

Digitalization for Energy Saving and Emission Reduction

Subjects: Green & Sustainable Science & Technology

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Digital technologies find a wide use on the energy market both on the energy supply and demand side. Many digital technologies such as smart home systems reduce the production of the energy necessary to produce goods and services in all aspects of our lives.

Keywords: digitalization ; energy ; smart home ; Internet of Energy ; energy saving ; smart grids

1. Introduction

Currently, digital technologies find a wide use on the energy market both on the energy supply and demand side. Sustained progress on energy efficiency will keep the growth of aggregate energy demand for data center networks in check over the next years ^{[1][2][3]}. Predictions that digital technologies such as smart meters, smart lighting, and thermostats in commercial buildings will considerably reduce energy consumption are based on a limited rebound effect on consumer energy demand ^{[4][5]}. This reduction would mean total energy savings of 6.5 pWh by 2040, which is twice the total energy consumption of non-OECD countries (countries that do not belong to the Organization for Economic Co-operation and Development (OECD)) ^[6]. Thence, digital technologies offer enormous potential benefits in terms of energy use. With regard to the above, it is often expected that the digitalization of industries will continue in the near future and that digital technologies will have a far-reaching impact on energy consumption in certain areas of application or in combination ^[7].

Digital technologies can act as catalysts to help established and new entrants develop new business models, such as through the use of advanced analytics to segment customers and find target groups for new services. They can also be disruptors, opening the door to new entrants such as technology platforms aggregating the production of decentralized (or distributed) energy resources (DERs) so that owners in wholesale power markets can bid on them ^[8]. Governments should consider exploring a variety of real-world experiments from which to learn. Smart offices, for example, have demonstrated the power of digital technologies to increase the efficiency of lighting, heating, cooling, and water heating by tapping into decentralized sources for flexible load generation and storage. The impact of such systems is substantial: commercial buildings have energy savings and yields equivalent to more than 10% of annual local energy costs and greenhouse gas emission reductions of up to 40% thanks to load shifts and improvements in energy efficiency. Digital technologies can also be enablers that enable new performances, such as the reduction of maintenance time and cost by the use of automated drones equipped with cognitive capabilities to inspect facilities on site ^{[9][10][11]}.

However, digitization brings new security and data protection risks as it changes markets, businesses and jobs. The digitization of energy adds that huge amounts of data, ubiquitous connectivity, and rapid advancements in artificial intelligence and machine learning enable new applications and business models for global energy systems, from autonomous cars and shared mobility to 3D printing and connected devices. Digital technologies are helping to integrate a higher proportion of variable renewable energy into the grid to better align energy demand with solar and wind power ^[12].

Many digital technologies such as smart home systems reduce the production of the energy necessary to produce goods and services in all aspects of our lives. For example, in the recent years the International Energy Agency (IEA) has launched an interagency initiative to examine the potential impact of digitalization on energy efficiency and the impact on policy makers. The energy supply sector will benefit from increased productivity and efficiency, as well as improved safety for workers ^[13].

2. Digitalization and Residential Emission Reduction

In general terms, the ongoing digitalization of the energy market helps to optimize the use of energy and reduce residential emissions. All of these can help to save great amounts of money, especially in the case of poor households who become the victims of the renewable energy deployment and various “green” initiatives. For example, the researchers found that families who remain in poverty often move to larger homes, increasing their energy expenditure. Many of these larger homes are rental properties bought during the Great Recession (the 2007–2009 economic downturn and the global financial crisis) or when the house prices were low in general allowing to acquire more cheap and affordable property ^[14]. Creating more economic opportunities for low-income residents could lead to a fairer approach to reducing energy consumption through gentrification, she said. The report suggests that city leaders take the age of their housing stock into account before making investments. Lifting people out of poverty and out of old, inefficient homes has helped Minneapolis reduce its greenhouse gas emissions over the past decade. A recent report analyzed the link between emissions from poverty and housing stock in a dozen cities. That helps, according to a recent report of the American Council for an Energy Efficient Economy that examined the relationship between emissions and poverty in housing stock in several cities in the United States ^[15]. A key element of this effort is the introduction of smart home technologies in homes to increase energy efficiency and prevent residents from wasting electricity. With new-build projects, it is relatively easy to design a house intelligently and energy-efficiently, as properties are designed and wired with the necessary technologies in mind. Existing properties, however, can be made more difficult due to property constraints, as uneconomic floor plans, wasteful heating systems, and building materials used can all help reduce a home's energy-saving potential. Smart homes are able to identify the best energy sources at the right time and reduce costs. Consumers can reduce energy consumption and electric heating costs by up to 50% by using AI-based forecasting without compromising comfort. Advances in solar technology have made it a viable source of energy for a wide range of residential locations. The popular electric vehicle can serve as an energy storage system if required. Another area of energy consumption that often goes unnoticed by smart home technology is the bundling of audio and video (AV) multiroom sources and smart home sources in one place for more effective building management. Smart Home Technology (SHT) refers to devices or systems of devices that provide home residents with networked and improved services to monitor, manage and control home functions related to energy consumption, safety, health and wellness, entertainment, and other aspects of home life that benefit from automation and control. Scripts or explicit programming can guarantee reductions in energy consumption and carbon emissions in the case of smart energy for the home. Without such scripts there is no shutdown for smart home devices if they exceed a certain threshold of emissions and energy consumption.

Popular examples of SHTs include Google Nest or Amazon Alexa, which offer voice activation for music and Internet searches (even though ordering a taxi or buying items from Amazon are also embedded there as possible options). Another thing is Nest thermostats that enable automated heating and programmable heating and ringing security doors that allow video viewing and remote monitoring of the home ^[16].

3. Impacts of Digital Technologies on Energy Consumption

In general terms, smart home technology (SHT) refers to devices that provide connected, automated, or advanced services to a certain extent to home residents offering them important feedback of the energy consumption data and information. Home automation systems monitor and control home attributes such as lighting, air conditioning and indoor air quality, entertainment systems, and appliances while making home energy flows and consumption more visible and amenable for the consumers ^{[17][18]}. The term “smart home” has been used for more than two decades to describe household-controlled energy systems. It sets a certain blueprint of how sustainable and intelligent technologies optimize household energy consumption, reduce waste, and reduce electricity bills ^[19]. Smartphones and apps give households more insight into the energy consumption of their devices. Controlled energy systems have proved easier for homeowners' lifestyles than normal, nonautomated homes, especially for the elderly and disabled ^{[20][21]}. Estimates vary, but industry advocates of connected home and smart home technologies estimate that households could cut their energy bills by 10% to 25% ^{[22][23]}. However, such claims are speculative, given the lack of robust research. For example, the European standard EN 15232-1 (Energy Efficiency and Buildings Directive 2010/31/EU), in line with Directive 2009/72/EC and Energy Ticket 2050, promotes integration of smart home technologies in order to reduce demand electricity in residential areas ^[24]. Technology such as electric heat pumps and variable refrigerant flux (VRF) systems are available to meet heating needs and help meet greenhouse gas targets for most climates. Many countries all around the world have also put forward many “rule of law” and subsidy programs to promote smart home integration, such as optimizing heating systems, supporting energy storage in buildings, and deploying smart meters ^{[25][26][27]}. Social research in Australia and the UK shows how the IoT increases energy demand ^[28]. One can identify some well-hidden energy impacts that should be taken into account in IoT research and energy-saving forecasts ^[29]. For example, the American Council on Energy-Efficient Economies (ACEEE) has published a white paper that discusses the impact of smart home technology on

consumer energy use and grid reliability. The paper examines the factors that drive consumers to use smart home technologies and the strategies for competitive, sustainable, and secure energy [30]. The paper provides a good example and a strategy for other countries to follow.

Although many consumers see smart home technology as a recent innovation, it is actually the latest in a long line of breakthroughs in home orientation [31][32][33]. The invention of dishwashers and microwaves brought enhanced automation to the home, and with the advent of the Internet, a brand new networking infrastructure with networked functionality was introduced. Smart home technology has not only had an obvious effect on increasing the functionality of an average home but has also had a significant impact on the energy industry [34][35].

With regard to all of the things mentioned above, it is also interesting to see how the COVID-19 pandemic has shown how valuable it is to engage private customers. As spending on do-it-yourselfers increases, private customers are beginning to recognize the potential of energy management solutions for residential buildings to reduce energy consumption [36][37]. Therefore, the consumers should be encouraged to learn about the demand flexibility in their use of electricity and how to benefit from this flexibility. This might be especially relevant for the customers with inertial processes (such as cleaning, washing, or cooking dinners) independent of the time of the day and the peaks in electricity consumption who can easily shift their periods of high consumption to the periods of low electricity cost without disrupting their daily routines and reaching continuous optimization [38][39][40].

In the coming period, the supply from utilities and third parties will increase the government set standards for accessing customer data that can be used to develop new energy management products at home. Home automation suffers from platform fragmentation and a lack of technical standards, a situation where a variety of home automation devices in terms of hardware variations and differences in the software are running on them making the task of developing applications that work in different and inconsistent technology ecosystems more difficult [41][42]. Because of the nature of these devices, there are security, data security, and privacy issues, and patches for bugs in the core operating system may not reach users of older or cheaper devices. Therefore, the marketing departments of home automation companies and other companies with unique technologies must examine methods and strategies to sell their products and services to consumers. Statista Research predicts that by the end of 2018 more than 45 million smart home devices in the United States' households will be installed, making the average sales per household \$490. The annual growth rate of the home automation industry will be 22% year-on-year, or \$20 billion in the United Kingdom alone [43]. This can be attributed to a number of factors, including the continued increases in energy costs, decreasing costs of smart home technologies, current government policies, and incentives for energy consumption and increased awareness among customers of the environmental impact of consuming activities.

The smart home market will grow to become \$1.353 billion in 2025, representing a net growth rate of about 12%. Even though the sales of the smart devices are growing fast in China and Southeast Asia at the moment, North America is expected to hold the largest market share by 2025, driven by growing demand for reliable energy management systems for the home, improved security in the home and the growing popularity of smart devices such as tablets and smartphones. The recently available statistics show that 12–16% of United States households already own a smart device, leaving the entire segment of the global market unaffected by the fact that mass adoption itself is a challenge [44].

Therefore, it can be shown that the growth of the smart home industry is driven by a number of factors, including the increasing number of Internet users, the proliferation of smart devices, and the growing disposable income of people in developing countries. For example, some home automation companies are promoting their technological concepts that promise the perfect combination of luxury, relaxation, pleasure, and comfort made possible by intelligent technology. Enjoyment permeates a broad spectrum of ambience and aesthetics through networked technologies such as mood and scene lighting, automated water fountains, intelligent toilets, and audiovisual systems. Other uses include the care for the elderly citizens or the disabled when the smart home technologies monitor the vital statistics of their residents and are capable of helping them to get by in their daily lives. In summary, the smart homes are a trend that is likely to be growing in the years to come and to become ubiquitous.

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