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# Advanced Metering Infrastructure

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## ABSTRACT

Advanced metering infrastructure (AMI) (or smart meter) is a system that allows utilities to communicate with customers and monitor energy usage in real time. It is a two-way communication system to collect detailed metering information throughout a utility's service industry. The system collects, stores, analyzes, and presents energy usage data, providing utility companies the ability to monitor electricity, gas, and water usage in real time. It is required for the operation of the smart homes and buildings and is an indispensable part of the smart grid. This paper introduces the reader to AMI.

***KEYWORDS:*** *energy, power systems, power industry, meters, advanced metering infrastructure, AMI, smart meters, smart water metering*

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## INTRODUCTION

To bill a customer for utilities such as electricity, natural gas, or water, the amount the customer uses must be measured. This is usually done with a meter. In the past, in order to see how much utility power a home was using, a meter reader had to come around to each individual house and take the reading. With the introduction of the smart meter, readings can then be taken through the grid. Most utility companies around the world are transitioning from analog meters to smart meters [1].

Advanced metering infrastructure (AMI) provides a number of important functions that were not previously possible or had to be performed manually, such as the ability to automatically and remotely measure electricity use, connect and disconnect service, detect tampering, identify and isolate outages, and monitor voltage. AMI has become a key technology in a broader evolution due to our growing need for efficient, cost-effective, environmentally sustainable energy and the increase of smart technology.

The energy industry is increasingly focused on customer satisfaction, reliability, cost savings, and energy efficiency. As a strategic response, many utilities are turning to advanced metering infrastructure (AMI) technology. AMI is a system that allows customers' electricity consumption to be managed remotely. AMI systems use smart meters and communication networks to collect and transmit real-time consumption data. Current trends in energy saving technology and customer engagement have caused a group of forward-looking utilities to assess the costs and benefits in the implementation of AMI.

## WHAT IS ADVANCED METERING INFRASTRUCTURE?

Advanced metering infrastructure (AMI) is an integrated, fixed-network system that enables two-way communication between utilities and customers. It is an important component of the smart grid system which allows for a two-way flow of communication between the meters and utility companies. It uses advanced meters, communication networks, and data management systems. AMI is used in electric metering and can help utility companies collect a range of data, including indicators of tampering, data collected at set intervals, details regarding power

outages, and the quality of electricity supplied. Unlike traditional automatic meter reading, AMI's two-way communication model enables more comprehensive data collection and helps companies remotely manage meter functionality.

AMI refers to systems that measure, collect, and analyze energy consumption and with measuring equipment such as electricity meters, gas meters, and water meters. As illustrated in Figure 1, AMI is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers [2]. It comprises several interconnected components which include the following [3]:

- *AMI Meters*: At the heart of AMI systems are smart meters, which are the digital gas meters, electric meters, and water meters that record energy consumption. These meters with low-powered communication devices that automatically collect meter reads. A typical smart meter is shown in Figure 2 [4]. For customers, the first step towards the smart grid is the installation of smart meters. Smart meters are wireless, high-tech, digital communication devices that will replace the old, analog electricity meters and allow remote electricity readings. Using smart meters provides us with some environmental benefits as well as eliminating the need for manual meter reading.
- *Communication Networks*: Communication networks serve as the backbone of the two-way communication between smart meters and the AMI head-end system. They can be either wireless or wired, depending on the specific topology of the system. These networks transmit data wirelessly between the AMI meter and the utility. Communication networks can transmit usage information to water, gas and electric utilities by using radio frequency signals, cellular networks or broadband connections, or by using power line communication. A typical network that provides multiple communication paths for metering interface units (MIU) is shown in Figure 3 [5].
- *Data Management Systems:* The data management system is the central repository where all meter data is collected, stored, processed and analyzed. Here, raw data from smart meters is converted into actionable insights. These are systems that collect, store, analyze, and present energy usage data.
- *Consumer Energy Displays*: These are displays that show customers their energy usage. Data processing and analysis benefit not only the utility companies but also their customers. When the utility has all the necessary data insights, it relays those insights to the customer, who can then access detailed energy usage information on demand.

Figure 4 shows how AMI works [6]. The meters measure and store the energy consumed by the subscribers. Data is transferred wirelessly through the Internet to the data management system. The received data are analyzed on the server and useful reports can be prepared from them. After collection, the data from the meters is transferred to a database where the energy supply company can monitor and analyze the amount of consumption of the subscribers and bill accordingly. AMI typically provides a substantial payload of information.

## APPLICATIONS OF ADVANCED METERING INFRASTRUCTURE

Advanced metering infrastructure (AMI) is an electronic device that records and collects the real-time information about electricity usage of the customers. Government agencies and water, electricity, and gas companies are turning to AMI systems as part of a larger "smart grid" initiative. Figure 5 shows various components of the smart grid [7]. Functions enabled by an AMI include remote automated meter reading (AMR), remote service connect and disconnect, rapid detection and location identification of outages, voltage and power quality monitoring, and detection of electric theft. Common areas of application of AMI include the following [8]:

- *Water Utilities:* Water is an increasingly discussed commodity as it is one of vital substances we need to live on this earth. For example, water is used in drinking, cooking, cleaning, bathing, gardening, and farming. Water utilities rely on AMI meters to provide comprehensive flow data. A water meter is a device that measures the amount of water consumed in a home or building. If the data points to excessive water use patterns, which might indicate a leak, the company can notify the customer or make the necessary repairs. The types of water meters used by utilities have evolved over time. As the technology changed, meters that allowed for automated meter reading (AMR) became more prevalent. AMI meters provide for remote collection of water use data - in real time. AMI offers frequent water usage data that can be monitored to understand consumption patterns, identify leaks before the bill comes, and improve overall facility water management. AMI can help utilities manage water resources by providing

frequent and accurate water usage data. Figure 6 shows a water metering system [9]. The Smart Water Networks Forum (SWAN) is an organization that encourages water utilities to adopt smart water technologies.

- *Automatic Meter Reading:* The automatic meter reading (AMR) is a metering technology that collects consumption data from the water meters and transfers it to a central database for billing and other purposes. Water utilities are implementing advanced metering infrastructure (AMI) systems, which extends current advanced meter reading (AMR) technology by providing two-way meter communications. AMI differs from AMR in that AMI allows two-way communications with the meter and the customer. Smart water meters use AMI to allow for two-way remote communications with meters. Although AMR is inferior to AMI, it is less expensive and hence has a higher market share. Water utilities are often not sure whether to fully convert to AMI or run an AMR water grid. They will find the most "future-proofed" investment in AMI deployments.
- *Demand Response:* In addition to enabling real-time monitoring of energy usage and distribution, AMI technologies can facilitate demand response programs, incentivizing customers to reduce their energy usage during peak demand. This can help to avoid power outages and prevent the need for costly infrastructure upgrades. AMI enables real-time monitoring of energy usage and enhances the implementation of demand response programs, which encourage consumers to reduce their energy usage during peak demand periods, helping to balance load and prevent outages. With AMI, utilities can monitor energy usage in real time and send signals to customers to reduce their consumption when demand is too high.
- *Automation:* AMI fully automates the reading, meter data collection, and billing processes, making it a long-term and sustainable business solution for companies. Currently, automated meter reading used by the most of the utilities is not having two-way communication; it does not meet the requirements of smart grid implementation. Advanced metering infrastructure (AMI) is an architecture for automated, two-way communication between a smart utility meter with an IP address and a utility company. It is typically automated and allows real time, on-demand interrogations with metering endpoints.

**BENEFITS**

Advanced metering infrastructure (AMI) provides numerous benefits to electric and water utilities AMI can help utilities manage resources effectively. It improves a utility's ability to collect frequent and accurate water usage data to improve billing, leak detection, and water resource management. It allows for remote meter reading, which increases billing accuracy. It can provide real-time insight into the status of the electric grid, which can help utilities make proactive decisions. Other benefits of AMI include the following [10]:

- *Faster Response:* The ability to remotely manage meters not only eliminates the need for manual meter readings, but it also enables faster response times in the event of a power outage.
- *Efficiency:* AMI allows meters to be read remotely, saving time and reducing expenses and emissions each month. It enables remote connect and disconnect so members do not have to wait for a scheduled appointment to start, stop or transfer service. An updated communications network helps automate the distribution system.
- *Outage Management:* In the event of a power outage, AMI systems can automatically detect and report the outage to the utility, reducing the duration of outages and improving service reliability. AMI can also help utilities pinpoint the location of the outage, enabling quicker repairs.
- *Theft Detection:* Energy theft is a significant concern for many utilities. With AMI, utilities can monitor energy usage patterns and detect irregularities that might suggest theft. For example, if a meter is recording low or no consumption over an extended period despite the premises being occupied, it might indicate that energy is being stolen.
- *Enhanced Customer Service*: Smart meter is a digital device allowing two-way communication between the utility company and the customer, cutting out the need for meter-checking agents and eliminating the practice of estimated bills. AMI systems can help customers manage their energy consumption more effectively. Utilities can also use AMI data to provide customers personalized energy-saving tips and recommendations, further enhancing customer service.
- *Green Technology:* AMI can support green initiatives like demand response and distributed energy resources. Smart meters are a new, green technology that uses the same radio frequency (RF) fields as cell phones. They act as

interface points between the smart grid and commercial/home appliances. They are being regarded with great favor in homes and business globally. They are being deployed all over the world in an effort to create a new generation of utility service. As shown in Figure 7, the smart meter operates within a Home Area Network (HAN) which is in the Neighborhood Area Network (NAN), communicating with the utility company and with other smart meters in the area [11].

Some benefits of AMI are displayed in Figure 8 [12].

## CHALLENGES

Although AMI provides utilities with a real opportunity, it can be a challenge to determine how to manage the data collected and how to make that data useful to the utility customers. While smart meters adequately perform their function, they are also sources of dangerous, powerful electromagnetic radiation. In spite of the many potential benefits of smart meters, their deployment has created public opposition that centers on health risks and the formation of anti-smart-meter organizations. Other challenges of AMI include the following [13,14]:

- *Radiation:* The greatest challenge that smart meters face is that the radiate RF emissions which may be dangerous for health of humans. Smart meters have become a target for those who like to fearmonger about EM radiation it produces. As a result of industrialization, urbanization, and modern technology, the environment has been subjected to electromagnetic pollution. Current technologies such as smart meters (or AMI) have become a source of electromagnetic pollution from generated electromagnetic radiation. All electrical/electronic devices produce electromagnetic pollution, which depends on the amount of voltage and current they use. Consumers are increasingly concerned with the level of radiation that is emitted by these electronic devices.
- *Privacy:* AMI systems are highly vulnerable to privacy threats and potential infrastructure damage. Some critics have expressed concerns regarding the cost, health hazard, fire risk, security, and privacy invasion of wireless-only smart meters and their interaction with home area network. Breach of privacy is a common problem associated with smart meters. The privacy has to do with the information extracted by analyzing the data obtained from smart metering. The data delivered back and forth through smart metering systems should be protected so that they are not accessed by the wrong people. Programming the meters, with data mining and machine learning algorithms, to detect intruders is not easy.
- *Cost:* In order to successfully deploy new and innovative technology, such as AMI, it is imperative that utilities evaluate the cost-effectiveness. Smart meters are still new to many people. They are expensive and this is the reason they are not favored by everyone. Some people fear that smart meters will be used to invade our privacy. The massive smart meter big data creates pressure on data transmission line and incurs enormous storage costs. Utilities are tasked with showing that these benefits exceed the costs, particularly the capital costs of the system, to state commissions. Costs of the AMI system can be subdivided into three general monetized categories. These categories include: capital expenses, operations and maintenance, and customer engagement.
- *Thefts:* Large-scale thefts of electricity related to smart meters have been reported. Smart meters are more susceptible to attacks and network intrusions by energy thieves (or non-technical loss) than conventional analog meters. AMI provides new capabilities for tamper and theft detection. Several utilities are now working to develop better data analytics to differentiate actual theft incidents from the many different events that can trigger tamper alarms. In many cases, people tampering with meters risk getting burned, electrocuted, or even killed.
- *Bandwidth:* AMI requires requisite bandwidth to supply more than merely metering and power quality information. AMI systems need to have appropriate bandwidth and broadcast capabilities to allow for demand response/load management as well as distribution automation.
- *Cybersecurity:* Cybersecurity risks have been identified and how they would be mitigated. Cybersecurity criteria used for vendor and device selection, relevant cybersecurity standards and/or best practices would be followed. Corporate accountability is ensured for the successful implementation, and how the project would support emerging smart grid cybersecurity standards. . DOE developed a dedicated, secure website of cybersecurity resources, which served as a central repository of tools, guides, presentations, and resources.

## CONCLUSION

Advanced Metering Infrastructure (AMI) is a system of technologies that enables two-way communication between utility companies and customer's electricity

meters. AMI typically involves installing smart meters and digital devices that can measure and record energy usage in real-time. AMI or smart meter is a high-tech meter that measures electricity consumption and provides additional information to the utility company unlike the conventional, analog meter. Smart meters are gradually replacing old, conventional meters around the world. Studies show that it is possible to reduce household consumption of electricity by introducing smart meters. The smart meter and smart water grid are gaining momentum worldwide. The utilities all around the world are turning towards AMI as a part of smart grid initiatives. More information on AMI or smart meters is available from the books in [15-21] and the following related journals:

- *Journal of Energy Storage*
- *Journal of Modern Power Systems and Clean Energy*
- *Energies*

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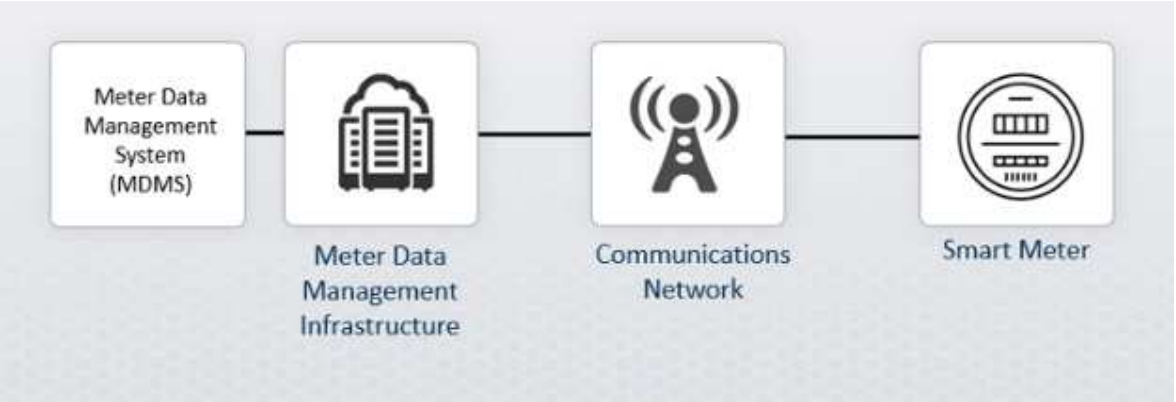


**Figure 1 Components of AMI [2].**

**Figure 2 A typical smart meter [4].**

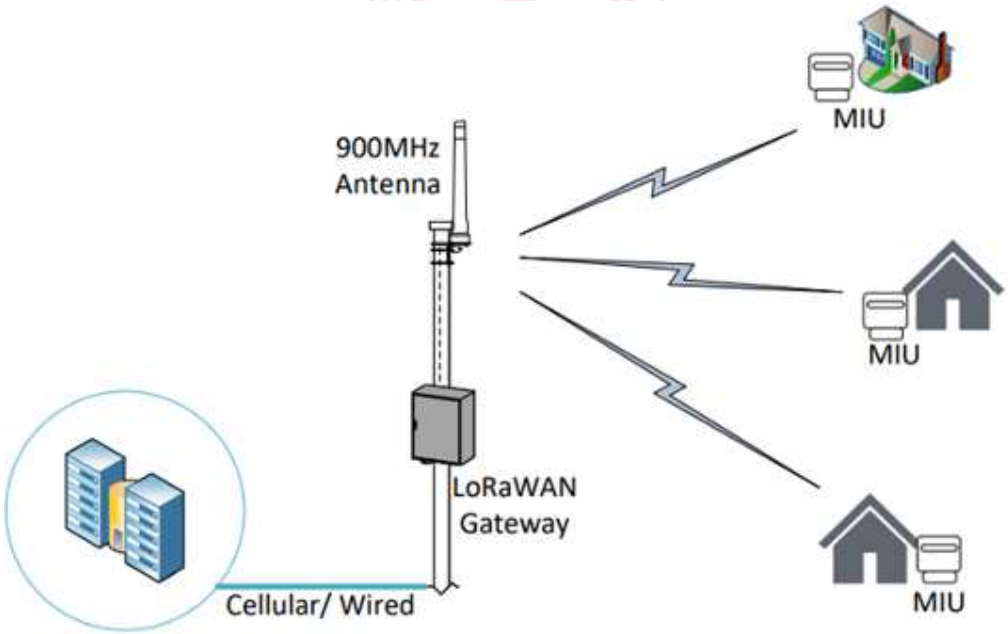


**Figure 3 A typical network that provides multiple communication paths for metering interface units (MIU) [5].**

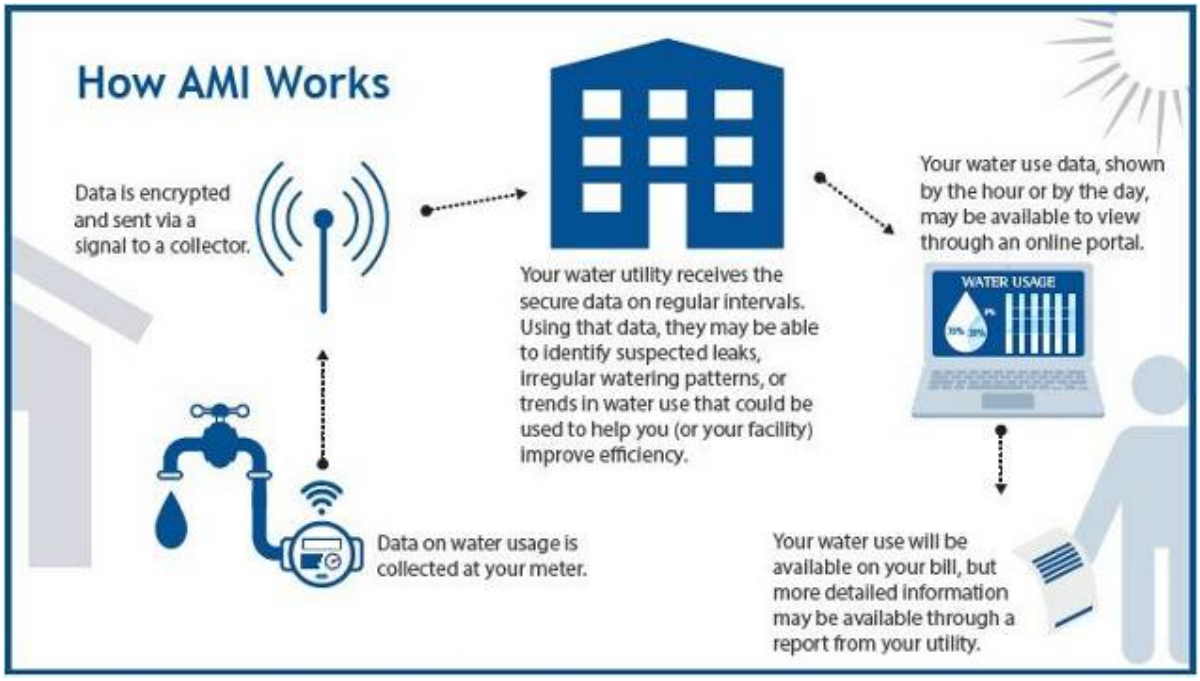


**Figure 4 How AMI works [6].**

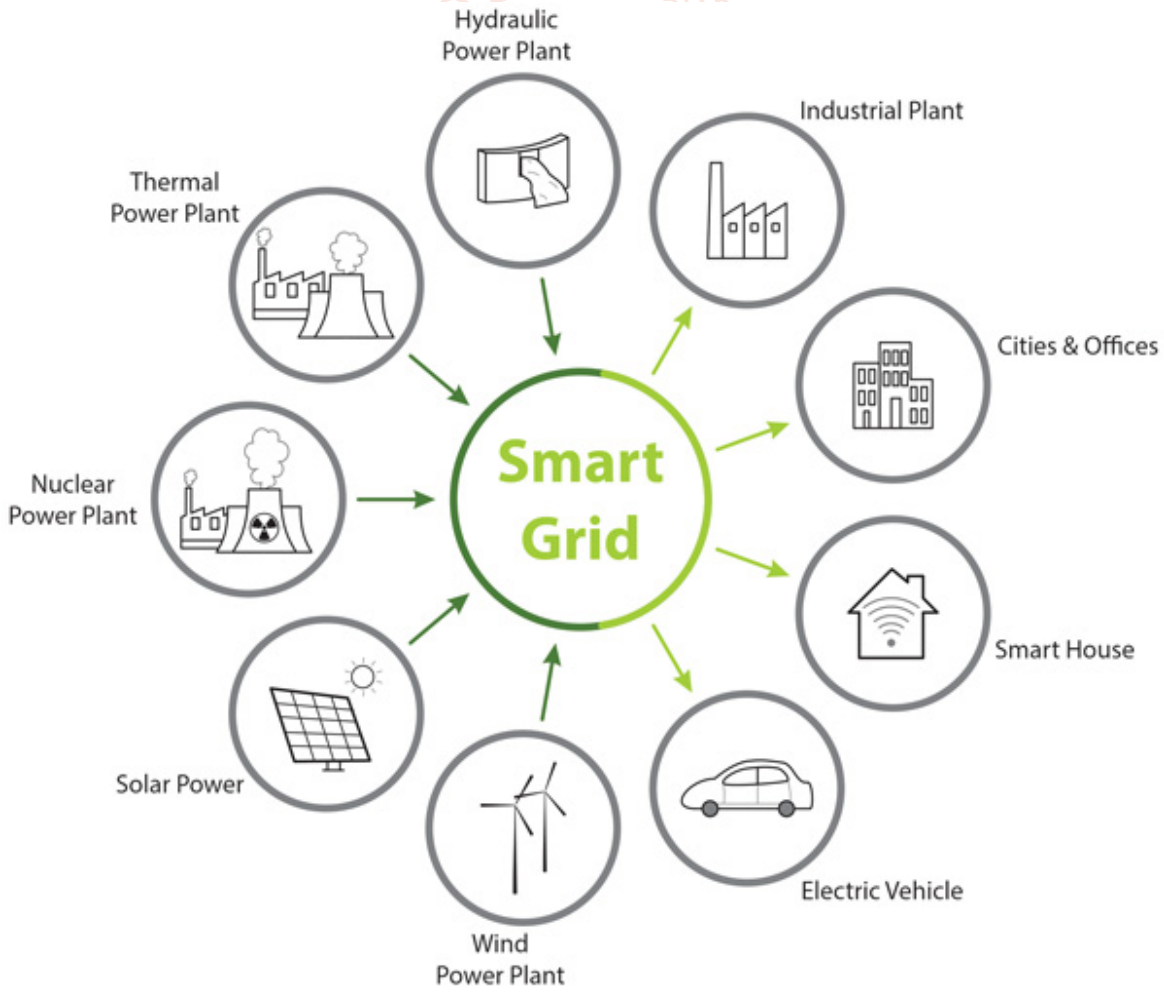


**Figure 5 Components of the smart grid [7].**


**Figure 6 Water metering system [9].**

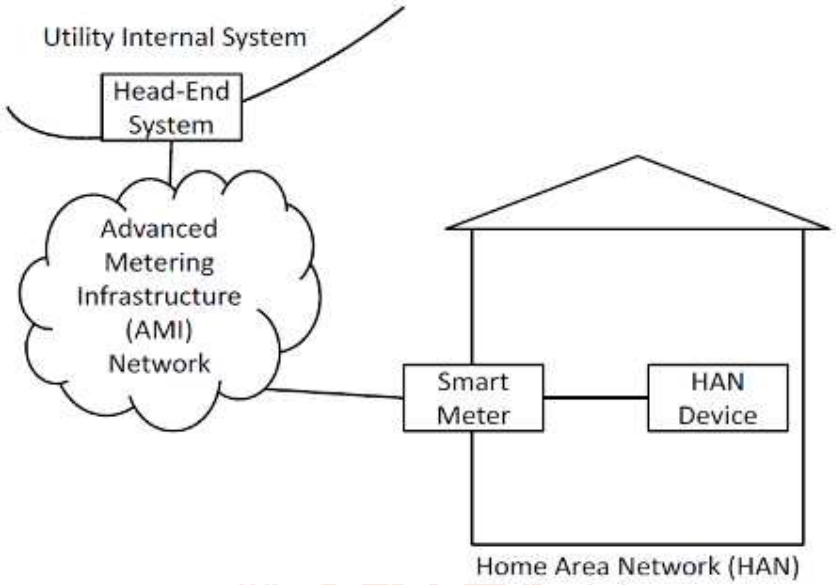


**Figure 7 A system including smart metering and a HAN [11].**

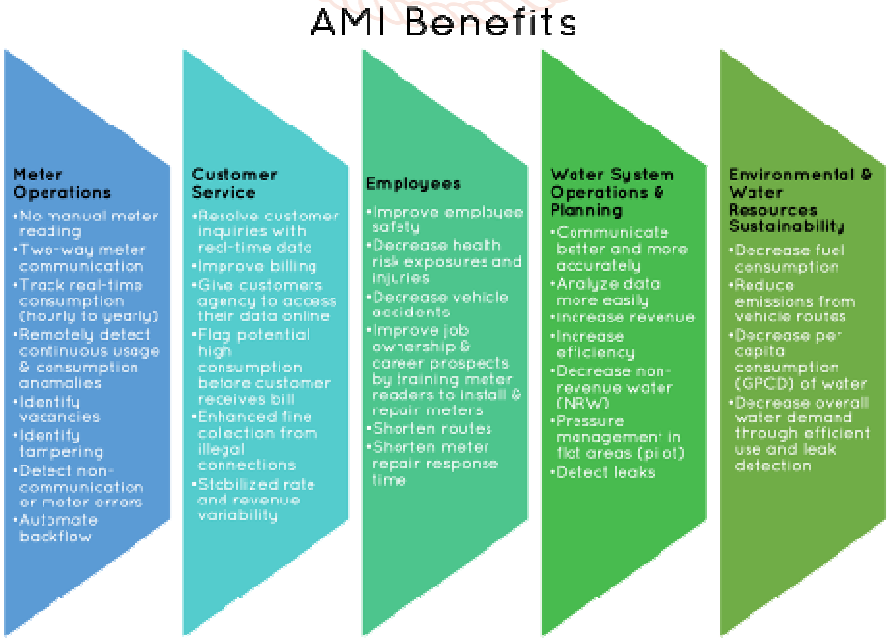


**Figure 8 Some benefits of AMI [12].**