How the Internet of Things Will Enable Vast New Levels of Efficiency

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ABSTRACT

In the last few years, the world has witnessed major growth of everyday devices that are Internet-enabled, a concept commonly referred to as The Internet of Things (IoT). The Internet of Things is brought about by a combination of low cost sensors, computing technology, and networking which allow objects, buildings, and other infrastructure to communicate with each other and to be remotely accessed via the Internet. We will continue to see an acceleration of interconnectedness between the physical world and the digital world; IDC predicts that by 2020 there will be an installed base of 212 billion connected things, including 30.1 billion connected autonomous things or things that can make decisions based on built-in rules running locally or remotely (Lund, MacGillivray, and Turner 2013). In this paper, we will explore how Machine-to-Machine (M2M) communications and IoT enables us to push beyond energy efficiency at the device level, into a profound new level of efficiency at the systems level while preserving privacy and security and enabling new energy services. We know that Information and Communications Technology (ICT) is already driving efficiency gains across many industries and infrastructures. In this paper, we will highlight various supply and demand side energy management applications, demonstrating how these technologies bring forth new possibilities in collecting real time data which enables new mechanisms such as predictive analytics, energy load disaggregation, automation, and complex multi-dimensional optimizing algorithms. We will highlight the role these technologies play in enabling new energy efficiency, building commissioning, and demand response services and include insights from research and demonstration projects to show the impacts of smart, connected devices and analytics solutions in residential, commercial, and industrial applications.

Context and Background

There are now more computers, in the form of microprocessors, manufactured each year than there are people on the planet. It's estimated that ten billion processors are manufactured each year and the number is growing rapidly, as is the number of transistors that make up processors. (Ballay, Lucas, and McManus 2012) These processors are inside of a wide range of devices well beyond popular mobile devices such as phones, tablets, and laptops. Processors are found inside of modern appliances such as washing machines and refrigerators, inside wearables such as watches, eye glasses, and running shoes, and embedded inside a wide range of industrial and energy consuming equipment. Modern automobiles for example, have many dozens of processors responsible for a wide range of applications from in-vehicle infotainment to engine and braking control, and airbag systems. In the twenty first century we are seeing microprocessor-based controllers replace many of the mechanically complex devices that characterized the 20th century. The complexity of intricate electromechanical systems is increasingly being handled by software.

The primary reason for this microprocessor revolution is cost savings. Replacing the intricate mechanical systems with software is more economical and results in more reliable outcomes. While cost savings has been a primary cause for this microprocessor revolution, the real game changer that can unleash the vast potential of intelligent devices is connectivity (Ballay, Lucas, and McManus 2012).

Unlocking the Value of IoT

Internet connectivity is becoming increasingly ubiquitous, allowing not only people to stay connected but also things. IoT can be characterized as an advanced version of Machine-to-Machine (M2M) Communication, where each object connects and communicates with other objects that recognize and respond without human intervention (Kumar, Prasad 2012). We will continue to see an acceleration of interconnectedness between the physical world and the digital world; IDC predicts that by 2020 there will be an installed base of 212 billion connected things, including 30.1 billion connected autonomous things or things that can make decisions based on built-in rules running locally or remotely, such as intelligent thermostats or smart grids (Lund, MacGillivray, and Turner 2013). As such, IoT has the potential to revolutionize pervasive computing (also known as ubiquitous computing) and its applications. Once isolated devices, can now relate to their environment, to other surrounding devices, and to data stored in the cloud.

The IoT paradigm has allowed for new opportunities in data acquisition, decentralized data analysis, and decision making and actuation. IoT is essentially all about tiny sensors collecting data and automatically sending that data to aggregation points such as intelligent gateways or directly to servers in the cloud to be analyzed and acted upon. Often with IoT the temptation is to focus on the "things", but the reality is that the primary value comes from the data that these things (and groups of things) generate, and the amount of data generated is massive. In fact, machine-generated data is expected to grow by a factor of 15x between 2014 and 2020 (Gantz, Reinsel 2012). From a business perspective, it is key to extract real-world insights and business intelligence from the data, and to apply this knowledge to enhance efficiency, operations, or customer service. With this data frame of reference in mind, think of the functions of an IoT implementation as measure, analyze and actuate. Let's consider each function.

Measure

Measurements are most often associated with sensors, but as more of our world is instrumented our phones, credit cards, cars and many other devices are carrying and sending data. In a smart city scenario the sensor might be associated with air quality, in the electric transmission grid it might be a synchrophasor[1] measurement of voltage, or in a factory or data center the power consumption of a particular piece of equipment. In many applications the measurements from sensors are aggregated into a gateway for communications. This aggregation might be to accumulate all the different measurements that are being collected by a

[1] Synchrophasor- Wikipedia definition - A phasor measurement unit (PMU) is a device which measures the electrical waves on an electricity grid, using a common time source for synchronization. Time synchronization allows synchronized real-time measurements of multiple remote measurement points on the grid. In power engineering, these are also commonly referred to as synchrophasors and are considered one of the most important measuring devices in the future of power systems.[1] A PMU can be a dedicated device, or the PMU function can be incorporated into a protective relay or other device

complex system such as a wind turbine or a HVAC unit or the aggregation could be from multiple smaller devices such as smart meters in a neighborhood or appliances in a household.

Another extremely important application of the gateway is to connect legacy devices to the network. Not all of these internet-enabled devices will be "greenfield", built from the ground up to take advantage of IoT and the system of systems. In utility and industrial settings, many pieces of mechanical and electrical equipment have multiple decade lifespans. A gateway "bolted-on" can bring these older "brownfield" devices into a modern IoT implementation.

Analyze

As this data is collected, it's often sent to the cloud or an on premise server for analysis. For example, one of the results of smart grid technology deployment is that utilities are amassing vast quantities of data. Meter readings alone can account for huge increases. It's not uncommon for a large utility to go from the scale of 24 million readings a year to 220 million readings per day as Advanced Metering Infrastructure (AMI)is deployed (Prochazka 2013). And that's just meter data. As these systems moved from manually-read meters to automatic meter readings, utilities identified other value streams which allowed easier paths to justify AMI system implementations.

Some examples include:

- Outage Detection and especially nested outage detection: Enhanced outage management ranks as the first true real-time application for smart meters. Real-time analysis (best performed by a Complex Event Processor or CEP) is needed to handle major contingencies. An example of a CEP in action would be rolling thousands of outage alerts up to a common upstream node on the distribution grid (such as a common feeder or a substation) to create one master outage instance which could be used to support targeted crew dispatch.
- Load research and forecasting: AMI data revolutionizes load forecasting by providing granular point-of-consumption data. This granular data is useful for building forecasts in a variety of contexts: to determine power flow loads on specific parts of the distribution infrastructure, to aggregate consumption up to locational marginal pricing nodes (LMPs) on the transmission grid in support of power trading, and to plan load shed events (preferably demand response and/or dynamic pricing, not rolling blackouts). Suffice it to say that improved load forecasting is a killer analytic app for the smart grid, and time-interval data is the fuel that feeds it.
- Asset utilization: Smart meter data can also be used to improve distribution network planning. Historically, distribution sizing is a very conservative exercise where planners err on the side of overcapacity, absent any detailed data on utilization trends, especially for transformers. Smart meter data can be aggregated to reflect the transformers they are connected to, and then utilization can be compared to the capacity of the transformer to build detailed capacity utilization trend analysis. Examples of questions that this type of analysis can answer include: What percentage of the time is a transformer operating within 10 percent of its peak rating? Are there certain times of day or times of year when transformers are nearing overload? What is the minimum size transformer that could be used to replace an aging transformer?

- Other intelligent devices throughout the grid are also generating data, which when combined with other information sources, can yield tremendous insight. And the point of that insight is to take action, which is where actuation comes in.

Actuate

This could be as straightforward as scheduling a specific device for maintenance because of the readings it's sending or more sophisticated such as triggering congestion fees for driving in a city when the air quality readings reach a certain contaminant level.

Some examples of electric utilities leveraging this new data to optimize power systems are describe below:

- Voltage profile optimization. With smart meters, it is now possible to collect voltage readings from the edge of the distribution network. This data can be collected and matched with other voltage readings further upstream in the distribution network, then analyzed to optimize voltage regulation. Voltage conservation can be used for technical demand response and/ or to improve overall power delivery efficiency. An additional longer-term opportunity is to wield smart meter voltage data for conservation voltage reduction, an energy conservation technique that regulates the incoming voltage to buildings.
- Power quality optimization. Reactive power readings from smart meters can be captured and analyzed to measure power quality and to determine adjustments in the distribution network to reduce power harmonics, increase delivery efficiency, and provide a higher quality product to customers. While these standards vary from utility to utility – a sample set can be found at https://www.pacificpower.net/con/pqs.html.
- Peak demand optimization. Time-interval consumption data follows a time-based sampling methodology. Within any given timeframe, there will be a maximum draw of power – in other words, a peak demand reading. Peak demand data can be analyzed to learn more about consumption patterns, including the identification of 'heavy-hitter' appliances like pool pumps, central air conditioners, electric hot water heaters, and in the future, electric vehicles.

Security and Privacy

As IoT systems are implemented, it is critical that security be designed in from the outset. Connectivity introduces new vulnerabilities, particularly if the application includes actuation. Think of the sensor measuring valve pressure in a manufacturing process, an oil pipeline or voltage at an electric substation. If the measurement is spoofed with an inaccurate value, the automated action initiated could be disastrous. Every device and the connections between them should be secure. This includes utilizing mechanisms to establish trust with cloud-based resources or Internet services. Think of the automated outage system for an electric utility described above. Even the weather feed information should be authenticated. Figure 1below highlights the ingredients of a comprehensive security approach that includes end-to-end security spanning hardware, software, and services.

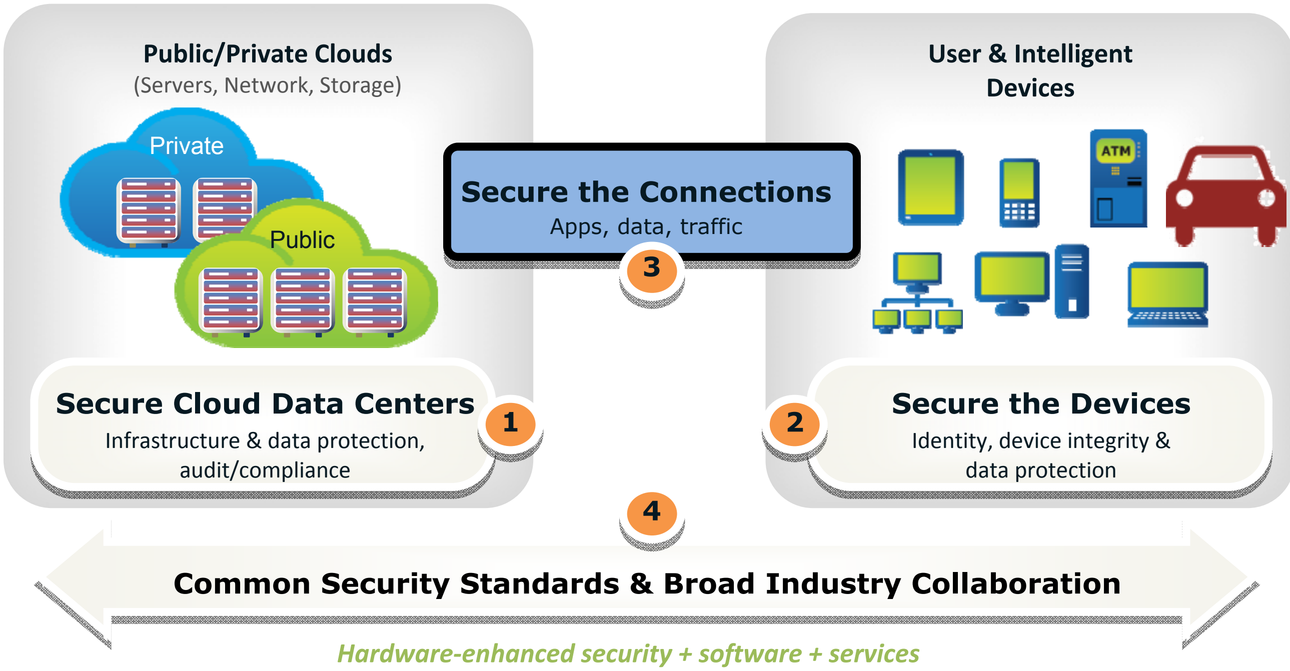

Figure 1. Foundation of IoT Security- Cloud to Chip Security: Privacy, Protection & Trust. Source: Intel Corp. 2014

Similarly privacy should be a consideration in the architecture of the IoT system. Particularly Personally Identifiable Information (PII) should be treated very carefully. This is critical both to protect individuals and to comply with emerging regulations globally. Energy use data in particular is very sensitive as many things about a household can be inferred from it over time. Fortunately there are many technologies available to protect and anonymize data and identity.

Internet of Things and Energy Efficiency

With regards to efficiency, attention has been placed on how the IoT and M2M communications can enable significant improvements in operations efficiency and energy efficiency, significantly greater than what can be achieved at a discrete, device level. A number of new terms have emerged in recent years to describe Internet-enabled efficiency, such as “enernet”, “soft grid”, or “intelligent efficiency”, the last coined by The American Council for Energy Efficiency (ACEEE). These descriptors emphasize a systems-based holistic approach to efficiency, as opposed to historic efficiency gains arriving from replacing stand alone devices and equipment, such as lighting, appliances, pumps, motors, and HVAC with more efficient equipment. While replacing stand alone equipment with more energy efficient equipment can result in energy savings, this isolated, non-networked approach results in a lost opportunity for incremental energy savings. Furthermore, in many cases persistent savings from the retrofit can be fleeting without significant efforts via retro-commissioning. Consider for example the case of replacing certain HVAC equipment- without ongoing commissioning the efficiency of the system can decrease over time. However, in the case of an intelligent, connected piece of HVAC equipment, the system can be continuously monitored and commissioned and even have predictive and self-healing properties. The IoT enabled system can also communicate and coordinate with other HVAC systems on a campus and via Cloud-based management software to optimize efficiency for a group of these systems.

In the ACEEE report, A Defining Framework for Intelligent Efficiency, the authors write "systems efficiency is performance-based, optimizing the performance of the system overall—its components, their relationships to one another, and their relationships to human operators". They further define the efficiency of a system by "1) how its energy use is managed within the technologies and how they interact with one another and 2) the choices made by the people involved".

Intelligent Efficiency is characterized as adaptive, predictive, and network connected. Information and communication technologies (ICT), paired with user access to real-time information are the underlying enablers. They go on to write that if homeowners and businesses were to take advantage of available information and communication technologies to enable system efficiencies, energy use in the United States could be reduced by 12-22%, which equates to tens or hundreds of billions of dollars in savings *(*Elliott, Molina, and Trombley 2012*)*.

Energy Applications for Internet of Things

There are a number of great examples of how the Internet of Things and data analytics are enabling tremendous operational and energy efficiency gains and enabling new business models. In this section, we will highlight a few examples.

Smart Grid

EPRI estimates that the efficiencies enabled by smart grid technologies could bring about energy savings of 56-203 billion kWh and 60 to 211 million metric tons of CO2 per year in 2030 (2008). The smart grid is a lot more than the electric grid becoming smart. Each segment of the electric value chain becomes smarter with deployment of modern technologies, many of which are internet-enabled. The figure below shows the key components that make up the smart grid, both on the customer side of the meter and the utility side of the meter.

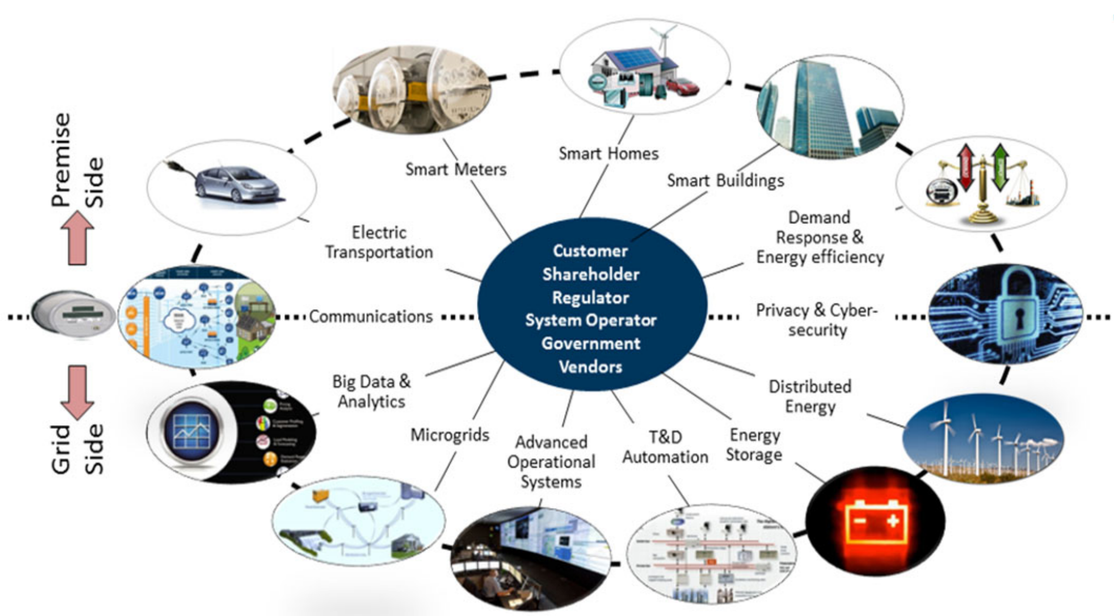

Figure 2. Key Dimensions of Smart Grid. Source: Modern Grid Solutions.

As you can see, the smart grid is much more than simply smart meters, however, smart meters are a good example of IoT technology's enabling ability to drive new levels of efficiency and insight that have serious financial impacts both for utilities and for their customers.

According to CenterPoint Energy, over seventy percent of surveyed consumers who are using home energy monitors (either in home or via a web portal) paired with their smart meters, have made energy-saving changes, and some reported saving up to $100 per month and reducing their summer electricity use by as much as 37 percent. These savings were attributed to having more frequent and detailed visibility into their electric usage (Prochazka 2013).

On the utility side, recently consulting firm Accenture estimated that each smart meter installed could generate $40 to $70 per meter in annual savings via analytics. Multiply that by a utility that has millions of customers. Asset management analytics provide the greatest value, followed by grid operations analytics, revenue protection analytics, and outage analytics (2013)

For example, today most utilities replace equipment based upon a preset timetable. With smart monitoring and diagnostics, this can become much more sophisticated – and efficient. Devices are replaced only when they are about to fail and replacement is prioritized based upon the criticality of the asset.

Another example of the impact of smart grid technologies can be demonstrated on the distribution network through conservation voltage regulation (CVR). Even though CVR has been utilized for some time now, a variety of new techniques and smart grid technologies allow for more impactful energy savings, including the installation of tap-changing transformers, line drop compensators, capacitor banks, along with energy management software and integrated Distribution Management Systems (DMS). The Pacific Northwest National Laboratory (PNNL) estimates that the total energy savings possible in the U.S. from CVR could be as high as 6,500 megawatts, or 56,940,000 megawatt-hours (Fuller et al. 2010).

Smart Buildings

Another example is how machine-to-machine and IoT technologies are making smart buildings even smarter and expanding energy savings opportunities

According to Jones Lang LaSalle's Global Property Sustainability Perspective, with today's advanced technology, building owners can realize 15 to 20 percent energy efficiency improvements in the first year, even at buildings that have already implemented strong energy management programs. Building owners are increasingly installing intelligent building systems not just for energy efficiency but also to improve operational performance, and to reduce risk and improve capital planning. These systems monitor building performance in real-time, detect inefficiencies, troubleshoot possible causes, make automatic adjustments, alert facilities and maintenance staff to issues, store data into enterprise resource planning systems, and even identify tools and resources that can help improve or fix situations.

Jones Lang LaSalle credit the recent technological advancements that have recently emerged to enable real-time remote monitoring and control of buildings and drive never before seen levels of automation and efficiency:

1. Wireless meters and sensors- used to collect data from each piece of building equipment.

2. Internet and Cloud computing- Millions of data points feed into the system every minute, from buildings all across the globe. The high-capacity computing power of the cloud enables a smart system to collect and analyze data effectively.
3. Open data communication protocols – Protocols, such as ASHRAE's open-source BACnet, have been around for a while, providing a way for buildings with different systems to communicate with one another. However, most building control vendors programmed with their own proprietary systems which caused lack of interoperability across platforms. More recently, vendors are providing translation into a common protocol in order to make them interoperable.
4. Powerful analytics software – intelligent solutions understand how various systems and components interact with one another and can identify probable cause for anomalies and adjust operating conditions to continually maintain peak efficiency or, if components are found to be working harder than necessary, the algorithm can pinpoint the issue and actuate.
5. Remote centralized control – When intelligence is applied across a building portfolio the performance of similar facilities can be compared to identify optimization opportunities. Economies of scale also come into play, as the portfolios of many companies can be monitored from a central command center staffed by facilities professionals 24/7.
6. Integrated work-order management – Smart building systems can automatically correct some issues and can issue alerts and work orders to facilities and maintenance staff as needed via the control system.

The process of continuous data collection, analysis and actuation enables continuous commissioning (Jones Lang LaSalle, 2013).

Intelligent, Connected HVAC RTUs

A more specific example can be demonstrated by what Daikin Applied is doing in the area of intelligent, connected HVAC Rooftop Units (RTUs). Daikin Applied's Rebel system is already the most energy efficient packaged RTU on the market, now they are leveraging IoT to achieve even greater levels of efficiency through a systems of systems approach. Advanced energy sensors and an intelligent wireless gateway are attached to each HVAC RTU for buildings on a given campus to monitor and control the HVAC energy consumption and operational control signals. Data is compressed, encrypted, and periodically uploaded to the Cloud where energy consumption, frequency drift, end point voltage, and predictive failure and maintenance scenarios can be analyzed. In addition to improving the operational efficiency of the individual HVAC units, they can now establish a local area network among the fleet of HVAC units across the campus to aggregate their collective energy consumption into Demand Response (DR) events. Given that HVAC consumes up to 40% of the energy used in commercial buildings, the savings can be substantial (http://www.c2es.org/technology/overview/buildings). Daikin Applied's simulation analysis for this new technology estimates 24% to 35% in energy savings from fan, cooling, and heating energy consumption when packaged units are retrofitted with these advanced control packages. By continuously monitoring HVAC RTUs and continuously re-commissioning their control parameters, operating efficiency is dramatically increased (up to 16% of building energy savings, especially of HVAC units (Brambley et al. 2011).

Recommendations for the Utility and Energy Services Industry

The challenges facing the power industry in the coming years are multi-faceted. Most of the industry agrees that the current utility business model is not sustainable. Utilities are facing a decline in revenue while at the same time requiring significant investments to address an aging infrastructure to improve grid reliability, integrate distributed energy resources, address new customer demands, and meet privacy and security concerns. Add to these challenges the fact that around 50 percent of the engineering workforce at utilities in the U.S. is approaching retirement. New talent is needed to chart the path for future utility success and the competition for this talent is fierce.

Addressing these challenges is a tall order, especially in the face of uncertain regulatory changes. That said there are things utilities can do that enhance their current operations while setting them up for greater success as new business models emerge. Utilities that are aggressively investing in information technologies across their operations and integrating end-to-end solutions in a way that helps remove departmental silos and identify value added service opportunities and improved customer orientation will have more business agility and be better positioned for success. By integrating intelligent, flexible and scalable technologies, utilities can enable end-to-end analytics to turn big data into actionable information, which will aid in both efficient business transformation and human transformation. This will be important for utilities competing with other industries in their search for knowledge workers that will continue the evolution.

The shift from isolated systems to Internet-enabled devices that network and communicate with each other and the cloud is generating unprecedented opportunities that can be seized by utilities and energy solutions providers to develop new services, enhance productivity and efficiency, improve real-time decision making, solve critical problems, and develop new and innovative customer experiences. However, to fully seize these opportunities, it is important that utilities and energy service providers have skilled information workers and even Data Scientists that understand these ICT-enabled systems and can extract valuable insights from the incredibly large and diverse quantities of data generated by these systems. This data can be grouped into four main categories (as shown in Figure 3).

- Meter Data – moving from one reading per month per customer to multiple readings per customers every 15 minutes or more.
- Operations Data – increased implementation of distribution, substation and field automation sending data to the central location every 2 seconds plus Phasor Measurement Unit (PMU) data coming in 30-60 times a second
- Asset Data – Between asset maintenance reports, newer asset health monitors and the increased focus on online condition monitoring, increased data is being brought into the utility on the health of the assets.
- Customer Data – In addition to meter data, numerous utilities are working on energy efficiency and demand response programs, time-of-use rates, and other customer related programs. All of this is bringing in new forms of data.

Actionable intelligence could be in the form of better operational procedures, predictive maintenance, better service to customers and a host of other areas.

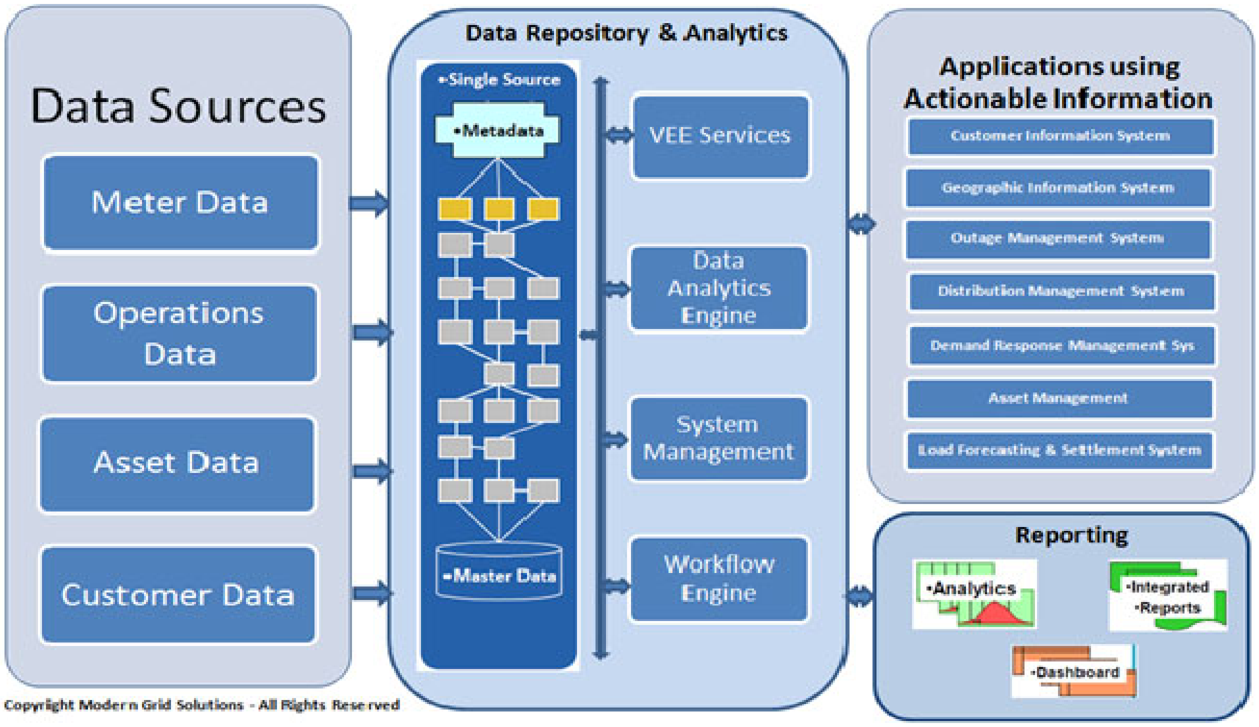

Figure 3. Utility Data Sources. Source: Modern Grid Solutions. Copyright Modern Grid Solutions – All Rights Reserved

The Data Scientist could assess the kinds and volumes of data coming into the utility and identify value that could be extracted from the data. This role is very common in other industries like retail and so on – however less common or non-existent in the utility industry. For this to happen in the utility industry, utilities and vendors need to come together to identify specific skill-sets, train personnel in the context of the problems that need to be solved, and as a result this will open up opportunities for the development of new products and services.

While the case of the Data Scientist is just one specific example that has been examined in detail, these new data sources stemming from the existence of IoT, offer new opportunities for energy service professionals within utilities and beyond.

Some of them are listed here:

- Energy/facility manager (commercial and industrial facilities): With new sources of device and systems data, energy and facilities managers are better prepared to (1) manage the energy consumed in their facilities depending on time of day, day of week and so on (2) manage local energy supplies either through PV and or localized genset, and (3) better predict future energy needs and costs, and (4) in the extreme case, be able to arbitrage the cost of energy by moving the usage between natural gas and electricity, and lastly (5) working with the wholesale/retail markets to buy/sell energy
- Utility energy efficiency office: Between energy efficiency and demand response, new or expanded jobs/roles are being identified within the utility for managing the customer's consumption either for the long-term or for peak management. New streams of data and analytics provide meaningful insights into their customers'

energy usage patterns which will enable better customer service and more efficient and cost effective demand side management programs. More remote monitoring and analytics will help improve the utility's understanding and segmentation of their customers for new products and services, will enhance the cost effectiveness of energy efficiency programs, enable continuous commissioning, and will improve upon energy measurement and verification (EM&V) of projects.

- Pure services providers: Increasing volume, velocity, and variety of energy usage and energy systems data , paired with analytics in the cloud, is a creating a surge of new energy service company entrants into the marketplace, offering utilities and/or utility customers products and services to monitor, manage, and reduce energy usage and costs.

Conclusions

The growing interconnectedness and intelligence of energy systems and the built environment promises new levels of efficiency, optimization, and services. As operations technologies (OT) and information and communications technologies (ICT) continue to converge it will bring new challenges and vast opportunities for energy services providers, energy producers, and consumers. Energy consumers across residential, commercial, and industrial classes will better understand how they use energy, and how they can reduce consumption and costs. These technologies may also change the way these consumers think about energy, some will find themselves transforming their relationship with energy by leveraging network connected, distributed energy resources to become energy producers, turning what was once a service cost, into an asset. The survival of established energy suppliers may very well depend on their innovation and ability to integrate advanced information technologies and workers into their businesses. Insights from vast new data streams will inform new business models for energy services and as a result utilities will face growing competition from new entrants, both large and small. To realize the full economic and environmental value that IoT represents for the energy sector, close collaboration will be needed amongst federal, state and local policy makers, utilities, energy service providers, technology companies, and energy consumers. Comprehensive interoperability, privacy, and security strategies will be essential to achieving the full potential from IoT. There is no doubt that connected devices, web-based monitoring and real-time analytics offer immense untapped energy efficiency opportunities, the question that remains is how will the industry respond?

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