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A guidance note on Climate-Smart School Construction Planning

DRAFT FOR DISCUSSION

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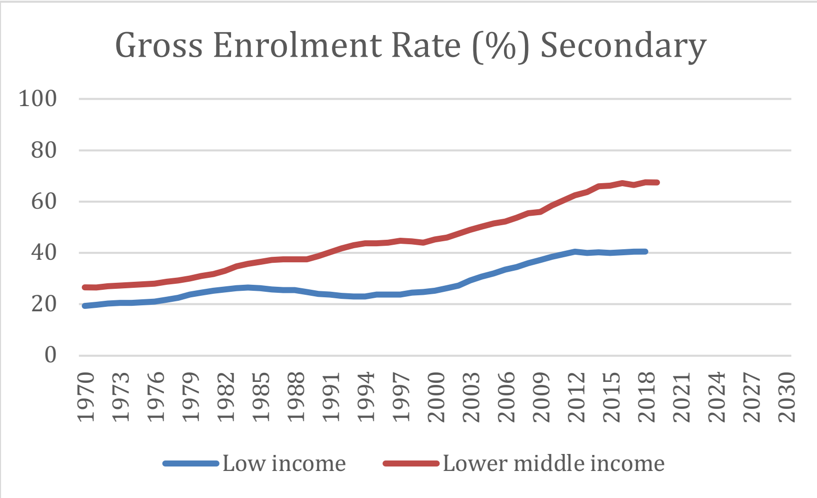
The need for Climate-Smart School Construction Planning

If the world is serious about meeting the fourth SDG target - ensuring that all boys and girls complete primary and secondary education - then this will require a huge number of new schools and classrooms to be built over the coming years. However, there is very little discussion on either how these are to be built, who will realistically pay for these, or where they should be located. Alongside this, the world is increasingly grappling with uncertainties surrounding climate change. This note is motivated by the need to take both these facts seriously, and to ensure that the expansion of schooling is planned in a way to maximise learning, while ensuring schools are resilient and climate-smart.

The latest estimates suggest that only two in five children attend secondary schools in low income countries, and just seven out of ten children in lower-middle income countries[1]. This means that many countries will need to double their number of secondary schools, or alternative pathways by 2030. It is estimated[2] that these countries need more than four million additional secondary classrooms to be built just to cover existing populations.

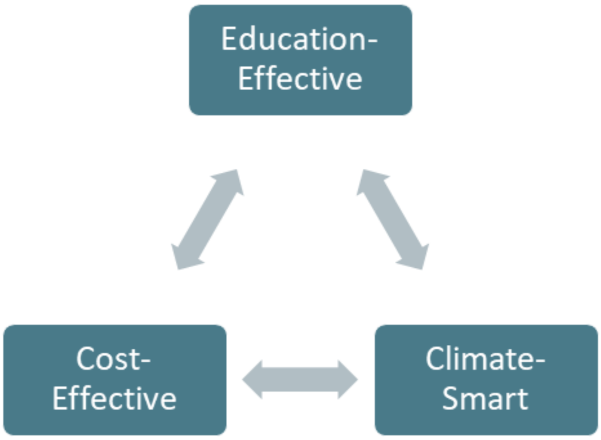


At the same time, the world is facing both a learning crisis and a climate crisis. These are interlinked in a number of ways, with evidence showing that the conditions in classrooms (such as temperature, air quality, light and acoustics) have a significant effect on learning. As the climate changes, the locations, designs and energy sources of schools also need to change to ensure children can learn.

How to build this volume of new school infrastructure is rarely discussed in sector planning, beyond modelling numbers and setting out minimum standards for schools. However, this construction will take place in a world where there is an increase in the frequency and intensity of extreme weather and climate events, as well as unprecedented environmental shocks[3]. This needs to be internalised in education sector planning, so we can adapt how schools are built to both build resilience to shocks, and reduce risks.

Increasing temperatures, and increased frequency of extreme weather events such as floods, droughts and hurricanes, can all affect the resilience of the school infrastructure and the effectiveness of the education system. On the other hand, the materials used in the construction, and its sources of energy, food and water all contribute to the lifetime carbon emissions of that school. By integrating this thinking into planning discussions, building climate-smart schools can help to reduce emissions and reduce the disruption to learning during shocks.

In a world of low learning outcomes, limited resources and a changing climate, meeting these challenges is going to require school construction and adaptation planning that is education-effective, cost-effective and climate-smart.



We break this down into key areas for discussion. Firstly, we discuss what we mean by a climate-smart education system. We then look at the importance of school locations and how advances in geo-spatial techniques for school catchment area planning can be expanded to take into account climate risks and educational challenges. Next we look at how schooling construction methods can adapt to take into account innovations in materials and design to both lower the carbon footprint, but also improve learning. We also look at how designs to allow more light and ventilation can facilitate learning and reduce disease transmission, while ensuring schools are a suitable temperature for children to study. Finally we discuss how school feeding and water systems can be incorporated into climate-smart planning.

What do we mean by climate-smart?

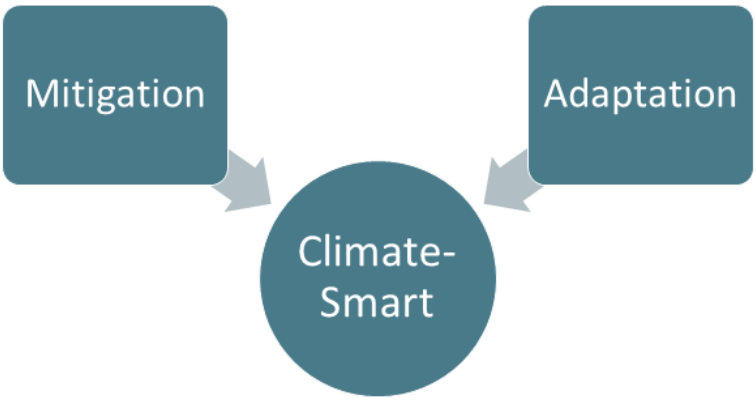
There are two ways to help address climate change: mitigation and adaptation. Mitigation measures are aimed at reducing greenhouse gas emissions. Adaptation measures focus on reducing the vulnerability and risks generated by climate change.

For mitigation, the UNFCCC points out that there is a direct relation between climate change and the concentration of greenhouse gases in the atmosphere. A Climate-Smart education system is based on a mitigation strategy that sets out how to reduce its emissions and contribute towards meeting the goals of the Paris Climate Accords[4]. Currently, the needs and voice of the education system are absent from most climate discussions, and often not included in countries Nationally Determined Contributions to climate mitigation[5].

For adaptation, context specific plans are required that take account of both rising temperatures and the likelihood of extreme weather events. A climate-smart education system is based on an adaptation strategy that sets out how to make the right investments so that schools can withstand both the everyday stresses and likely shocks that climate change will bring.

To create a climate-smart education system we recommend two steps. Firstly, planning for adaptation so that existing and new infrastructure can meet the challenges that the climate crisis will create. Secondly, setting out how to implement these plans through the relevant policies and programmes to support mitigation and adaptation.

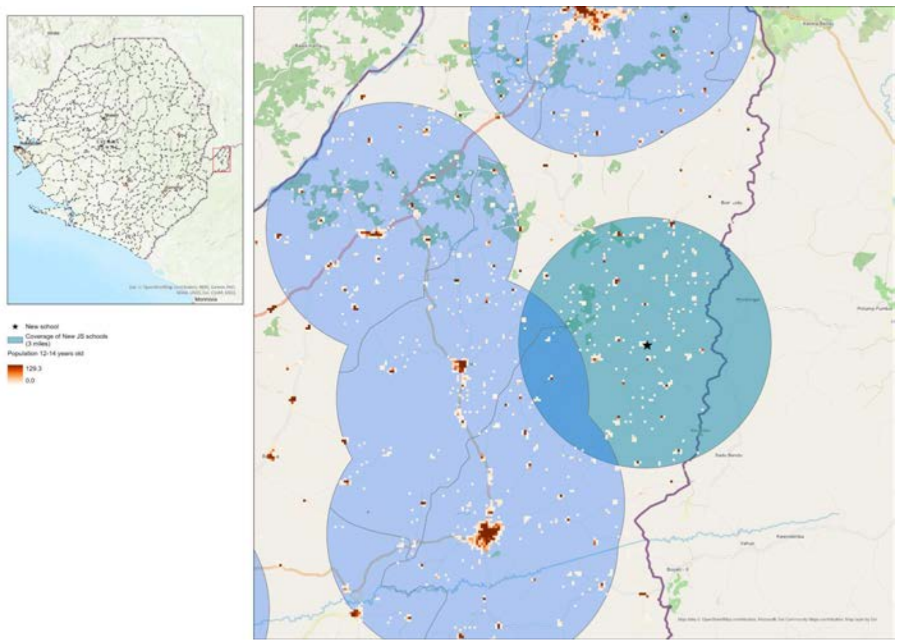
This is the foundation of a resilient, Climate-Smart system that can respond to environmental stresses and strains and play a role in reducing carbon emissions within the education sector. A Climate-Smart education system requires the right policies, incentives and investments – and this note tries to highlight innovations that can help this be achieved while also expanding schools to meet the SDG's over the coming decade.



Location planning for maximising access and minimising climate risks

Where schools are located plays a key role in the equity of education systems - with many poorer children having to travel long distances to school, losing studying time and requiring energy. This has impacts not just on children's access but also their learning, with a 10 minute increase in travel time reducing a child's ability to read and write in different languages by between 7 and 26 percentage points in Ghana[6]. This is particularly pertinent at the secondary level, where the need for specialist teachers makes the trade-off between school size and costs very real.

Technological advancements, and the use of Geographic Information Systems (GIS) can improve the selections of school locations to maximise access and learning. This can help to make the best use of limited resources, with recent evidence from Guatemala finding that 350 optimally placed schools would have had the same impact on the share of children living in under-served areas as the 7,000 schools that actually were opened in the past decade[7].



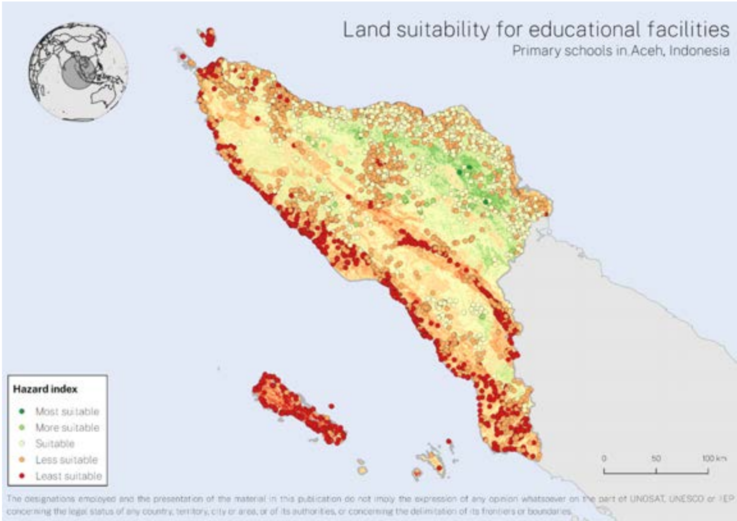
Tools are being developed to make this simpler and more accessible, including open-source plug-ins for QGIS - with the potential of geospatial analysis for school planning explained in more detail in a recent note by Fab Inc on behalf of the GIS in Education working group[8].

However, these tools can also be expanded to also consider climate smart planning - and make the location analysis for new schools not just education-effective and cost-effective, but also climate-smart.

This is feasible in many contexts - geodata on water features, elevations, weather patterns, seismic activity and more are widely available[9] and can be incorporated to estimate the risks from hazards such as floods, landslides, hurricanes and earthquakes for potential school locations.

Techniques can also be used to model the frequency of these events as the climate changes, even in low-data contexts[10]. Taking these risks into account during the planning of new school locations increases safety and can also reduce the costs of adaptation that might be required.

This can then be included in scenario modelling of locations, to ensure that new school locations balance costs (by not being too small a catchment at secondary) with accessibility (by optimising the number of children nearby) and environmental risks.



This is not just a technical matter, with a need to see beyond high-level planning and give thought to the processes through which these locations can be agreed at the local level. In Malawi, USAID has worked closely with the ministry, local authorities and stakeholders to identify the land tenure arrangements and the land that is available at the local level, developing three ranked options (Option A, B and C) of exact sites for each new school and ensuring that the right people are 'in the room' to agree the final site to be chosen. This local knowledge of climatic conditions (e.g. localised flood risks or malaria swamps) should be incorporated into any fine-tuning of location choices[11].

Given the current coverage of secondary schools is typically higher in urban areas, construction in the more remote areas is likely where the greatest future need will be. However, construction in these areas can often be more costly due to the greater logistical challenges and low population densities. Building next to a main road can lower costs, but more remote children are likely to be further from these main roads[12]. Moreover, the road network can also contribute to the ability of children to access schools. Education access is just one part of a broader discussion on rural development, likely involving not just Ministries of Education, but also Ministries of Finance, Infrastructure and others.

The number of pupils enrolled and the school size is an important consideration for the teacher workforce needs, particularly at secondary level, with the need for subject specialists. In order to effectively teach the breadth of subjects in the curriculum, a certain number of teachers is needed. If the number of pupils is low though, this can lead to low use of teachers' time, and inefficient costs per child. Ensuring a level of enrolment sufficient to efficiently utilise teachers time, should therefore be balanced against the need to provide access to schooling even in areas of low-population density. Bike and school bus schemes can help to transport the child to the school in a way that is equitable and climate-smart.

However, this needs to be balanced, as the time that children take to get to school impacts on learning[13], and how children and teachers get to schools has climate implications. For example, in Beijing 20% of the morning traffic is due to driving-to-school trips, increasing both congestion and emissions. Policymakers can aim to lower this congestion and the environmental costs by optimizing the spatial balance between school supply and demand[14].

Overall, innovations in spatial modelling, and improved data on environmental risks and population estimates can help improve planning of where schools should be located - taken alongside consultatory processes with local communities, improvements can be made to catchment planning systems to help improve learning outcomes and climate resilience. Alongside this, climate and cost-effective secondary school planning is about managing trade-offs - between the costs of staffing smaller schools closer to children, with the environmental costs of transport for schools that are further away.

Materials and methods for climate-smart school construction

In addition to their location, the physical infrastructure of schools have significant impacts on children's enrolment, attendance, completion rates and learning achievements[15]. It can also protect the lives of teachers and pupils, in the case of a natural hazards. In the case of one such hazard, it is estimated that 875 million school children are in high seismic risk zones[16].

In areas prone to natural hazards or conflict, school buildings must ensure safety and can even be transformed into shelters as short-term solutions. The increased frequency of extreme weather events highlights the importance of ensuring that schools are constructed with materials and methods that are climate-smart.

Discussions on expanding infrastructure relate to both the construction of new schools, and also the expansion of the capacity of current schools - to reduce the number of students per classroom and/or expand the facilities they offer (laboratories, playgrounds, libraries). In both cases though, this means construction - and the construction sector is one of the most important sources of pollution worldwide consuming 36% of global energy and producing 39% of CO2 emissions[17].

Often, these discussions on adaptation centre around the costs - as adaptations to existing schools, or to the design and construction of new schools, can increase initial costs. While this is true, estimates suggest that with good planning, these can be kept to within 5 to 10 percent of initial costs[18]. More importantly, many of these adaptations can also reduce the operating costs of schools, meaning that these climate-smart investments can repay themselves many times over during the lifespan of the school infrastructure. This is a key consideration in ensuring value for money of education infrastructure investments, particularly in the resource constrained environments in low and lower-middle income country education systems.

What to build schools from will depend on the context. Given the economic and environmental costs of transporting materials, planning should endeavour to source locally from renewable sources where possible to minimise the impact of construction. A focus on local materials gives a range of options from traditional concrete, iron, and bricks, to processing mud and waste materials, or bamboo, palm leaves, jute, and more[19].

These materials are best when matched to the characteristics of the area where the building will be located, as well as the building's use and risk profile. In Colombia, a pilot school located in the region characterized by heavy flooding and a high risk of seismic activity was made of reinforced concrete on stilts, which avoid flood damage and are resistant to earthquakes, but the front exterior wall is made of plastic wood, inspired by a typical instrument of the region, the marimba. This design also strived to provides the school with good ventilation and lighting[20].

Innovative construction methods are adapting traditional (and new) techniques and materials to local conditions for more sustainable or ecological results. In many cases, these alternative forms of construction allow important economic savings by significantly reducing operating costs and promoting construction activity itself.

For example, a pilot in Malawi[21] has shown that schools can be built using 3D-printed walls technology and locally-sourced materials for the doors, roof and windows. In this way, a new school can be built in under a week, and with less of an environmental cost than traditional concrete-based construction. The 3D-printed buildings use less concrete than other methods and the 3D cement mixture also emits less carbon dioxide compared to traditional concrete.

The materials used for the roofs of schools is also important, and can affect both the temperature under the sun, as well as the acoustics during rain. Metal corrugated roofs, whilst low-cost, can be very noisy during rainy seasons and disrupt children from being able to hear the teacher.

One low-cost method used to reduce temperatures can be painting the roofs of schools white.

In Egypt, a more innovative project took this further and converted flat rooftops into outdoor "Green Roof Classrooms"[22]. This had benefits to both climate adaptation and opening up new learning spaces to enable more child-centric teaching. Green roofs can reduce heating and cooling costs, as the top layer absorbs and retains heat; whilst the lower layer absorbs rainwater, with 'evapotranspiration' occurs between the roof and the plants produces a cooling effect[23]. Children also benefit from learning how to grow and conduct experiments, and spending more time outdoors in nature.

Picture source: Egypt: Green Roof Classrooms improve the education experience (worldbank.org)

Heating, cooling and generating energy to facilitate learning at sustainable costs - Getting to a good temperature for learning

Creating a comfortable environment in the school grounds and within classrooms are important factors in educational attainment[24]. Moreover, the temperature range for optimal learning is relatively narrow, and recent research has confirmed that children (especially boys) prefer cooler temperatures than adults[25]. This has important considerations for standards, which are typically written based on parameters for adults[26].

Ensuring that classrooms are warm or cool enough requires passive and active measures. Passive measures are those that do not require the use of energy and active measures are those that rely on energy generation. There can also be a relationship between them, where certain passive measures such as adequate external shading, insulation, big windows to increase ventilation and painting roofs white can increase or decrease the need for active measures.

As the climate changes more buildings need active measures, such as mechanical cooling, to maintain interior thermal comfort. Many tropical nations, especially in Sub-Saharan Africa, utilize sandcrete blocks which allow hot, or cold, temperatures to pass through relatively easily. As a consequence, if they have air conditioner's they have to use more energy to cool the building. Innovative construction methods have found that changing the composition of building materials, such as adding bio-based material to the commonly used sandcrete in Ghana[27], can significantly improve the thermal performance of buildings and generate significant energy savings compared to air-conditioning.

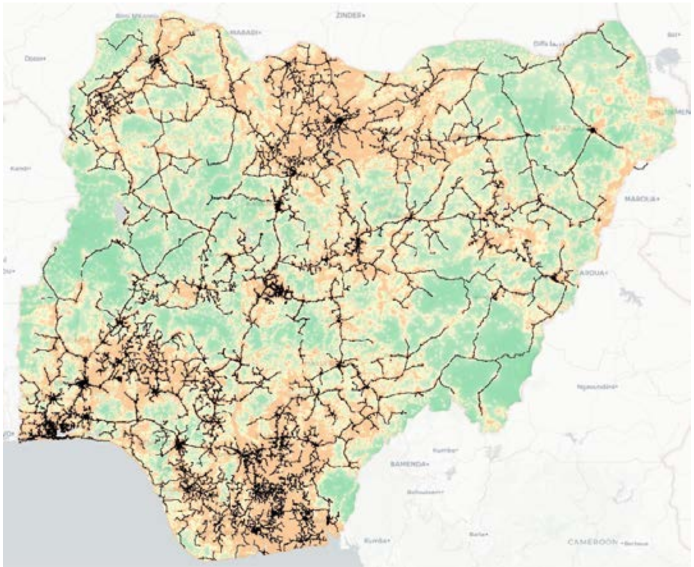
The air quality also has implications for health and education outcomes of children. Damp, dingy classrooms can produce allergic respiratory symptoms and increase the transmission of respiratory infections with evidence finding that student absences increase by 10–20 percent in classrooms with poor ventilation[28]. Moreover, these conditions can also harbour mosquitos, with studies in Pakistan finding greater prevalence of malaria in schools that have poor hygienic conditions, which can be combated through reducing dampness inside classrooms[29].

Evidence also shows that the lighting inside classrooms can significantly improve children's learning, especially if it is natural light. Classrooms that receive a high level of daylight offer students a 20% better learning rate in maths and 26% in reading, compared with classrooms that received little natural light[30]. However, the number and size of windows also has implications for construction costs due to the cost of glass and slightly higher complexity of construction. It is important to weigh up these (relatively minor) up-front costs with the benefits to learning during the design and construction of new classrooms.

Moreover, insufficient natural lighting also adds to the needs for artificial lighting which can increase operational energy costs for the school. This is a particular concern in remote areas if electrical connections to the grid are not available, and more costly and polluting sources of energy, such as diesel generators are used.

This question of how the energy is generated, that is then used for regulating temperature or lighting, is also important for climate mitigation. When planning new schools, or upgrading existing infrastructure in a Climate-Smart way, it is important to explore how school energy generation can be less reliant on carbon intensive fuel sources, such as diesel generators, and how renewables, such as solar power, can be part of the energy solution.

This requires a national strategy that understands the energy usage in existing school infrastructure and a plan to retrofit existing buildings to adapt to local level climate change impacts. This should be combined with policies that require new infrastructure to generate energy in low or zero-carbon ways.



This can build on the data that is available on electricity infrastructure. For example this map shows the distribution lines which connect high-voltage transmission infrastructure and population density in Nigeria[31]. This can also highlight the more remote areas without electricity infrastructure where schools might require greater support for electricity generation.

This will enable schools to play a role in carbon reduction and potentially increase their resilience, as they will be less reliant on energy infrastructure, or expensive diesel in order to operate. Investing in renewable energy can be cost-effective in the long term, educationally effective and climate-smart.

Food and water sources that support learning without costing the earth

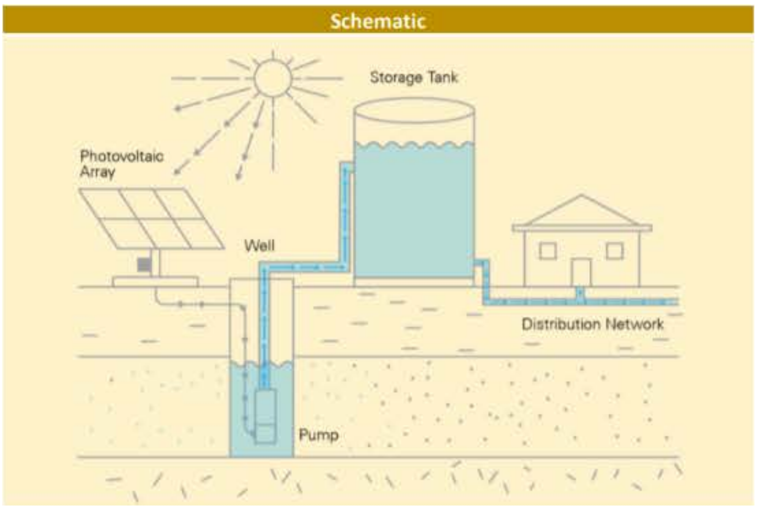
School meals have significant benefits for the students, improving their nutrition which has a direct impact on school performance and increases attendance. However, cooking requires energy. Because of the high volume of meals prepared, schools that use fuelwood and charcoal for cooking contribute to deforestation in their communities. For example, in Kenya the school feeding problems contribute to the deforestation of more than a million acres of forest. Furthermore, cooking school meals indoors with traditional stoves can expose children to harmful emissions.

An alternative is to shift to more efficient and less polluting cooking practices, this includes using electric cooking or modern fuels (such as biogas, LPG or ethanol), and using fresh food with the highest nutritional value. This option can contribute to the local economy enabling the market penetration of fresh produce and dairy products between smallholder farmers and families and schools[32].

WASH (Water, Sanitation and Hygiene) facilities are also important for keeping children healthy with an estimated 443 million school days lost each year due to water-related illnesses[33]. WASH facilities can also have benefits for keeping children in school, particularly adolescent girls, with previous evidence from Yemen finding that 4-8% of the increase in the proportion of girls enrolled in village schools could be attributed to improved water supplies[34].

Implementing WASH strategies in schools have been shown to be effective, with evidence finding a reduction in the number of missed school days by 54% per year in China, and a reduction in diarrhoea illness of 50% in Kenya[35]. However, these measures require the WASH facilities to be in place, which are frequently lacking. In Latin America, nearly 70 of schools report a deficit of restrooms for students[36]. Resolving this will require greater incorporation into planning, particularly in the context of Covid-19 where good hygiene has become even more prominent. Similarly, as the climate changes, greater thought is also needed on the ways this water is sourced and pumped.

Solar-powered water systems that can reduce the impact of declining water levels and extreme weather events by enabling pumping from deeper levels below the ground – even during droughts when many shallow wells go dry. At the same time, they produce lower emissions than comparative systems that often rely on diesel. These innovations can provide a climate-smart alternative that can mitigate against further climate change, whilst adapting to the impact of extreme weather events.



Picture source: Using Solar Powered Water Systems to Improve Climate Resilience in Rural Myanmar (UNICEF)

Conclusions

The path to meeting the fourth SDG target and addressing the learning crisis will require a huge amount of school construction, and must be undertaken in a world where the climate is changing. This will require planning that mitigates the emissions from this initial construction, and the ongoing operation, of these schools; whilst adapting schools to both the everyday stresses and likely shocks that climate change will bring. This will require climate-smart school construction planning.

There are a number of promising practices and innovations that can support this, as well as a broad range of factors to consider. Advancements in GIS and geospatial data can help improve the location planning of new schools, enabling policymakers to maximise access whilst minimising climate risks. The materials and methods used to build these new schools also have important considerations for climate-smart construction, where the combination of local materials and innovative methods can help to build schools that are less carbon intensive, and that can withstand the increasing likelihood of extreme weather events.

In addition to the initial construction, the materials and designs also affect the conditions for the children that will be using these schools. Getting to the right conditions, in terms of temperature, air quality, light and acoustics, has significant benefits for children's learning, but requires planning to ensure that the energy requirements to achieve these do not result in unsustainable economic and environmental costs. Similarly, the food and water sources and facilities at the school are also important for supporting students' access and learning – with particular benefits for girls[37] - but require planning to mitigate, and adapt to, the changing climate.

Climate-smart school construction can also be a driver of wider benefits. Construction of education facilities can make up a sizeable share of a countries public sector construction[38], and introducing these concepts and methods can help provide an opportunity for these to be taken forward into construction projects for other sectors.

Moreover, these concepts and methods can also be incorporated into the teaching and learning that goes on within those school buildings, demonstrating how much can be achieved by climate-smart investments, and instilling positive environmental habits across students and the wider communities. Schools that have implemented climate education programs have seen energy savings of more than 10 percent and waste reduction of more than 15 percent[39].

Education has a crucial role to play in raising awareness about the urgency of the climate crisis. For the youngest and future generations who will be most impacted by climate change, positive influences during early life can contribute to a society that is equipped with the understanding, values, knowledge and skills to tackle the causes and impacts of climate change.

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Endnotes

[1] The World Bank estimates the gross enrolment ratio (GER) at secondary in 2018 as 41% for low income countries and 68% for lower middle income countries.

[2] Using world bank data from 2018 on pupil numbers and gross enrolment rates, we estimate first the school age population and then number of additional pupils that will be added to reach 100% GER at secondary, and assume a ratio of 40 pupils per classroom for these additional children only. For low-income countries this is 36 million children enrolled divided by 41% GER gives a school age population of 89 million, an increase of 53 million children enrolled and 1.3 million extra classrooms required. For lower middle-income countries this is 249 million children enrolled divided by 68% GER gives a school age population of 369 million, an increase of 120 million children enrolled and 3.0 million extra classrooms required. This is a total of 4.3 million classrooms required over low and lower middle income countries, and does not take into account population growth up to 2030 which would increase this further.

[3] Nicholls et al. 2012.

[4] United Nations. 2015.

[5] UNICEF East Asia and Pacific Regional Office. 2019.

[6] Afoakwah and Koomson, 2021.

[7] Rodriguez-Segura and Kim, 2021.

[8] Fab Inc., (forthcoming).

[9] Humanitarian Data Exchange (https://data.humdata.org/) is one notable source for such data.

[10] Kabenge M, Elaru J, Wang H, Li F. 2017.

[11] Fab Inc., (forthcoming).

[12] This is an important reason for considering value for money more broadly than just at the lowest unit costs. For example, the FCDO's 4 E's method of Economy, Efficiency, Effectiveness and Equity - with the 4th E of Equity acknowledging that often reaching the most disadvantaged requires additional costs, but doing so can still be considered value for money.

[13] Afoakwah & Koomson, 2021.

[14] Lu & Zheng. 2017.

[15] Barrett et al, 2019.

[16] INEE, 2009.

[17] Fernandez, Yurivilca & Minoja. 2019.

[18] Duckworth-Pilkington, P., 2012.

[19] Robles et al, 2015.

[20] Robles et al, 2015.

[21] Pensulo, C. 2021.

[22] Abdel, M. 2020.

[23] Nargi, L. 2021.

[24] Goodman et al. 2018; Haverinen-Shaughnessy et al. 2015.

[25] Roaf, Brotas, and Nicol. 2015; Teli, James, and Jentsch. 2013.

[26] Barret et al. 2019.

[27] Opoku et al., 2020.

[28] Shendell et al, 2004.

[29] Gul and Ghaffar, 2014.

[30] QA Education Magazine. 2018.

[31] Electrical Distribution Grid Maps - Humanitarian Data Exchange (humdata.org). Facebook Data for Good.

[32] World Food Programme. 2020.

[33] UNDP, 2006.

[34] Ministry of Foreign Affairs the Netherlands. 2012.

[35] UNICEF, 2015.

[36] Inter-American Development Bank, 2012.

[37] Chigwanda, 2016.

[38] Inter-American Development Bank, 2012.

[39] Inter-American Development Bank, 2012.