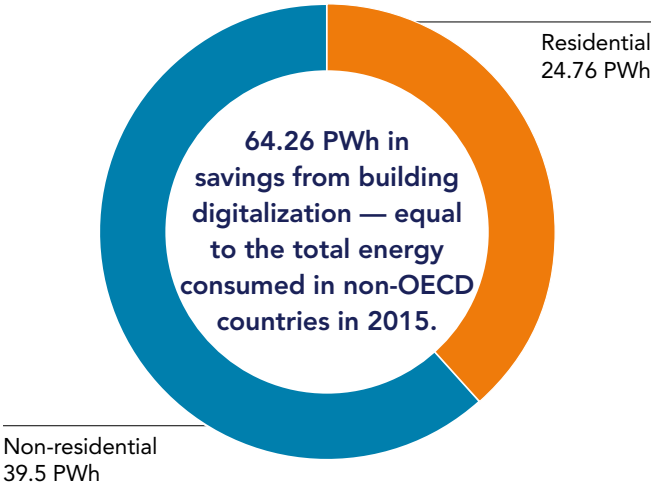
It all starts with better designed buildings. Today, cloud-based 3D design software can take advantage of AI and a technology called Building Information Modeling (BIM) to create more intelligent design options that cut costs and save energy. Studies have found that the energy tools built into BIM software 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.

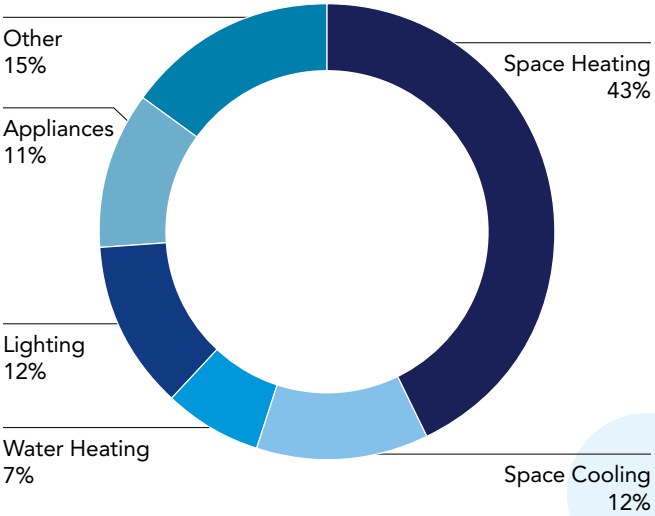
Building Digitalization Energy Savings

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]

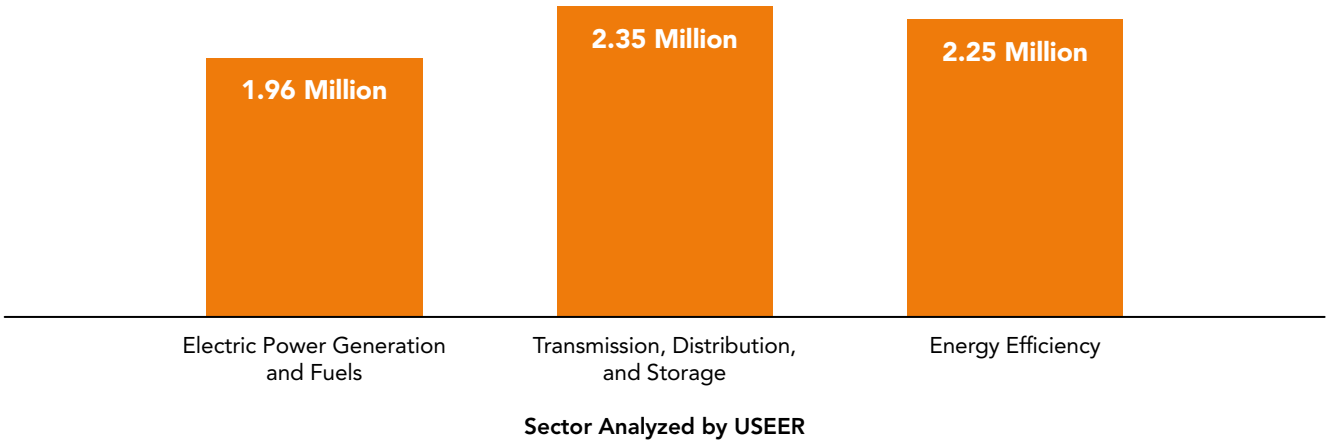
Tech-enabled jobs. Technologists and energy experts continuously seek ways to manage resources more efficiently and develop and discover new sources of energy. With progress in the energy field, roles that bridge various disciplines have emerged quickly and in large numbers. In addition to closing the 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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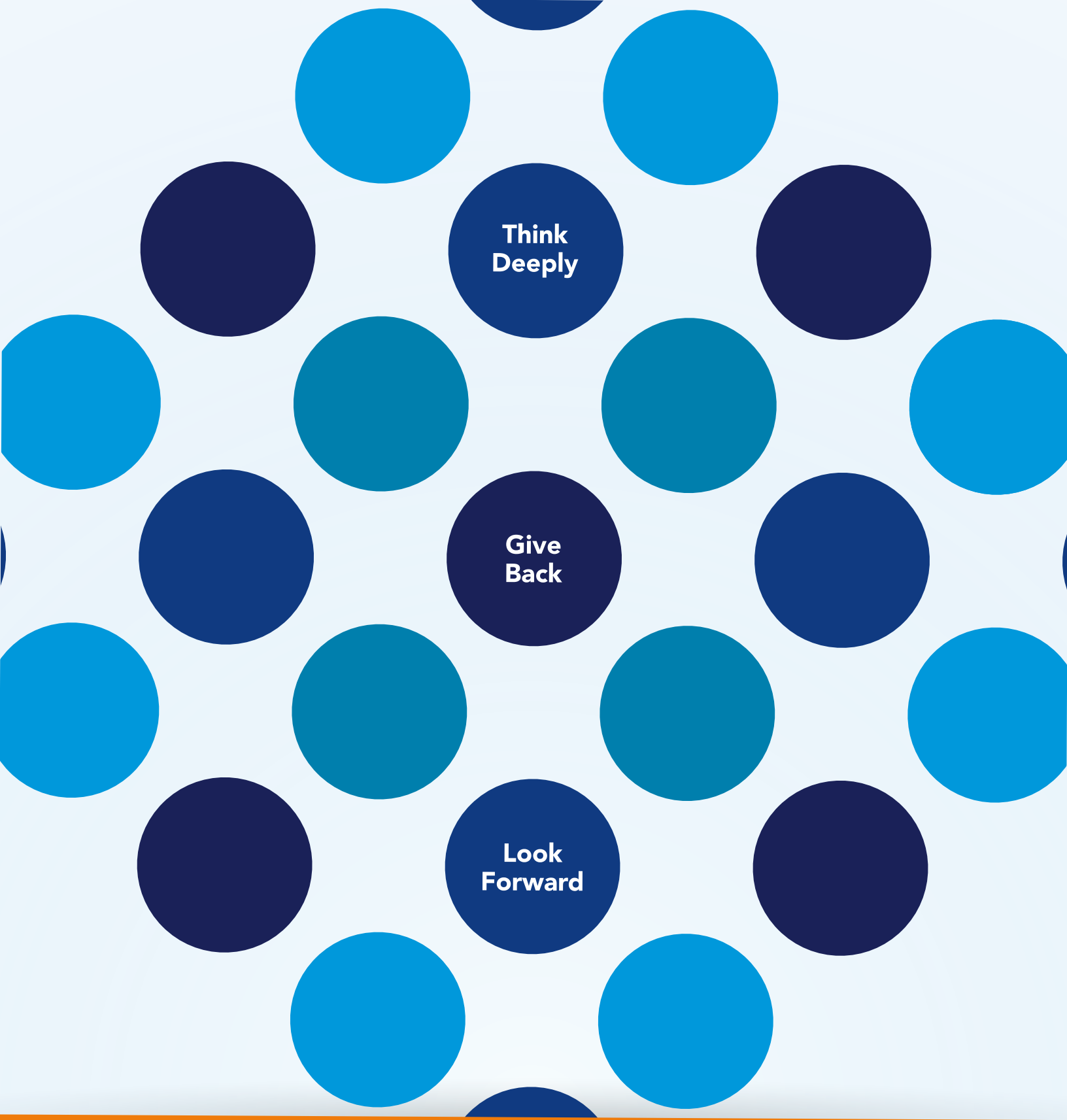

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