SUSTAINABLE ENERGY DEVELOPMENT IN URBAN BUILDINGS DURING VIRUS-19 PANDEMIC

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ABSTRACT

Statistically, buildings were a very large sector consuming energy from different countries, producing many CO_2 emissions. For example, in the United States, buildings accounted for 35% of total energy consumption and 72% of total electricity consumption. In the E.U., energy consumption in the building sector was 40% of final energy consumption. The International Energy Agency (IEA) noted that existing buildings consumed 40% of the world's total energy and produced CO_2 emissions of 40% of total global CO_2 emissions. The Covid-19 pandemic outbreak, which was first identified in Wuhan, China, in December 2019, had almost touched everyone's life and affected every sector in the economy in all parts of the world. The outbreak's impact was the daily routine life had come to a standstill, many sectors such as business, transport, and many more industries had come to a halt. The curtailment in many activities reduces the energy demand and consumption, which brought damage to the energy industry. It was found that the energy demand in commercial and industrial sectors declined, but the energy demand in residential and health and emergency services increased. In order to maintain sustainable energy development consistently in buildings, It was of interest to explore how to tackle the increase of energy demand in the residential sector. However, the demand for energy at the national level increased during the Covid-19 pandemic outbreak. Programs toward zero energy building, nearly zero energy building, or net-zero energy building were options to reduce the energy demand in the residential sector. Various alternatives could be done to achieve zero energy building, nearly zero energy building, or net-zero energy building such as from demand side (demand-side management), supply-side (supply-side management), and by changing in energy consumption patterns (human factor).

Keywords: Covid-19 Pandemic, Urban Buildings, Energy Consumption, Building Retrofitting Technologies

INTRODUCTION

Buildings are a very large sector consuming energy. In the United States (U.S.), buildings account for 39% of total energy consumption and 72% of total electricity consumption. In the E.U., energy consumption in the building sector in 2012 was 40% of final energy consumption. The International Energy Agency (IEA) notes that existing buildings consume 40% of the world's total energy and produce 40% of global C.O. emissions. In most countries, the contribution of old buildings (those > 30 years old) is more than 60% of existing buildings. Old buildings are buildings that are not efficient in energy use. Buildings are a very large sector consuming energy. In the United States (U.S.), buildings account for 39% of total energy consumption and 72% of total electricity consumption. In the E.U., energy consumption in the building sector in 2012 was 40% of

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The coronavirus disease (COVID)-19 pandemic outbreak has almost touched everyone's life and affects every economic sector (Aktar et al., 2021; Qarnain et al., 2020). This outbreak was first identified in Wuhan, China, in December 2019 and continues to this day in all parts of the world. The impact of the Covid-19 pandemic outbreak is that the daily routine of life has come to a standstill. Many sectors such as businesses, transport, and many more industries have come to a halt. During the lockdown (i.e., limited restriction, partial lockdown, full lockdown), curtailment in many activities such as mobility, economic activity, construction and manufacturing, dropped the global energy demand. The decline in energy demand and consumption brings damage to the energy industry. Only important sectors like healthcare, food and beverages, energy, communication and I.T., financial, logistics, construction, strategic industries, basic services and public utilities, business sectors that serve daily needs have been permitted to operate (Pergub DKI No. 33/2020). Many countries include Indonesia-imposed curfew, mandatory stay-in-home orders and lockdown of cities and countries. Due to the forced restrictions "stay in home", the people's daily needs would be affected, one of them is the energy consumption in the residential buildings.

This study tries to analyze the energy consumption that continues to increase in urban buildings in the event of continuing COVID-19 or a future pandemic or other possible extreme events. In addition, this research also tries to explore various innovations to overcome the continuing increase in energy consumption so that sustainable development goals can be achieved from the perspective of urban buildings.

IMPACT OF COVID-19 PANDEMIC ON ENERGY CONSUMPTION

The COVID-19 pandemic impacts energy consumption in various sectors of the economy, such as the transportation sector (for example, public transportation, private cars), the building sector, and others. Regarding the building sector, there are several types of urban buildings with different functions that have been affected by the Covid-19 pandemic (see Table 1). However, the impact of the COVID-19 pandemic on energy consumption in these buildings varies. Most of the buildings have experienced a decrease in energy consumption due to the COVID-19 pandemic, and very few have experienced an increase in energy consumption, for example, residential buildings. It is because of the lockdown orders implemented in the urban area.

Some surveys and studies have been done to analyze the impact of the COVID-19 pandemic on demand for energy (see, e.g., Geraldi et al., 2021; Jiang et al., 2021; Siddique et al., 2021; Cheshmehzangi, 2020). The results show that short-term demand decreased when implementing lockdowns, but demand is expected to recover gradually after relaxing locking action. The downturn-recovery dynamics will go away when the second wave of the pandemic was on its way. Commercial and industrial demand is decreasing, but residential demand is increasing. At the district level, the demand for thermal energy for buildings decreases, but the demand for buildings increases. The peak times for electricity demand also change. Demand during normal morning peak times decreases, but at potential new peak times may increase.

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Table 1. Types of Building and Their Functions

Types of Building	Functions
Residential	Dwelling
Office	Office, Council Office, Government Office, Business Park, Financial and Professional Services
Retail	Shopping, Shopping Centre, Supermarket, Superstore, Retail Park, Market
Local Service	Bank, Chemist, Community Centre, Post Office, Church, Mosque, Synagogue, Laundrette, Library, Youth Centre
Leisure-Restaurant	Art Centre, Bing Hall, Cafe, Bar, Museum, Restaurant, Public House, Take Away, Nightclub, Public Baths
Education	School, Nursery, Primary School, Secondary School, University, Further Education College, High School
Health and Emergency Services	Hospital, General Hospital, Dental Hospital, Fire Station, Police Station, Children's Hospital
Hotel-Accommodations	Hotel, Guest House, Hostel, Youth Hostel, Motel, Inn
Industrial	Factory, Manufacturing, Industrial Estate, Electricity Sub Station
Transport	Bus Station, Coach Station, Railway Station,Filling Station, Garage
General Commercial	General Commercial

Consumption of private cars decreased during lockdowns but increased sharply after the lockdown is lifted. What may be worse is that 56.3% of respondents will reduce bus use post-COVID-19. Energy demand for producing regular products (e.g. clothing and travel necessities) decreases, but producing medical products and personal protective equipment (PPE) is increasing.

It was reported that a total 626.6 Mtoe (Mt of oil equivalent) reduction calculated for eight regions worldwide. The order of decreasing energy demand from the eight regions ranked from the U.S., European Union, China, India, Japan, Africa, Southeast Asia (SEA) to South Korea. As a result, the year-on-year average growth rate in 2019 is calculated as 1.1%, and the year-on-year average growth rate in 2020 is calculated as 6.2%.

The Covid-19 pandemic also affects the energy intensity. Although the gross domestic product (GDP) decreases with the decrease in energy demand, the projected energy intensity in China, the U.S. and Japan have varying values. Under the two predicted scenarios, the U.S. will have a high rate of change in energy intensity (+29.3%), followed by Japan (+7.8%), while China did not show any significant changes (+2.8%). Like China, energy intensity in the E.U. is projected to experience a slight increase at +1.03%, concluding with an 8.3% decline in GDP and an 11% decrease in year-on-year energy demand.

The COVID-19 pandemic has a significant and profound impact on various aspects of the lives and livelihood of people around the globe due to the lockdown (i.e. restricted restriction, partial lock, or full lock). The lockdown restricts multiple activities, e.g. mobility, economic activity, construction and manufacturing, which reduces global energy demand. In Indonesia, the national electricity consumption amid the Covid-19 pandemic recorded a growth of 5.46 percent as of June 2020 compared to June 2019 (Liputan6.com, 2020). However, even though it had increased nationally, the prognosis for electricity consumption fell to 1,084.36 kWh per capita until June 2020. This figure is down 0.79 percent compared to the first quarter of 2020, which amounted to 1,093 kWh per capita. In terms of islands, one system experienced negative growth, namely Bali, which fell 17.79 percent. Then when compared to January 2020, the electricity consumption has decreased by up to 7.06 percent. Based on the islands, eight systems experienced a decline of more than five percent, namely West Sumatra by 7.12 percent, South Sulawesi and Southeast Sulawesi by 7.68 percent, and Bali by 32.87 percent. Then East Java 6.33 percent, Central Java 6.28 percent, West Java 10.57 percent, Banten 12.82 percent, and Disajaya and Tangerang 5.62 percent. Currently, PLN's electricity supply is very abundant. However, the 3,000 MW generators are not operating due to the Covid-19 outbreak, which decreased PLN's electricity sales by 6.33 percent compared to the first quarter of 2019.

As reported by Pikiran Rakyat (2020), in West Java, the consumption of electricity for household customers during the work from home (WFH) period continued with the large-scale social restrictions (PSBB) policy increased by 13%-20% per month. On the other hand, industrial electricity consumption fell 40%, business fell 20%, social and government each fell 10% (PT PLN, 2020). In general, electricity consumption in West Java in last May 2020 fell 16% compared to the normal period before WFH. "Usually electricity consumption grows 3% per year. If the growth rate is taken into account, the total decline in electricity consumption last May 2020 was 19%. The increase in household customer groups' consumption occurred because people were more active at home during that period. This condition caused electronic devices to increase and ultimately contributes to the increase in electricity bills. During WFH, people used T.V.s, lights, and air conditioners. Approaching Lebaran, some people also used electric ovens to make cakes. The contribution of electronic devices, such as T.V., to electricity consumption, was around 15%-20%. Lighting equipment contributed 15%-20%, while A.C. reached 60%-70%. It led to an increase in electricity consumption during WFH and led to an increase in the electricity bill on the June 2020 bill. About 98% of the cause of the increase in electricity bills in June 2020 was due to the increase in customer usage.

Recent analyses of several countries' electricity consumed since the COVID-19 lockdown order revealed a significant drop in electricity demand (Krarti and Aldubyan, 2021). In particular, Italy's electricity has fallen 28% after 42 days since the start of the lockdown. Like Italy, the U.S. has experienced a significant drop in electricity demand, with the highest drop occurring on 27 March 2020. The limited data available for China shows that March saw the highest reduction in electricity demand. These changes appear to follow the rate of spread of COVID-19 in each country, with electricity demand significantly lower for China in March (11.5%), for Italy and the United States in April (19%), and for India in May (9.5%). In the U.S., the impact of COVID-19 on energy demand due to stay-at-home orders and associated restrictions depends on decisions made by state and local governments. New York City, the city in the U.S. most affected by COVID-19 in this period, experienced a significant drop in energy demand, especially in May, with an average decline of 17% compared to the same month in 2019. Electricity demand in Los Angeles most affected during April 2020, with an average decrease of 12%. The decline in energy demand was not large in Chicago (around 7% for April and May) and was negligible or slightly higher in Houston (energy consumption was 4.6% higher in April and unchanged in May). The most recent data for July 2020 shows that, compared to the same period in 2019, the peak rate of reduction in electricity consumption (weather correction) in France, Germany, Italy, Spain, UK, China and India during the lockdown period was more than 10.%. Weekly energy demand is expected to be cut by 9% under the restricted limit, 17% under partial lock and 24% under full lockdown.

It seems that the lockdown due to the COVID-19 pandemic has an impact not only on the electricity demand (demand side) but also on the supply side. Reduced electricity demand has an acute impact on the generation and supply of fossil fuels such as coal rather than cheaper renewables. Renewable energy appears to be consolidating its position in the electricity mix to meet depressed electricity needs. For example, renewable energy surpasses coal and nuclear to become the second-largest source of electricity after natural gas in the U.S. A similar trend has been observedin China, where renewable energy is the second-largest source of electricity after coal. In Europe, renewable energy is increasing its dominance in the electricity mix over nuclear and natural gas. In particular, the contribution of renewable energy (i.e. solar and wind) variables to the electricity mix reached 90% in Germany, 80% in Spain, and 65% in Italy during the lockdown period from Marchto May 2020. The decline in energy demand and consumption is wreaking havoc on the energy industry. For example, the COVID-19 pandemic led to the bankruptcy of at least 19 industrial energy companies in the United States. Reducing electrical energy demand would decrease the electricity generation from the power plants or decrease the power plants' capacity factor. As a result, the cost of producing electricity would increase. The increase in the cost of producing electricity could affect the lifetime of the energy industry.

ENERGY CONSUMPTION REDUCTION TOWARDS SUSTAINABLE RESIDENTIAL BUILDINGS

The target of reducing energy consumption in existing residential buildings is sustainability housing. As noted by Jones (2012), sustainable housing refers to a variety of content. First, the house must be sustainable in physical conditions, such as low energy, water and material use. Second, a sustainable house must be resilient and adaptable to changing functions or climate change. Third, support 'welfare' and a healthy lifestyle for the community. Also, it must be part of a socially and economically dynamic community. Fourth, it is about measurable physical attributes and the design aspects of creating space and responding to the aesthetic and cultural identity. Finally, it should encourage a sustainable lifestyle and environment for its residents and the surrounding community.

In order to achieve sustainable energy development in residential buildings, people in a residential building is expected to be able to meet its electrical energy consumption from the electricity it generates. The examples are through rooftop solar PV (solar PV installed on the roof of the building, or Building Integrated Solar PV (BIPV) as shown in Figure 1. Buildings like this usually have characteristics that have low energy requirements. If the electricity generated by the building can meet the electrical energy consumption of the building, then the building is called a Zero Energy Building (ZEB). If the electrical energy consumption of the building is very high, likely, the energy needs cannot be met by the electrical energy produced by the building. To overcome this, we can get the shortage of electricity consumption from the building from renewable energy sources from around the building. In this way, a building whose electricity consumption is met is called a nearly Zero Energy Building (nZEB). If the shortage of electrical energy cannot be fulfilled by the energy generated around the building, and the renewable energy source must be imported from other places (from outside the area of the house), then the building is called the Net Zero Energy Building (Net ZEB) (Marszal, 2012; Pless and Torcellini, 2010).

Figure 1. Building Integrated PV (BIPV) (PV- Façade)

There are three main solutions for improving the energy performance of existing buildings towards sustainable energy development in residential buildings, they are:

(i) Modify the walls of the building (building insulation),
Modifying the building wall is passive energy efficiency measures related to retrofit steps carried out on the condition of the existing building parts, such as retrofitting external walls, upgrading existing windows, and green roofs to improve sustainable buildings (Lin et al., 2020).

(ii) Reducing energy consumption,
Reducing energy consumption is to activate energy-efficient measures. It includes improvements to building service systems and energy-efficient control strategies. It reduces energy consumption, such as installing lighting sensors, efficient lighting systems, improving building airtightness, and smart building management systems for temperature control/heating/cooling. Human behavior changes the energy consumption patterns of building occupants in various ways, such as individual metering. In particular, some energy efficiency retrofitting steps are easy for households to implement, including replacing all compact fluorescent lamps (CFL), especially incandescent lamps, with LED lighting fixtures. Indeed, LED fixtures can reduce electricity consumption by up to 40% compared to CFL and by more than 800% compared to a 60 W incandescent bulb.

(iii) Promote on-site energy production by utilizing renewable energy sources (Tonne, 2021).
Promote on-site energy production by utilizing renewable energy sources are energy efficient measures that cover the use of renewable energy, including:

- Install a building-integrated Photovoltaic (BIPV) system to generate electricity using roofs, walls, windows, and shading devices. For example, the BIPV has shown that it can reduce heating and cooling requirements and generate electricity to achieve a near net-zero energy state for residential buildings (Fong and Lee, 2021). The PV system is shown in Figure 2.

- Install on-site PV system (Figure 2) or Wind turbine system (Figure 3) or integrate the PV system and the Wind Turbine system (Figure 4). Then, the system can be connected to the grid, as shown in Figures 5 and 6.
- Consider an integrated solar system to combine PV and solar thermal technologies such as the thermal photovoltaic collector and the photovoltaic module - integrated storage collector solar water heater (Lin et al., 2020; Luoa et al., 2020).
- Deploy building-integrated solar thermal systems to supply most household hot water and space heating needs for various climates.
- Determine the solar cooling technology to meet the needs of air conditioning.
- Use solar thermal cooling, solar electric cooling, solar combined cooling: solar thermal collector, and ground source heat pump.

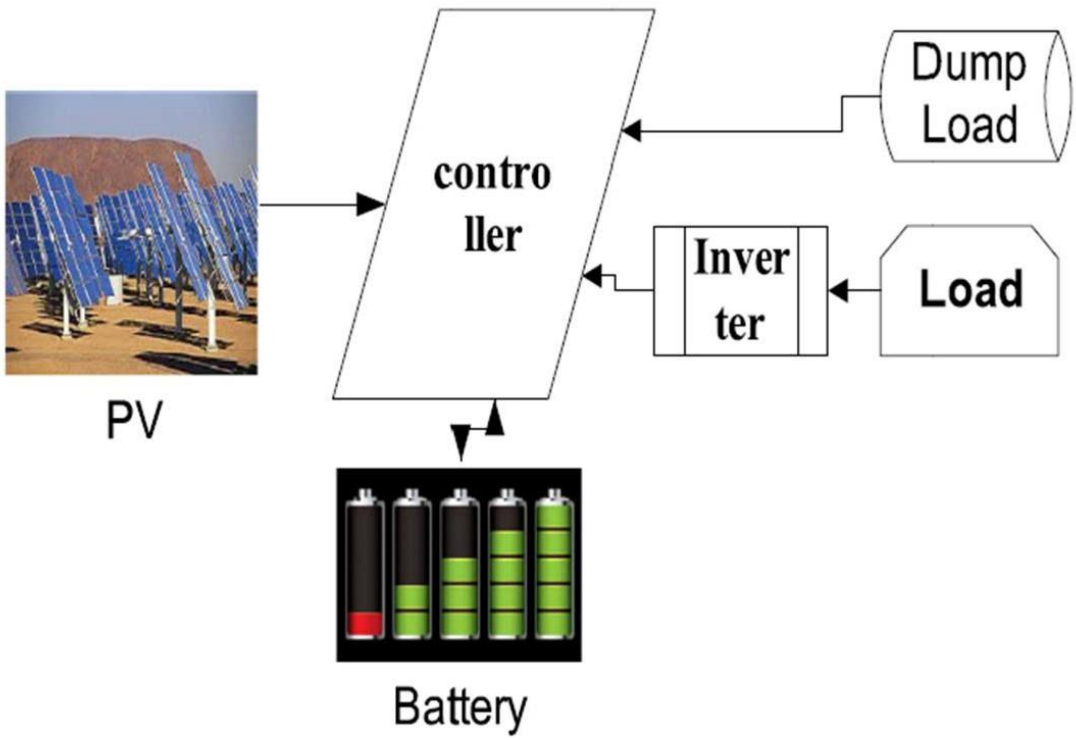

Figure 2. Solar PV System

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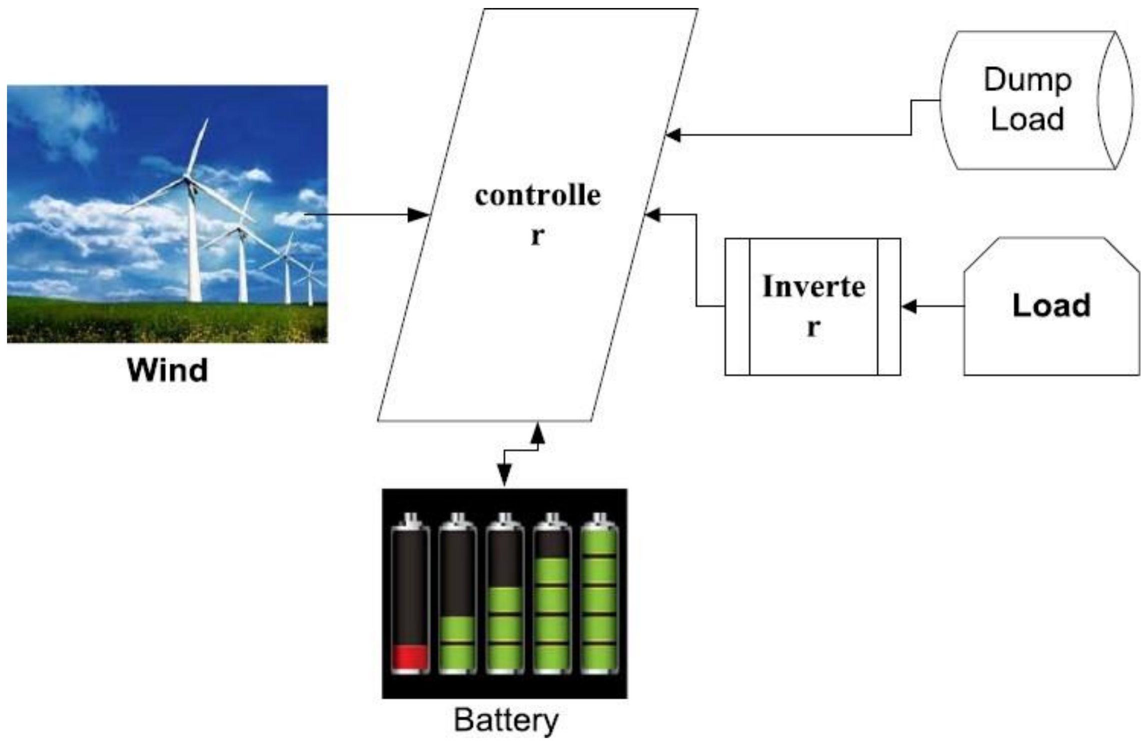

Figure 3. Wind Turbine System

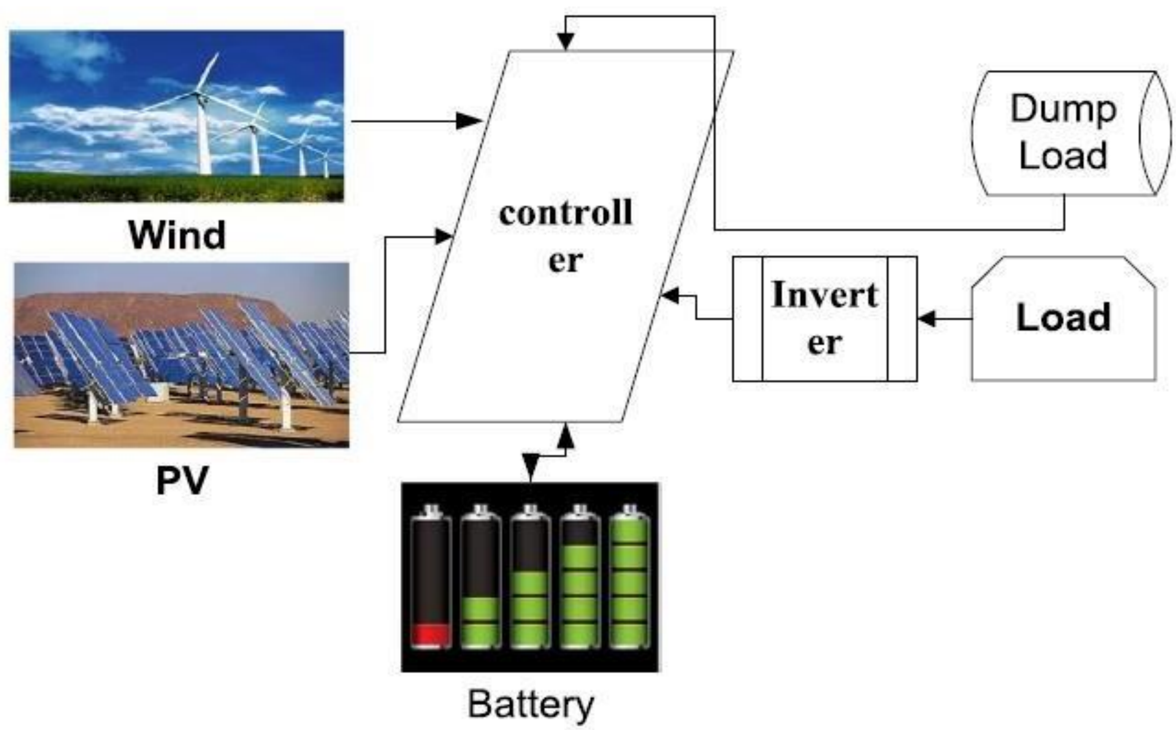

Figure 4. Hybrid Wind Turbine and Solar PV Systems

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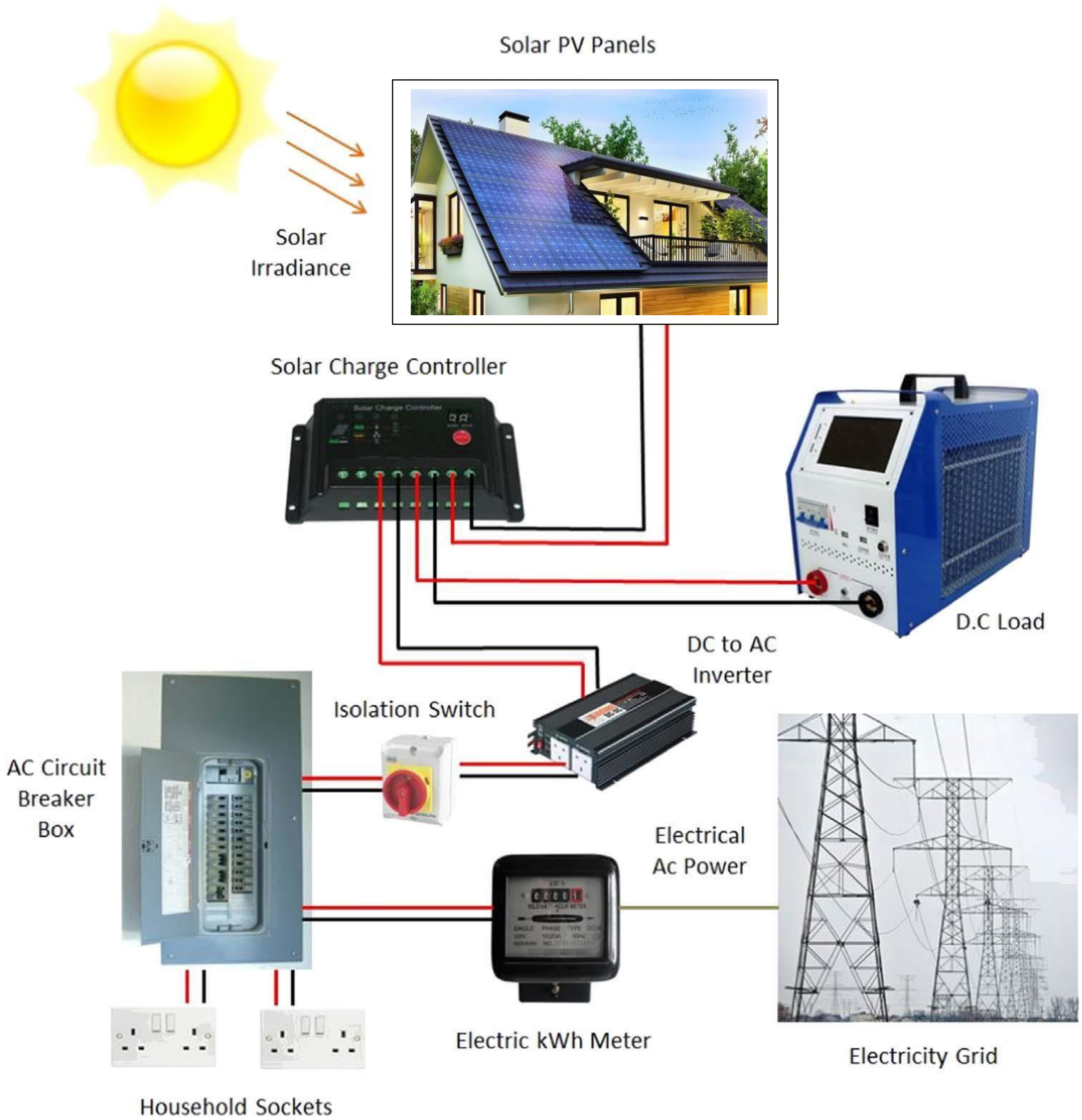

Figure 5. Photovoltaic (PV) System Connected to the Grid without Battery Storage

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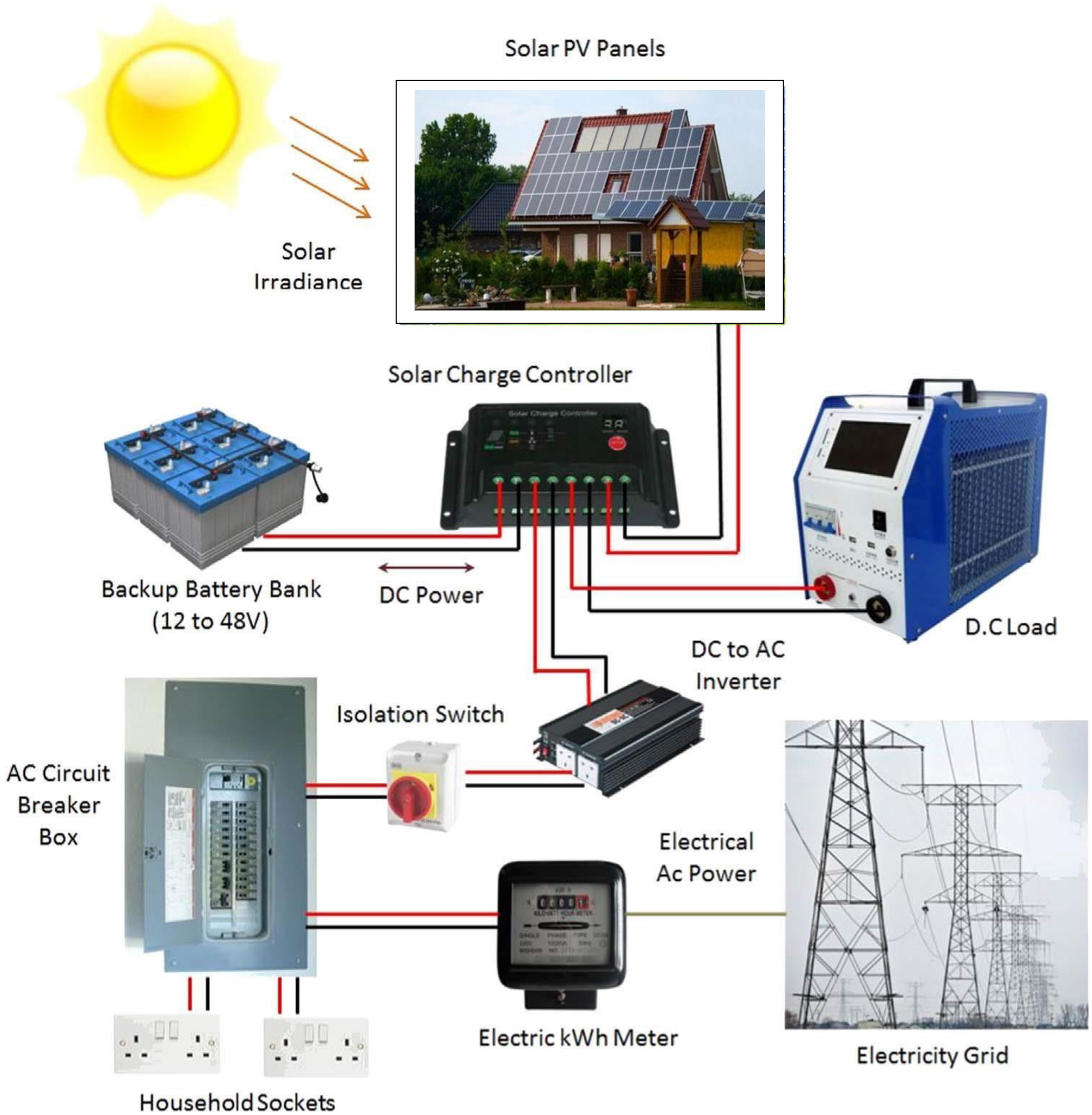

Figure 6. Photovoltaic (PV) System Connected to the Grid with Battery Storage

BUILDING RETROFIT TECHNOLOGIES

Table 2 illustrates the main types of possible retrofit technologies used in building applications (Ma et al., 2012).

Table 2. Category of Building Retrofit Technologies (Ma et al., 2012)

Category	Building Retrofit Technologies
Supply-side management	– Solar thermal systems – Solar PV/PVT systems – Wind power systems – Biomass systems – Geothermal power systems – Electric system retrofits, etc
Demand-side management	– Building fabric insulation (i.e., roof, wall, etc) – Windows retrofits (i.e., multiple glazing, low-E coatings, shading systems, etc) – Cool roof and cool coatings – Airtightness, etc. – Control upgrade – Natural ventilation – Lighting upgrade – Thermal storage – Energy-efficient equipment and appliances – Heat recovery, etc.
Human factor	– Comfort requirements – Occupancy regimes – Management and maintenance – Occupant activities – Access to control, etc.

Building retrofitting technologies can be categorized into three groups, namely supply-side management, demand-side management, and changes in energy consumption patterns, namely the human factor. Retrofitting technologies for supply-side management includes retrofitting of the building's electrical systems and the use of renewable energies, such as solar hot water, solar photovoltaic (PV), wind energy, and geothermal energy, as alternative energy supply systems to provide electricity and/or thermal energy for the building. Since the last few years, there has been increasing interest in using renewable energy technology to retrofit buildings due to increasing awareness of environmental issues. The use of renewable energy technologies can provide more benefits for commercial office buildings. The utility tariff structure includes electricity prices disaggregated by the time of use and applied demand charges. Retrofitting technology for demand-side management consists of strategies to reduce buildings' heating and cooling requirements and the use of energy-efficient equipment and energy-efficient technologies. The demand for heating and cooling of buildings can be reduced by reinforcing building fabrics and other advanced technologies such as airtightness and window shading. Low energy technologies can include advanced control schemes, natural ventilation, heat recovery, and thermal system storage. For different retrofit measures, the costs of implementation and the potential benefits that can be achieved differ. It can be found that retrofitting of fabrics, building service systems, and measurement systems require fewer investment costs while providing far more environmental benefits than retrofitting using renewable energy technologies. Therefore, the project's targets and the client's concern for the environment have a significant impact on the choice of retrofit technology.

CONCLUSION

This study analyzes the impact of the Covid-19 pandemic on energy consumption in urban buildings. The results show that electrical energy consumption at the national level has decreased due to the Covid-19 pandemic. The reduced electrical energy consumption was caused by the lockdown order where people had to work from home. As a result, energy consumption in residential buildings increased. The increase in the consumption of electrical energy in residential buildings will cause buildings to become a major source of CO_2 emissions, making buildings no longer support the principles of sustainable development. To solve this problem, the existing buildings must be converted into zero energy building (ZEB), nearly zero energy building (nZEB), or net-zero energy building (Net ZEB). The energy performance of thebuildings can be improved by introducing energy-efficient equipment at the demand side (demand-side management),introducing renewable energy technologies and electrical system retrofits at the supply side (supply-side management), and also by changing energy consumption patterns (human factor). The implication of this study is the need for policies that regulate minimum energy consumption in the housing sector and encourage the use of renewable energy in residential buildings. For further research, it is important to analyze other impacts on residential buildings besides CO_2 emissions due to the COVID-19 pandemic, such as reducing plastic waste.

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