



Research article

Framework for the analysis of renewable energy grid policies in the context of COVID-19



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ARTICLE INFO

Keywords:

Covid-19
Solar energy
Public policy
Photovoltaic systems
Finance

ABSTRACT

COVID-19 is a severe global pandemic that has caught the whole world unprepared. In the absence of a clear timeline for this pandemic to end, it is need of the hour to investigate the effect of this pandemic on both previous and anticipated investments. Global economic unrest has hindered the ramping deployment of Renewable energy projects. The most quick actions that may be taken to mitigate the effects and to up-rise the investment portfolio policies are a very critical tool in hands of government for a very immediate effect have also been made without keeping the context of COVID-19 into account. New variants of diff rent nature are being discovered and every now and then new lock downs are happening. In this context different policies have to be evaluated under the pandemic scenario. A case study of a large scale renewable energy project for a higher education institute in Pakistan is being used to measure the difference during COVID and pre COVID times. This paper provides a framework to investigate the impact of COVID on renewable energy system projects under current net-metering, net-billing and self-consumption policies. A recent investment in a photovoltaic system is assessed based on previously projected financial benefits versus the pandemic effected ones. This research concludes that investing in photovoltaic systems are still a viable option even in an extreme pandemic situation with less than 0.5 years increase in payback period, and the government can still provide a stimulus for investing in green energy by implementing net-metering policies on a larger scale.

1. Introduction

COVID-19 global pandemic has severe consequences affecting public health and livelihood, comparable to the Spanish flu in the early 20th century. It has proven fatal and critical for millions of people. Moreover, drastically affected the livelihood of a large percentage of the world population. As a result, it has produced a strain on market purchase trends and has locked wealth in vaults, thus has created economic unrest causing daily wagers to be under the most strain. Study done in [1] shows unemployment caused due to COVID-19 lockdowns is worsening life threatening situations. According to the Index of Global Economic Policy Uncertainty, this pandemic is even worse than the financial crisis after the collapse of Lehman Brothers, despite that a similar scenario was observed during the 2008 economic crises however even that did not have this much of drastic effects worldwide [2].

Consequently, Governments have to split the funds into health care and public support. Either constrained by financial outlook or fearing a higher level of infection, the public prefers staying at home; far lesser people are on traveling via road and air. Industries and offices are working on their lower capacity. Such changes have profoundly affected global energy consumption. Time can be divided into pre and post COVID era for a meaningful discussion in this paper.

Multiple renewable energy projects are to be deferred until the pandemic is under control based company Morgan Stanley planned a decrease in photovoltaic system installations from 48 to 17 percent in the second, third, and fourth quarter of the year 2020, which did not materialize however the COVID scenario forced the company to make such polices similar is the case with other investors also [3]. The decline in ARE projects have significantly increased especially in under developing countries [4]. During pandemic, it is observed the demand for electricity

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<https://doi.org/10.1016/j.heliyon.2022.e10123>

Received 30 June 2021; Received in revised form 20 August 2021; Accepted 25 July 2022

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in this pandemic is significantly by 14% [5]. Globally the energy consumption drops by 4% in 2020 which was increasing with the rate of more than 2% for last 10 years [6]. In pre-COVID times, renewable and sustainable sources of energy were leading the path towards the green revolution. This pandemic has struck the manufacturing and services sector, disturbing the manufacturing facilities, supply chain, and sales. International energy agency (IEA) deems COVID-19 as the biggest shock since the second world war. It has projected an overall 5–6% decrease in energy and electricity demand whereas developed economies like the US (9%) and constituent countries of the European Union (11%) will face even higher consumption reductions [7]. However, the effect of pandemic has badly hit the developing countries. Countries like Pakistan, India, Brazil, Mexico and South Africa are the among the top nations to be affected. One of the major driving factor to this affect is the brisk deflation of local currencies, specially Pakistan where inflation has reached new heights and the effect has also been on solar PV industry which has lead to increase in capital cost [8, 9]. Therefore, in order to revive the sector and reduce the impact of pandemic on it, several beneficiaries and promotions from the government's side to boost private investment in it. However, an intelligent management for handling the situation is required and introducing a favorable framework can turn this situation to be more of benefit than a curse for the renewable sector [10]. This reduction in electricity demand has increased the share of renewable energy in the electricity supply compared to coal, gas, and nuclear. The utility of increasing RES (Renewable Energy Sources) is price competitive at a grid level. The statistics have confirmed that RES share has been increased remarkably around the globe, as shown in Figure 1 [5] the load has decreased drastically thus the renewable energy input in the energy mix remains the same as before consequently increasing the RES share in the grid.

A significant increase in solar PV deployment has been seen in the last two decades globally due to the introduction of netmetering policies [11, 12, 13, 14, 15, 16]. Net-metering allows the consumers to become prosumers by feeding power to the grid. They don't need to invest in energy storage; thus reducing the initial cost of the solar PV systems. This net-metering policy made investments in solar PV very lucrative, and the IRR went up to 22–25 percent. Whereas, the mass scale feed-in tariffs (FITs) and feed-in premium systems (FIPs) are globally the most widespread instrument to ease the deployment of RES. Net-metering and net-billing policies, have made a similar effect in the small scale domestic and commercial deployment. As many as 62 Countries apply some variant of feed-in system [17]. The reports have shown that in April 2020, zero-carbon electricity systems, solar and wind have reached a record-high share of 23% across the EU and UK [5]. Likewise, Ørsted (A RES power company) during the COVID-19 achieved a 27% increase in profits from continuing operations in the first quarter.

COVID-19 pandemic has positively impacted the efforts put up towards more sustainable energy. This pandemic now affects this brief

transitional period of fossil fuels to renewable sources of energy. This brings up a big question of the overall sustainability of ongoing renewable energy projects and their financial outlook. It can also be taken up as an opportunity to study the impacts of such landscape shocks along different transitional trajectories, whereas sustainable transitions take several years to mature. Past landscape shocks were short-lived with only sudden implicit consequences that changed the overall global view of energy production and sourcing. For example, nuclear incidents of Chernobyl in 1986 and Fukushima in 2011 or the oil crisis of 1970 [18]. A published research [19] suggests the emerging market countries which are primarily are developing countries have shown higher level resilience from 2008 Financial crisis than even more faring and richer of G7 countries during and aftermaths of this crisis. However, COVID-19 is a more global and sudden shock that can have a long-lasting effect on lifestyle triggering a macroeconomics crisis around the world in the early months of year 2020 [20]. With the ever-worsening outlook of pandemic and in the absence of any proven remedy else than a new born vaccine [21, 22] provided current crisis of more contagious COVID-19 strains, we can clearly say that this pandemic will be offering a completely new perspective to investment security and sustainable renewable energy transition, likes of which has never been taken in account in planning newer deployments.

The impact of pandemic has been huge and the investments trends in the renewable energy sector have changed. The research in this article evaluates various Renewable energy policies and how they mitigate the effects of pandemic [23]. The paper discusses the COVID-19 scenario in detail with regards to Pakistan in section 1. The renewable energy scenario in Pakistan is explained in section 2. The case study for the National University of Sciences and Technology (NUST) has been presented in section 3, whereas section 4 contains the results and conclusion.

2. COVID-19: Pakistan's economic perspective

Coronavirus (COVID-19), which was first detected in Wuhan, China, has been declared a pandemic by the World Health Organization (WHO) because of its rapid spread. People from all over the world have been affected by it. According to WHO, Pakistan being a developing country with lower health service facilities and economically fragile position, has been one of the most affected countries. In June 2020, Pakistan was among the countries having the highest cases reported per day in the world. The country shares its border with multiple epicenters: India and Iran. In particular, currently India is facing the worst COVID-19 crisis across the globe. Second most populous nation is bracing itself for a more comprehensive lockdown to break the second viral wave creating more uncertainties in economic activities. Pakistan is facing the third viral wave and is in a state of complete lockdown to mitigate the effects of various variants of COVID-19 causing unprecedented spikes in newly detected cases.

Pakistan Federal Health Minister confirmed the first COVID-19 patient on February 26, 2020 [24]. The government acted swiftly to impose a ban on nearly all activities, including travel and gathering. Educational establishments were the first to comply with the government's severe closure order and anticipated to be one of the final institutes to open, similar to the prior Scenario COVID-19. Academic activities, on the other hand, were never prohibited/discontinued, and distance learning activities swiftly took their place in a short period of time. This brief era was used to establish the infrastructure required to do such operations. All educational establishments were closed for the first time between March 1st and March 13th, 2020 however, this was to continue for the following year as well [25], during which the majority of academic activities were conducted online from home.

Due to economic collapse and the fear that people might die of hunger rather than the epidemic, the lockdown was relaxed under preventive conditions by resuming some critical operations. While the ease of shutdown may have been beneficial to the country's economy, it resulted in a significant spike in the number of confirmed COVID-19 cases. On

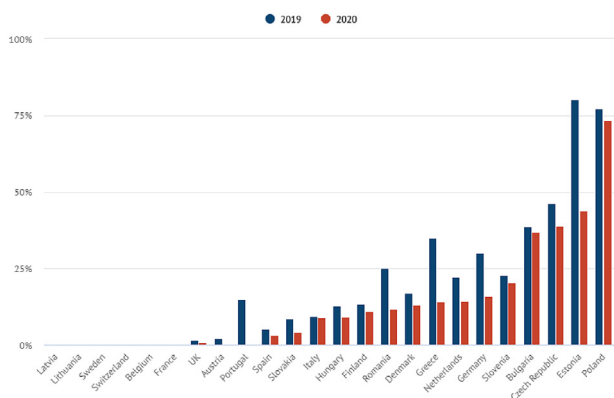


Figure 1. Electricity demand change in pandemic era.

May 9th, 2020, the Pakistani government removed the lockdown, declaring that the country could no longer tolerate the impacts of the lockdown due to its terrible poverty. Educational institutions remained closed; colleges resorted to online education, and students were given summer vacations. The consequences of releasing the lockdown were severe, as many failed to take preventative steps, and Pakistan's COVID-19 case count increased to 100,000 in less than a month [26].

Pakistan just missed its opportunity to flatten the curve by imposing a temporary lockdown. Pakistan's administration chose a strategic lockdown strategy, closing down locations with a high number of confirmed cases. Country performance was exemplary and the country again controlled the spread of virus and opened up however the victory was short lived thus the country again went into smart lock downs with work from home policies in November, this reduced the COVID-19 cases. However a third smart lock down was imposed soon after reviewing the surge in COVID-19 currently the country is going towards a complete lockdown once again to control the surge keeping in view the rise of cases in the neighbor country india.

Figures 2 and 3 shows the rising curve of COVID-19 confirmed cases and deaths from day zero of disease spread in Pakistan. We can see from the exponential rise of the curve that it is nowhere near flattening. The number of new confirmed cases increases day by day and is around 4,000 new cases in 24 h, reported mid of May 2021. The whole world is facing economic crises due to this pandemic, but developing countries like Pakistan are struggling to keep up with world economics. Pakistan was already going through mild recessions even before the period of COVID-19 spread due to several reasons,

- 1) In the current fiscal year 2020, the State Bank of Pakistan (SBP) feared the country's growth might fall below 3.5%, while IMF predicted it to be even lower than 2.4%. Pakistan is facing the price inflation issue without much development in the infrastructure [28].
- 2) Pakistan faced several security threats, which also involved physical activities from its neighboring country during the past year 2019.
- 3) Low tax base collection, import dependencies, increasing debt forcing the government to take more loans to keep it functional.
- 4) Locust invasion started early previous year 2020, which destroyed the agricultural produce followed by heavy rains between seasonal changes [29].
- 5) Expenditures related to health care were already not sufficient enough for the public, and this pandemic forced the government to spend more on health-related activities.

Nonetheless, IMF (International Monetary Authority) has predicted Global GDP to fall by 3% this year, five times more than the period occurred between 2008-2009 [30]. Keeping in view all the reasons mentioned above and the effects of lockdown due to COVID-19, the government decided to trade off the economy over the lockdown to stop the spread of the pandemic and keep the economy stable. Still, the government is trying to implement standard operating procedures (SOPs)

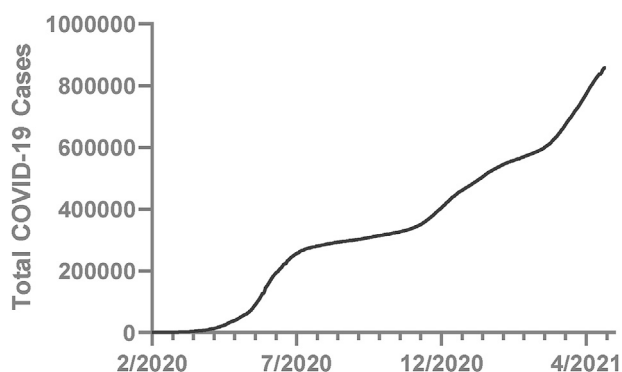


Figure 2. Total COVID-19 cases in Pakistan [27].

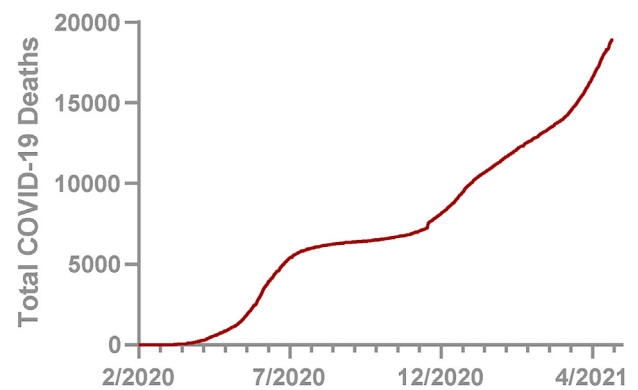


Figure 3. Total COVID-19 related deaths in Pakistan [27].

for all the running organizations and businesses, implementing new policies and sealing down the areas with many infected cases. The total tally has gone above 865,000 till the mid of May 2021 in the third wave, yet the curve is still following an exponential rise. The education system is most impacted genres of industry around the world, due to the closure of schools, colleges and universities globally. According to UNESCO, around 188 countries have closed down their educational institutions until the betterment in the pandemic situation [31].

Due to the rise in cases, the educational institutes are still closed till further notice; all over Pakistan, smart online systems are being introduced by Higher Education Commission (HEC) Pakistan under the name of Distant and Virtual Learning [34].

Considering all these factors, we can not say when the educational institutes will resume routine operation because that is very risky [35]. We may have to face the multiple years with universities and schools closed. According to UNESCO, 1.5 billion students have been affected by this pandemic. This has lessened the energy load stress for institutes up to 40% a similar scenario has also been observed world wide in various other educational institutes also [32, 33]. Simultaneously, the residential load of domestic users has been increased, on average, by 25%. This change in electricity consumption patterns is because people stay, work, and take classes online from home. The change is energy consumption for the post pandemic year can be observed in Figure 4. The institutes and commercial buildings that are equipped with RES now have excessive energy. Which is going to waste as it lacks net-metering, Feed-in laws (Feed-in Tariffs (FITs), and Feed-in Premium (FIPs) systems) [36]. If these buildings support FITs, it would meet the increased demand of households and stream energy into the grid. We can conclude that the educational institutes energy consumption patterns have been drastically reduced during this pandemic thus they can be made into a perfect case study to measure pandemic effects for a worst case scenario.

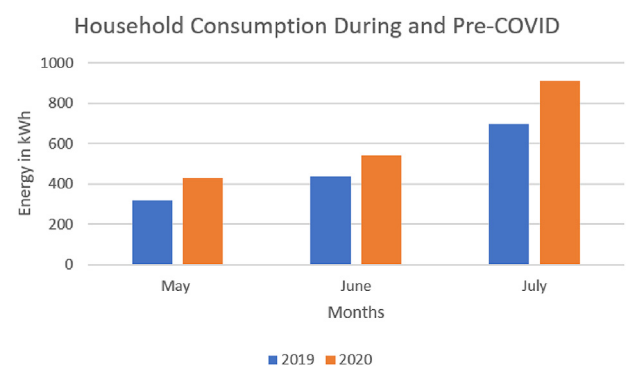


Figure 4. Increase in household load consumption contrary to educational institutes.

Table 1. Renewable sources in Pakistan.

Source	Location	Deployment Capacity (MW)
Hydral Power	Gilgit Baltistan, KPK and Azad Jammu Kashmir	7455
Wind Turbines	Gharo, Jamphir, Kitty Bandar, Karachi up to Hyderabad, Islamabad and some area of KP	695
Photovoltaic Energy	Bahawalpur, Thar and Cholistan Deserts in Punjab and Sindh, Quetta and Peshawar in KPK and Balochistan	81
Biomass Based Generation	Central Punjab and Upper Sindh	564

3. Renewable in Pakistan

Distribution generation sources are the most diversified combination of electricity generation for any area. The term Distribution Generation (DG) is mostly defined in different perspectives and various ways as in literature, various authorities have defined it according to their assessment and focus of research. Distribution generation sources are used to provide active power for the distributive network directly. This ensures many advantages, such as reducing power losses, better economic dispatch operation, area-specific network generation, reduction in transmission losses, high reliability, improved power quality, dispersed energy production, fewer carbon footprints, and improved power capacity. Despite the demerits of deploying DG sources, such as the bi-directional power flow cases reduction in voltage unbalance in the system, sufficient headway has been made in this technology. Such a system can be easily implemented in developing countries like Pakistan.

With the advent of distributed generation sources, more penetration of renewable energy sources at the distribution network levels has become possible, making it easy for the network operator to perform monitoring, regulation, and corrective actions. The power produced by renewables is intermittent and dependent upon meteorological conditions. Since these conditions vary along the geographic terrain of a country, the geographic dispersion of renewable is preferred for maximum utilization of different diversified renewable sources. This deployment scheme of renewable allows near-uniform energy to be fed to the power grid. Therefore, energy production from renewables and geographically distributing them across the grid can increase the reliability of renewables and overcome their reliability issue. There will be no need to raise the bar of system spinning reserves requirement in such a configuration.

Pakistan has been bestowed by mother nature with prodigious weather and rich geography. From sky-touching and the world's tallest mountain ranges of Himalaya, Karakoram, and Hindukush in the north to the 1046 km coastline in the south and widespread stretches of scorching desert along the eastern border with India and Western border with Iran, Pakistan experiences extremely diverse weather simultaneously

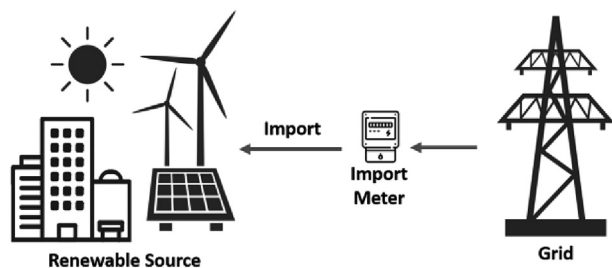


Figure 5. Self consumption.

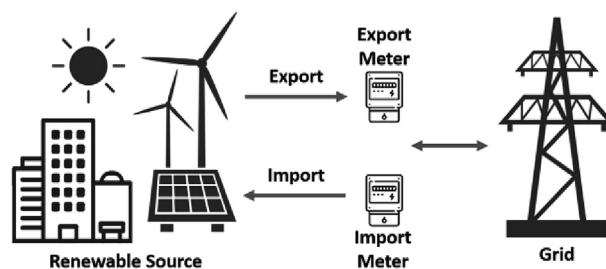


Figure 6. Net-billing.

throughout the country posting an ideal condition for the installation of the different diversified renewable source. Some of such DG sources and their potential location in Pakistan are presented in Table 1.

However the PV systems are such that they can be deployed mostly all across the globe with various results. The current energy harnessing scenario from diversified DG sources in Pakistan is getting better with each passing day. Microhydro plants have been installed in KPK and Gilgit Baltistan, producing more than Mw [12]. Similarly, biogas installation is producing 1800m³/day. The incumbent government has set the ambitious targets of increasing these sources' production by approximately 100% until 2020 [13]. Similarly, substantial investment is being made in the photovoltaic sector, such as Quaid e Azam solar power park with a cost of 131 million dollars and a capacity of 100 MW [14].

Electricity consumption has shifted from one sector to another during the pandemic. Households consumption reduced from 51 percent to 48 percent in July–March FY 2018–19 which rose in Mar 19 to Mar 20 from 38.07 percent to 44.90percent. In the post pandemic era the share has increased to 49.1 percent in July to March FY2020-21. However, the share of industrial consumption decreased from 34.34 to 29.45 in FY 2019–20. However, a growth is seen in FY 2020–21 from 25.5 to 26.3 percent in the industrial sector [37]. The discussed case of an educational institute provides us with an analysis of work case scenario to assess the worst effects on any sector regarding to the Grid policies.

Energy harnessing from these diversified distributed renewable sources is beneficial if integrated with the national grid tackling the indeterminacy issue. However, in the event of islanding operation such as in smart grids, relying on a single renewable energy source poses a severe threat to system security and integrity. Hence, every source has great significance in the problems of energy reliability. Moreover, the systems being deployed in various areas are partially using the facilities of net-metering, which needs to be made even better in the current case of COVID-19. This is reducing the load on the transmission lines and the country's distribution systems. According to Islamabad electric supply company (IESCO) representatives, the electricity being net-metered is consumed in the same feeder reducing the power dispatch to the substations. The concept is termed as wheeling locally. Pakistan, a country where the transmission system is overloaded, can benefit by making such policies better and consumer-friendly to reduce the power losses due to overloading the transmission and distribution lines.

The introduction of energy storage systems can increase the system's reliability at center cost, making the system more robust of contingencies. If such infrastructure is implemented at various locations on a small scale community level, the country's power sector can be a great lift to fight the energy crisis. Such a small setup of community-scale comes in the category of Nano grids. This paper gives a brief overview of the introduction and architecture of Nano grid using DG sources in Pakistan.

3.1. Renewable energy for educational institutes

Solar system power plants have been very feasible solutions to fulfill educational institutes' needs because the load and the sun hours are nearly the same; thus, maximum power can be utilized locally, which gives the maximum benefit to the consumers who are the educational institutes. Whereas in higher educational institutes, the requirement of

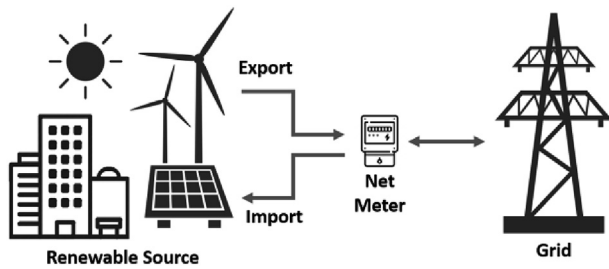


Figure 7. Net-metering.

electricity is for 24 h; however, the maximum energy consumption is in the day time; thus, solar power is an ideal solution to mitigate the energy expenses. In Pakistan, under the Punjab UJALA program, primary schools are being solarized [38]. Whereas various higher educational institutes have also invested in solar energy, these institutes include IBA Sukkur, National university of sciences and technology (NUST), University of engineering and technology (UET), and some other institutes. These institutes have utilized solar power to reduce energy expenses.

Transportation sector of Pakistan had a consumption of 15.6 MTOE of Energy in FY 17–18 which reduced due to escalation in Inflation to 14.5 MTOE. However, in pandemic the sector is more severely hit due to the reduction in the demand of transportation to 13.99 MTOE in FY 19–20. COVID waves have produced the sharpest decrease in all economic indicators in almost 30 years, prompting considerable anxiety for most businesses. COVID-19 has a huge impact on the worldwide renewable energy supply chain. If the incentives are not aligned with clean energy goals, renewable energy investments are likely to plummet, resulting in a domino effect. Wind energy, for example, has already begun to experience the predicted catastrophe. As a result, wind energy installations are expected to decline by 4.9 GW worldwide by 2020. The solar business is in a similar predicament. Due to the COVID-19 epidemic, renewable energy predictions for 2020 have decreased by 28% (SEIA 2020a). According to reports, workers in the solar energy business were fired or suffered as a result of the COVID-19 epidemic. While the predictions did not come true, a downward trend was observed in developing countries such as India [39].

3.2. Cashback policies for renewable

In Pakistan, organizations and individual users purchase energy through distributors, who charge them based on the number of units utilized. If the

Table 2. System specifications.

System Specs		
	Power	Manufacturer
Module	390 W	Trina solar
Inverter	25kW	SMA USA
System Design		
Number of inverters		9
Number of panels		646
Total Power		253 kWdc
DC to AC ratio		1.17
Modules per string		19
Number of strings		34
Tilt angle		28
Azimuth angle		180 (true south)
GCR		0.3
Total area covered		1266 sqm
System costs in USD		
Total system cost		170,033
O&M cost per year		6000

customer begins producing electricity on a smaller scale than the distributors, he or she can assist the distributors by supplying electricity back to the grid. As a company or educational institution, such as ours, numerous rules described below can be implemented in order to receive the payback amount invested in renewable energy integration. Solar energy is often generated via photovoltaic panels put on the roofs of buildings.

- 1) *Self Consumption*: Renewable energy generated under this approach is exclusively utilized by the individual who installed it. Electricity customers routinely employ this policy to reduce the load on the grid and meet their needs. Figure 5 illustrates the one-way flow of electricity from the grid to the building; the owner of the renewable energy sources consumes all of the energy produced. This approach is optimal if consumer demand is constantly greater than the energy generated by their renewable energy plant. If the generated energy is greater than the required energy, the excess energy must be squandered. This is a common scenario for solar panels installed on private residential rooftops. Their need falls during the solar energy's peak time, which is in the afternoon or when the building/home is left with little or no electricity during vacations and holidays. Excess energy created is wasted, when it could have been used to earn the payback.
- 2) *Net-billing*: In this policy, the renewable generation owner gets the discounted bill for a month by getting the net amount of billing. Bills are generated by subtracting the amount of electricity sold back to the grid on a selling rate of electricity, which is usually less than the grid's buying rate. If the owner balances the net amount of electricity bill through selling, the net bill for that month would be zero. Figure 6 shows the flow of electricity to and from the grid to a building with an attached renewable energy system. Two separate meters count the units of electricity. The owner then billed the net-billing from both meters with different buying and selling rates set by the power supplier.
- 3) *Net-Metering*: In net-metering policy, the renewable generation unit owner is credited back in terms of units for the excess electricity generated and supplied back to the grid. This policy suits the long term use if the generated energy is more than the owner's demand. The benefit of this is that if the energy is supplied back to the grid, then the meter runs in a reverse mode, and the billing would be of net units. Figure 7 depicts the flow of net-metering. Electricity credits are accumulated against the owner of the generated energy for the whole month. Then it can be claimed by the consumer in the future.

4. Case study

4.1. Methodology of assessment

SAM (System Advisory Model) from NREL was selected as the simulation software for the analysis due to its robust nature of solving

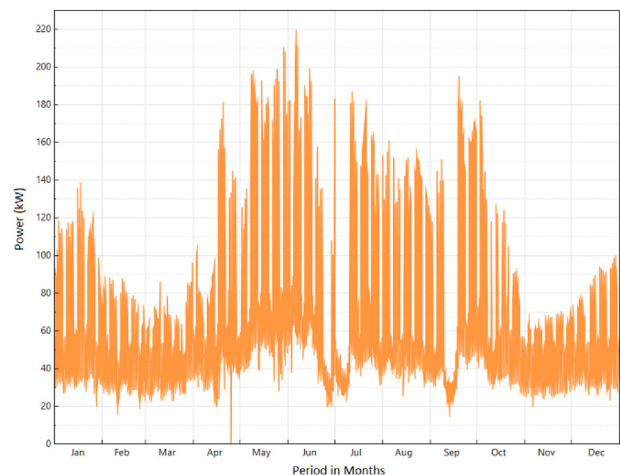


Figure 8. Yearly load profile of university building.

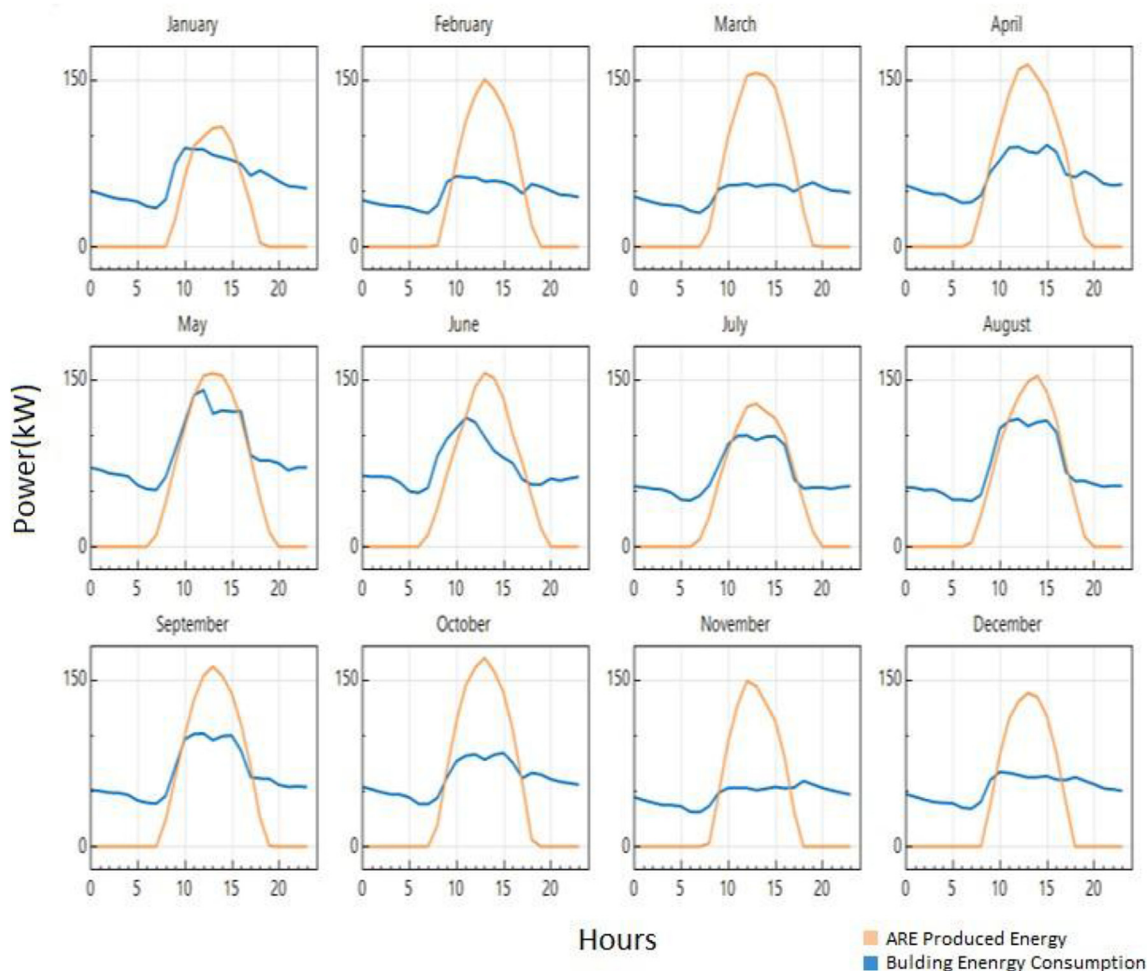


Figure 9. Monthly average of load comparison in 24 h window.

technical and financial parameters simultaneously [40]. The tool calculates various critical technical parameters, including capacity factor, annual energy yield, and losses, along with all essential financial parameters to evaluate the project economically. It has been widely used to model the economic factors related to private PV systems installed for residential as well as commercial purposes [41]. The tool has validated models of solar PV integration and has a vast database of commercially available system components, especially the solar PV modules and inverters. The weather datasets are updated regularly and weather files of various locations can be assessed using the software. The tool has

recently become part of PV feasibility reports required by the US and many other governments as a trusted tool for accurate feasibility studies.

The tool provides various parameters to assess the solar PV system in a particular area and location. These parameters give the decision-makers technical and financial analysis to decide for a particular project deployment and also allows parametric optimization to get the maximum benefit from the system [42]. Energy yield, performance ratio, capacity factor are the most critical parameters for a system for technical analysis, while the Levelized cost of energy, payback time period, net

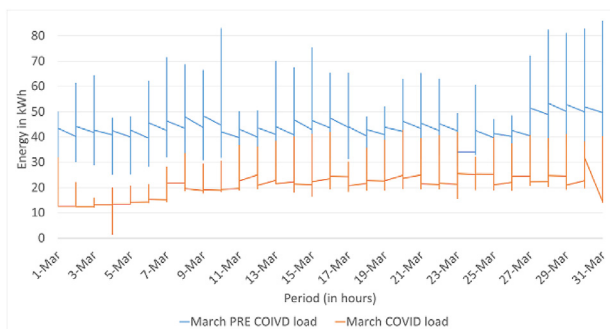


Figure 10. Load comparison for the month of March.

Table 3. Monthly unit consumption.

Month	Actual units consumed	Scaled down units consumed
1	38291.30	15316.52
2	46976.79	18790.71
3	44999.12	17999.64
4	55680.13	22272.05
5	54337.75	21735.10
6	66568.35	26627.33
7	53569.09	21427.63
8	52537.52	21015.00
9	50539.39	20215.75
10	59650.66	23860.26
11	41251.41	16500.56
12	31510.31	12604.12

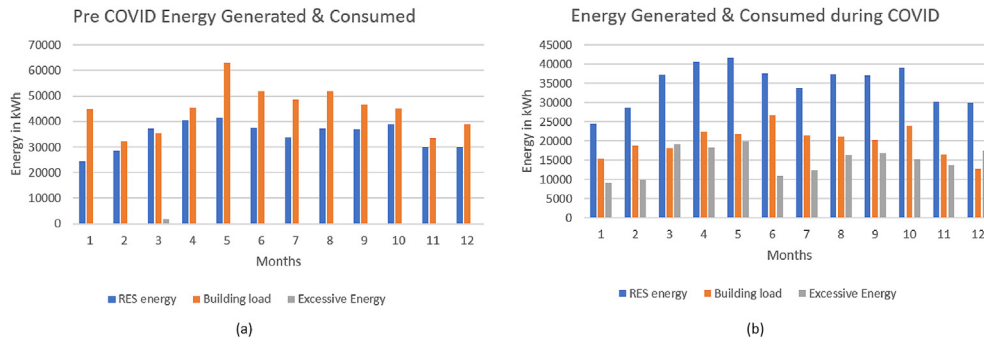


Figure 11. Energy consumption related to the produced energy through PV system (a) Full load energy, (b) Reduced load energy.

present value, return on investment are the most used parameters for financial assessment of the solar PV system.

4.2. Deployed infrastructure

National University of Sciences and Technology (NUST) is Pakistan's leading university of science and technology. US-Pak Center for Advanced Studies in Energy (USPCAS-E) at NUST has a very high research impact across the country. Under this Research center at NUST, a solar photovoltaic power system is deployed recently to aid demand of energy center power requirement whereas, pass on excessive generated power to other buildings. Deployed system specifications are stated in Table 2. The university has a local grid network operated by university staff. The grid station is of 132kV with a total power capacity of 6MVA. This grid station energizes three 11kV radial feeders. These feeders are then responsible for sending the power to 37 buildings. The energy center demand profile is discussed thoroughly in the following section, along with the impact of COVID-19 on the overall demand response profile.

4.3. Demand response profile

The energy consumption profile for the whole year is presented in Figure 8. This presents load profile of an academic building. The two significant dips in the graph show the annual religious holiday at the end of June, July, and September. The electric consumption increases in summers due to the air conditioning loads, whereas consumption also increases in December and January due to heating loads. A comparison of monthly load profiles is shown in Figure 9. The reduced load does not meet the PV system's energy, and there is an excess amount produced each month, especially in the peak sunlight hours.

4.4. COVID scenario

The world was repeatedly hit by the COVID-19 pandemic in different waves, consequently lockdowns were imposed. Due to these lockdowns, the academic institutes were mostly closed all along the year and education was delivered online by with the support of skeleton staff during these difficult times as per government regulations. During this time, for the purpose of this study, the energy consumption data of the building

was recorded in March. A similar pattern is expected to occur due to the fact that a bare minimum and a necessary load was running and same is the case this year.

A comparison of load profiles from pre COVID-19 March, 2019 and COVID-19 hit March, 2020 is presented in Figure 10. We can see during pandemic time, the load has been considerably reduced, only some air conditioning for the skeleton staff and the research lab equipment contributed to the load curves. Whereas, it can be seen that the weekends may be identified in the curve. A minimal amount of difference can be observed, which shows the absence of the essential staff. The computers and various devices in the labs were still consuming electricity; thus, the load was not zero even on weekends.

4.5. Data preparation

The dataset we have is of March 2020, the month from which lockdown was imposed in Pakistan. To run the simulations, we needed an estimated data for the future load consumption keeping in view that COVID lockdown prevails.

The total number of units (kWh) used in the COVID scenario was 40% of the total units consumed in the same month the previous year. The load pattern of the lockdown was taken from March and normalized. To get a realistic estimate, we took into account the number of units consumed by the building in the previous year, scaled down by a factor of 40% for each month as shown in Table 3. Using the SAM tool, we then mapped the date of March 2020 by scaling it down every month based on the units consumed in that month last year. Annual load growth was taken as 5%. From the graph, we can see that in summer, the load consumption increased due to the air conditioning needed for the minimal working staff as well as data centers and research labs.

5. Simulations and results

The simulations for the desired system were done on SAM software for two cases, including the full load profile of the building in average

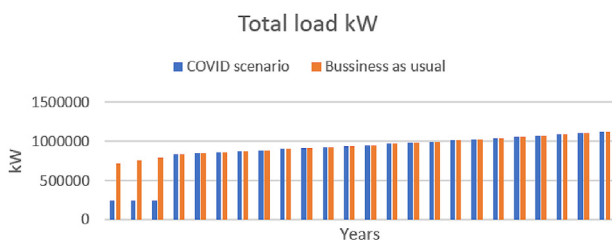


Figure 12. Total load comparison with 3 years of reduced load due to COVID.

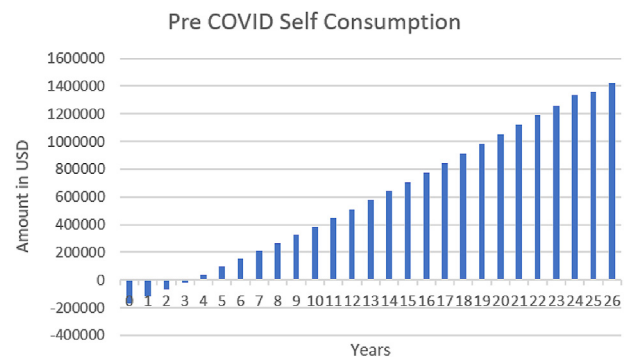


Figure 13. Cumulative Cashback for Self Consumption on full load before COVID.

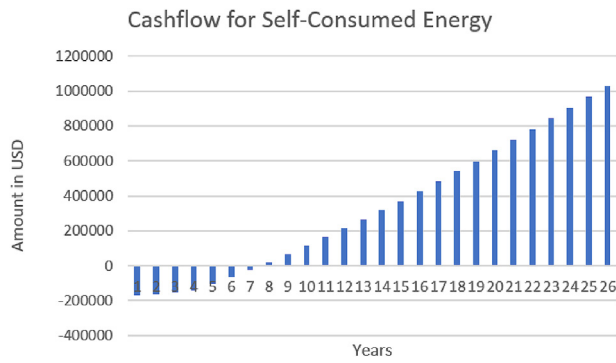


Figure 14. Cumulative cashback for self consumption after COVID.

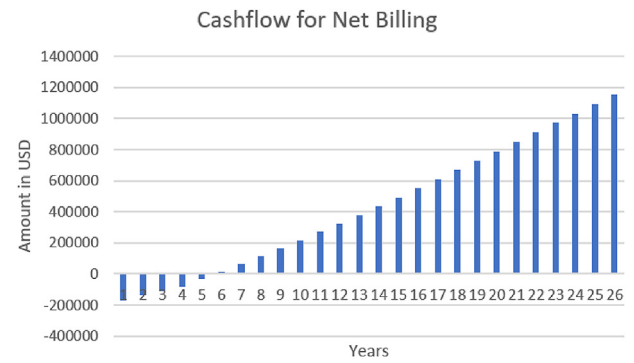


Figure 15. Cumulative cashback for net-billing (post COVID).

condition and the reduced load profile based on March 2020. Under the average load, the PV system was integrated to reduce the electricity purchased from the grid for economic benefits. Figure 11 shows the comparison of produced, consumed and unutilized PV produced energy for both before and after COVID scenarios. The system has been designed for the full load thus very small amount of energy is bought from the grid however the case is not the same in COVID scenario where allot of access energy is being produced.

For a realistic scenario in simulations, we reduced the load profile for only three years onward from the start of COVID lockdown, as shown in Figure 12. In the proposed study, we are assuming that institution is carrying its operation using online learning platforms for at least 3 years. The institute building understudy would run on reduced load for these three years and move back to its full load profile. Hopefully, by that time, the COVID-19 situation comes under complete control resulting in educational institutes opening.

Taking in account the current policy of not incorporating net-metering for the PV system, the excess energy produced not being utilized is being wasted. The PV not being utilized to its potential wastes the resources and, in turn, increases the payback period by a considerable factor. The comparison of payback periods for both average full load and reduced load under the COVID situation is shown in Figures 13 and 14 respectively.

The simulations done using the current policy of not utilizing net-metering is not an ideal situation in the COVID scenario. The payback period increases, and energy is being wasted throughout the year. So in this study, we also present simulations and results for other PV policies that can be implemented in the current system.

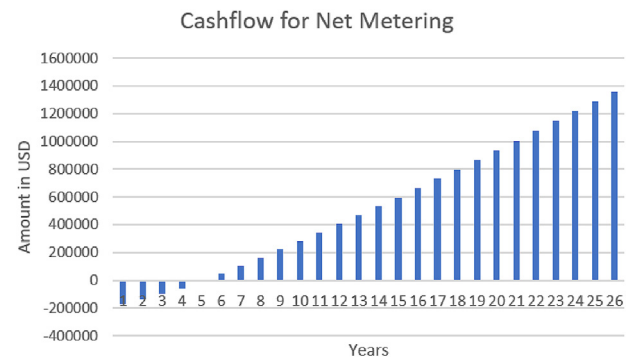


Figure 16. Cumulative cashback for net-metering (post COVID).

5.1. Net-billing

In net-billing policy, the user is credited against their bill instead of units. In this monthly policy, the bill is adjusted through a specific selling excess electricity rate to the grid.

For the simulation, a realistic billing rate was set according to the tariffs of IESCO, which is 0.14\$ per unit for buying from the grid and 0.07\$ per unit for selling excess electricity to the grid. The grid then charges the net bill to the building. In our case, simple payback period will be of 4.7 years as shown in Table 4. This policy will allow the institute to perform a net-billing business with the distribution company however, the advantages of such a system enhance in comparison to the self consumption setup in COVID scenario due to reduced loads, a

Table 4. System metrics under different policies.

Metric	Pre-COVID	Post-COVID		
	Self Consumption	Self Consumption	Net Billing	Net Metering
Annual energy (year 1)	417,032 kWh	417,032 kWh	417,032 kWh	417,032 kWh
Capacity factor (year 1)	18.8%	18.8%	18.8%	18.8%
Energy yield (year 1)	1,646 kWh/kW	1,646 kWh/kW	1,646 kWh/kW	1,646 kWh/kW
Performance ratio (year 1)	0.80	0.80	0.80	0.80
Levelized COE (nominal)	8.42 ¢/kWh	9.32 ¢/kWh	9.32 ¢/kWh	9.32 ¢/kWh
Levelized COE (real)	5.80 ¢/kWh	6.77 ¢/kWh	6.77 ¢/kWh	6.77 ¢/kWh
Electricity bill without system (year 1)	\$80,605	\$35,475	\$35,475	\$35,475
Electricity bill with system (year 1)	\$23,024	\$18,806	-\$2,143	-\$8,230
Net savings with system (year 1)	\$57,581	\$16,669	\$37,617	\$43,705
Net present value	\$477,560	\$120,445	\$197,951	\$257,356
Simple payback period	3.3 years	6.5 years	4.7 years	4.1 years
Discounted payback period	3.6 years	9.3 years	5.9 years	4.9 years
Net capital cost	\$170,034	\$170,034	\$170,034	\$170,034
Equity	\$170,034	\$170,034	\$170,034	\$170,034

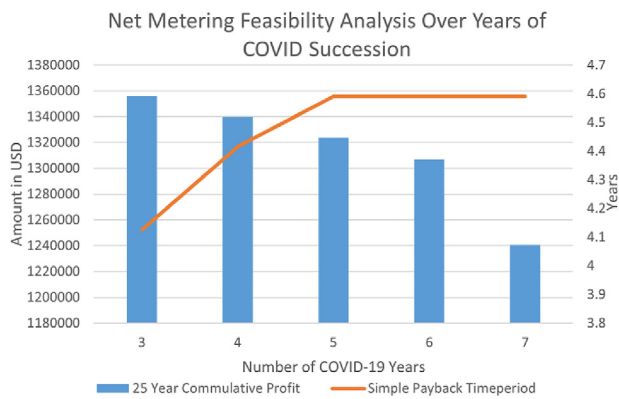


Figure 17. Payback time-period for net-metering.

graphical representation can be seen in Figure 6. As well as after simulations we can observe a change in the cash flows in post covid scenario as seen in Figure 15.

5.2. Net-metering

In net-metering simulations, the number of units produced and consumed is counted, and the net excess amount of units are credited against the user. If the generated energy through PV system is more than the building's energy, then through net-metering. In that case, the consumer gets the credit against the electricity given back to the grid. These unit credits can then be utilized in the upcoming months. In the COVID scenario discussed above, net-metering simulations would credit the institution building for the excess amount of electricity generated, resulting in accumulating credited units and reducing electricity bills in the coming years when the institutes open with full electricity load.

Table 4 lists all the net-metering simulation metrics for the installed PV system where as according to the 2019 policy of Pakistan 6% debt percentage for 12 years has been used with a 7.56% WACC. We can see that the payback period reduced to 4.1 years using this policy. Figure 16 shows the cash flow for the system in the upcoming years.

5.3. Long term COVID scenario

Historical data of Spanish flu predicts that COVID-19, once controlled, can again spread in any area. The development of the vaccine is the first step towards eradicating such pandemic cannot be forecast in this scenario. So it is advisable to look at the investments made for the long-term following: the sensitivity analysis presented in the case of COVID and the effects of COVID reduced electricity loads on academic institutions.

The Figure 17 represents the effect of cumulative net savings based on the reduced load for 3–7 years. It can be seen that the total earning of the project does not find a significant change even if the scenario of reduced loads along with the optimal policy of net-metering is retained along with other components, as stated before.

6. Conclusion

This study presents a detailed Techno-economic evaluation for PV systems in academic institutes working in distance learning mode in the COVID scenario. The study focuses on a recently deployed solar power plant and performs a comprehensive assessment of the recorded change in loads due to the COVID-19 lockdown, in-turn, which causes a change in the surplus units being produced. The research evaluates the policy of net-metering. The said method may be deployed any where to look into future scenario for solar system deployment where a drastic change in load may occur due to any circumstances. It may be concluded that the effect on a lcoe and pay back time period would be very minimal until the

change is expected to be permanent which may change the initial feasibility of the project. It can benefit the system if available. The financial Solar PV assessment of the business system as the usual scenario has been presented as a base case to portray the project's profitability as per the design. A comparison has been made with a hypothetical scenario of long term situation of this pandemic being carried on for more extended periods up to 3–7 years. This results in a change of 0.5 years delay in payback time period in extreme case, with the best available policy framework implementation. This is making the project feasible even in case of pandemic however, a difference of cost equivalent to the initial investment has been observed. A policy analysis was conducted, analysing alternative regulations that the government could implement to reduce the profit losses associated with solar systems implemented at academic institutions. The best outcomes have been obtained through a net-metering programme accompanied by financial incentives. The research highlights another facet of investing in solar photovoltaic systems that remains profitable even if COVID-19 reduces energy consumption in some sectors and is one of the few investments with a strong IRR even in these exceptional circumstances.

Declarations

Author contribution statement

Abdul Kashif Janjua: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

M Kashif: Analyzed and interpreted the data; Wrote the paper.

Farooq Ahmad, Ahmed Rasheed: Contributed reagents, materials, analysis tools or data; Performed the experiments.

M S Younis: Conceived and designed the experiments; Wrote the paper.

S A A Kazmi: Conceived and designed the experiments; Analyzed and interpreted the data.

K Imran: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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