Energy for Sustainable Development 65 (2021) 101–106

Contents lists available at ScienceDirect

Energy for Sustainable Development

Pandemic and bills: The impact of COVID-19 on energy usage of schools in South Africa

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ARTICLE INFO

Article history:
Received 17 May 2021
Revised 15 September 2021
Accepted 2 October 2021
Available online 7 October 2021

Keywords:
School electricity
Energy usage
Smart meter
School energy profiles
COVID-19
Pandemic
School responses

ABSTRACT

The COVID-19 pandemic continues to wreak havoc on global operations and economies. Inadvertently, lockdowns and working from home have reduced the daily carbon footprints of inter alia transport and office buildings. A beneficial consequence of carbon footprint reductions is the ability to measure the differential demand of occupants, to benchmark the base load of buildings, and identify opportunities for efficiency improvements. In this paper we evaluate the change in energy demand in five public schools in South Africa with changes in occupancy due to the COVID-19-imposed lockdowns. We make recommendations to carry these savings into the everyday operation of the schools, and estimate the savings for forthcoming closures.

Introduction

South Africa's public (non-private) schools face many challenges, especially budgetary constraints, and even more so for schools in the lower four of the five affluence quintiles (Booysen et al., 2019). These budgetary constraints are compounded by the rising cost of water and energy, of which schools are heavy and often wasteful users (Booysen et al., 2019; Reuters, 2021; Samuels et al., 2020). Given the lack of financial resources in the educational domain and the troubled state of basic education in the country, any reduction in wasteful expenses could be put to good use, for example to help to pay teacher salaries or invest in educational infrastructure. Since the country's predominant source of electricity is that generated by its large coal-based state-owned generator, a reduction in usage also results in a substantial reduction in greenhouse gas (GHG) emissions.

One of the unintended consequences of the COVID-19 pandemic's lockdowns has been a reduction in greenhouse emissions, albeit temporarily (IEA & Key World Energy Statistics, 2020). This reduction was driven by the lower energy requirements in large office buildings and also by diminished transportation requirements as people worked from home. Moreover, as economic activity subsequently slumped, energy consumption decreased further, with commensurate reductions in the environmental impact (IEA & Key World Energy Statistics, 2020). This provided an opportunity to evaluate energy usage patterns and relate GHG emissions. Effects of the pandemic on climate change have not been evaluated significantly (Sovacool et al., 2020).

The South African government has responded to the pandemic with a focus on provision of healthcare capacity and short-term fiscal interventions to counter the multi-sectoral decline in economic activity. With regards to the education sector, school closures were implemented, due to lockdown regulations, and measures were taken to ensure student education could proceed safely as far as practically possible (Spaull et al., 2020).

Similar to large office blocks, a reduction was expected in schools' energy usage with unoccupied or partially occupied schools. The occupancy levels of schools was also based on the regulations.

Schools in South Africa and their COVID-19 response

Each of South Africa's nine provinces has a dedicated education department guided by the national education ministry. The provincial education departments are responsible for public schooling from the receptions year (grade RR) to 12. South Africa's public schools are categorised into five quintiles based on the affluence of the surrounding areas, where one is least affluent and five is most affluent. Quintile four and five schools constitute fee-paying schools, whose parents contribute financially towards the school's funds through fees. Quintile three

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https://doi.org/10.1016/j.esd.2021.10.001

schools tend to be fee-paying, however these schools are situated in poorer communities. Quintile one and two schools constitute no-fee schools, which means that parents are considered too poor to contribute to school funds through fees. The government contributes more per student for these poorer schools.

Covid-19 induced lockdowns in South Africa meant that the movement of citizens and normal day operations of the public and private sectors were restricted with the exceptions of health services. There were levels to the lockdowns ranging from level 5 to level 0 - decreasing in restrictions and freedom of movement.

During the Level 5 lockdowns (the most restrictive stage of lock down due to COVID – discussed in detail in section1.2), schools were also closed, with students reverting to remote learning (Dzinamarira & Musuka, 2021; Ziauddeen et al., 2020). Despite being met with some opposition, schools eventually reopened with social distancing enforced. Initially, this resulted in partial occupancy, as temporary revised education plans were adopted – students attended schools every second or third day, and it was commonplace for well-resourced schools to use blended learning. Furthermore, mobile classrooms were used by the Western Cape Education Department (WCED) to allow schools to operate with 1.5 m physical separation, which necessitated classrooms to be reduced to partial capacity. Similar to non-educational buildings, this partial occupancy due to physical distancing was expected to have an impact on the building energy usage (Zhan & Chong, 2021). Changes in energy uses could be due to factors such as changes in occupancy of students and staff, frequency and duration of use of equipment and appliances, and COVID-induced arrangements (e.g. the usage of more classrooms due to social distances, phased re-opening of schools, and added ventilation in classrooms, increased use of air-conditioning for climate change etc.). All of these factors could impact electricity usage, savings and carbon emissions of the schools. Additionally, ZAR 50 million ($ 3.53 million) were assigned to the manufacturing of 100 mobile classrooms. Although these additional classrooms could have had the intended consequence of an increase in the electricity usage in schools (PMG, 2020), none of the schools in our sample had mobile classrooms added during the time horizon of our study.

An education-focused COVID-19 timeline

This section presents a timeline of events relevant to COVID-19 in South Africa, and specifically includes events relevant to the education system. The main events, listed in Table 1, were used to assess the possible influences on electricity usage in schools and will be correlated with measurements at the schools in our sample set. Only the first-wave levels of lockdown are shown. The dates of lockdown levels are shown where the country went into isolation with strict rules from the 23 March 2020 for a month, this was level five lockdown - schools were closed until the 1st of May. Level four saw schools re-opening in phases, only grade 12 of the secondary school grades and the senior primary school grade (i.e. grade 7) returned to school from the 1st of June 2020. The move to level three of lockdown was announced on the 29th of May 2020. This meant a phasing-in of the rest of the grades which includes primary school grades RR and R (the first years of primary education, which precedes grade 1), 2, 3 and 6 and secondary school grades 10 and 11 on the 6th of July (grades 1, 4 and 5 were not phased in at this point). On the 12th of July, there was a call to increase the ventilation in schools, which may have increased impacts of electricity usage. Thereafter, the move to level two of lockdown followed, which saw schools continue their schooling until the December break. COVID-19 measures were maintained for the safety of the students and staff. The effects of level one lockdown were also evaluated. In our article we correlated these events with our schools' energy data.

Table 2
School term dates.

	2019	2020
Term 1	09 Jan – 16 Mar	15 Jan – 21 Mar
Term 2	02 Apr – 15 Jun	08 Jun – 25 Jul
Term 3	09 Jul – 21 Sep	24 Aug – 24 Oct
Term 4	01 Oct – 7 Dec	02 Nov – 16 Dec

Due to the pandemic, term dates varied substantially from 2019 to 2020 (South African Government, 2020). The school term dates and holidays are shown in Table 2, and highlighted clearly in the figures in the results section. These lockdown-imposed school closures were from 18 March to 1 June and from 27 July to 24 August of 2020.

COVID-19 and related regulations have affected many important sectors in South Africa and globally. Not only were sectors such as the health (Garba et al., 2020; Mbunge, 2020), food (Arndt et al., 2020), environmental (Aktar et al., 2021; Barouki et al., 2021; Naderipour et al., 2020) and economic sectors (Norouzi et al., 2020; Takyi & Bentum-Ennin, 2020) affected, their energy use was also reduced, thereby also impacting on the energy sector (Abu-Rayash & Dincer, 2020; Brosemer et al., 2020; Edomah & Ndulue, 2020; Eryilmaz et al., 2020; Jiang et al., 2021; Mastropietro et al., 2020; Sovacool et al., 2020). Although a special issue has been published on energy research during the first part of COVID-19, no research exists on the impact of COVID-19 on energy usage at schools. In this paper we assess the impact of COVID-19 restrictions on school energy usage and quantify the financial savings and environmental impact of these changes. The assessment

Table 1
COVID time table.

2020 dates	Description	Level	Ref
18 March	Schools closed early due to COVID-19 in country	–	(The Presidency, 2020a)
19 March	Regulation 6 - closure of schools until April 15th (eventually the 1st of July)	–	(Department of Cooperative Governance, 2020)
23 March	National lockdown Level 5 for 21 days	5	(The Presidency, 2020b)
9 April	Two-week extension on 21-day Lockdown	5	(The Presidency, 2020c)
1 May	National lockdown Level 4 lockdown 1st of May. Phased re-opening of schools to be provided.	5	(The Presidency, 2020d)
13 May	Need for re-organisation of schools stated	4	(The Presidency, 2020e)
24 May	Resumption of classes for grades 7 and 12 students planned for 1 June	4	(The Presidency, 2020f)
29 May	National lockdown Level 3	4	(The Presidency, 2020g)
1 June	School reopening postponed. Staff could report to work on 1 June.	3	(Department of Basic Education, 2020a)
25 June	Provisional reopening of school at 50% capacity announced with move to digital platforms. Grade R, 1, 2, 3, 6, 10 and 11 to return 6th of July.	3	(Department of Basic Education, 2020b)
12 July	Call to increase ventilation in schools.	3	(The Presidency, 2020h)
23 July	Reopening of schools. Grade 7 and 12 returned on the 8th of June. On 6 July grades R, 6 and 11 returned. However, schools closed between 27 July and 24 August.	3	(The Presidency, 2020i)
27 July	Schools closed until 24 August 2020	2	
17 Aug	National lockdown Level 2	2	(The Presidency, 2020j)
20 Sep	National lockdown Level 1	1	(The Presidency, 2020k)

Table 3
Summary of the five schools in our energy data set.

Primary/Secondary	Quintile	No of pupils	Size of building [m^2]	Hostel (Y/N)
(School 1) Primary	5	600	9731	N
(School 2) Primary	5	800	6894	N
(School 3) Secondary	5	720	10,613	Y
(School 4) Secondary	5	550	7609	Y
(School 5) Secondary	4	1200	12,132	N

was done to understand the impact of occupancy on the energy requirements of a school (the delta), and also to quantify base load demand, which could be used to identify untapped potential for savings in aging buildings, similar to a pre-COVID-19 study by (Odell et al., 2021), who showed savings in schools. We focus on five schools in Stellenbosch, in Western Cape province of South Africa and compare their energy usage during the pandemic to the preceding 12 months.

Method

We used a mixture of smart-meter data and bills to evaluate the change in electricity usage at the five schools in Stellenbosch. Table 3 shows information about the schools included in the energy analysis. The time periods analysed were from November 2018 to October 2019 and November 2019 to October 2020. In addition to the energy impact, we assessed the impact of the lockdowns on the cost of this electricity. Although a reduction in electricity costs reduced expenses, we also had anecdotal evidence of parents stopping to pay school fees, offsetting reductions in electricity expenses. We therefore obtained two years' fee contributions from three schools, two quintile five schools and one quintile four school, to assess changes in contributions.

To determine the electricity usage of the schools we used two methods. The Stellenbosch council's smart meters that are used for billing were used to measure usage in 30-min intervals over a two-year period from November 2018 to November 2020. This data was also used to determine the cost of the electricity usage, as the schools were on Time-of-Use tariffs. These costs were cross-validated with monthly electricity bills over the same two-year period.

Results

Energy usage analysis

Fig. 1 shows the monthly usage and bills of schools during 2019 and 2020 for both schools with hostels, in Fig. 1 (a) and (c), and schools without hostels, in Fig. 1(b) and (d). These results clearly demonstrate substantial reductions in usage from April 2020, when the country went into lockdown and schools closed. When compared to 2019, the average monthly reduction from April to October was 33 for schools with hostels, and 25 for schools without hostels. These reductions are substantial, and resulted in average cumulative monthly reductions of 9MWh per school with a hostel and 3MWh per school without a hostel to October. The schools' bills were reduced between ZAR 11,000 and ZAR 50,000 over the April, May and June periods. One of the schools showed a sudden increase right after the first two months of lockdown, hence there was an increase in bills in June by ZAR 4000. Some schools had increases in their electricity bills before the lockdown started. These schools show reductions in electricity costs when the lockdown started, as expected. Total billing reductions over the whole year ranges from ZAR 25,000–185,000.

Because of the variance in the energy usage between schools, we also compared the effect of all the schools by normalising the energy usage of each school according to the maximum-energy usage of the school over the entire period (i.e. 2018/2019 and 2019/2020). These comparative results are shown in Fig. 2a with the lockdown levels and with the shaded areas indicating the periods of school closure in 2019 (in grey) and 2020 (in red). The solid line constitutes the usage of the median school, with the shaded areas denoting the schools with the maximum and minimum normalised usage. The figure shows the high level of similarity between the schools from November to March, before the move to lockdown Level 5 on 26 March 2020. From the last week in March, a sharp reduction is observed as schools were forced to shut their doors. This trend holds for all five schools. In June, as staff and children returned to a partially-opened school usage increases, but since the schools are only partially open, only to levels substantially less than those seen in the previous year during the July holidays. This is accentuated by the sharp diversion between the years' profiles in the second half of July, when the schools opened from holidays in 2019. The

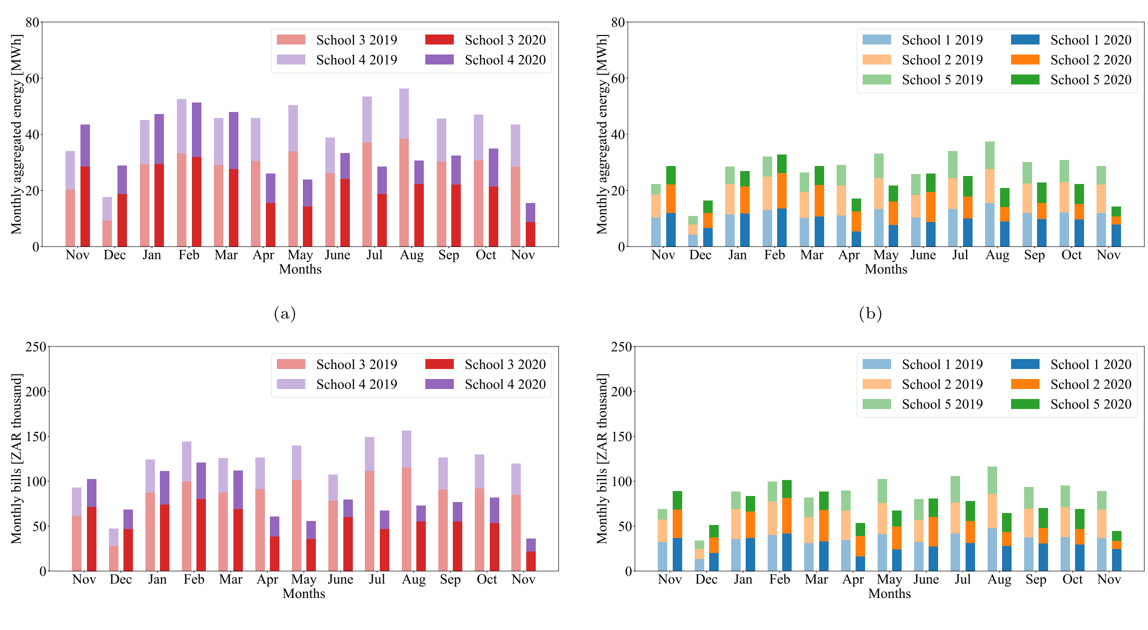
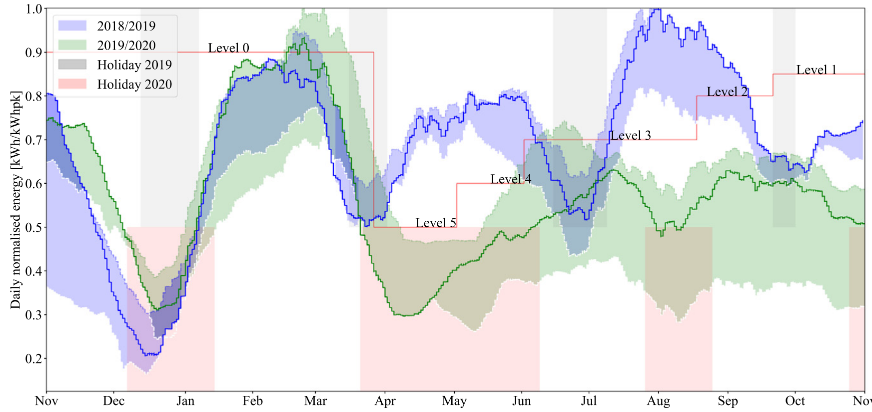
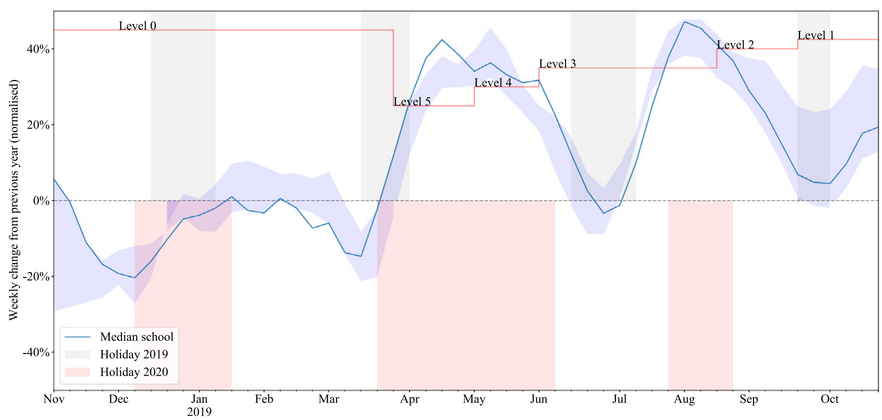


Fig. 1. Energy usage between 2018/2019 and 2019/2020, monthly aggregated for schools with hostels (a) and schools without (b). Monthly bills between 2018/2019 and 2019/2020, schools with hostels (c) and schools without (d).



(a) Normalised-energy usage between 2018/2019 and 2019/2020 (rolling average of energy over 28 days)



(b) Normalised-energy differences between 2018/2019 and 2019/2020 (aggregated weekly).

Fig. 2. Comparison of energy usage over the two-year period.

same trend is seen in the overlapping range of the last week of September, when the schools were still partially open in 2020, but a holiday was in effect in 2019. Thereafter, the plots diverge again.

It is clear that the energy usage during the lockdowns in 2020 was equal to or lower than the holiday periods of 2019. An interesting conclusion is that more energy-using devices could probably have been turned off during the holidays of 2019. Another observation is that even during the Level 5 lockdowns, a substantial base-load energy was still observed at each of the schools, possibly indicating further potential savings. The minimum load (energy per hour) detected at any school was 6 kWh over the second set of 12 months.

The difference in normalised-energy usage was also calculated for each week of the period under investigation. These differences are shown in Fig. 2b for the median, minimum, and maximum using schools. The figure clearly shows the two peaks of increase in the differences over the lockdown periods, and a zero-crossing delta over the period where schools were closed over 2019 for a short holiday and partially open during 2020 in the last week of June.

Table 4 lists the reduction in energy usage per calendar day over specific-time periods, which is calculated by comparing the total usage per day for the 2018/2019 period with the 2019/2020 period. Level 0, meaning not in lockdown, is included to show the energy usages in the period before the lockdown transition to Level 5. The duration of the levels are shown in parentheses.

The expectation is that school would use more energy when the students are present, hence level 5 would be expected to yield the greatest decrease in electricity usage (assuming that more students are at home and schools were closed) and then lesser reductions would be present towards the less restrictive levels of lockdown i.e. level 1. This difference in energy usage is in reference to the previous year's energy usage for the same period.

We used the results in Table 4, the complete school closure during the Level 5 lockdown to calculate an estimated energy usage per student. For the five schools in the order from School 1 to School 5, this results in a reduction during Level 5 per student of 9.2 kWh/month, 3.6 kWh/month, 19.9 kWh/month, 7.0 kWh/month, 2.0 kWh/month.

Table 4
Energy reduction in kWh (average change in kWh/day).

	Difference in schools' energy usage [kWh/day]				
	School 1	School 2	School 3	School 4	School 5
Level 0 (69 days)	22.14	33.80	−30.93	55.14	−21.75
Level 5 (34 days)	−184.91	−96.18	−477.82	−127.74	−78.15
Level 4 (31 days)	−184.35	−90.13	−635.16	−232.81	−99.52
Level 3 (77 days)	−117.47	−62.03	−400.84	−204.05	−68.26
Level 2 (34 days)	−134.91	−196.76	−390.47	−242.03	−52.82
Level 1 (29 days)	−52.28	−151.34	−196.52	−94.97	−3.48

Table 5
Projected energy reduction in kWh (average change in kWh/day).

	Difference in schools' energy usage [kWh/day]				
	School 1	School 2	School 3	School 4	School 5
Holiday usage (38 days)	−154	−173	−394	−153	−105

The projected reduction of usage for schools is shown in Table 5. The difference in usage is based on the holiday usage when adequate switching off procedures were followed. The average weekly reduction in usage is 1370 kWh/week.

Conclusion

In this paper, we assessed the flip side of the absence coin, by empirically analysing energy savings achieved in schools in our sample over the lockdown period. These results quantify usage due to occupancy, and also the baseline despite zero occupancy.

We observed average energy reductions of 33% for schools with hostels, and 25% for schools that do not have hostels. These are the equivalent of reductions of up to 11.63 kWh per student per month per school, and monthly bills by as much as ZAR 50,000 ($ 3490) or ZAR 65 per student per month ($4.55 per student per month).

To allow a like-for-like comparison, we normalised the energy usage at each school to a peak observed value, and plotted the schools' normalised usage year-on-year. The results show a substantial reduction ranging between 30% and 40% during the hard lockdown.

The results further showed that savings per student ranged between 2 and 20 kWh/month. It was also found that energy usage during hard lockdowns or even holidays in 2019 still showed substantial base-load which indicates a need for future explorations of energy saving interventions and technologies for schools in South Africa.

The projected savings for 2021 were based on the reduced usage due to school closures as a result of the second and third waves of COVID-19 in South Africa. With the COVID-19 school closures and assumed extended school closures of the third wave in 2021, the projected savings range from 3.49 kWh/student/week to 6.98 kWh/student/week based on the 2020 reduced COVID-19 usage. Based on the implementation of adequate switching off procedures, the average projected savings range from 3.54 kWh/student/week to 7.08 kWh/student/week.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank MTN South Africa, Stellenbosch University Social Impact, and the Western Cape Education Department for their financial support of the project.

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