

The Internet of Things: Making sense of the next mega-trend

The third wave of the Internet may be the biggest one yet

28 billion reasons to care...

The Internet of Things (IoT) is emerging as the third wave in the development of the Internet. The 1990s' fixed Internet wave connected 1 billion users while the 2000s' mobile wave connected another 2 billion. The IoT has the potential to connect 10X as many (28 billion) "things" to the Internet by 2020, ranging from bracelets to cars.

...and the train is leaving the station

Breakthroughs in the cost of sensors, processing power and bandwidth to connect devices are enabling ubiquitous connections right now. Early simple products like fitness trackers and thermostats are already gaining traction.

Lots of room to participate

Personal lives, workplace productivity and consumption will all change. Plus there will be a string of new businesses, from those that will expand the Internet "pipes", to those that will analyze the reams of data, to those that will make new things we have not even thought of yet.

Benchmarking the future: early adopters

We see five key early verticals of adoption (Wearables, Cars, Homes, Cities, and Industrials) as test cases for what the IoT can achieve. Focus on: new products and sources of revenue and new ways to achieve cost efficiencies that can drive sustainable competitive advantages. Key to watch: privacy and security concerns - a likely source of friction on the path to adoption.

Focus: Enablers, Platforms, & Industrials

The IoT building blocks will come from those that can web-enable devices, provide common platforms on which they can communicate, and develop new applications to capture new users.

Enablers: we see increased share for Wi-Fi, sensors and low-cost microcontrollers.

Platforms: focus on software applications for managing communications between devices, middleware, storage, and data analytics.

Industrials: Home automation is at the forefront of the early product opportunity, while factory floor optimization may lead the efficiency side.

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The Internet of Things – What is it?

While the first two stages of the Internet’s development had profound implications for the technology industry, the implications of the Internet of Things will prove even more far-reaching as by its very nature it is a trend that we believe will reach beyond tech to touch every industry, from healthcare to retail to oil and gas exploration and homebuilding.

What is IoT? The Internet of Things connects devices such as everyday consumer objects and industrial equipment onto the network, enabling information gathering and management of these devices via software to increase efficiency, enable new services, or achieve other health, safety, or environmental benefits. The term was first proposed by Kevin Ashton, a British technologist, in 1999 when he was at MIT.

Just as the first two waves of the Internet era led to profound changes in the economy, the Internet of Things will create new winners and leave in its wake a host of losers based on companies’ abilities to adapt to a world where things are connected. With this report, we attempt to take an overly broad topic and to help understand the core verticals and technologies that will be among the first to be disrupted.

Making S-E-N-S-E of the technology

IoT will rearrange the tech landscape, again. IoT has key attributes that distinguish it from the “regular” Internet, as captured by our S-E-N-S-E framework: Sensing, Efficient, Networked, Specialized, Everywhere. These attributes may tilt the direction of technology development and adoption, with significant implications for Tech companies – much like the transition from the fixed to the mobile Internet shifted the center of gravity from Intel to Qualcomm or from Dell to Apple.

Exhibit 1: Making S-E-N-S-E of the Internet of Things

Key attributes of the IoT and how it differs from the “regular” Internet

S-E-N-S-E	What the Internet of Things does	How it differs from the Internet
S ensing	Leverages sensors attached to things (e.g. temperature, pressure, acceleration)	More data is generated by things with sensors than by people
E fficient	Adds intelligence to manual processes (e.g. reduce power usage on hot days)	Extends the Internet’s productivity gains to things, not just people
N etworked	Connects objects to the network (e.g. thermostats, cars, watches)	Some of the intelligence shifts from the cloud to the network’s edge (“fog” computing)
S pecialized	Customizes technology and process to specific verticals (e.g. healthcare, retail, oil)	Unlike the broad horizontal reach of PCs and smartphones, the IoT is very fragmented
E verywhere	Deployed pervasively (e.g. on the human body, in cars, homes, cities, factories)	Ubiquitous presence, resulting in an order of magnitude more devices and even greater security concerns

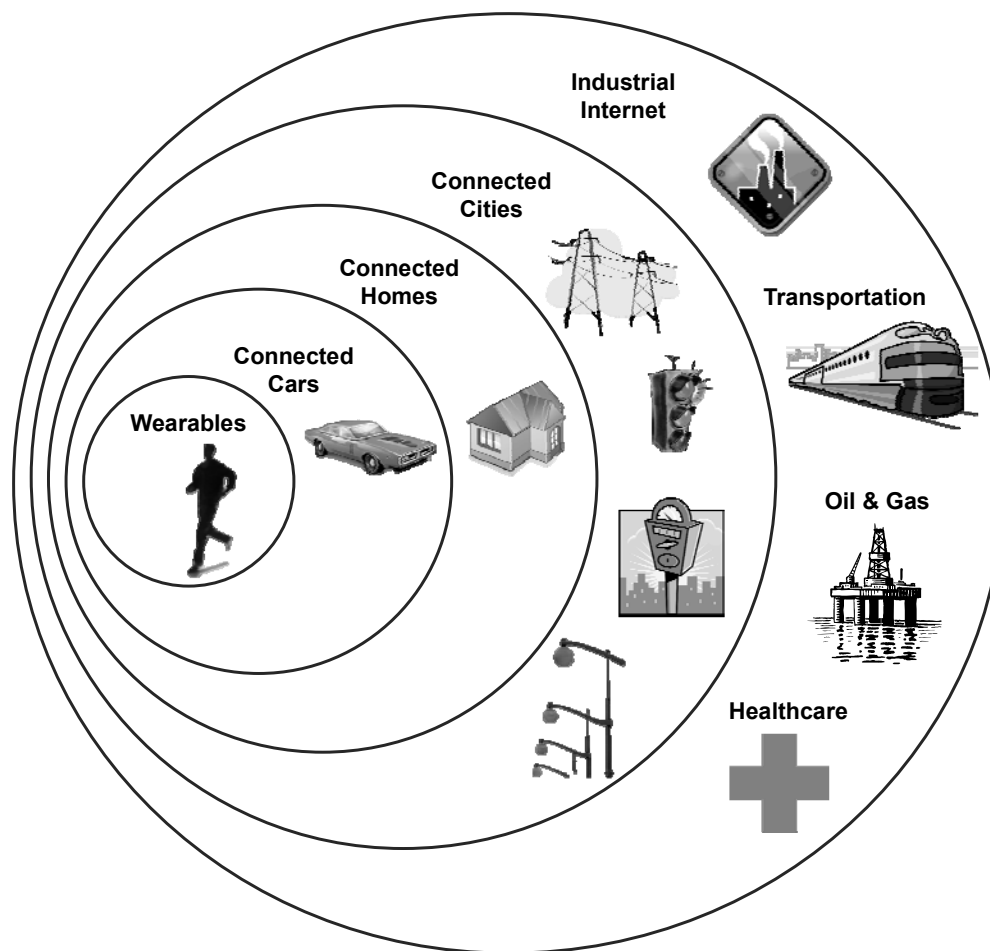
Source: Goldman Sachs Global Investment Research.

Hope and challenge:
The IoT connects stuff, not just people, leading to greater fragmentation of software and hardware amidst an explosion of data

Key verticals of adoption

By definition, the Internet of Things has enormous breadth that can be difficult to get one's arms around. In our view, it can be broken up into five key verticals of adoption: **Connected Wearable Devices**, **Connected Cars**, **Connected Homes**, **Connected Cities**, and the **Industrial Internet**.

Exhibit 2: The IoT landscape



Source: Goldman Sachs Global Investment Research.

What is driving the momentum we are seeing today?

Why now? Enablers of the IoT

A number of significant technology changes have come together to enable the rise of the IoT. These include the following.

Key obstacles are gone: the cost of connectivity has declined at the same time that new ways to analyze mountains of data have developed

- **Cheap sensors** – Sensor prices have dropped to an average 60 cents from \$1.30 in the past 10 years.
- **Cheap bandwidth** – The cost of bandwidth has also declined precipitously, by a factor of nearly 40X over the past 10 years.
- **Cheap processing** – Similarly, processing costs have declined by nearly 60X over the past 10 years, enabling more devices to be not just connected, but smart enough to know what to do with all the new data they are generating or receiving.
- **Smartphones** – Smartphones are now becoming the personal gateway to the IoT, serving as a remote control or hub for the connected home, connected car, or the health and fitness devices consumers are increasingly starting to wear.
- **Ubiquitous wireless coverage** – With Wi-Fi coverage now ubiquitous, wireless connectivity is available for free or at a very low cost, given Wi-Fi utilizes unlicensed spectrum and thus does not require monthly access fees to a carrier.
- **Big data** – As the IoT will by definition generate voluminous amounts of unstructured data, the availability of big data analytics is a key enabler.
- **IPv6** – Most networking equipment now supports IPv6, the newest version of the Internet Protocol (IP) standard that is intended to replace IPv4. IPv4 supports 32-bit addresses, which translates to about 4.3 billion addresses – a number that has become largely exhausted by all the connected devices globally. In contrast, IPv6 can support 128-bit addresses, translating to approximately 3.4×10^{38} addresses – an almost limitless number that can amply handle all conceivable IoT devices.

The IoT value proposition – a driver of new product cycles and another leg of cost efficiencies

- **Revenue generation** – Companies are focused on the IoT as a driver of incremental revenue streams based on new products and services. For example, since the beginning of the year AT&T has introduced a Connected Car service in partnership with a number of automobile manufacturers, including Audi, GM, Tesla and Volvo, which offer high-speed 3G or 4G connections for a monthly subscription fee of \$10. By the end of 2014, 30 of GM's 2015 vehicle models will have LTE support, enabling vehicles to act as a Wi-Fi hotspot with connectivity for up to 7 devices, as well as access to OnStar for remote vehicle access, diagnostics and emergency service.
- **Productivity and cost savings** – Businesses are also embracing the IoT to improve productivity and save costs, such as capex, labor, and energy. For example, Verizon is saving more than 55 million kWh annually across 24 data centers by deploying hundreds of sensors and control points throughout the data center, connected wirelessly. The result is a reduction of 66 million pounds of greenhouse gases per year.

Case study: Verizon saves 55 million kWh of electricity through IoT application

Focus on: Pipes, Apps, and Things

Standards in motion:
Companies are already gathering in competing alliances to set IoT standards such as the Industrial Internet Consortium (IIC) founded by AT&T, Cisco, GE, Intel and IBM

Security in focus:
A study by HP found 70% of the most commonly used IoT devices contain security vulnerabilities.

The pipes: building the infrastructure to connect the world's devices

Before there could be 300 million cars in the USA, there was a program to build the interstate highway system. Without highways, traffic jams would be too big, and folks would still be travelling by train. The same holds true for the IoT today. And its interstate highway system is less likely to fall out of an ambitious government-sponsored plan than it is from a network of private enterprises already well underway. Expanding the telecom, cable, and satellite pipelines that carry traffic through broader Wi-Fi networks is a critical part. But also providing devices with the sensor, memory chips and software necessary to communicate with the pipes is key.

The apps: developing the software platforms that will unlock the torrent of data

Riding on this super-charged network of "pipes" will be a wave of data that can be used:

- to make lives easier (think: turn on your heat before you get home),
- drive efficiency (think: turn on your washing machine when electricity usage and prices fall in the middle of the night), and
- help us anticipate things without a trip to a specialist (think: full-body health monitors or car engine diagnostics).

But before this can be accomplished, we need to establish common software standards, build reliable platforms (think iOS or Android) that others can build from, and develop sophisticated software that can analyze more data than has ever been analyzed (think Big Data) to fully realize the potential of the IoT.

The things: identifying where connectivity legitimately adds value and is not merely intrusive

One of the biggest stumbling blocks to IoT development is likely to be concerns about privacy and security. ("OK, I now come home to a warm house, but did I just compromise my credit card and provide people with knowledge of my whereabouts to achieve that?") Finding the "things" that will genuinely make our lives better, save us money, conserve natural resources, or drive better efficiencies will be critical to the IoT realizing its full potential. Expect fits and starts just as we saw in the fixed-line Internet (remember walled gardens?) and the mobile Internet waves (think: games). But we identify key areas right now where "things" are becoming connected:

- Building and home automation addressing HVAC, security, lighting, entertainment, appliances, and assisted living
- Manufacturing applications that monitor machinery, connect factories and optimize supply chains
- Resources such as smart electricity grids and electric vehicle infrastructure.

Enablers: framing the IoT opportunity

The Communications Technology and Semiconductors industries are at the center of enabling IoT devices. CommTech companies will connect the smartphones, tablets, cellular networks, and Wi-Fi networks that are central to allowing so many devices to communicate with each other. Semiconductor companies will supply an array of sensors and chips that allow devices to collect data, understand images and motion, process the information and communicate seamlessly.

CommTech Impact: from Wi-Fi to the “Fog”

CommTech touches so many things across the Internet but we expect to see the most profound impact from the sector on the IoT across three areas: Wi-Fi, cellular, and “Fog” computing.

- **Wi-Fi.** The IoT will require primarily wireless communications. As a result, we expect Wi-Fi to be the key communications standard for IoT, much like DSL/Ethernet was for the fixed Internet and 3G/4G for the mobile Internet.
- **Cellular.** In an IoT world, no device will be left off the network. Cellular connections will be needed for hard to reach or mobile objects (e.g., cars or even health wristbands).
- **The “Fog”:** Much has been written about “cloud” computing where data is stored outside of your local device, often on servers in large data centers sometimes thousands of miles from where the data was generated. But in the age of the IoT, we expect more of the network intelligence to reside closer to the source: what technologists call the network edge or the “fog”. Look for the rise of fog computing architectures, as most data will be too noisy or latency-sensitive (think: it needs to get there and back super-fast) or expensive to be carried all the way back to the cloud.

Semis Impact: the age of sensors and more

Semiconductors are found in the most mundane devices nowadays from children’s toys to bottle openers. In the age of the IoT, look for an even greater proliferation as devices rely on an increasing number of chips working in tandem to collect, process and communicate data. We see the biggest growth in sensors and low-cost microcontrollers.

**Chips proliferate:
A single device can contain multiple sensors along with chips for processing, connectivity and power management.**

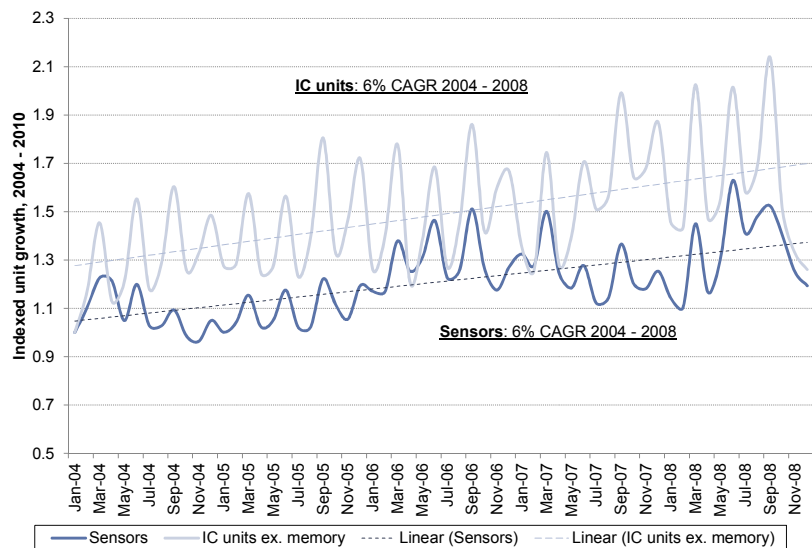
- **Sensors.** Sensors have outgrown other semiconductor units by five percentage points over the last two years, and we expect that trend to continue as they proliferate. IoT devices lean heavily on image, motion, touch and environment sensors, along with so-called sensor hubs to manage the sensor traffic and reduce the workload on the central processor to save battery life.
- **Connectivity.** Just as with CommTech, connectivity will drive the use of semiconductors to manage the communications, driven by Wi-Fi, Bluetooth, ZigBee, NFC, and other IoT standards.
- **Cheap brains:** More devices will use microcontrollers or low-cost microprocessors given their lower price points and power requirements relative to traditional semiconductor architecture.

Enablers: framing the IoT opportunity (cont.)

Two of the key enablers of the IoT are a drop in the cost of sensors and the proliferation of cheap processing. Sales of both sensors and microcontrollers – low cost chips that act as the brains of the devices – are growing faster than the overall semiconductor market.

Exhibit 3: Sensor growth outstripped the overall semiconductor market from 2011-2013 (5% CAGR vs. semis at 0%)

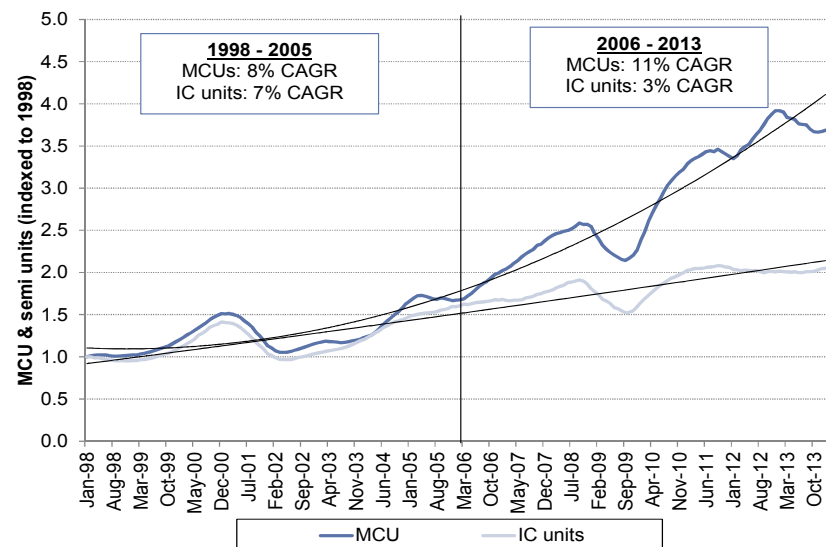
Indexed IC units and sensor units to January 2011



Source: SIA, Goldman Sachs Global Investment Research.

Exhibit 4: Microcontroller growth has significantly outpaced the semiconductor market

Market size and unit CAGR



Source: SIA, Goldman Sachs Global Investment Research.

Platforms: the role of software across the IoT

**Software is a big slice
IDC estimates that
1/5th of the money
spent on IoT will go
towards software**

With every connected device (remember, market research firm IDC forecasts 28 billion of them by 2020) there will be software to enable it to communicate with other devices and central databases gathering data to make our lives more efficient. But the software for the IoT will be different from the software on our desktops, tablets, or even our smartphones. The first wave of the Internet (fixed line) brought with it common software applications like Microsoft Windows and Google. The second wave of the Internet transitioned to mobile software where Apple's iOS and Google's Android systems provided standards that enabled large number of devices to easily communicate. The third wave – the IoT – will also require the development of standards to allow heterogeneous IoT devices to communicate and leverage common software applications. On the enterprise side, setting of standards will be a drawn-out process over the next decade, particularly with competing consortiums. On the consumer side, the IoT has already begun to see de facto standards emerge as defined by mobile titans attempting to link and leverage their large installed bases.

Enterprise software: from data flow to analytics

Much like some of the task-specific devices they will help enable, we believe the most successful enterprise IoT software vendors initially will target small sub-sectors or specific verticals where they can dominate rather than attempt to offer a one-stop shop solution. Alternatively they might seek to master a particular stage of the machine-to-machine (M2M) data flow process, such as:

- **managing** the communication with connected devices/sensors;
- providing **middleware** for integration to data repositories;
- **storing** and **securing** the data; and
- **analyzing** and **visualizing** the data.

Consumer software: a platform-centric approach that favors the mobile leaders from the 2nd wave

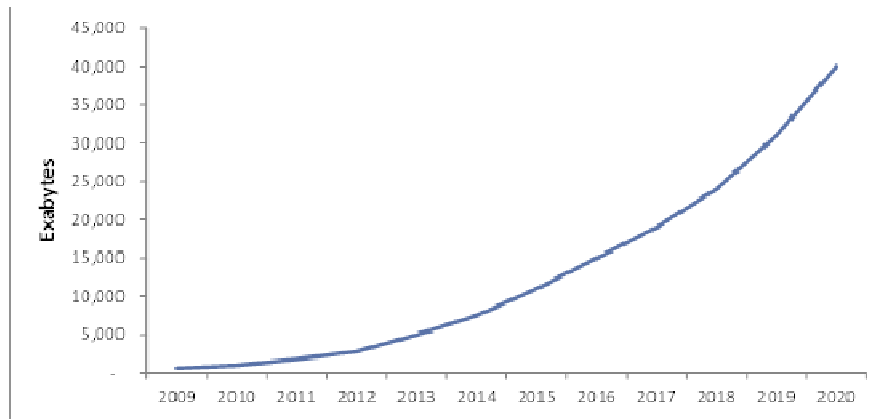
In the consumer world, it looks to us that the same mobile leaders that came to dominate the second wave of the Internet are best positioned to provide the platform-centric worlds that the IoT will likely need. As standards (intentional or unintentional) come into place, we expect the pace of innovation to accelerate. New functionality will be enabled by communications compatibility allowing third party hardware and software providers to layer innovation onto common platforms (like Instagram on an iPhone). As a result, look for two classes of software to develop:

- **The platforms.** Standard bearers that will lay the software foundation for others (think: iOS, Android, and others). These platform providers are also likely to seek to dominate the “smarter” device categories where the opportunity is largest.
- **The long tail.** Some of the “things” in the IoT will be smarter than others and look for a myriad of third-party providers to develop them software that powers and analyzes the long tail of devices and sensors that are “less smart.”

Platforms: the role of software across the IoT (cont.)

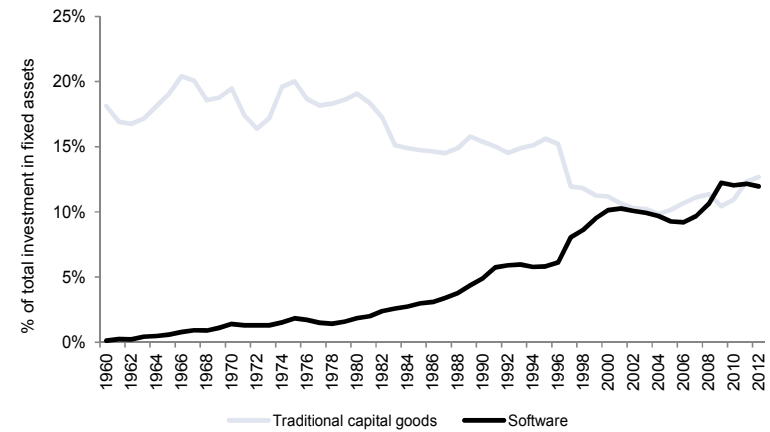
A key enabler of the IoT is the emergence of Big Data technologies for analytics that enable enterprises to glean insights from significantly larger data sets at less than 1/10th of the cost of traditional database technology. As the amount of data collected by connected devices swells, we expect increased investment in analytical platforms and visualization technologies that will allow business managers to make sense of the information and react to it.

Exhibit 5: Worldwide data growth projections



Source: IDC "The Digital Universe" December 2012.

Exhibit 6: Investment in software is on the rise, signaling a shift away from hardware



Source: BEA, Goldman Sachs Global Investment Research.

Industrials: a wide open opportunity seeking attractive early-stage verticals

The global industrial sector is poised to undergo a fundamental structural change akin to the industrial revolution as we usher in the IoT. Equipment is becoming more digitized and more connected, establishing networks between machines, humans, and the Internet, leading to the creation of new ecosystems that enable higher productivity, better energy efficiency, and higher profitability. While we are still in the nascent stages of adoption, we believe the IoT opportunity for Industrials could amount to \$2 trillion by 2020. The IoT has the potential to impact everything from new product opportunities, to shop floor optimization, to factory worker efficiency gains that will power top-line and bottom-line gains.

Case study: NCR incorporates sensors into its ATMs and point-of-sale devices and monitors the data to help predict when certain parts are likely to need replacement.

Rethinking business models as stuff becomes software-centric even as everything is “hardware”

With several infrastructure booms coming to an end, industrials companies are looking for the next source of growth and shifting from sales of pure “hardware” to software. Traditionally, we think of hardware as a computer device, but in the IoT world, everything becomes a computer device as software capability is added in. As a result, fixed investment growth is increasingly moving towards software as opposed to traditional capital goods equipment, creating new business models that more seamlessly integrate hardware and software offerings, which support better recurring revenue streams and greater customer stickiness.

Specifically, we expect IoT to impact three main verticals within industrials in the short term:

1. **Building Automation**
2. **Manufacturing**
3. **Resources**

Connected cars and connected cities also will overlap a number of other sectors. Overall, we believe the IoT will improve energy efficiency, remote monitoring and control of physical assets, and productivity through applications as diverse as home security to condition monitoring on the factory floor.

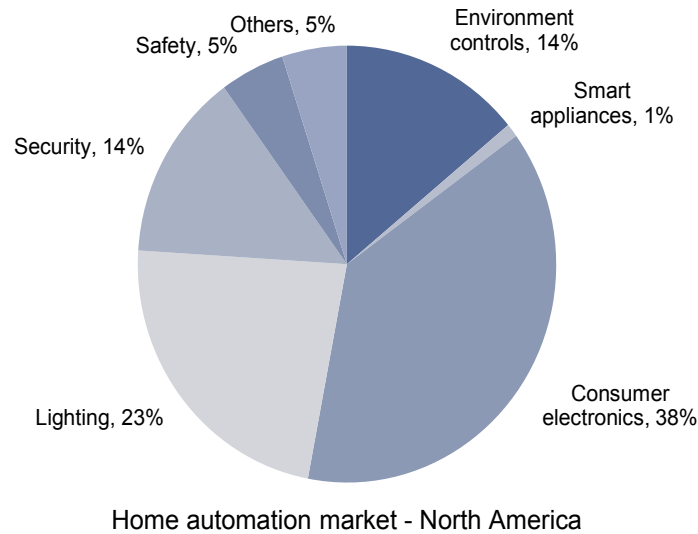
Home automation at forefront

We expect home automation to be at the vanguard of IoT adoption given homes account for more than 30% of electricity usage, have natural overlap with consumer-oriented devices (e.g., smartphones), and ample room to further digitize. While the concept of “smart homes” has existed since the 1960s, the house remains one of the few elements in our lives still governed by physical/analog solutions. To this end, the Consumer Electronics Association estimates only 10% of new homes in the United States have home automation currently. However, as the base of smartphone users grows significantly (1.9bn today to 4.0bn in 2016, as estimated by the Goldman Sachs CommTech team), coupled with increasing digitization within the home, we see home energy efficiency, home comfort, and security as key areas of focus for industrials.

Industrials: a wide open opportunity seeking attractive early-stage verticals (cont.)

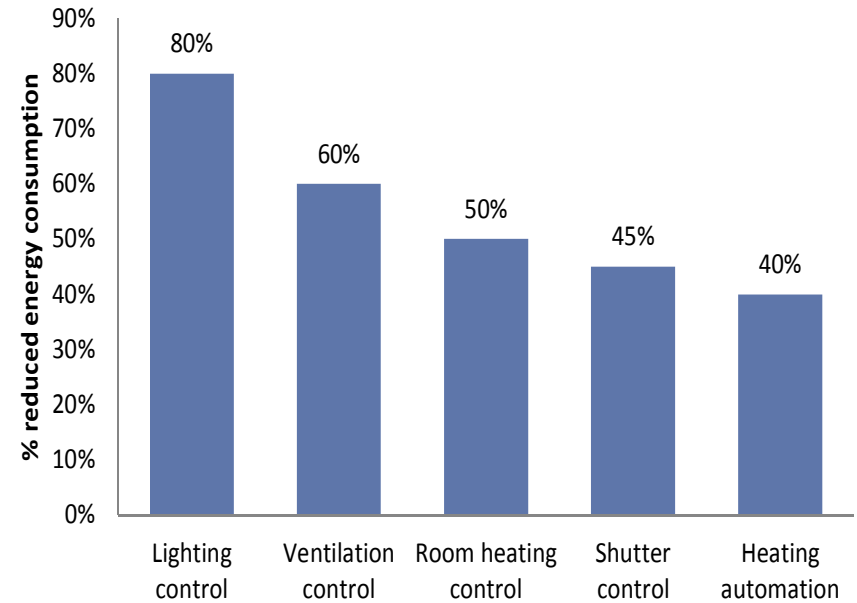
The potential for the IoT to impact efficiency across a wide range of sub-sectors is enormous. Home automation is an early area of adoption because of the potential to reduce energy costs, improve security and increase comfort.

Exhibit 7: Energy efficiency, home comfort and security will be key areas of Industrial focus



Source: ABB, Goldman Sachs Global Investment Research

Exhibit 8: IoT can help reduce home energy consumption by over 40% in various applications



Source: Goldman Sachs Global Investment Research.

Disclosure Appendix

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