Ecomagination

# Digital Efficiency

## Driving Decarbonization and Unlocking Business Value Across Industries

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# EXECUTIVE SUMMARY

"Digital solutions, enabled by the Industrial Internet, can now increase output, use natural resources more efficiently, and lower environmental impact — we call this 'Digital Efficiency.'"

The emergence of digital technologies is ushering in a new era of productivity across business and industrial operations, while also offering a new tool to approach global environmental challenges. Digital solutions, enabled by the Industrial Internet, can now lower operation costs, increase output, use natural resources more efficiently, and lower environmental impact—we call this "Digital Efficiency." In today's competitive and volatile global landscape, Digital Efficiency is a critical differentiator, enabling businesses and industrial organizations to find opportunities for growth and competitiveness. At the same time, Digital Efficiency represents an important opportunity for helping to solve global resource challenges.

The potential impact of Digital Efficiency is significant. In a hypothetical scenario where just a handful of digital solutions are scaled across key industries, we estimate that they would return $81 billion in annual cost savings to businesses, while avoiding up to 823 million metric tonnes (Mt) of carbon dioxide emission per year. Intel's computing power and GE's Industrial Internet operating system, Predix™, are already providing a foundation for a range of digital solutions that improve energy and water efficiency across aviation, railways, ground transportation, manufacturing facilities, power plants and buildings. In 2012, GE estimated that a 1 percent efficiency improvement across industrial sectors could lead to an increase in global Gross Domestic Product (GDP) of $15 trillion (2005) dollars by 2030 (General Electric 2012). Two years later, GE highlighted the vast potential for the Industrial Internet—the integration of complex physical machinery with networked sensors and software – to enable industries to enhance the productivity of natural resources such as energy and water use in industrial operations (General Electric 2014). In most industrial segments, improving the efficiency of industrial machines by 1 percent requires a dedicated new technology introduction cycle that can take up to 5 to 10 years to develop. Since the launch of the Industrial Internet, we have seen that digital solutions are providing efficiency improvements, economic gains, and environmental benefits far beyond the 1 percent target without a lengthy technology introduction cycle or replacing hardware.

For example, Intel® Building Management Platform (Intel® BMP) uses Internet- of-Things

**Figure 1. Digital Efficiency**

The combination of industrial machines and Internet-enabled software can create positive economic and environmental outcomes.

## Industrial Hardware

## The Industrial Internet

## Digital Efficiency

**Industrial Hardware**

- Design improvements
- Advanced materials
- Integrated hardware approaches

**The Industrial Internet**

- Big Data analysis
- Machine learning techniques
- Predictive maintenance
- Asset and system optimization
- Predix™ — GE's new software platform for the Industrial Internet
- Powerful Intel® processors embedded in machines allow for software developed on Predix to run at the most effective point, either embedded in operations or in the cloud.

**Digital Efficiency**

- Industrial-scale resource savings
- Fuel consumption reductions
- Water conservation
- Reduced emissions

Source. GE

(IoT) technologies to drive down costs, which is transforming the market dynamics for software vendors, systems integrators, and solution providers. In one particular implementation, Intel's building management system reduced building power consumption by 8 percent (Intel IoT Smart Building Solution Brief 2015). Another example is GE's new Digital Power Plant, which optimizes power plant operations and can reduce fuel consumption by up to 4 percent.

GE and Intel are not alone in our recognition of the potential of Digital Efficiency. The global e-Sustainability Initiative (GESI) recently found that an Industrial Internet-enabled world of 2030 can be cleaner, smarter and more prosperous. They found that Information and Communications Technologies (ICT) can bring about a 20 percent reduction in global carbon dioxide emissions by 2030 through the application of Internet-enabled solutions in energy, health, buildings, agriculture, education and manufacturing. This would also reduce costs by $4.9 trillion by 2030, with $1.2 trillion in reduced electricity expenditures, and $1.1 trillion in reduced fuel expenses (Global e-Sustainability Initiative and Accenture Strategy 2015).

With 50 billion machines expected to come online by 2020, the market potential for solutions based on the Industrial Internet is tremendous (Evans 2011). The insight gained through industrial data, analytics and physics will allow businesses to find unique opportunities for growth such as new service offerings and business models. Businesses that want a competitive advantage must embrace the new growth and productivity opportunities of digital services or risk being disrupted by third parties who wield these digital tools to provide new services to industrial customers.

> "The time is now for businesses around the world to lead their own Digital Efficiency revolution to increase their competitiveness and manage the environmental impact of their operations."

Likewise, the ability of digital technologies enabled by the Industrial Internet to provide global environmental benefits will be dramatic and provide large market opportunities. This is particularly clear in the context of the historic agreement at the UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015. Our analysis indicates that by 2030, the global gap between individual country carbon dioxide targets and "business-as-usual" carbon dioxide emissions is expected to grow to 2.6 gigatonnes (Gt) CO2 per year by 2030. This means that digital solutions alone have the potential to close nearly one-third of the gap between expected carbon dioxide emissions and stated country commitments.

The Digital Efficiency journey has just begun. At GE and Intel, we have seen early solutions take hold to drive meaningful value to business and positively impact major global environmental challenges. The time is now for businesses around the world to lead their own Digital Efficiency revolution to increase their competitiveness and better manage the environmental impact of their operations. The future has just begun and the best is yet to come.

**Figure 2. Planes, Trains And Automobiles**

If just a handful of new digital solutions could be scaled across industrial systems and global transportation networks, businesses could hypothetically save $81 billion/year and global carbon dioxide emissions could potentially be reduced by up to 823 Mt/year.

| Industry | Cost Savings (Billion USD) | Potential Global Carbon Reduction (Mt/yr) |
|---|---|---|
| Power | $14 | 495 |
| Lighting | $30 | 132 |
| Aviation | $14 | 45 |
| Railway | $3 | 19 |
| Ground Transportation | $20 | 132 |

Close the global carbon gap by almost

**30%**

C02 emissions could be reduced by

**823Mt**

annually

equivalent to 174 million cars

Industry could save

**$81B**

Per year in fuel costs

### Digital Industrial at Work

Intel® processors paired with Predix, GE's platform for the Industrial Internet, provide the foundation for digital solutions that will improve efficiency and emissions across aviation, railways, ground transportation, manufacturing, power plants and buildings.

### Buildings Get Smart

Intel's Smart Building Management System uses Internet-of-Things technologies that are expected to reduce power consumption by 8 percent while reducing costs, adding new capabilities and changing the dynamics for building management software.

### Power Plants Go Online

GE's Digital Power Plant solutions improve operations and can reduce fuel consumption by up to 4 percent using integrated hardware, software and analytic solutions.

All data sourced from: Unlocking the Low-Carbon Economy with Digital Technologies, GE and Intel Working White Paper, January 2017

# INTRODUCTION

"Given our common commitments to technology innovation and environmental sustainability, GE Ecomagination and Intel joined forces to leverage the power of the Industrial Internet to help address the world's toughest natural resource challenges."

As a 125-year old technology company, General Electric (GE) has always believed in progress, investing, and taking risks to improve technology and build a brighter future for our customers and the world around us. From the invention of the first practical incandescent light bulb to building America's first central power station, the GE tradition of life-changing innovation is unparalleled.

Intel® invents at the boundaries of technology to make amazing experiences possible for business and society, and for every person on earth. By harnessing the capability of the cloud, the ubiquity of the Internet of Things, the latest advances in memory and programmable solutions, and the promise of always-on connectivity, Intel is disrupting industries and working to address global challenges.

GE and Intel share a common commitment to economic growth and environmental sustainability. A decade ago, GE decided that meant redefining what it means to be green, so in 2005 GE Ecomagination™ was launched. GE's Ecomagination is a business strategy to provide advanced technology solutions that improve resource efficiency and economics for our customers, and improve efficiency in our own operations. GE's vision is to make a global impact on environmental outcomes and economic growth. From Intel's perspective, the integration of technology presents an opportunity for improved resource management and environmental sustainability. Intel strives to continuously improve the environmental footprint of its operations and products through energy efficiency, emission reductions, and resource conservation, while creating technology solutions that help others do the same.

Given our common commitments to technology innovation and environmental sustainability, in 2015 GE Ecomagination and Intel joined forces to leverage the power of information and communications technologies (ICT) to help solve the world's toughest natural resource challenges. A fundamental part of this partnership is to understand and accelerate the role of ICT in natural resource management. This is an important emerging area of research that contains two components: (1) making ICT itself more sustainable through improvements in the efficiency and productivity of ICT operations; and (2) using ICT to enable more effective management of resource production and consumption patterns at the global level to produce positive economic and environmental outcomes. This second component is what we call "Digital Efficiency" and is the primary subject of this paper.

### SUSTAINABLE INFORMATION AND COMMUNICATIONS TECHNOLOGIES

Significant progress has been made to make ICT itself more sustainable. One example involves improving the efficiency of data centers. On aggregate, these efforts have been extremely successful and have helped to keep server power demand constant over the last decade. Improvements in storage, network and infrastructure have also helped improve efficiency and will play an important role in stabilizing the electricity demand requirements of data centers (Shehabi 2016).

Intel has been a pioneer in this area. In response to increasing industry-wide pressure to reduce data center operating costs and increase energy efficiency, Intel has been looking at ways to improve efficiency and capacity without increasing the cost of operation. For example, Intel converted a 5,000 square foot wafer fabrication facility into a high-density data center with a rack power density up to 43 kilowatt hours (kWh) per rack using Intel architecture-based servers. The new data center has a total capacity of 3 legacy data centers. The data center also utilizes free air cooling that allows Intel to run its data center temperature up to 95°F, a Power Usage Effectiveness of 1.06 and with a server cooling density of 1,100 watts per square foot, which is 10 times the industry average in cooling density and efficiency (Musilli 2014) .

In another case, Intel used design best practices to convert two vacant silicon wafer fabrication building modules into extremely energy efficient, high density, 5+ megawatt data centers, each with its own unique design and cooling properties (Krishnapura 2015). The stabilization of energy demand from the ICT sector allows for ICT solutions to enable Digital Efficiency, without increasing the energy demand of the ICT sector itself.

**GE Ecomagination**

Ecomagination (www.ge.com/about-us/ecomagination) is a business strategy to provide advanced technology solutions that improve resource efficiency and economics for our customers, and improve efficiency in our own operations. GE's vision is to make a global impact on environmental outcomes and economic growth. Established in 2005, GE's Ecomagination program has been at the forefront of resource productivity solutions for more than a decade. Since its founding, the GE technologies and solutions in the Ecomagination portfolio have generated $232 billion in revenue. GE has maintained its commitment to efficient resource solutions by investing $17 billion in research and development over this period.

**Intel**

Intel has a long history of commitment to the environment, a philosophy that began with its founder, Gordon Moore. We are moving toward a world where everything is smart and connected. Integration of technology presents an opportunity for improved resource management and environmental sustainability. We believe that innovation is key to a sustainable future for our planet. Intel (http://www.intel.com/content/www/us/en/environment/intel-and-the-environment.html) strives to continuously improve the environmental footprint of our operations and products through energy efficiency, reduced emissions, and resource conservation, while creating technology solutions that help others do the same. Intel continues to explore opportunities to design and deliver new technologies to address environmental challenges, including developing more energy-efficient products, and applying information technologies to help measure, model, and manage energy and natural resources more efficiently.

### WHAT IS DIGITAL EFFICIENCY?

In addition to these efforts, ICT technologies also have the potential to positively impact the planet and address some of the world's most pressing economic and environmental challenges by enabling more effective management of global production and consumptions patterns. For example, ICT can be used to optimize routes in global ground, sea and air transportation networks to save fuel. ICT technologies can be used in buildings to manage and minimize resource use. ICT can be used to optimize industrial operations across the globe to maximize production, minimize operating costs, and conserve natural resources in the process.

This is the power of ICT to improve economic and environmental outcomes for industries and businesses across the globe—and it is why we are so excited about the potential of Digital Efficiency at GE and Intel. Indeed, we see the emergence of the Industrial Internet as a transformative event that opens the door to positive economic and environmental natural resource management. Recent analysis validates our excitement about the importance of Digital Efficiency. The Global e-Sustainability and Accenture Strategy found that the potential environmental emissions avoided through Digital Efficiency are nearly 10 times greater than the emissions savings generated by making ICT itself more sustainable (i.e., through data center efficiency) (Global e-Sustainability Initiative and Accenture Strategy 2015).

"We see the emergence of the Industrial Internet as a transformative event that opens the door to positive economic and environmental natural resource management across global businesses."

Digital Efficiency itself is enabled by the emergence of the Internet of Things (IoT), which has the potential to transform the way we interact with our world. IoT is the networking of physical devices, vehicles, buildings and other items embedded with electronics, software, sensors, and actuators that enable these objects to collect and transmit data. IoT-enabled technologies such as self-driving cars and personal fitness bands have recently captured the public's imagination.

At GE and Intel, we see IoT breaking down into three distinct categories: (1) consumer internet; (2) enterprise IT; and (3) Industrial Internet. GE estimates that the Industrial Internet presents a $225 billion market opportunity, as compared to a consumer market of $170 billion. We think today's innovations triggered by the Industrial Internet will ultimately be more impactful than those by the arrival of the personal computer.

**Figure 3. Industrial Internet Timeline**

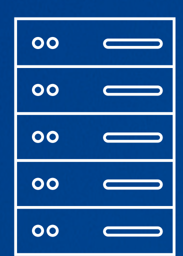
Industrial software systems have evolved over the last 50 years from monolithic systems that provided machine-level control, to today's Industrial Internet, which facilitates resource optimization for global industrial networks.

1950s–1960s

## Monolithic

Enabled Machine-Level Resource Optimization

The first generation of industrial control software used large mini-computers connected to industrial machines with no connectivity to other systems. They had limited security.



1950 1960

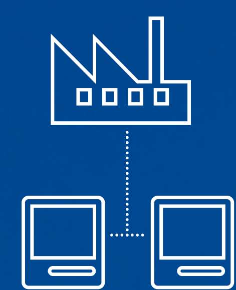
- **1959** Texaco's Port Arthur refinery becomes the first chemical plant to use digital control.
- **1969** The first nodes of what will become the Advanced Research Projects Agency Network (ARPANET) are established. ARPANET was the precursor to today's Internet.

1970s–1980s

## Distributed

Enabled Facility-Level Resource Optimization

The second generation of industrial control software was distributed across multiple independent workstations connected through proprietary communications protocols. They had limited security.



1970 1980

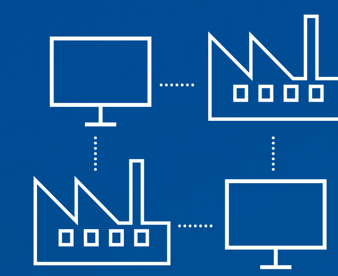
- **1982** The Internet protocol (TCP/IP) is established. This standard enabled seamless communication between interconnected networks.
- **1985** The number of hosts on the Internet (all TCP/IP interconnected networks) reaches 2,000.

1990s–2000s

## Networked

Enabled Enterprise-Level Resource Optimization

The third generation of industrial control software were distributed and networked, and computers could be interconnected through a secure local area network (LAN). The systems spread across multiple LANs and across geographies.



1990 2000

- **1990** The Internet grows to over 300,000 hosts.
- **1991** After the ARPANET project was concluded, all commercial restrictions on the use of the Internet are removed.
- **1994** The concept of the Internet of Things (IoT) is first developed. The basic idea was to affix sensors to common objects in order to connect these items to the Internet.
- **1999** The Massachusetts Institute of Technology (MIT) establishes the Auto-ID Center to conduct research focused on IoT. During the same year, the world's first machine-to-machine protocol, MQ Telemetry Transport (MQTT), is developed.
- **2008** The first international IoT conference takes place in Zurich.

2010s–Today

## Industrial Internet

Enables Global Network Resource Optimization

Over the last decade, cloud computing, network bandwidth increases, hardware improvements, and software advances have enabled the emergence of the Industrial Internet.

2010 2020

- **2010** The number of Internet hosts exceeds 800 million.
- Improvements in information technologies enable the IoT to be applied to industrial machinery.
- **2012** GE announces its commitment to a $1 billion investment in software and analytics and launches the Software and Analytical Center of Excellence in California.
- **2013** GE develops Predix, the first software platform for the Industrial Internet.
- **2014** GE's portfolio grows to 31 Industrial Internet applications within its Predictivity suite of solutions using the Predix platform. The Industrial Internet Consortium is established to further the development, adoption, and widespread use of the Industrial Internet.
- **2015** GE releases Predix, the operating system of the Industrial Internet. Predix is a cloud-based platform designed for building and powering industrial-strength applications.
- **2015** GE and Intel joined forces in order to leverage the power of ICT to help solve the world's toughest global natural resource challenges.
- **2016** Intel® scales its architecture for IoT through a wide range of product offerings. Intel® Quark™, Intel Atom™, Intel Core™, and Intel Xeon® processors each support a wide range of performance points with a common set of code, analytics, encryption, and new application requirements in IoT.
- Intel announces the availability the Intel® Building Management Platform to help small- and medium-size buildings become smart and connected. GE announced new products, acquisitions and partner programs to enable further adoption of Predix, the operating system for the Industrial Internet.

Source: GE research, the Computer History Museum (www.computerhistory.org).

## INTRODUCING THE INDUSTRIAL INTERNET

GE developed the term "Industrial Internet" to refer to IoT focused on industrial applications. The history of digital technologies in industrial applications can be traced back to 1959 when Texaco's Port Arthur refinery became the first chemical plant to use a digital control system. Industrial applications in factories, worksites, aviation, shipping and locomotive represent the greatest economic opportunity for IoT.

The industrial sector accounts for the largest share of energy consumption delivered to end-users. The world's industrial sector accounts for more than half of total delivered energy (Energy Information Administration (EIA) 2016). This is why the Industrial Internet is transformative and opens the door to accelerated resource productivity and reduced environmental impact across global industrial systems such as power generation, oil and gas, aviation and rail transportation.

GE and Intel are not alone in our acknowledgment of the potential for Digital Efficiency. In fact, recognition of the potential role of ICT in addressing environmental sustainability is growing. The global e-Sustainability Initiative (GESI) is an organization that has partnered with major ICT companies to become a source of information, resources and best practices for achieving integrated social and environmental sustainability through ICT. GESI's #SMARTer2030 report finds that an ICT-enabled world of 2030 can be cleaner, healthier and more prosperous, with greater opportunities for individuals everywhere. In particular, the report concludes that ICT can bring about a 20 percent reduction in global carbon dioxide emissions by 2030 through application of Internet-enabled solutions in energy, health, buildings, agriculture, education and manufacturing. ICT would also cut costs by $4.9 trillion by 2030, with $1.2 trillion in reduced electricity expenditures and $1.1 trillion in reduced fuel expenses (Global e-Sustainability Initiative and Accenture Strategy 2015).

The economic and environmental opportunity is enormous and the journey has just begun. At GE and Intel, we have seen early solutions take hold to drive meaningful value to business and improved resource management. The time is now for businesses of all sizes around the world to lead their own digital natural resource productivity revolution, increase their competitiveness, and better manage the environmental impact of their operations.

**Information and Communications Technologies**
ICT is an extended term for information technology (IT). ICT highlights the importance of communications and the integration of telephone and wireless technologies with information technologies.

**Internet of Things**
The Internet of Things (IoT) is the networking of physical devices, vehicles, buildings and other items embedded with electronics, software, sensors, and actuators that enable these objects to collect and send and receive data.

**The Industrial Internet**
GE coined the term Industrial Internet to refer to IoT in industrial applications. The focus on industrial applications is important from a sustainability perspective because the industrial sector accounts for over half of global energy consumption.

**Digital Efficiency**
The use of Industrial Internet applications on industrial machines to reduce natural resource consumption while increasing economic or business output.

# GLOBAL ECONOMIC AND ENVIRONMENTAL CHALLENGES

"One of the most pressing global economic challenges today is the global productivity slowdown. Global industrial digitization with a focus on the efficient use of input resources represents one promising solution to increase the global rate of total factor productivity."

Two years ago, GE documented the range and severity of global resource challenges (General Electric Ecomagination 2014). Much has happened since to increase the importance of Digital Efficiency as a potential solution to global economic and environmental challenges.

A major economic challenge today is the global productivity slowdown. Total Factor Productivity (TFP) is an economic variable that measures the growth in output after accounting for changes in capital and labor inputs. TFP is essentially a measure of the economy's long-term technological change or technological dynamism. Recent data suggests that the global TFP rate has fallen to zero. This is down from 1 percent in 1996-2006 and 0.5 percent in the crisis years of 2007-2012 (The Conference Board 2016).

One of the most promising opportunities for increasing global productivity is the application of digital technologies. Global industrial digitization, with a focus on the efficient use of input resources, represents a promising solution to increase the global rate of total factor productivity. In 2012, GE estimated that a 1 percent efficiency improvement across industrial sectors could lead to an increase in global Gross Domestic Product (GDP) of $15 trillion (2005) dollars by 2030 (General Electric 2012). Two years later, GE highlighted the vast potential for the Industrial Internet–the integration of complex physical machinery with networked sensors and software – to enable industries to enhance the productivity of natural resources such as energy and water use in industrial operations (General Electric 2014).

Furthermore, in most industrial segments, improving the efficiency of industrial machines by 1 percent requires a dedicated new technology introduction cycle that can take up to 5 to 10 years. Since the launch of the Industrial Internet, we have seen that digital solutions are providing efficiency improvements, economic gains, and environmental benefits far beyond the 1 percent target, without a lengthy technology introduction cycle or replacing hardware.

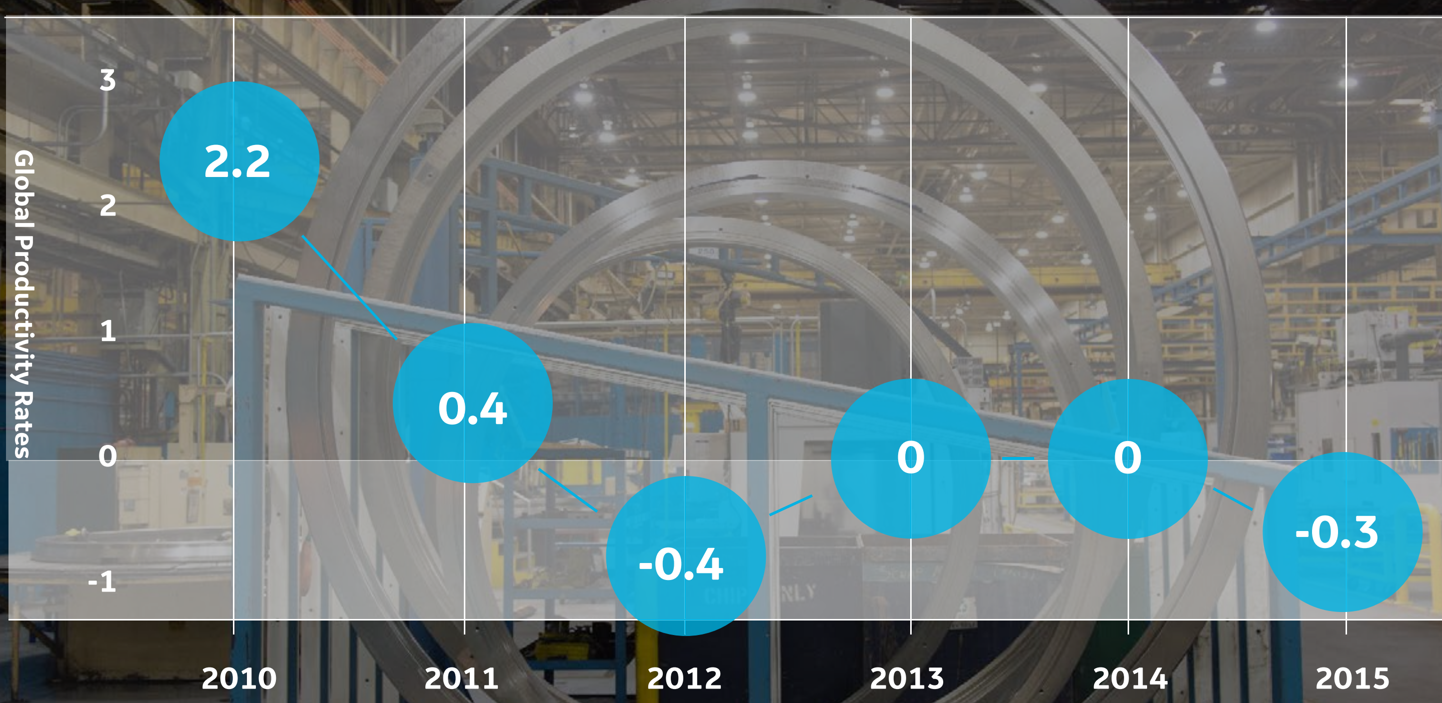
The intensification of challenges over the past two years is not limited to the global economy—global environmental challenges have increased as well. For example, water scarcity has intensified over the past two years and the risks are even greater than previously thought. About 66 percent of the world's population, which is 4 billion people, live without sufficient access to fresh water for at least one month of the year. Previous estimates indicated that between 1.7 and 3.1 billion people lived with moderate to severe water scarcity for at least a month out of the year. Water scarcity can result in economic losses due to crop failure, limited food availability and poor business viability, and can threaten environmental biodiversity. Water shortages have also precipitated or heightened the potential for global conflicts in places like the Middle East and Africa (Mekonnen 2016).

From a business perspective, increasingly global water scarcity represents significant risk. First, water shortages have a negative impact on the ability of businesses to conduct operations and produce products and services that depend upon water as a key input to production. Steam power plants require water for cooling, and shortages can curtail or even halt operations. Second, short and long-term water droughts adversely impact local communities and labor forces, which in turn impact local businesses.

Since 2014, the rising tide of climate change has continued unabated. According to the United States National Aeronautics and Space Agency (NASA), two key climate change indicators—global surface temperatures and Arctic sea ice extant—have broken numerous records throughout 2016. Each of the first six months of 2016 set a record as the warmest respective month globally in the modern temperature record, which dates to 1880. The extent of Arctic sea ice at the peak of the summer melt season now typically covers 40 percent less area than it did in the late 1970s and early 1980s. Arctic sea ice extant in September, the seasonal low point in the annual cycle, has been declining at a rate of 13.4 percent per decade (Lynch 2016).

**Figure 4. Global Productivity 2010-2015**

The global rate of total factor productivity has fallen to zero. Digitization and a focus on economic outcomes, facilitated by analytics, is one potential solution to increase the global rate of total factor productivity.




Source: The Conference Board 2016

**Figure 5. The Rising Tide of Climate Change**

Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting many different types of information about our planet and its climate on a global scale. This body of data, collected over many years, reveals evidence of a changing climate.

**Sea Level Rise**
Global sea level rose about 17 centimeters (6.7 inches) in the last century. The rate in the last decade, however, is nearly double that of the last century.

**Shrinking Ice S heets**
The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost 150 to 250 cubic kilometers (36 to 60 cubic miles) of ice per year between 2002 and 2006, while Antarctica lost about 152 cubic kilometers (36 cubic miles) of ice between 2002 and 2005.

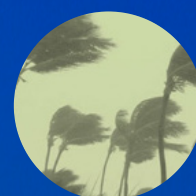
**Declining Artic Sea Ice**
Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades.

**Global Temperature Rise**
All three major global surface temperature reconstructions show that Earth has warmed since 1880. Most of this warming has occurred since the 1970s, with the 20 warmest years having occurred since 1981 and with all 10 of the warmest years occurring in the past 12 years. Even though the 2000s witnessed a solar output decline resulting in an unusually deep solar minimum in 2007-2009, surface temperatures continue to increase.

**Glacial Retreat**
Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska and Africa.

**Decreased Snow Cover**
Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and that the snow is melting earlier.

**Warming Oceans**
The oceans have absorbed much of this increased heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of 0.302 degrees Fahrenheit since 1969.



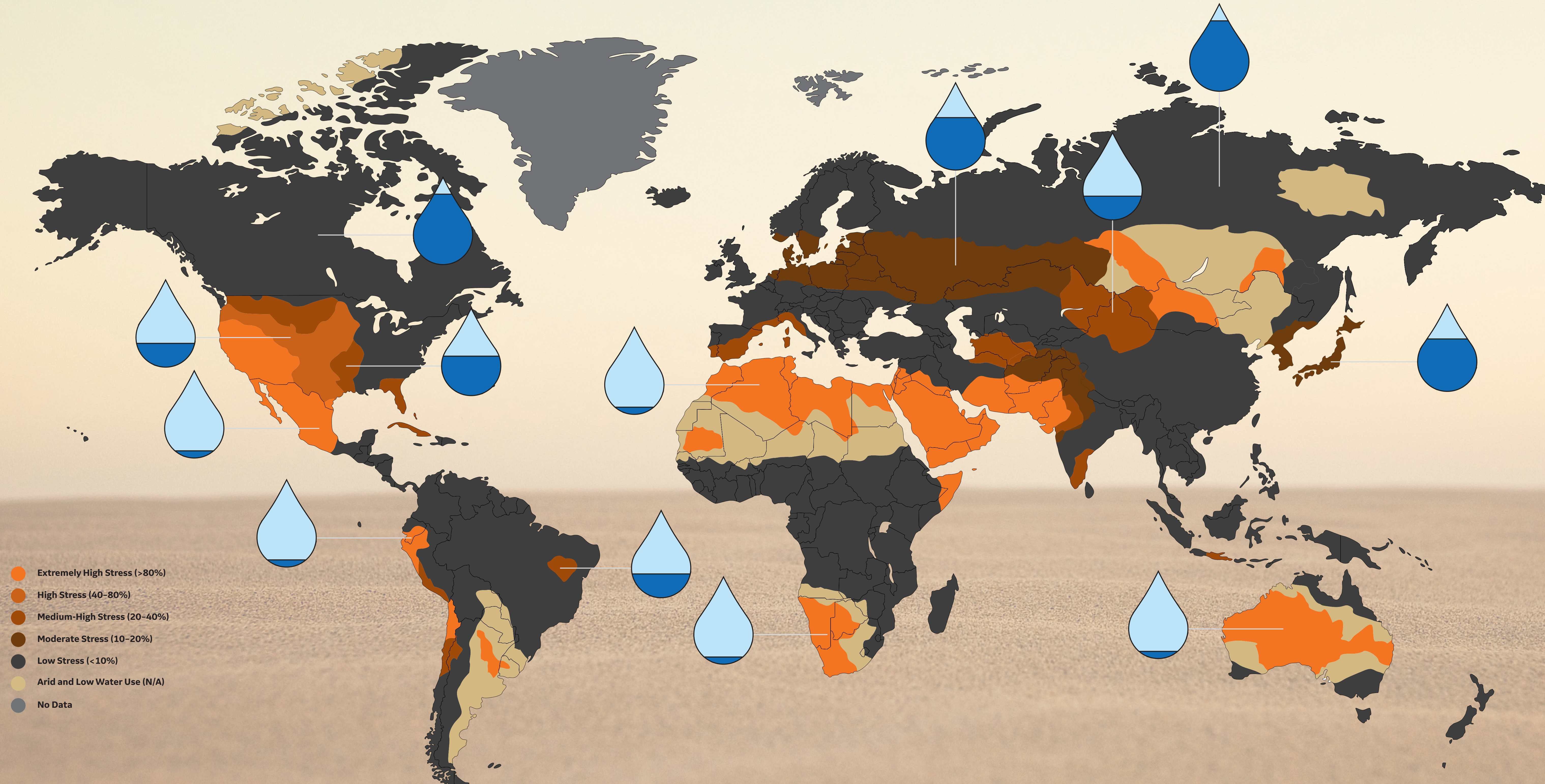
**Extreme Events**
The number of record high temperature events in the United States has been increasing, while the number of record low temperature events has been decreasing, since 1950. The U.S. has also witnessed increasing numbers of intense rainfall events.

**Ocean Acidification**
Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30 percent. This increase is the result of humans emitting more carbon dioxide into the atmosphere and hence more being absorbed into the oceans. The amount of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.

Source: NASA 2016

**Figure 6: Global Water Scarcity**

1.2 billion people live in water scarcity as of 2013. Recent analysis suggests water scarcity is increasing.




Source: World Resources Institute (WRI) Aqueduct Project. Data provided by The Coca-Cola Company. Hydrologic modeling performed by ISciences, L.L.C.

# INDUSTRIAL INTERNET ON THE RISE

Global economic and environmental challenges have continued to intensify since 2014. Fortunately, the potential for digital solutions to help address these challenges has also grown. Rapid innovation in this arena has now unlocked opportunities to apply digital solutions to industrial operations to drive business value and address global resource issues in new and exciting ways.

One of the new innovations that is enabling Digital Efficiency is Predix — GE's new software platform for the Industrial Internet. Predix is purpose-built platform-as-a-service (PaaS) for developing, deploying, operating and monetizing Industrial Internet applications. Highly optimized for the unique and demanding requirements of industrial applications, Predix works with operating assets from any vendor or vintage. Predix captures and analyzes the unique volume, velocity, and variety of machine data generated across the industrial world within a secure, industrial-strength cloud environment.

Machine data and the connectivity platform are only one aspect of the Industrial Internet. Intel® processors underlie GE's Predix solutions and provide both high power and flexibility. Powerful processors embedded in machines allow for software developed on Predix to run at the most effective point, either embedded in operations or in the cloud. Applications built on the Predix platform, leveraging embedded sensors and compute power, complete the anatomy of Digital Resource Productivity. Applications built by GE, Predix users, or third-party system integrators transform data, connectivity, and compute power into actionable insight and optimized outcomes.

In this manner, the combination of GE software and Intel hardware will provide the foundation for Digital Efficiency by enabling the development of Industrial Internet applications that provide the full range of potential economic and environmental benefits.

### BRILLIANT FACTORIES: GE-INTEL SMART MANUFACTURING PILOT

A new combination of hardware and software is already being piloted at GE's Greenville, South Carolina gas turbine factory. Sensors powered by Intel are attached to GE light fixtures and send data to gateways, which aggregate the information and send it to the Predix cloud. The sensors measure the temperature of the air near the turbine collars as their rotors are attached, allowing factory workers to know when the part is cool enough to safely add the next rotor. This pilot is part of Intel's Smart Manufacturing initiative which is taking advantage of the Internet of Things (IoT) to converge historically disparate information technology with operational technology systems and optimize operations across the entire manufacturing value chain.

# DIGITAL EFFICIENCY IN ACTION

In 2014, GE highlighted several examples of Digital Efficiency in action, including:

- GE's PowerUp Platform™, which harnesses the Industrial Internet to drive higher wind farm output and create new revenue streams for wind farm operators running on an Intel® Core®-based gateway;
- GE's Flight Efficiency Services™, an Internet-enabled aviation navigation service that examines flight data to design more efficient flight patterns; and
- GE's RailConnect 360 Movement Planner™ enables more locomotives to run on the same railroad track at faster speeds and with greater efficiency.

In the past two years, the Industrial Internet has made marked advances resulting in both economic and environmental benefits, and demonstrating the potential of what is to come as these new solutions are developed and deployed, and scaled across industries.

### RENEWABLE ENERGY: GE'S BRILLIANT WIND FARM

For example, GE's PowerUp Platform has been extended to become the Digital Wind Farm. With this solution, GE extends analytics and optimization beyond a single wind turbine to the entire wind farm. GE harnessed the power of the emerging Industrial Internet to create the Digital Wind Farm, a dynamic, connected, and adaptable wind energy platform that pairs wind turbines in a wind farm with digital infrastructure to optimize efficiency across the entire wind farm. This platform can account for the wind farm's topology, surrounding geography, wake effects, and other inputs to control individual wind turbines and optimize the operation as a whole. Through these techniques, the Digital Wind Farm technology boosts a wind farm's energy production by up to 20 percent and could help generate up to an estimated $50 billion value for the wind industry. The Digital Wind Farm uses interconnected digital technology to address a long-standing need for greater flexibility in renewable power.

### GROUND TRANSPORTATION: INTEL'S COMMERCIAL VEHICLE FLEET MANAGEMENT SYSTEM

Another example is Intel's fleet management system for commercial vehicles. Intel has assembled and tested a fleet management system proof of concept that can be customized to easily fit into a wide variety of commercial vehicles including taxis, school buses, and logistic freight vehicles. The architecture features an in-vehicle system based on the Intel® Atom™ processor E3827 and supports data management, telematics, smart surveillance, and mobile applications. Rather than fleet operators maintaining data manually, this solution collects real-time telematics data from sensors located inside the vehicle and sends it over an Internet connection to the cloud, where it can be distributed to stakeholders or further processed by the data analytics software. The system gathers data associated with vehicles, terminals, stops, users, and driver schedules, allowing operations to run more efficiently and creating optimized routes. Additionally, this proof of concept gathers driving pattern data. The occurrences of aggressive acceleration, braking, and turning were reduced by 57 percent, 30 percent, and 17 percent, respectively. Due to the study, the drivers reduced their speed, which improved fuel economy. The Intel proof of concept provided data to help improve routes and driving behavior, as well as reduce fuel consumption and greenhouse gas emissions (Intel 2015).

### ELECTRICITY GENERATION: GE'S DIGITAL POWER PLANT

One of the most impactful instances of Digital Efficiency in action is occurring in the electricity sector, where GE's new Digital Power Plant platform, running on Intel® Xeon® based servers, is already at work. GE's Digital Power Plant and Digital Power Plant for Steam are software platforms built upon Predix that provide power plant operators with improved fuel efficiency, increased output, reduced unplanned downtime and lower operations and maintenance costs. These solutions work, in part, by creating a "Digital Twin" that mirrors the real-world power plant. The Digital Twin is a physics-based virtual model of the physical power plant that provides a basis for planning and predicting the performance and operations of the real-world asset. GE's Digital Twin concept is being applied in Industrial Internet applications in other sectors.

The Digital Power Plant is currently being used in the gas-fired Futtsu Power Station, which sprawls on the edge of Tokyo Bay in Japan. Futtsu is capable of generating over 5 gigawatts (GW) of power—enough to supply 5 million homes with electricity. Futtsu's operating company, Tokyo Electric Power Company (TEPCO), installed the Digital Power Plant to squeeze more efficiency out of the plant. By using the Digital Power Plant, TEPCO is able to perform predictive-based maintenance based on real-world evidence, not on a fixed schedule. This helps avoid unplanned downtime, inefficiency, and economic losses associated with stopping high-efficiency power plants.

The Digital Power Plant has the potential to increase power plant efficiency in the fleet of existing electricity generators around the world. GE estimates that the Predix-based software may improve power plant efficiency by an average of 1.5 percent. This may not seem like a significant improvement—but when scaled up at the plant level, this level of improvement can translate into millions of dollars in saved fuel costs.

When scaled globally, these efficiency improvements can point to significant reductions in carbon dioxide emissions. For example, in a hypothetical scenario, if the Digital Power Plant were installed on all compatible power plants and the efficiency of each power plant improved by 1.5 percent, then annual global carbon dioxide emissions from thermal power plants would fall from 12.2 to 11.7 Gt CO2/yr. That's a reduction of 495 Mt CO2/yr, or approximately 4 percent of annual global power plant carbon dioxide emissions. This is the potential power of the Industrial Internet and the impact of Digital Efficiency.

The Digital Power Plant can be extended beyond thermal plants. The Digital Hydro Plant is GE's fourth major Predix-based Digital Power Plant solution. The Digital Hydro Plant extends GE's digital solutions to the hydropower vertical with possible benefits including up to 10 percent reduced maintenance costs, 1 percent increase in plant availability and up to 3 percent increased revenue.

### BUILDINGS: INTEL® BUILDING MANAGEMENT PLATFORM (BMP)

Intel is using its technology to improve the performance of the world's building stock. Building automation solutions have been around for decades, but its high cost has been difficult to justify for many commercial, industrial and institutional facilities. Intel's use of new, more affordable, IoT technologies has driven down costs, added new capabilities and changed the dynamics for building management. Tatung, ECS and Intel developed an IoT-based solution using an intelligent gateway service that brings energy savings to businesses, minimizes water and power consumption and provides superior building services. The implementation of this solution at ECS facilities is expected to reduce power consumption by 8 percent in the first year and between 20 and 30 percent thereafter (Intel IoT Smart Building Solution Brief 2015).

Expanding on this experience, in October 2016, Intel announced the availability of an Intel Building Management Platform (Intel BMP) to help small- and medium-size buildings become smart and connected. Intel BMP has built-in security and manageability essentials to manage command data from a broad set of building systems and sensors, and to filter and transfer data to the cloud or on-premises servers. This helps make buildings smarter, more energy efficient and creates a more sustainable, enjoyable and productive use of the building by its occupants. This platform-as-a-service (PaaS) solution reduces development time and effort for solution providers by offering a pre-integrated platform on which they can deploy a wide range of affordable applications and services.

Intel's efforts in this area don't stop with the BMP. Intel is also working with Daintree Networks, which was acquired by Current, powered by GE™, in April 2016. The Daintree Wireless Area Controller features the latest Intel chip, which was designed for IoT. Intel is adding a smart lighting network to its headquarters in Santa Clara, California. This open networked wireless solution for lighting and building control, monitoring, and optimization, reduces energy and operating costs, improves the occupant experience, increases businesses productivity and scales to manage a portfolio of buildings. This also paves the way for Intel to add conference room management and other applications such as temperature sensing in the future. This is another example of how digital technologies can be applied in a business environment and provide tangible environmental benefits.

**Figure 7. GE's Digital Power Plant**

In a hypothetical scenario where GE's Digital Power Plant is installed on compatible power plants and it improves the efficiency of each power plant by 1.5 percent, then annual global carbon dioxide emissions from thermal power plants would fall from 12.2 to 11.7 Gt CO2/yr. That's a reduction of 495 Mt CO2/yr. or 4 percent of annual global power plant carbon dioxide emissions.


Source. GE

# DIGITAL DECARBONIZATION

These examples are powerful. But imagine a world where they are scaled across global business, industries and transportation networks. In a hypothetical scenario where a handful of these digital solutions are implemented across key industries, we estimate that they would return $81 billion in annual cost savings to businesses, while avoiding up to 823 Mt of carbon dioxide emissions per year. That's enough carbon emissions reduction potential to help close the gap between proposed carbon targets and expected emissions under a business-as-usual scenario.

The ability of digital technologies enabled by the Industrial Internet to provide global environmental benefits will be dramatic and provide large market opportunities. This is particularly clear in the context of the historic agreement at the UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015. Our analysis indicates that by 2030, the global gap between individual country carbon dioxide targets and "business-as-usual" carbon dioxide emissions is expected to grow to 2.6 Gt CO2/year by 2030. This means that digital solutions alone have the potential to close nearly one-third of the gap between expected carbon dioxide emissions and stated country commitments.

## Figure 8. Planes, Trains and Automobiles

If just a handful of new digital solutions could be scaled across industrial systems and global transportation networks, businesses could hypothetically save $81 billion/year and global carbon dioxide emissions could potentially be reduced by up to 823 Mt/year.

| Industry | Application | Example | Potential Resource Savings (%) | Potential Cost Savings (Billion $/yr.) | Potential Fuel Global Carbon Reduction (Mt/yr.) |
|---|---|---|---|---|---|
| **Power** | **Power plant fuel optimization** | **GE Digital Power Plant** | **4.00%** | **$13.8 of coal** | **495** |
| **Aviation** | **Airline flight network optimization** | **GE Flight Efficiency Services** | **8.00%** | **$14.0** | **45** |
| **Railway** | **Rail network trip optimization** | **GE RailConnect 360 Trip Optimizer** | **6.30%** | **$3.1** | **19** |
| **Cars & Trucks** | **Vehicle fleet optimization** | **Intel Vehicle Fleet Management System** | **8.00%** | **$20.4** | **132** |
| **Buildings** | **Building energy management system** | **Intel Smart Building Management System (SBMS)** | **8.00%** | **$30.0** | **132** |
| **Global Total** | | | | **$81.3** | **823** |

**Source: Estimated digital technology potential based on input assumptions from the International Energy Agency (IEA), the International Civil Aviation Organization (ICAO), the International Union of Railways (IUR), the International Institute for Applied Systems Analysis (IIASA), the U.S. Energy Information Administration (EIA) and the U.S. Environmental Protection Agency (EPA).**

# CONCLUSION

While these solutions represent meaningful potential, we must move faster and do more. Scaling these approaches beyond these specific solutions can open a tremendous opportunity to accelerate economic growth and decarbonize the energy system. However, this digital environmental movement will require an ecosystem of industrial operators, data scientists, developers, technology providers, large and small companies, and policy makers. The beauty of the Industrial Internet is that it is an inherently open platform that allows each member of the community to contribute and draw unique value. Through this architecture, the ecosystem can do far more, create more value, and move faster than any single solution provider, and ultimately drive greater global environmental impact.

To be sure, a new world of possibilities is being unlocked through the Industrial Internet. Digital solutions currently available and under development are just the tip of the iceberg. At GE and Intel, we are excited about the opportunity to play a role in helping to confront global resource challenges and accelerate the pathway to the low-carbon economy using digital technologies.

The future has just begun and the best is yet to come.

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