Education and the electrification of rural schools

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Smart Villages

We aim to provide policymakers, donors, and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries—technological, financial and political—and how they can be overcome. We have chosen to focus on remote off-grid villages, where local solutions (home- or institution-based systems and mini-grids) are both more realistic and cheaper than national grid extension. Our concern is to ensure that energy access results in development and the creation of "smart villages" in which many of the benefits of life in modern societies are available to rural communities.

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Contents

Acronyms:

- UNDESA: The United Nations Department of Economic and Social Affairs
- UNESCO: United Nations Organization for Education, Science and Culture
- UNDP: United Nations Development Programme
- SOGERV: Sustainable Off-grid Electrification for Rural Villages
- OECD: Organisation for Economic Co-operation and Development
- IEG: Independent Evaluation Group
- IRFOL: international Research Foundation for Open Learning
- IADB: Inter-American Development Bank
- GNESD: Global Network on Energy for Sustainable Development
- EFA: Education for All
- ERC-IFC: Energy Regulatory Commission of Kenya- International Finance Corporation
- E4SV: Smart Villages Initiative
- UNICEF: United Nations Children's Fund

Introduction

Introduction key points:

- *Education features very highly in both the UN Millennium Development Goals and the Sustainable Development Goals.*
- *Whilst progress is being made, there are still huge gaps in terms of educational outcomes in developed vs. developing countries*
- *Within developing countries inequalities exist between rich and poor, and rural and urban.*
- *Collectively 188 million children attend primary schools that are not 'connected to any type of electricity supply', meaning almost one out of every three go to a school without electricity (based on about 660 million children being enrolled in primary school worldwide) (UNDESA, 2014).*
- *Energy can make a key contribution to improved education and educational access in rural areas. However, it is one part of the solution with multiple and diverse challenges faced by rural schools.*
- *Off-grid renewable energies can play a key role in school electrification.*

The Smart Villages Initiative aims to provide policy-makers, donors, and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries and how they can be overcome. This report aims to give an overview of the links between electricity access and education through a review of the literature in this area. It will serve as a starting point to inform the activities of the Smart Villages Initiative in relation to energy and education. While this report focuses on electricity in schools, it is recognised that energy for other purposes such as cooking, hot water, and (in some regions) space heating, also plays an important role in improving educational quality.

Chapter 1 of the report covers the energy requirements of schools, the challenges faced regarding electrification, and the possibility of schools acting as anchor loads for mini-grids. Energy access enables the use of modern information and communication technologies (ICT) in schools, and Chapter 2 of the report is concerned with ICT, the barriers to system deployment, some successes and failures, and the merit of distance education. Chapter 3 examines the knock-on effects of electrification and ICT on productive enterprise and employment. The report ends with some concluding comments.

Education featured very highly in the UN Millennium Development Goals (Unwin, 2009). The 4th Sustainable Development Goal is to 'Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' (UNDP, no date).

In terms of more specific global goals, the 'goal driving the global education agenda from now to 2030 aims for universal education from pre-primary through secondary, with relevant and effective learning outcomes' (Robinson and Winthrop, 2016). Whilst progress is being made, there is a '100 year gap' between 'educational outcomes in developed and developing countries both today and into the future' (Robinson and Winthrop, 2016).

For example, in India 'less than half of rural fifth graders could read a second-grade text in 2014, and just 26 percent could do division' (Robinson and Winthrop, 2016). 'In Kenya, Tanzania and Uganda in 2013, only one-third of third graders were at or above second-grade level literacy and numeracy skills' (Robinson and Winthrop, 2016). In terms of primary education, whilst 9/10 children of primary school age are in school around the world, there are still 'enormous disparities' both across and within countries (Robinson and Winthrop, 2016). Secondary education also remains a huge challenge, and according to projections 'by 2035… only 63 percent of the world's 20 to 24-year-olds will have completed upper secondary school' (Robinson and Winthrop, 2016). Dropouts are a continuing issue; Education for All[1] found that 'in 32 countries, mostly in sub-Saharan Africa, at least 20% of children enrolled are not expected to reach the last grade.' (EFA, 2015)

Within developing countries themselves, further inequalities preside, notably for Smart Villages—the urban/rural divide. In Nigeria '71 percent of the poorest children are out of school versus only 2 percent of the richest children' (Robinson and Winthrop, 2016). In addition, '40 percent of rural children are out of school versus 9 percent of urban children' (Robinson and Winthrop, 2016). Schools located in rural areas tend to be the 'least favoured' for funding, despite the fact that education is tied up closely with productivity, which can improve living standards (Jiminez and Lawand, 2000). Jiminez and Lawand argue that bridging the gap between rural and urban in this sense can allow these areas to become 'more economically sustainable and reverse the trend of migration from the rural to the urban areas' (Jiminez and Lawand, 2000). The concern here is how the electrification of schools can help improve rural education in the first place.

One headmaster in Malawi poignantly noted: 'Why is it different here in rural areas, why the level of services—education, health, water and so on—is so different to that in urban areas? It is because we do not have electricity. Give the rural areas access to electricity with these solar systems and we will be the same.' (Davies et al, 2015).

In a Smart Village, energy access aims to help equalise the rural-urban divide and provide real opportunities in the rural context. The extent to which the electrification of schools specifically, and the provision of technology to these institutions, can contribute to global goals and the barriers and challenges faced will be explored in the course of this report.

Collectively 188 million children attend primary schools that are not 'connected to any type of electricity supply', meaning almost one out of every three go to a school without electricity (based on about 660 million children being enrolled in primary school worldwide) (UNDESA, 2014). In sub-Saharan Africa data suggests that approximately nine out of every ten children 'go to primary schools without an electricity connection', and in Peru less than half of rural schools are connected to the grid (UNDESA, 2014). However, progress is being made. For example, 'Rural India saw substantial improvement in nearly all aspects of school facilities and infrastructure between 2003 and 2010. The share of schools with electricity more than doubled, from 20% to 45%' (EFA 2015). Energy access is critical at all levels of schooling—primary, secondary, higher education, and vocational centres (Practical Action, 2014).

1 Education For All is a global movement by UNESCO that commits to providing basic education for all, including youth and adults. Further information on the movement and its goals can be found here: http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-all/

This report does not intend to expound energy as the sole solution to the development of education. However, it focuses on energy as a part of the potential solution and a key contributor to improved rural education. Some of these other 'parts' will be touched on as we consider school electrification and the potential of information and communication technologies (ICT) to enhance educational opportunities in schools. The interrelatedness of many strands of rural development will consequently become apparent.

Rural schools 'often lack basic equipment, such as furniture and adequate textbooks—the presence of electricity does not affect these important constraints' (WB, IEG 2008). Further fundamental enablers of education include 'access to clean water, the availability of basic shelter, personal safety, health of students, free or affordable costs of schooling… sufficient and well-trained teachers', teacher status and morale, overcrowding, and distance from school (Unwin, 2009; Herselmen, 2003; EFA, 2015). The challenges for education are also dependent on the demographics and specific political and social environments. For example, in East Asia and the Pacific, massive urbanisation in China presented a 'major challenge to the education system (EFA, 2015). Other challenges include widespread poverty, weak 'capacity for implementation of complex policies', conflict, complex crises, natural disasters, HIV/AIDS, gender discrimination, and investment, to name but a few (EFA 2015). A lack of electricity cannot solve all such issues but may contribute to the improvement of some key areas.

Rural electrification programmes have tended to focus on incremental grid connection (UNDESA, 2014). However, off-grid renewable energies have a key role to play in electrifying rural schools. In areas that are unlikely to receive grid electrification, renewables can help to level out the access gap. Even for schools that can reach the grid, the provision of renewable energy can offset grid reliability issues and even provide a source of income (selling excess energy back to the grid). In Zambia, the Ministry of Education 'was among the first sectors to realise that the use of solar energy can greatly improve pupils' learning and working conditions' (Mfune and Boon, 2008). Sudan, Tanzania, the Philippines, Brazil, Argentina, and Papua New Guinea, amongst others, have also utilised solar PV for school electrification (UNDESA, 2014). As such, many of the examples drawn on in this report are focused on the use of solar PV; however, this is not intended to be to the exclusion of other options but merely as a consequence of modern trends and school-specific projects conducted thus far.

Mini- and micro-grids have also been experimented with for community-wide electrification in rural areas; for example, in Nepal, Sri Lanka, Lao PDR, Mongolia, and Vietnam (UNDESA, 2014). Prior to the use of PV, often electricity for remote schools has been and continues to be supplied via diesel/gasoline generators (Jiminez and Lawand, 2000). Diesel generators face problems with limited availability, environmental consequences (production of black carbon), and cost (with the expansion of solar PV being driven by higher prices of diesel since 2004) (Practical Action, 2014).

Chapter 1: The Electrification of Schools

Chapter Summary: This chapter outlines the possible energy use and supply requirements for rural schools, before analysing the benefits of electrifying schools, the challenges faced, and the use of schools as anchor loads for mini-grids. Benefits of school electrification include increased study time, improved educational performance, staff retention, and positive benefits for gender equality and the wider community. With regard to the challenges of electrifying schools, crucially, a lack of household access can prevent the full benefits of energy for education being realised. Other challenges include financing and capacity building.

1.1 School energy requirements

Section 1.1 key points:

- *A needs assessment is required on a case-by-case basis to ascertain the real energy requirements in line with local preferences, needs, and resources.*
- *There are numerous potential applications of electricity within schools. At the most basic level, lighting and phone charging form key uses of the energy. At a more advanced level, ICT and television may be factored in amongst other applications depending on the needs of that particular school.*

UNAMID/Schools in Kabkablya/CC BY-NC-ND 2.0

The issue with outlining requirements is that what can be achieved, what is locally relevant, and what the preferences are will, of course, vary. How you actually implement a school electrification project, particularly as part of community electrification, should be 'dependent on both a needs assessment, where community stakeholders express all of their needs, and a market assessment' where the project explores 'potential energy-using activities that could be economically viable' (SOGERV, 2015). The financial constraints of the school will of course be central to the requirements identified.

In the case of Papua New Guinea Teachers' Solar Lighting Project, 'Asking what teachers want, or how end users would use electricity, rather than presuming what they need' would have altered the design from a single type of system to a variety of technologies (Sovacool, 2013).

For reference, included below are the system design requirements for a rural school in Malawi, after a needs assessment was undertaken (Tembo and Mafuta, 2015).

Case study: Malawi rural school system requirements

School Classroom blocks

The system has been designed to run all lighting for 3 hours each night (528 Wh) plus provide 94.29 Wh of AC electricity each day for TV. Three days of autonomy are also accounted for in the design. The system has been installed in two classroom blocks which are being used for students' study at night and TV shows.

System specification:

- PV Array – 9 x 80 W panels
- Charge Control – Steca 40 Amps
- Deep discharge Deltec batteries - 10 x 102Ah

Staff room

This has been designed to provide 546.3 Wh/day consisting of lighting (374 Wh/day), phone charging (108 Wh/day) and laptop use (64.3Wh/day).

System specification:

- PV Array – 3 x 80 W panels
- Charge Control – Steca 20 Amps
- Deep discharge Deltec batteries - 4 x 102Ah

(Source: Tembo and Mafuta, 2015)

At a more generalised level, examples of common school applications of energy are as follows:

- Lighting (Indoor, Outdoor and Emergency): There is improved quality of light with electricity compared to Kerosene (as well as safety and health concerns) (Jiminez and Lawand, 2000). In addition, schools can also be used in the evenings for training, 'adult education, cultural events, community meetings', etc. (Jiminez and Lawand,2000). Students lacking lighting in the home can stay at school to study and teachers can prepare for lessons and carry out administrative tasks (Practical Action, 2014).

- Communications (Radio/Telephone/Email/Fax): Communications aid the efficient running of the school and can be used for routine activities such as procuring supplies (Jiminez and Lawand, 2000). It is also needed in case of medical emergencies/evacuations (Jiminez and Lawand, 2000). Basic communication tends to require very little energy.

- Computers and ICT: This will vary depending on the technology; for example, the charging demands of tablet technology vs. an on-site computer lab with varying usage.

- VCRs, Televisions, Radios, Film/Slide projectors: Such technology can act as an enabler for distance education, as detailed in the latter half of this paper.

- Water Delivery and Treatment: 'The provision of some clean, potable water is essential for the operation of any school' (Jiminez and Lawand, 2000). Solar energy can be harnessed for such activities.

- Food Preparation: Some 'governments and NGOs in developing countries run programmes to provide meals in schools' (Practical Action, 2014). Cooking energy and the consideration of options like clean cook stoves therefore need to be taken into account when planning a project to provide energy services to a school, particularly as where traditional stoves are used time must be given by students and staff to firewood collection (Practical Action, 2014). Food preparation is particularly important 'given the importance of balanced nutrition for child development and concentration' (Practical Action, 2014).

- Refrigeration: This may be necessary where schools need to preserve food/medical supplies (Jiminez and Lawand, 2000). Beyond this it may also be required for staff accommodation.

- Heating and Cooling: Before considering the heating/cooling options the initial strategy should be 'load reduction': 'ensuring that the building is well insulated and sealed' to reduce heating loads (Jiminez and Lawand, 2000). This will reduce the energy demand. 'Extremely warm conditions can also exacerbate illnesses such as dehydration, fatigue, and heat stroke. Space cooling can be important to keep rooms and offices at a comfortable temperature for staff and students—low-power electric fans can make a significant difference' (Practical Action, 2014). The energy requirements of air conditioners may be excessive, bearing in mind the schools' other needs and financial constraints (Jiminez and Lawand, 2000).

- Water-heating technology (e.g. solar water heaters) may also apply to kitchen and bathing facilities—the demand in this area will normally be small unless facilities cater for students taking hot showers (Jiminez and Lawand, 2000).

- Washing Machine: This may be installed for the use of the teacher and their family, providing the 'washing of additional school articles is minimized, then the electric load will not be excessive' (Jiminez and Lawand, 2000).

- Kitchen Appliances: These may also need to be taken into account where food preparation occurs or for teachers' homes. Such appliances should be selected and used so as to 'avoid overloading the RE generating system' (Jiminez and Lawand, 2000).

- Power Tools: For maintenance of the school, particularly in very remote areas, electricity may also be required for simple power tools such as drills so emergency repairs can be undertaken (Jiminez and Lawand, 2000).

As noted, all these potential requirements will depend on the size of the system, and/or the energy the school can afford, as well as their priorities and number of students and teachers. For example, a school's ability to prepare food may be valued more highly than the educational benefits of a TV where children have limited access to a substantial meal each day.

One company, Zim Solar (Zimbabwe based) offers tailored packages for rural off-grid schools at different levels. This can help us in getting a rough indication of what the overall energy requirements may be.

At the basic level, an off-grid 12V DC Solar Power System includes:

- 2-4 x Lights total for two classrooms (more may be required for large rooms)
- 2 x Lights to two offices
- Examination Light
- Solar Rechargeable Lantern
- Solar Rechargeable Torch
- 2 x Cell Phone and Lantern charging ports

In this system there is no provision of ICT, nor would the school be able to use any other mains-operated appliances (needs to work from battery voltage).

At the more advanced level, Zim Solar offers an Off-Grid 230V/50Hz AC Solar/Mini-grid Power System. The package includes:

- 4 Lights total for two classrooms (more may be required for large rooms)
- 2 Lights to two offices
- Examination Light
- Solar Rechargeable Lantern
- Solar Rechargeable Torch
- 2 Cell Phone and Lantern charging ports
- TV
- VCR/DVD Player
- Overhead Projector
- Desktop Computer or Laptop
- Computer Monitor Screen
- Printer

However, Zim Solar also notes that the system would be designed according to budget and the necessary appliances in the particular case, what they consume and how long they operate (Zim Solar, no date).

1.2 The benefits of electrifying schools

Section 1.2 key points:

- *Lighting can provide extended teaching and working hours, although more research is needed to track the benefits of this through to educational attainment.*
- *Energy has been linked with positive gains in educational performance and quality of education, and reductions in truancy and illiteracy.*
- *Attracting teaching staff to rural locations is a recurring concern for many countries. Providing energy access can contribute to improved living conditions to attract trained staff.*
- *Electrification has been linked to more gender-equal access to education.*
- *The electrification of schools may also have positive impacts on wider issues such as water and sanitation, rural to urban migration, healthcare, and resilience to natural disasters.*

The principal benefits for education related specifically to electrification may be: firstly, 'improving the quality of schools, either through the provision of electricity dependent equipment, or increasing teacher quantity and quality'; secondly, 'increased study time' (WB IEG, 2008). However, we should bear in mind that overall there is a distinct lack of systematic data relating to actual learning outcomes (Robinson and Winthrop, 2016).

IEG's analysis of data for nine countries (once factors such as parental education, household income and school facilities are taken into account) found electricity had a direct impact on rural education (IEG, 2008). The likelihood of having a secondary school may even be increased by electrification. A study in Peru and Ghana indicated that electrified communities 'have significantly better roads and higher probability of having a secondary school' (IEG, 2008). The benefits are also not confined to children and teachers; electrification may allow schools to be available for adult literacy in the evenings (IEG, 2008).

In the following section, benefits of school electrification are considered in turn, including: lighting, educational performance, staff retention, gender implications, and other benefits. However, even with such benefits, electrification alone does not necessarily harness the full potential of energy for education.

1.2.1 Lighting and extended working/teaching hours:

Lighting is a serious issue for many schools. The argument is that light can allow teaching to take place in the early morning and late at night, extending classroom hours. Studies in Nepal, Argentina, and Kenya have suggested this to be the case (UNDESA, 2014). For example, in Argentina 'classes at un-electrified schools could not start until mid-morning when it was bright enough inside the classroom to read' (UNDESA, 2014). In one Kenyan example, power provision made it possible 'for teachers to provide extra teaching in early mornings and late evenings to make up for material not adequately covered during normal teaching hours due to lack of teachers' (Kirubi et al, 2009).

In India, rural schools are often 'poorly constructed and have rooms that remain dark even during the day, especially when the small windows have to be closed to prevent the heat from coming in' (Maithani and Gupta, 2015). The lack of light can prevent children from looking at their books or writing (Maithani and Gupta, 2015). Maithani and Gupta argue that 'in thousands of schools, lights and fans will make a huge difference in encouraging attendance and facilitating greater attention'. Furthermore, the quality of light is also improved when the switch is made to electrical sources, such as Compact Fluorescent Lamps or Light Emitting Diodes, away from traditional sources like kerosene, candles and wood (UNDESA 2014). The previous use of kerosene may only provide limited light and have cost implications (Eckley et al, 2014). Providing children with access to quality lighting diminishes the necessity of parental contributions to fund batteries or paraffin, and this in turn can help reduce the marginalisation of poorer students (Davies et al, 2015).

Solar Aid's 2015 impact report also found that 'Access to clean, safe light helps students to do their homework for an extra hour a night'. Headteachers at schools SunnyMoney worked with reported improved pupil performance, attendance, and motivation (SolarAid, 2015). One study in Zambia found that 'A survey conducted by the Energy Regulation Board (2006)' in one area indicated that 'solar energy is enabling students to study longer hours in the night and some schools have recorded improved examination results and increased enrolment because solar energy is acting as an attraction for students to schools that have electricity.' (Mfune and Boon, 2008). In addition, in a survey in Malawi on school lighting (129 responses), the survey asked students if they studied at night – 90% said yes and 10% said no (O'Reilly, 2014).

Whilst there is evidence that provision of lighting results in increased study time, the causal chain for lighting has not been followed through to 'improved results and higher educational attainment' (IEG, 2008). In Uganda, in a 'randomised field experiment, unexpectedly, solar lamps lowered test scores by 5 points' (Furukawa, 2013). However, it was reported that lamps increased study time by 30 minutes so this decrease may be 'due to flickering from lack of full charge'—lowering productivity (Furukawa, 2013). Still, the nationwide learning in the case of Uganda has suggested that 'solar lamps likely have insignificant effect on educational attainment' (Furukawa, 2013). Further evidence is required to ascertain the direct benefit to outcomes such as attainment (beyond anecdotal). SolarAid are now managing a study funded by DFID and Stanford, looking at the impact of pico-solar lights; specifically on 'performance, attendance and dropout rates' (SolarAid, 2015). It may be that electricity alone is not enough for there to be a direct knock-on effect on attainment. Improvements in educational quality may need to occur in other areas as well, such as improved resources and trained teaching staff (alongside, and perhaps even facilitated by, energy access and technology) before a real impact is made.

Lighting is also important for teachers. In Malawi trainee teachers noted in one set of interviews that 'they need access to lighting in the evenings for lesson preparation and planning' (Davies et al, 2015). However, extending schooling hours could result in teachers being over-burdened, in light of their responsibilities outside of school hours as well.

1.2.2 Educational performance

With regard to the more general relationship between electricity consumption and education, in 210 countries there is a 'strong correlation (above 66%) with electricity consumption per capita and higher scores on the education index' (UNDESA, 2014). For example, in Argentina staff reported a significant reduction in truancy after electric light installation (UNDESA, 2014). In Sudan and Tanzania solar energy enabled a jump in completion rates for primary/secondary schools from less than 50% to close to 100% (UNDESA, 2014).

One study in Brazil found that a major impact of electrification 'has been reducing illiteracy and improving the quality of education' (Diniz et al, 2006). A study in the Philippines on the School Electrification and Education project of the Alliance for Mindanao Off-grid Renewable Energy Programme (AMORE), found that the programme was 'able to influence the performance of student beneficiaries in terms of the National Attainment Test' (Faustino and Medina, 2014). Furthermore, the 'extent of utilisation of multimedia learning materials' was found to influence the National Attainment test performance of students (Faustino and Medina, 2014). In Kenya, the ability to utilise mass media helped supplement normal classroom instruction; this in turn helped with preparations for national exams (which had been biased against rural/remote school children) (Kirubi et al, 2009). However, Gustavsson, in a study in Zambia, found that 'there is no evidence of actual improvements of school children's marks as a consequence of access to solar services,' although there were increases in study time (Gustavsson, 2007).

The direct and non-anecdotal links to educational performance are still hard to pin down, as we have seen when examining lighting specifically. Energy and technology are, of course, not the only influencing factors when it comes to school performance (Faustino and Medina, 2014). These can include family income, school grade, attendance and nutrition (Faustino and Medina, 2014). Whilst energy can contribute to alleviating some of these issues, it is only part of what contributes to the problem. One of these connected areas is the retention and quality of teaching staff.

1.2.3 Staff retention

'The failure of teachers to take up posts in remote locations and frequent absenteeism from such postings are problems in many countries' (IEG, 2008). Attracting teaching staff, particularly quality staff, to rural areas is a real and ongoing concern. The general view is that a lack of electricity 'exacerbates the already high teacher-turnover rate, which has a negative impact on the quality of education' (Jiminez and Lawand, 2000). Teacher shortages can be seen in that, as of 2012, according to Education for All (EFA), 29 of 161 countries with available data 'had pupil/teacher ratios in primary education exceeding 40:1' (EFA, 2015)

In the case of South Africa, one study noted that the most experienced/skilled teachers tend to reside in urban areas, this being 'largely due to the availability and accessibility of relevant resources and facilities' (Herselmen, 2003). Herselmen notes that in South Africa the result is that, in rural areas, the 'majority of scholars are receiving education of inferior quality by teachers without the appropriate facilities and resources needed to sufficiently teach' (Herselman, 2003).

The reasons for teacher shortages in rural areas include living conditions. Independent Evaluation Group's (IEG) impact study of 'support to basic education in Ghana' found that a 'teacher's living conditions, including whether his or her home had electricity, affected the incidence of absenteeism and teacher morale' (IEG 2008). Furthermore, 'In rural areas of Kenya, 75% of head teachers reported that recruiting and retaining teachers was a problem—but 60% said better lighting would encourage teachers to work in remote regions. Over a third of teachers said that they use a solar light for marking, lesson planning and extra classes.'(Solar Aid, 2015).

Tanzsolar, who have initiated a rural school electrification programme in Tanzania, found that many of the rural teachers in the Mara region are housed on-campus with no access to power 'not even to charge their mobile phones'—and attribute the lack of qualified teachers to (in part) the lack of such services in remote locations (Tanzsolar, 2012). In one region in Malawi, it was felt that younger teachers were particularly reliant on energy access, therefore this was potentially influential on where they chose to teach (Davies et al, 2015). Mobile phones were seen as playing an important role in 'communicating with family and friends' and trainee teachers surveyed were 'conscious of needing to charge their phones' (Davies et al, 2015).

An improved working environment may also aid the quality of teaching provided to students. A survey of electrified schools (solar PV) in Argentina found that 63% of staff/faculty that participated had 'been able to improve the quality of their work thanks to the better working conditions and teaching aids electricity offered' (UNDESA, 2014). If electricity can effectively contribute to the retention of teachers, then this can in turn impact school quality 'encouraging students to stay on longer or enabling them to do so as their grades improve from better teaching' (IEG, 2008).

However, electricity is still just one of the basic facilities or incentives that contribute to teacher reluctance to work in deprived areas; others may include housing and healthcare (UNDESA, 2014). A key finding in one Malawi survey was that 'the role of electricity in attracting/retaining teachers is closely bound with the issue of teacher housing availability and quality' (Davies et al, 2015). In order to attract teachers a broader package of basic services and incentives needs to be considered. The Education For All initiative has emphasised that, 'To attract and retain good teachers, policy-makers need to improve teacher education, deploy teachers more fairly, provide incentives in the form of appropriate salaries, and create attractive career paths' (EFA, 2015).

1.2.4 Gender implications

Electrification also has potential gender-equality implications when it comes to education. In Mali, electrification of schools saw an increase in girls' school attendance, improved performance, and 'drastically improved boy-to-girl ratios' (UNDESA, 2014). In Bhutan, electrification contributed to more years of schooling; however, notably, 'girls still benefit relatively more than the boys, as RE [rural electrification] contributes to 0.65 years of additional schooling for girls and 0.41 years for boys' (ADB, 2010). Enrolment of girls in Nepal also increased by 23.3% across a sample of electrified schools (UNDESA, 2014).

1.2.5 Other related benefits

Using energy to kick-start education has knock-on effects on sanitation, health, migration, and resilience; the school's energy system can in turn serve useful functions for the wider community as well.

Resilience: Electricity can facilitate the use of emergency radios or disaster warning alarms (UNDESA, 2014). Some research has also indicated that 'communities with higher levels of education are more resilient in the face of natural disasters' (Robinson and Winthrop, 2016).

Healthcare: Where healthcare centres in the community lack energy, the school may help with vaccine refrigeration (UNDESA, 2014). Access to ICT in schools could also help to enable better health education. For example, 'a global review of electrification efforts and health found that access to ICT increased awareness of health issues, leading to changed behaviour which improved health outcomes and reduced fertility' (UNDESA, 2014).

Notably, in the longer term, research has indicated that 'half of the decline in child mortality globally between 1970 and 2009 is due to mothers having higher levels of education' (Robinson and Winthrop, 2016). Furthermore 'Educated parents are more likely to be healthy themselves and also have well-nourished children, to get them vaccinated, and send them to school' (Robinson and Winthrop).

Water and Sanitation: The importance of toilets and running water at schools is of course central to the health and well-being of the students during school hours. Whilst water and sanitation are not the particular focus of this paper, it is worth noting that energy can help to solve some of these issues.

In Kenya it has been observed that 'toilets would seldom be cleaned due to lack of water, while water-borne diseases especially skin infections, typhoid, and cholera were particularly common. The result of such disease was rampant absenteeism of both students and teachers from school' (Kirubi et al, 2009). Water pumping was a top priority for power use in this case (Kirubi et al, 2009). The headmaster of the school in question noted that the '2-3 hours previously dedicated to gathering water' were then dedicated to evening study. Energy provision to schools can also benefit the wider community in this regard. For example, in Brazil 'the Luz no Saber Programme electrified 3,000 rural schools with grid and solar PV systems that then used their electricity to furnish potable water to communities through irrigation and pumping systems' (UNDESA, 2014).

By providing electricity-enabled water pumping systems, such as in the Brazil and Kenya examples, electrification can aid wider water and sanitation issues, which in turn may help to reduce absenteeism and even aid the wider community.

Migration: An interesting possible benefit of electrification in the context of smart villages is that it may work to reduce rural/urban migration and encourage youths to stay in the village, as witnessed in Colombia (UNDESA, 2014). Student enrolment in Nepal increased 'dramatically' and worked to persuade parents to keep children in the village instead of sending them to urban areas (UNDESA, 2014). However, in the longer term, once these children are educated this could provide even more incentive to move to urban areas to obtain skilled jobs. Indeed some studies have 'documented the positive relationship between the educational attainment of an individual and his or her propensity to migrate from rural to urban areas' (Todaro and Smith, 2012). Yet of course this is not a reason to view school electrification with trepidation. Energy access, amongst many other things, can help create employment opportunities by enabling the productive uses of energy and encouraging entrepreneurship—potentially creating more skilled jobs in rural areas. When these activities happen alongside educational initiatives it could provide incentives to stay in the village, not only in the short term for education but also in the longer term too.

UN Migration Agency/IOM's Global Solar Lanterns Initiative/CC BY-NC-ND 2.0

1.3 Challenges for electrification: Successes and failures

Section 1.3 key points:

- *Electrification of schools is often bundled into broader rural electrification projects.*
- *Appropriate and substantial capacity building is needed where local personnel are to take on ownership and responsibility for maintenance of the electricity system in the long term.*
- *Attracting private sector investment can prove problematic: one solution is to take a more collaborative approach to financing with multiple investors.*
- *Financing plans need to account for system sustainability and maintenance. One way of doing this in order to fund maintenance is to use energy access to support the establishment of a productive enterprise. However, issues can occur regarding ownership of the funds and responsibility for the enterprise itself.*
- *Reliability of devices and technical issues can present a challenge. Regulatory frameworks and quality standards at a national level can help guard against this.*
- *Theft presents a repeated concern for school electrification projects. The electrification of the wider community and perhaps neighbouring villages may reduce the tendency for theft.*
- *In order to maximise the benefits of electrification for education, household access to energy should also be enabled. It can raise awareness about the value of education with parents, reduce household costs and free up money for educational purposes, enable girls to have more time for study and school, and reduce absenteeism in general.*
- *Care needs to be taken that teachers are not overburdened by responsibilities for maintaining the energy system.*

Electrification of schools (on a large scale) is often bundled into broader rural electrification projects, for example Nepal's Rural Energy Development Programme, Sri Lanka's Energy Services Delivery Project, and in Kenya, where the Kenya Power and Lighting Company operated 500 rural electrification schemes 'covering health, schools and community water' (UNDESA, 2014; Cook, 2011). However, there are some projects and companies that are focusing on schools in particular: for example, the Brazil photovoltaic rural school electrification programme in Minas Gerais, and the Papua New Guinea Solar Lighting for Rural Schools initiative (Diniz et al, 2006; UNDESA, 2014). In terms of companies, TanzSolar in Tanzania operates a Solar Schools programme and Zim Solar has solar packages that are tailored specifically to schools (TanzSolar, 2012; Zim Solar, no date).

Of course, the nature of the challenges faced depends upon the specific project and location.

For example, one electrification project in the Philippines found challenges relating to peace and order, with local conflicts sometimes resulting in the temporary cessation of project work and the evacuation of residents (Winrock International, 2005). The conflicts resulted in loss of community lives as well as solar PV panels, and drug trafficking further contributed to the law and order issues (Winrock International, 2005).

The following sub-sections set out the key challenges to electrifying schools at a more general level, highlighting key areas that can result in project failure or enable success, whilst drawing on examples from school electrification experiences. Other challenges, specific to a mini-grids system where schools are the anchor, will then be discussed. The sub-sections cover in turn capacity building, financing, technical issues, theft, household electricity access, and teacher burdens.

1.3.1 Capacity building

As with any electrification programme, capacity building is essential to the success of school electrification. 'Effective partnerships build local capacity so that a self-sustaining renewable energy market can function without external support or dependence on international actors' (UNDESA, 2014). Lack of skills, both technical and business, can be a major impediment to energy access, across the board and at all levels (technicians, government officials, etc.) and training programmes are required to counter this (Holmes, 2016). Schools are no different.

'An evaluation of Thailand's renewable energy sector noted that "the absence of skilled manpower and spare parts" is a "prime" barrier' to electrification (UNDESA, 2014). You need personnel trained to maintain and repair installations 'to ensure quality control and safety standards' (Tembo and Mafuta, 2015). Such work needs to be done not only initially but periodically as required due to 'turnover in the ranks of users and technicians' (Jiminez and Lawand, 2000). Those who provide the training also need to have 'sufficient experience and understanding of local conditions' (Jiminez and Lawand, 2000). To encourage capacity building, Grameen Shakti in Bangladesh has sponsored 'technical degrees in engineering and related fields for employees that commit to staying with the organization long-term' (UNDESA, 2014). However, as discussed later, it is important to be conscious of the increased burden on teaching staff should they, in a stand-alone electrification project, be expected to be responsible for the system that is put in place.

There needs to be mitigation for the fact that not all people may be willing to participate in such training, and also that a few days' training may not be enough to build real technical expertise and capability in a complex area. As well as detailed training there still needs to be support in place while responsibility for maintenance is transitioned, and care taken to identify appropriate and willing personnel for this task.

In Malawi, the responsible and effective management of projects at the community level was identified as a major challenge: more 'investment is needed to prepare and support communities in the form of longer development cycles, additional training, and setup of technical and organizational support mechanisms' (SOGERV, 2015). A possible approach which is being explored by SOGERV is to recruit an entrepreneur to manage day-to-day operations (SOGERV, 2015). The entrepreneur would be local, embedded and aware of community energy requirements, and could be 'incentivized to provide a market based energy solution' (SOGERV, 2015). This should act to aid financial performance and improve the local technical capacity (SOGERV, 2015). In particular, this approach is also a possible aid to the financial sustainability issue dealt with subsequently. In Papua New Guinea, Sovacool noted that 'An energy service company "fee for service" model, where each school board could have paid a small fee to hire one full time person responsible for servicing and maintaining all solar panels, batteries, and parts within a district, could have potentially minimized problems with maintenance and vandalism' (Sovacool, 2013).

Obtaining the community buy-in in order to plan for capacity building in the first place can also present an issue for electrification projects. In one project in the Philippines, residents expressed scepticism and cynicism when hearing of electrification activities; this can arise out of previous neglect by the government such as unfulfilled promises, etc. (Faustino and Medina, 2014). It is necessary to not only build capacity but also awareness and trust, and care should be taken to ensure that individuals selected for training are capable of acquiring and applying the necessary skills.

1.3.2 Financing for sustainability and maintenance

Access to affordable financing is a repeated difficulty across the energy access space (Holmes, 2016). Schools, whilst they may receive some priority at the national level, still face problems when it comes to finding adequate financing for electrification and this can result in failure of electrification programmes. Rural electrification programmes in China, Honduras, and the Philippines, amongst others, have previously relied on massive subsidies (UNDESA, 2014). Such subsidies have in some cases 'drained' the resources of state-owned electricity companies 'with highly damaging effects on their overall performance and quality of service' (UNDESA, 2014). This can cause these companies to be reluctant to extend energy access to the poor. When it comes to off-grid power (for rural areas unlikely to be connected to the grid) we need to consider both affordability and attracting investment in the project (although that may include government funding and subsidies).

In South America electricity typically supplies 10% of the total energy used in a school (the remainder being for cooking, hot water, etc.) but makes up more than 50 per cent of the total cost (UNDESA, 2014). Electricity needs to be affordable to justify it as a priority for school spending. Some teachers have also admitted that they 'believe scarce school revenue can be spent on other things such as books or more teachers' (UNDESA, 2014). Teachers' buy-in is central to success, particularly if they have responsibilities for maintenance and appropriate use.

What is especially concerning for rural schools is that funding formulas are, for the most part, based around 'student input and amount of institutional activities' (UNDESA, 2014). Restrictions such as funding formulas favour schools with numerous institutional activities: 'number of staff, staff salaries, number of enrolled students, buildings' etc.; this limits schools' ability to get funding for energy provision/technology in the first place where there aren't specific schemes in place (Lung et al, 2012). In addition, some rural schools have financing arrangements that are restricted to 'civil works (buildings) and teacher salary; other costs such as maintenance, books, food and water, uniforms, and outreach programs must be funded from other sources' (UNDESA, 2014). Focus on schooling in urban centres in preference to rural areas continues to present an issue: for example, the South African government was even taken to court in 2009 for the 'infrastructure backlog' before funds were allocated in the settlement (Skelton, 2014).

It has been observed in the field that governments need 'stable and supportive policy and regulatory environments to attract private sector capital' (Holmes, 2016). For example, in India, where the framework has failed to address financial concerns, project developers have reported 'difficulty in finding credit and financing for renewable energy projects' (UNDESA, 2014).

Attracting private sector funding can also be problematic due to a need for fast implementation (limiting community input), and the capital required for feasibility studies (UNDESA, 2014). In order to deal with financing issues UNDESA stresses the need to 'leverage innovative financing streams and partnerships' (UNDESA, 2014). For example, in recent years there have been collaborations involving government, business, NGOs, banks, and community-based cooperatives as a way of generating investment (UNDESA, 2014). Such collaborations can help to supplement any budget constraints whilst simultaneously allocating 'project-risks between the public and private sector' (UNDESA, 2014).

Funding also needs to sustain the operation and maintenance of the system in the long term, covering not only spare parts but also potential training due to the remote position of many rural communities. A lack of system maintenance has been common in past projects and leads to system failure (Jiminez and Lawand, 2000). In Papua New Guinea, the Solar Lighting for Rural Schools Programme distributed 1,700 solar PV kits across 2,400 classrooms (UNDESA, 2014). However, this programme failed when 'neither teachers nor school boards could afford to invest in maintenance…. Only a handful of units remained operational a mere five years after the programme had ended' (UNDESA, 2014).

Particularly for remote rural schools, access to centralised follow-up maintenance assistance may be limited (Jiminez and Lawand, 2000). For example, in a school electrification programme in Argentina, most of the problems occurred with regard to system maintenance and 'the training of the local residents' (Jiminez and Lawand, 2000). The programme produced a manual with step-by-step maintenance instructions, and educational aids were developed to try and remedy shortfalls in local technical capacity (Jiminez and Lawand, 2000). In addition, steps were taken by the local utility 'to ensure that their local offices verify system maintenance' (Jiminez and Lawand, 2000). A system of support and monitoring is necessary to keep systems on track, much of which can be owned and coordinated by the community itself.

Another study in Uganda on rural electrification noted one school in which, although in possession of 'solar panels and a large diesel generator', both had been 'inoperable since January 2009'—and at the time of the paper the school 'had yet to gather enough funding to hire an engineer' (Ezor, 2009). Instead, the school ran a petroleum generator for 1.5 hours to provide light in the evenings (Ezor, 2009). This is another example of the need for appropriate allocation of funds for repairs, and in this particular case, the need to take into account the increase in maintenance costs caused by geographic isolation (Ezor, 2009). There were very few skilled engineers on the island (in Kalangala district) and funds for repairs 'must include the additional costs of transportation and room and board for the engineer, and the importing of spare parts upon request' (Ezor, 2009).

In the case of Soluz, which provided PV systems to schools in Honduras, although the school was responsible for battery maintenance, Soluz performed the remainder of the maintenance tasks. The costs here were expected to be low as Soluz already had a maintenance infrastructure in the area (Jiminez and Lawand, 2000). Costs for remote locations lacking infrastructure need to be taken into account. Also, consideration is needed of the extent to which schools can realistically be held responsible for these activities, and whether they can bear the associated costs in relation to their other priorities.

Productive enterprises may be needed to make systems sustainable, as there needs to be financial support mechanisms in place for ongoing maintenance. In one project in Malawi the focus was on 'productive use' of a solar PV system installed at a school to 'increase system sustainability' (Tembo and Mafuta, 2015). In this project income-generating activities such as 'phone charging and video showing were incorporated into the solar PV design as a means of generating maintenance funds for system sustainability' (Tembo and Mafuta, 2015).

However, problems may occur with what is done with the income generated from such enterprises. In the Malawi example, generated funds became 'a source of suspicion and conflict amongst the energy committee members and the community at large' and there was also a lack of understanding that some profit needed to be kept for maintenance (Tembo and Mafuta, 2015). In addition, there needs to be clarity regarding responsibility for decision making 'pertaining to profits' (Tembo and Mafuta, 2015). Clear ownership structures need to be in place. Tri Mumpuni has noted from her experience working with on and off-grid community-managed hydro projects in Indonesia that consensus on the use of income is key, and that this can be used for wider community development, with education identified as a central means for improving living standards (E4SV, 2016).

1.3.3 Technical concerns

The supply of energy itself and the reliability of devices used (lights or ICT) can be problematic for school electrification efforts. For example, in Argentina, 'the main problems encountered were flickering lights, poor illumination, or frequent burn-outs… whilst interference had caused problems listening to the radio. Almost twice in every school, they had to call for technical assistance to the company and 29% declared the problems were not properly solved' (Alazraki and Haeslip, 2007). Key challenges for gaining access to lighting in one survey in Malawi highlighted a lack of money for the most part; however, other issues included equipment problems, such as dim light, fake batteries, and torches breaking (O'Reilly, 2014).

One of the ways to deal with such technical problems, as well as some of the financial issues, is to offset them through 'strong regulatory frameworks as well as national standards and certification systems' (UNDESA, 2014). Lack of standards of acceptance regarding installation can lead to system failure (Jiminez and Lawand, 2000). In Brazil, an assessment of the photovoltaic rural school electrification programme found that an 'adequate service infrastructure is required to make projects viable, mainly characterized by a technical network which guarantees the system's technical performance, system design, qualified technical support, and also avoids a lack of unreasonable and unfulfilled user expectations' (Diniz et al, 2006).

UNDESA argues that successful programmes work to strengthen technology 'from design and installation to maintenance and replacement' whilst 'falling into clear and consistent policy environments' (UNDESA, 2014). One programme in China for rural energy development carries out a 'start-to-finish' quality process by 'establishing manufacturing standards and practices, facilitating access to product certification, and introducing a randomized testing regime which penalizes companies at the production-line and retail stages for non-compliance with system performance requirements. It also culminates in the "Golden Sun" label to certify compliance with International Organization for Standardization (ISO) recommendations' (UNDESA, 2014).

1.3.4 Theft

Theft also presents a practical challenge to school electrification. 'Abnormally' high rates of vandalism and theft were noted in solar programmes in Papua New Guinea (Sovacool, 2013). Furthermore, in the Concessions Programme in Salta Argentina, solar panels that were poorly mounted were subject to theft (Jiminez and Lawand, 2000). In the Papua New Guinea example, such activities were seen as largely down to jealousy, which created 'a reluctance to commit to the technology' (Sovacool, 2013).

In the design phase of a pilot project installing solar lights in schools in Madagascar, discussions with the superintendent of the public school system found specific concerns in the design relating to the theft of the copper rod 'from an obvious location near the school entrance'. This resulted in it being re-located (Pavlik et al, 2013). By engaging the community some of the risks may be mitigated by harnessing local knowledge.

Focusing on the village as a whole with the school making up a key part, and electrifying the whole community rather than simply electrifying the schools as a separate entity, may aid in reducing the motivation to steal or vandalise such equipment, particularly where jealousy is associated with these activities. To go even further than this, inclusion of neighbouring villages in electrification programmes for multiple village projects may help reduce the extended risk of theft.

1.3.5 Lack of household electricity access

The educational impacts of energy are not confined to the school. Where schools are electrified and households are not, the full benefits of electrification may not be captured (UNDESA, 2014).

A positive link has been identified between household electrification and educational outcomes: 'Children in electrified households have higher education levels than those without electricity' (IEG, 2008). The provision of solar energy in the household can enable more studying time outside of the school environment (Gustavsson, 2007). In addition, in Bangladesh 'duration of school attendance by children corresponds with the duration of household access to electricity' (UNDESA, 2014).

The impact of household electrification on adults can have knock-on effects on children's education. For example, in Bangladesh, parents spent more time assisting the education of their children than prior to electrification—mothers and female family members in particular (Barkat et al, 2002).

Household solar electrification can present monetary savings for families, with potentially positive educational outcomes. One study by Solar Aid in Africa found that savings from what was previously spent on kerosene, batteries, and torches for lighting were now spent on food, farming, business development and, most notably in this case, on educational costs—books, uniforms, etc. (Eckley et al, 2014). Solar Aid also found from an analysis of some of their work in Africa that for the people education tends to be a high priority for investment: 80% of solar lights were purchased for students to use at home (Eckley et al, 2014). Additionally, when it comes to home access as well, although it may increase study time, the availability of TV may decrease the time spent studying, although it is possible that TV can provide educational benefits (IEG 2008).

The extension of electrification to households may also aid literacy and gender equality goals in the context of education. One Bangladesh study found that 'the overall literacy rate in electrified households is significantly higher (by 22%) and with much less gender inequity (female literacy rates being 31% higher in electrified than in non-electrified villages), than households in non-electrified villages' (Panjwani, 2005). Part of this is the contribution of the availability of electricity in households to raising awareness about the value of education (Panjwani, 2005). In Bhutan, women in electrified households were found to be more aware about education and health in comparison to males, this being partly due to an increase in social networking (ADB, 2010).

Indeed, electrifying schools as standalone entities could even lead to increased friction with 'other teachers or community members with lower levels of energy access' (Davies et al, 2015). This was also referred to in relation to theft and suggests a benefit in electrification as part of a broader community programme to mitigate for such issues.

Without household access to clean energy technologies alongside school access, little may be done 'to address the human health issues arising from dependence on solid fuels for cooking'

(UNDESA, 2014). 'Acute respiratory infections in children' are the principal cause of school absences in many countries (UNDESA, 2014). For example, in Uganda 'one-third of school absences come from such infections, which commonly last 7 to 9 days each' (UNDESA, 2014).

Additionally, when considering absenteeism, improvements in energy infrastructure could mean that children may spend less time fetching water or wood (EFA 2015). From a gender perspective, girls who are taken out of school to help their mothers with fuel collection can end up 'missing out on education; this perpetuates the cycle of female illiteracy and poverty' (Lambrou and Piana, 2006). A study in Bhutan found that "Children in electrified households completed more years of schooling compared to those in un-electrified households, with a more pronounced impact on girls than on boys. This is due to time saving on fuelwood collection and access to electricity" (ADB, 2010).

In India, one of the contributing factors to low enrolment, discontinuation, and dropouts is the 'opportunity costs' (Azim Premji, 2004). This refers to the value of time lost when 'children forgo work and attend school' (Azim Premji, 2004). For example, 'The role of the girl child and her burden of domestic work; the role played by boys in supplementing farm labour; the differential labour participation by children of different age groups; and the economic uncertainty and instability faced by really poor families, have all hindered sustainable schooling' (Azim Premji, 2004). Studies have found that these costs can be negligible for younger children but become high as children become older and more capable of productive work (Azim Premji, 2004).

What is interesting about the example above is the potential need to counteract boys (dependent on the social gender norms in place) potentially being pulled out of education for productive work. Energy is thus part of the solution, not the whole. For example, parents' awareness of the value of education for their children may play a role in this, and as noted energy may contribute to this too.

Integration of energy access initiatives and broader development appears to be key when we consider educational impacts and the relevance of the household level noted above. Many energy access programmes have tended to bundle schools as part of a village or community electrification programme, which the above evidence suggests would maximise benefits.

1.3.6 Teacher burdens

Extended hours for teaching could also lead to over-burdening teachers, particularly if they have added responsibilities for maintaining the electricity system. The majority of teachers who responded to a survey in Malawi had increased hours 'worked per day in a typical week', although this was less significant an increase for those who lacked a solar panel at home (Davies et al, 2015). The danger of increased hours being a burden to teachers was explored in focus groups, but none of the teachers claimed this was the case (Davies et al, 2015). Extended burdens on teachers is something that will be considered throughout the report.

1.4 Schools as anchor loads for mini-grid electrification

Section 1.4 key points:

- *Financial sustainability is a key concern for schools to act as a viable anchor load for a mini-grid. It has been noted that anchor loads more typically comprise productive enterprises. Any productive use at the school or nearby would have to avoid the interruption of educational activities and over-burdening of teachers.*
- *Ownership of the mini-grid system should be placed with the community as a whole rather than the school. However, decisions concerning the system will impact the school in particular and so a balance needs to be struck between school involvement in decision-making, and care that the burden of responsibility is not solely with the school.*
- *The system would need to be set up to avoid over-dominance of the school as the anchor load so that households and businesses have a reliable supply.*
- *A possible solution to some of the challenges would be to position the school as one of several anchor loads, reducing risks by increasing diversity.*

Mini-grids need 'up-front investments in infrastructure with a long service life'; therefore it is preferable to have an anchor 'who is likely to be at the location for many years into the future' (Bourgeois et al, 2013). Certainly this is the case when it comes to schools as part of the fabric of the community; however, the financial challenges raised above still apply. Other key concerns that will be discussed in this section include ownership, productivity/sustainability and the dominance of the anchor.

The experience of anchor loads for mini-grids has predominantly come from the use of telecom towers. Telecom towers as the anchor load have been piloted in various countries including Kenya, Bangladesh, and India (Bhattacharyya and Palit, 2014). However, the appropriate anchor depends on the community itself; for example, in Kenya island communities reliant on fishing 'have expressed an interest in the running of cold storage facilities' (ERC-IFC, 2015).

The ABC business model identifies three groups of customers for energy provision: Anchor, Business Groups and Community members (GNESD, 2014). Within this model the 'anchor load is predictable and offers a guaranteed source of revenue for the project developer, whereas business group and community members are usual customers for the project' (GNESD, 2014). Another model could also include sales of excess energy back to the grid for additional income (E4SV, 2016). Either way, responsibility for things like maintenance has to be carefully considered so that the school and teachers aren't left overburdened, or expected to run a productive business simultaneously with carrying out their school work, in order to finance the system.

As noted, one of the things we need to bear in mind when thinking of school electrification with a school as an anchor load for a mini-grid is local ownership. In one project in Malawi, engaging communities at all stages and giving communities 'clear responsibility for managing and maintaining the systems' was highlighted (Tembo and Mafuta, 2015). Indeed, in the Malawi project in question, they adopted the concept of an 'Energy Committee' as a 'vehicle for community ownership and participation' (Tembo and Mafuta, 2015). This means the ownership shouldn't be restricted solely to the school as it is still a community system. An issue that emerged in this model was that some teachers felt excluded from decision-making 'on the activities that are associated with solar PV system everyday use.' (Tembo and Mafuta, 2015). This was a major issue as 'the Energy Committee's decisions and activities had significant impacts on teachers, such as use of the school for charging and studying, interruptions to classes hence led to misunderstandings with the local committee' (Tembo and Mafuta, 2015). A balance has to be struck that respects the school's position, whilst not overburdening it with unequal responsibility.

In the EURO-SOLAR programme in Latin America, issues surrounding community ownership were also evident. As the majority of the EURO-SOLAR information centres were installed in schools, the assumption was that 'it would be reasonable to think that use for educational purposes would be guaranteed during morning hours, whilst in the evenings and at night they would be used by the community' (Canessa et al, 2014). However, this was not necessarily fulfilled, with disputes emerging between the community and the teachers/school (Canessa et al, 2014). Problems of community ownership in this case also contributed to drops in the productive use of the EURO-SOLAR kit since the initial support and enthusiasm (Canessa et al, 2014).

The second key issue is sustainability and productivity. Practical Action, while establishing micro-hydro mini-grids using community-based models in Malawi, Mozambique, and Zimbabwe, drew various valuable lessons which they aim to apply to future projects (Practical Action, no date). Of particular interest is that 'unless mini-grids are anchored to productive end use, financial viability is a challenge'. There were also lessons around ownership and management.

In the case of financial viability we run into problems when establishing schools as the anchor load. As we have seen, financing has presented a key challenge in the electrification of schools, and even if government completely funded the electrification of schools there would need to also be allocation of funds for maintenance and assistance in the longer term. In order to attract business investment as part of a partnership or otherwise, the attractiveness of the proposal is heightened when there is clear economic sustainability and productivity. The dependence on the school as an anchor load 'enhances business risks, as the threat of exit of such a buyer can have devastating effects on the business' (Bhattacharyya and Palit, 2014). Depending on the financing model, this makes it all the more important for schools to be able to demonstrate economic sustainability and productivity: for example, funding plans that account for long-term maintenance (we saw in a previous example a system going out of use due to an inability to pay for maintenance).

In the case of the community, having a productive use occurring at the anchor or indeed nearby would be beneficial not only in terms of providing maintenance but putting money and profit back into the community. However, responsibility for productive use would have to rest not with the school alone, particularly bearing in mind that the teachers are trained for their specific role and not to run a business.

Another potential issue with identifying an anchor load is if it undermines the goal of universal electrification, as the anchor could in some cases dominate the power consumption, and the remaining users are left to fight over what is left (Gollwitzer et al, 2015). There needs to be a balance in place to prevent over-dominance of particular anchor loads or other critical loads so that the supply of electricity to the community and businesses can be more reliable (Gollwitzer et al, 2015). Indeed, if the economic productivity of businesses in the community is what helps the mini-grid be financially viable in the longer term and provide jobs (Gollwitzer et al, 2015), this becomes even more important, especially when the school is the anchor and its economic productivity is limited.

It may be that a school could form one of several anchor loads within a village, thereby potentially reducing risks by increasing diversity. Additional anchor loads based on productive use would help mitigate issues of overburdening/interrupting teachers and problems of financial sustainability. In addition, this could help with matching supply and demand throughout the day.

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Chapter 2: Information and Communications Technology (ICT):

Chapter summary: This chapter covers the digital divide, the potential benefits that can be harnessed from the use of ICT for rural education, the challenges for the deployment of ICT and current trends, and case studies of ICT deployment in schools. A final section deals with the important relationship between teachers and the technology, which, as the report argues, is central to the successful deployment of ICT in rural schools.

There are many diverse uses of ICT for education, such as: 'computer assisted learning, web-learning, computer classes, online training, distance education, visualization software, eLearning, virtual learning, digital training, etc.' (Munienge and Muhandji, 2012). These uses can occur in multiple contexts such as 'radio, television, computers and the Internet in classrooms, computer laboratories, and other locations, as well as developing a structure to support mobile learning using different smart phone and tablet devices' (UNESCO, 2014).

2.1 The digital divide

Section 2.1 key points:

- *Adoption gaps between rural and urban populations, and rich and poor, are falling for mobile phones but increasing for the Internet.*
- *Poorer remote communities that Smart Villages is concerned with are excluded from ICT access, not just from a lack of funding for ICT but also in many cases a lack of energy supply to begin with.*
- *The internet can bridge the gap between rural and urban schools, whether through access to educational materials and web pages, or the ability to watch lectures via satellite or online.*

The World Bank recently highlighted the growing digital divide between rich and poor (Guardian, 2016). Whilst no other technology 'has reached more people in so short a time as the internet' the 'development potential of technological change had yet to be reaped' (Guardian, 2016). 'Adoption gaps between the bottom 40 percent and the top 60 percent and between rural and urban populations are falling for mobile phones but increasing for the internet' (World Bank, 2016). In China, large investments in rural connectivity are bringing success, with more than 90 per cent of villages having fixed broadband by end of 2015 (World Bank, 2016). In East Africa access and connectivity have been improving, with students enthusiastic about the changes (Hennessey et al., 2010).

The rural/urban divide is of particular interest for smart villages. Poorer remote communities are excluded from ICT access, not just from a lack of funding but in many cases from a lack of energy supply to begin with. Scarcity of resources in rural areas can be particularly stark. For example, research in China has shown that there are 'twice the number of computers in urban primary education centres… than in rural centres' (UNESCO, 2014). However, this can be influenced by policy; in Tajikistan they made the decision to 'provide all schools with a laboratory with the same fixed number of devices regardless of enrolment'; this then works in favour of small rural schools versus larger urban schools (UNESCO, 2014). The Internet can also be used to 'bridge the gap between rural and urban schools, through the use of educational web sites and lectures via satellite' (Herselman, 2003).

Another concern that can exacerbate the digital divide is where 'schools are the only place where certain children can readily access and take advantage of the learning provided by ICT' (UNESCO, 2014). As noted earlier, a lack of energy access at the household level can undermine the full impact of school electrification: the same can be said about ICT.

Section 2.2 key points:

- *Isolating the impact of ICT from other factors can prove challenging. However, a study based on more than 40 years of research, summarising 25 previous meta-analyses, found that computer use has a positive overall effect on achievement.*
- *ICT has the potential to improve the learning environment. As it tends to be learner-centred it can help enhance learning and engage students, perhaps even influencing attendance, motivation, and attainment.*
- *Access to the Internet is particularly influential and transformative, exposing students to a vast set of information and experiences. However, there needs to be guidance around its use for educational purposes and awareness of the potential impact on traditional cultural norms when exposed to the culturally diverse information available. Ultimately it is the individual's decision what to do with this information.*
- *ICT could reduce educational costs and increase efficiency.*
- *ICT access can have specific implications for women; giving access to a range of materials could influence their perceptions of gender.*
- *ICT can improve teachers' access to training and consequently improve the quality of their teaching. The same applies for school leadership. ICT can also be leveraged to lift the burden of school administration. It may add burdens to teachers' workloads, in terms of ICT skills training and professional development, but it can also lift them.*
- *Distance education can help facilitate learning for those in remote areas where teachers are overstretched, dispensing with the need for learners and teachers to be in the same location. Distance education can also provide high-quality educational resources, acting both to benefit pupils and to support overburdened and inexperienced teachers. Historically, radio and television have been used as key enablers of distance education.*

2.2 Potential benefits of ICT

The potential benefits of ICT are numerous: it has the potential to 'improve student achievement, improve access to schooling, increase efficiencies and reduce costs, enhance students' ability to learn and promote their lifelong learning, and prepare them for a globally competitive workforce'—in particular, the potential to develop skills in otherwise marginalised communities (UNDESA, 2014; Mingaine, 2013). However, 'while many studies have been conducted to determine whether or not computers and ICT affect academic achievement and other student outcomes measures favourably, there are currently few comparable data to support this claim' (UNESCO, 2014). Although there are studies that have found significant positive impacts, there are an equal number which find little or no impact (UNESCO, 2014). The methodological difficulty is often to isolate the specific impact of ICT from other factors (UNESCO, 2014).

However, a study by Tamim et al. in 2011 summarised 25 'previous meta analyses based on more than 40 years of research' and concluded that 'computer use in the classroom does have an overall positive effect on achievement' (UNESCO, 2014).

The following sub-sections explore the benefits of, and issues around, the use of ICT in schools in rural communities, examining in turn the quality of learning, the value and impacts of internet access, costs, gender issues, the impact on teachers, and distance education.

2.2.1 Quality of learning

It has been argued that 'technology can improve the learning environment and enhance the learning process if students are perceived as unique individuals with their specific needs, interests and different learning styles'. In this case technology can facilitate 'self-paced, individualized instruction and student centered learning' (Klimov, 2012). Responsibility for their own learning and awareness of how they learn can allow children to utilise strengths and work on weaknesses (Klimov, 2012). By decreasing the amount of direct instruction it can also give teachers an opportunity to assist students with particular needs (Munienge and Muhandji, 2012).

The literature indicates that if ICT is 'well-utilised' it can help to enhance learning and engage students—particularly as it tends to be learner-centred (Mingaine, 2013). In addition it has been argued that technology can 'play a crucial role in student skills, motivation, and knowledge' and that ICT can be used to present 'information to students and help them complete learning tasks' (Munienge and Muhandji, 2012). Some commentators found that 'students report higher attendance, motivation and academic accomplishment as a result of ICT programs' (Mingaine, 2013). This can help to counteract issues such as dropout rates, perhaps by making the schools' curriculum more interesting, to try and address this challenge (Mingaine, 2013). ICT can also be used outside to supplement learning in the classroom—for example, the Khan Academy is an online learning platform 'that provides free tutorial videos on disciplines ranging from elementary mathematics to computer programming' (World Bank, 2016).

There is 'robust evidence of the positive impact of computers on learning when these are specifically adapted and used to teach mathematics, science and literacy' (Díaz, 2015). Puentes Educativos in Chile provides students with smartphones and 'free Internet access, and teachers with training and specially designed online material, including hundreds of videos adjusted to the local curriculum' (Díaz, 2015). An impact evaluation showed that 'students from sixth grade increase their test scores in science and English by 10 per cent or more' (Díaz, 2015).

2.2.2 The value and impacts of Internet access

By facilitating access to worldwide information resources and the ability to develop knowledge within new contexts, technology can enable the opportunity for learning 'that can occur anywhere, at any time, or for anyone' (Klimov, 2012). The Internet has been fielded as having perhaps the most 'transformative impact' (UNDESA, 2014). Some studies suggest that the web is 'one of the best tools for exposing students to a broad set of information and experiences that can become central to their education, socialization, and future employment' (UNDESA, 2014). The Internet in itself has 'significantly contributed to furthering education in the world', with the web and search engines making 'information on demand a reality' (Ramani, 2015). Online courses provide 'low cost models for supporting learning' and new opportunities for developing countries (Ramani, 2015). In one case with street children in Columbia, Internet in school was found to entice 'a higher than usual number back to the classroom' (Mingaine, 2013). However, access to the Internet can be hampered both by cost and by low bandwidth quality (Unwin, 2009).

On the other hand, simply providing access to information is not enough, and whilst the Internet is a valuable source teachers need to establish 'precisely the purpose of the search for information' to help students actually acquire knowledge from it (UNESCO, 2011). There are also harmful aspects that teachers and students should be aware of, from 'information overload to plagiarism, from protecting children from online risks (fraud, violations of privacy, online bullying) to setting an adequate and appropriate media diet' (OECD, 2015).

In addition, the Internet can influence culture and traditions within communities: 'The Internet and social media are very powerful tools that can influence and shape human behavior' (Furedi, 2014). 'It is virtually intrinsic to the concept of culture that different people will possess different values, beliefs and motives' and 'these values, beliefs and motives can change once the internet is introduced in a community because people change the way they communicate, learn and do business' (van Hoorik and Mweetwa, 2007).

The influence of such technologies on culture and beliefs can be both good and bad, and difficult to predict. An example of a potentially positive impact on culture is that ICT and the Internet has been used by gender equality advocates all over the world to disseminate rights-based information (Gurumurthy, 2006). The Internet, for both men and women, 'has been a space that allows for anonymity and solidarity, for self-expression and for building connections' (Gurumurthy, 2006). This could positively contribute to women's sense of empowerment and alter their perceptions of their role in the community. A contrasting example is that the Internet and social media have been seen as playing a role in radicalising young Muslims—such a phenomenon causing particular trepidation in connection with vulnerable young adults and children in education (Furedi, 2014).

In terms of the rural context specifically, in Papua New Guinea the introduction of mobiles and cellular networks triggered a challenge with regard to how to promote and maintain 'their traditional culture through the use of the internet and mobile web' (Osao, 2016). In this case, communication technology 'has had a significant impact on all facets of rural life and culture' (Osao, 2016). However, it is notable that the challenge framed here can also be seen as an opportunity and the internet/ICT harnessed as a means to enhance and promote traditions and cultures.

In rural Zambia a study found that participants mainly felt that the Internet had a positive impact on culture, 'being able to communicate much easier, having access to information, being able to develop oneself and much more benefits are experienced' (van Hoorik and Mweetwa, 2007). Yet the concern came with some mixed feelings about influence where websites are predominantly western and there was scarce African content (van Hoorik and Mweetwa, 2007). Concerns were raised regarding western cultural influences, particularly on the young (van Hoorik and Mweetwa, 2007). Yet the Internet over time has grown to present a huge source of information that crosses cultures from all over the world. The internet can be a means of preserving culture if there are websites and networks that reflect those cultures and traditions, perhaps even helping those who have moved abroad to teach their children about the culture of their home country (van Hoorik and Mweetwa, 2007).

2.2.3 Cost

Other research suggests that fully utilised ICT could 'reduce the cost of education and increase efficiency' (Mingaine, 2013). For example, one teacher can reach multiple learners via the Internet and video conference technologies, costs of hard copy text books may also be spared (particularly as materials are often sparse in schools in developing countries) with teachers having direct access to content and up-to-date teaching resources (Mingaine, 2013).

2.2.4 Gender

Technology for education can also have specific benefits for women. 'Worldreader found that, on average, women spent six times as much time reading on mobile phones as men' (Robinson and Winthrop, 2016). One of the possible hypotheses for this is that the 'mobility and privacy of digital reading—and perhaps technology in general—drive adolescent women and girls to read more' (Robinson and Winthrop, 2016). By giving girls their own device and internet access it gives them the ability to engage independently with a range of material that could influence their conceptions of gender. Gender, of course, is a key concern here and needs to be taken into account when assessing ICT in education rather than just looking at overall enrolment (UNESCO, 2014).

2.2.5 Teachers, teacher training, and school leadership

ICT has the potential to have a positive impact on teachers' work as well as supporting educational objectives such as problem solving, skill development and assessing or searching for information (Mingaine, 2013). ICT was identified in one study as useful for teaching and personal work: 'making teaching more interesting, easier, and more diverse, more fun for them and students, more enjoyable and motivating to students' (Mingaine, 2013). On a personal level teachers in the same study gained better access to computers for personal use, 'improving presentation of materials in class, giving more prestige to teachers, giving more power to teachers in school, providing professional support through the internet and making management in school more efficient and effective' (Mingaine, 2013). 'In both sub-Saharan Africa and South America, electrification enabled teachers to become familiar with computers that they then used to engage in professional societies, conduct e-learning, better manage student marks and parental reports, search for educational content, and plan lessons' (UNDESA, 2014).

A particularly key element of the benefits of ICT for teachers is improved access to training, which can then theoretically help the improvement of educational quality for rural areas. Distance education can facilitate teacher training and 'create a cadre of teachers who have the skills and confidence to generate positive classroom environments and where appropriate deal with multi-grade methodologies, whilst having a better grasp of subject content, particularly in respect of initial literacy and mathematics' (IRFOL, 2004). Technology can act as an enabler to provide relevant training. In Chile, online programmes have been used to teach teachers how to use ICT in their teaching (IRFOL, 2004). In Egypt, India, Morocco, and Israel, interactive TV has also been used for short course training (IRFOL, 2004).

In China, television has been used for teacher training and in general, according to a study, 'trainees felt that it helped them improve their teaching… it contributed to a higher examination pass rate; it was primarily responsible for the large increase in the number of qualified teachers; and it was able to provide training at a cost saving' (Wang, 2000). The most identified reason for the success in China was the programme's reputation for quality, with trainees uniformly citing this as what drew them to educational TV (Wang, 2000). The technology alone is not enough; the actual materials that are used and the software program needs to be of a high quality and standard for there to be buy-in and widespread use.

Technology can be used in innovative ways to facilitate professional development. For example, in Indonesia 'teachers take short videos of their peers and then jointly review and discuss pedagogical approaches and particularly difficult topics to teach in informal, low stakes ways as part of their professional development' (Truncano, 22nd July 2014). Using ICT for teacher training can also have cost benefits, which make it more accessible, through leveraging online/CD based courses, or video case studies/radio programmes, although school principals should be consulted to ensure the training is relevant to their context (Unwin, 2009). However, whilst ICT may be cost effective it should not entirely replace face-to-face support (Unwin, 2009).

ICT can be leveraged to help raise the quality of school leadership and management. Particularly with trends towards more decentralised educational management, headteachers are 'required to take on new roles as change agents and instructional leaders' (IRFOL, 2004). TV training in China was extended to primary headteachers on a national scale (IRFOL, 2004).

As we will note in later sections, extra training is required for teachers for technology to be successfully implemented in the classroom. This can place a burden on their time, however ICT can also make their day-to-day work easier in the long run.

Technology can be leveraged to help with school administration. For example, smartphones have been used with customised Enterprise Resource Planning (ERP), in order to 'monitor all payments in and out of the school; school fees, teacher and staff salaries…' (Robinson and Winthrop, 2016). Burdens on teachers can also be lifted through technology by splitting the responsibility of creating lessons versus teaching them (Robinson and Winthrop, 2016). For example, the Bridge International Academies model has teachers receiving a 'daily teacher guide with lessons via tablets, which is essentially a scripted lesson plan for them to follow' (Robinson and Winthrop, 2016). This relieves the burden of creating lesson plans and content, freeing up time to focus on the students' development. 'One Bridge teacher in Nairobi expressed that the scripts gave her confidence and allowed her to focus on students who needed additional support' (Robinson and Winthrop, 2016). Such enablement may be particularly relevant in rural areas where limited teaching staff may be faced with large classes. This same tablet can lift administrative burdens with data collection and analysis allowing for central monitoring of many aspects of teaching and learning (Robinson and Winthrop, 2016).

'In cases both from Brazil and Kenya, the way teachers' roles are configured and how technology is leveraged unburdens them from the normally overwhelming list of tasks they face' (Robinson and Winthrop, 2016). We need to consider teachers' full set-up and environment in each context so that the overall result does not over-burden them. For each burden there may be a way to unburden, but to make full use of this, projects need to consider every stage from electrification through to ICT deployment, training, and use.

2.2.6 Distance education

Distance education can facilitate learning, particularly for remote areas where teaching staff may be overstretched. It dispenses with the need for learners and teachers to be in the same physical location (Roy, 2012). In addition, 'certain types of ICTs, such as teleconferencing technologies, enable instruction to be received simultaneously by multiple, geographically dispersed learners' (Roy, 2012). By providing high-quality, new educational resources and practices, distance education can not only benefit pupils 'but also offer support, respite and training to hard-pressed inexperienced teachers dealing with multigrade classrooms' in the rural context (IRFOL, 2004). For example, programs such as Nafham provide a free online education platform that hosts /produces video lessons covering Egyptian and Syrian curricula (Center for Education innovations, no date). However, such programs of course require technology to function; historically, distance education has actually been able to run through the possibly more viable alternatives—where ICT access is limited—of television and radio in the rural context (OECD, 2014).

Radios and televisions 'have been used as educational tools since the 1920s and 1950s' (UNESCO, 2014). These mediums can help reach individuals at scale and with low cost, opening up instruction to those in rural/remote areas as well as early school leavers by allowing them to follow curricula at a distance (UNESCO, 2014). Radio in particular can help access rural areas, running off batteries (UNESCO, 2014). The use of radio and television instruction is still widespread in many countries; for example, in Asia it has been used 'successfully' in Nepal, Sri Lanka, and Afghanistan to create 'innovative models for providing educational messages' and to create 'community awareness' (UNESCO, 2014). Indeed in the 'smart' village of Terrat radio was utilised for just this purpose, to educate the Masaai on land rights; the same concept applies to rural education (E4SV, 2016). In Samoa radio has been used by the Education Broadcasting Unit specifically to reach children in rural/remote areas (UNESCO, 2014).

<u>Television:</u> Television can also be used to show educational films. In the Amazonas media centre programme, classes are taught remotely by teachers in Manuaus via satellite television and lessons are beamed to students in schools in rural communities, who are supported by a professional face-to-face tutor in their classrooms' (Truncano, 12 February 2014). One lesson is usually shared by multiple municipal schools at the same time (Truncano, 12th February 2014). 'Each class is mediated by an onsite tutor who coordinates the questions and answers, provides further explanations and directions, and helps support the equipment to ensure that the experience is as 'interactive' as possible' (Truncano, 12th February 2014). The key here is coordination; the onsite teacher is needed as well as supplementary equipment such as textbooks/internet resources to support the televised session.

The Programme to Accelerate Educational Progress in the state of Amazonas provides an improvement in the quality of educational services in remote areas (where teachers are scarce), and expands access to education (IADB, 2014). As well as constructing new schools and improving existing ones, the programmes provide more than 500 existing schools with 'real-time access to educational services via satellite'; satellite links are supported by technology kits, satellite connectivity services and 'communications antennas' to enable remote access (IADB, 2014). In this particular initiative, access to education will be provided for more than 30,000 children/youths in 'riverside and inland areas who presently do not attend school' (IADB, 2014).

<u>Radio:</u> We should not underestimate the effect of using old technologies in new ways: in interactive radio instruction, 'radio broadcasts are used to prompt specific actions by teachers and students in the classroom' (Truncano, 22 July 2014). In Argentina, radios were used to keep

pupils informed of current events/play music (UNDESA, 2014). Interactive radio instruction has been used in South Africa and Guinea (IRFOL, 2004). In South Africa 'highly structured ready-made interactive radio lessons' beamed directly into classrooms can act as a model for teachers (IRFOL, 2004). Awareness of current affairs at an earlier age could also be interpreted as positive for the democratic engagement of pupils in the longer term.

However, whilst television and radio have benefits, we should bear in mind in the longer term that whereas computers and IT present an 'increased opportunity for interaction with teachers and pupils' that isn't possible through one way broadcasts (OECD, 2014).

2.3 Challenges to ICT and the Internet and emerging trends

Section 2.3 key points:

- *Connectivity to the Internet needs to be expanded and made more affordable, with work done to encourage Internet service providers to operate in rural and remote areas. Technologies also need to be adapted to operate in areas where Internet reliability is uncertain.*
- *Electrification is a necessity for ICT to be utilised in the first place, with the hardware costs and availability presenting further challenges for remote, low-resource settings.*
- *A lack of locally relevant content and context appropriate to users can present a key challenge.*
- *Shortage of time can present a barrier to integrating ICT into school culture and learning processes.*
- *A lack of ICT skills/qualified teachers can present a barrier, but ICT itself can also help mitigate this by enabling distance education and teacher training.*
- *Buy-in of school leaders can be crucial to successful implementation of ICT in schools.*
- *Scaling pilot projects has been observed as problematic, with one approach working in one context but not in another. Deployment of ICT programmes needs to be contextually appropriate and relevant.*
- *Placing computers in classrooms is not enough for ICT to be used effectively. There needs to be an integrated solution to tackle the multiple challenges for uptake, including teacher training.*
- *Tablets are forming a prominent trend in ICT initiatives for schools globally.*

Overall barriers to ICT include: Lack of competency with the technology, lack of support for teachers and learners (including technical support), lack of experienced and skilled teachers, limited communications, lack of financing, restricted access to hardware and software, and lack of cooperation (need buy-in from whole school) (Herselmen, 2003; Nye, 2013). Sabaliauskas and Pukelis (2004) point to problems of 'time constraints, in-service training, administrative support, match to teachers' pedagogical views, and teachers' beliefs on ICT'. In addition, for developing countries specifically there are some distinct barriers which include lack of IT skills, limited hardware availability, unaffordable costs for connectivity, and lack of culturally/locally appropriate content (Nye, 2013). A selection of these challenges will now be detailed: connectivity, hardware cost and availability, electrification, relevant content, shortage of time, lack of skills, buy-in of school leaders, scaling, and emerging trends.

2.3.1 Connectivity

For 60 per cent of the world's population, 'the internet remains unavailable, inaccessible, and unaffordable' and even with rapid increases in the penetration of mobile phones 'nearly 2 billion people do not own a phone' (Robinson and Winthrop, 2016). Much work still needs to be done to improve access to the internet, to harness the educational content and approaches this can provide. As the World Bank notes, 'Making the internet universally accessible and affordable should be a global priority'; connecting everyone to the internet is also a Sustainable Development Goal (World Bank, 2016). Worldwide, 'some 4 billion people do not have any internet access, nearly 2 billion do not use a mobile phone, and almost half a billion live outside areas with a mobile signal' (World Bank, 2016).

In addition to an electricity supply, telecommunication facilities are also needed; for example, 'a fixed telephone line, cable connection, mobile phone or other sustainable communication technology', to enable connectivity (UNESCO, 2014). Telephone lines can provide Internet and mobiles can enable connectivity via 3G/4G (UNESCO, 2014). Indeed, for rural and remote areas connectivity may be all the more important with potentially 'greater dependency on broadband internet given the unequal distribution of physical media (e.g. CD-ROM, DVD etc.)' (UNESCO, 2014).

Connectivity is seen as a key barrier to harnessing the Internet for education, whether through distance learning, research or other activities. Whilst there continue to be issues with poor infrastructure in many developing countries, 'many of these barriers have been successfully overcome through comprehensive project design and good management' (Gaible and Burns, 2005). For example, Enlaces in Chile and the Ugandan VSAT Rural Connectivity Project were successful in demonstrating the positive impact the internet and computers can have on teachers and students' learning in spite of these barriers (Gaible and Burns, 2005). However, connectivity costs can present a challenge. For example, monthly connectivity costs for schools in the Ugandan project mentioned were US$305 per school, with additional costs for computer maintenance, repair, and replacement (Gaible and Burns, 2005).

Work needs to be done to counteract the unwillingness of Internet Service Providers to 'operate in unprofitable rural areas with low population density, and limited school budgets to pay for Internet services' (UNESCO, 2014). In Azerbaijan, whilst adequately supplied with electricity, they are yet to supply rural schools—leaving only one quarter of schools with an internet connection (UNESCO, 2014). Lack of fibre optic lines and difficulties with using existing telephone lines also acted as significant barriers (UNESCO, 2014).

There are other innovative approaches regarding internet access, such as solar powered spaces like the ZubaBox—a container with solar panels on the roof and pre-installed software and monitoring to 'connect the 11 flat-screen monitors' within; internet connectivity is provided through 'Cellular USB, WIFI or VSAT' (Firefly, no date). One such use is for schools, although they can be used by the whole community.

Internet reliability is a significant issue for classrooms, particularly if a lesson plan is reliant upon it; non-web reliant tutoring systems and those that can function offline are therefore preferable for rural contexts (Nye, 2013). In the EURO-SOLAR kit programme in Latin America, lengthy interruptions to the connectivity to the internet was a factor in insufficient educational use of the systems and undermined its potential (Canessa et al, 2014). Where Internet connectivity is sporadic 'innovative approaches to caching and distributing digital content can enable off-line access to vast numbers of online resources in ways that can simulate on-line environments' (Truncano, 22 July 2014). For example, the eGranary Digital Library/ 'Internet in a Box' provides 'millions of digital educational resources to institutions lacking adequate Internet access' (Trucano, 22 October 2010). As we will see when examining tablet technologies, some are being adapted to work offline and in areas with limited connectivity, yet connectivity restricts the capacity for independent research and information access (dependent on what can be stored).

2.3.2 Hardware cost and availability

Whilst connectivity in regions such as sub-Saharan Africa expands, what is also needed is the funding for schools to be connected and purchase equipment, with accessibility and availability also presenting key challenges (Hennessey et al. 2010). When prices are high it limits accessibility to ICT (Truncano, 10 January 2014). Indeed, even when purchased the 'phenomenon of new computers remaining unpacked in boxes because they are too valuable to risk damaging has long been a cliché among those who work in this area' (Truncano, 10 January 2014). In Kenya a study focused on secondary education found that the 'high cost of acquisition and maintenance of ICT equipment was a barrier that had continued to constrain adoption and integration of ICT in schools in Kenya' (Mingaine, 2013). High costs and constraints can be incurred by the transportation of imported equipment, tariffs for electricity, etc. (Mingaine, 2013).

Widely available low-cost options for ICT are ever more important for smaller rural schools with financial constraints. Certainly lower-cost internet access devices such as tablets and smartphones are helping address device affordability to a certain extent (Ramani, 2015). Initiatives such as the Kenya Computer Exchange and New Education Highway Free Learning Centres (Myanmar), are also working to help improve access to learning materials by providing technology (Truncano, 31 July 2015).

In terms of software, initiatives such as Library for All (Haiti), Kytabu (Kenya), and Train your Brain (South Africa) work to deliver software/learning content for free or at reduced prices (Truncano, 31 July 2015).

2.3.3 Electrification

ICT is for the most part dependent on effective electrification of schools and preferably households as well. Limited rural electrification and frequent power disruptions can 'slow down the pace of ICT implementation in schools' (Mingaine, 2013).

2.3.4 Lack of locally relevant content/tailored technology

There is a need for ICT content to be developed locally and produced so there is 'contextually relevant course content' (Hennessey et al, 2010). In the case of sub-Saharan Africa, 'the situation is already changing somewhat via … The development of databases for open educational content tailored for individual SSA countries, such as TESSA, SchoolNet Africa and Commonwealth of Learning are also making an impact' (Hennessey et al, 2010). Often solutions for rural and isolated communities are designed elsewhere with 'little understanding of the practical day-to-day realities and contexts in which such technologies are to be used' (Truncano, 22 July 2014).

In the case of language, the danger is that content is developed more often than not in European languages rather than the indigenous languages of developing countries (Unwin, 2009). In these scenarios, to be 'effective, teachers need to familiarize themselves with electronic resources written in a second language and make themselves aware of the difficult concepts that are being taught' (Unwin, 2009). This then requires teachers to provide prior instruction in the indigenous language to students before using e-learning materials (Unwin, 2009). 'Teachers can also identify key concepts that are deemed essential for students' progress… and prepare lessons, presentations and other resources in the student's first language to help their understanding' (Unwin, 2009).

The content of educational programmes is something that should not be an afterthought or something which is merely imported. In an ideal scenario, content would be produced locally in local languages in line with local curricula. However, often 'there simply is not sufficient indigenous know-how to create and distribute educational content easily in digital formats' (Trucano, 22 July 2014). On the other hand, by opening up channels of communication between isolated schools themselves ICT can allow them to 'jointly access, develop and share learning materials pertinent to those specific communities' (Díaz, 2015).

The user interface may also not be appropriate for the context. Poor user interfaces are not limited to low quality devices; even high-end technology can be 'difficult to use because they were designed for other use cases or usage scenarios, by other groups of people, in other circumstances, for different purposes' (Truncano, 10 January 2014). The nature of the learning experience via tablets can be key. In the Azim Premji project for digital learning resources library, the resources 'seemed to add no value to the dialogic discovery driven process of actual learning—which was completely determined between the children and the teachers' (Livemint, 2010). Intuitive software also can restrict the need for training. In Ethiopia researchers found that 'even in the absence of teachers, children figured out how to use tablets provided to them by One Laptop Per Child… to teach themselves to read' (Economist, 2012b).

2.3.5 Time

Researchers have claimed in the past that 'shortage of time is the major and crucial barrier to change in the school culture and integrating ICT into the school and teaching/learning process'; teachers need time not only for training, but to process the new knowledge and decide how to apply it in class and integrate it with their own teaching style (Sabaliauskas and Pukelis, 2004).

2.3.6 Lack of ICT skills and qualified teachers

Teachers are central to successful implementation of ICT in schools. However, in many African countries a major issue is lack of qualified teachers, exacerbated by poverty and lack of teacher salary funding (Hennessey et al., 2010). In Kenya, in the implementation of ICT in public secondary schools, a study found that a particular impediment was the limited supply of qualified teachers, especially qualified teachers with ICT skills (Mingaine, 2013).

In Brazil, it was found that teachers in particular, and to a certain extent the older students, 'had greater difficulty adapting to new technologies and showed greater resistance to integrating the laptop into the educational context' (Prusa and Plotts, 2011). Some teachers expressed discomfort with using the computers, which researchers linked to a 'lack of facility' with the computers, with some teachers requesting extra training sessions (Prusa and Plotts, 2011). As well as initial ICT training, follow-up training for ICT is also necessary for teachers to refresh skills and bring up concerns (Unwin, 2009). Accreditation and rewards for successful implementation could also be effective (Unwin, 2009). The other challenges regarding teachers and tablets, and the necessary training will be detailed later in the report.

Another possible solution to a lack of teachers and teaching skills is the enablement of distance learning via TV lectures (reducing requirements on teaching staff), although, of course, 'teachers would need to be trained to supplement the TV lectures' (Maithani and Gupta, 2015). In addition, teacher training facilitated through ICT (e.g. online courses for professional development) can help develop skills for existing teaching staff.

It is also important to note that the impact of ICT may be dependent on class numbers: where numbers are high each pupil may only be able to use the computer for a few minutes (Cox et al, 2003).

2.3.7 Buy-in of school leaders

One of the key trends in education and technology is the acknowledgement that targeted outreach to training for school leaders is a cost-effective investment (Truncano, 26 June 2012). 'Fostering a school climate in which the introduction of technology brings excitement and enthusiasm is important in ensuring the success of any initiative, and it is only by getting principals' buy-in and support that this will happen' (Unwin, 2009). In sub-Saharan Africa Hennessey et al. (2010) identified a key challenge of 'negative attitudes among school leaders towards computers and the internet'. There can be a tendency where 'a principal is not perceived to be supportive of uses of new technologies in a school, they often tend not to be used productively in new ways by many teachers' (Truncano, 26 June 2012).

In a secondary school study in Kenya, it was found that there was recognition of the benefits of ICT in schools. 'However, some of them did not prioritise ICT in school as evidenced by respondents who did not strongly agree management was supporting implementation of ICT through allocating adequate funds to its implementation' (Mingaine, 2013). Schools managers need to be encouraged to allocate adequate funds, and should be included, as well as school leaders, in awareness raising and updates on ICT development and education (Mingaine, 2013). We should also bear in mind their influence in the wider community. In one study in Africa by Solar Aid, it was identified in some cases that head teachers were targeted to promote solar light as an educational tool, not only due to their position but because they are 'well respected and trusted members of the community' (Eckley, 2014).

2.3.8 Scaling

One of the challenges faced in terms of educational technology is that initiatives need to be scaled-up: there are 'too many pilot projects' (Truncano, 19 October 2011). One issue is that pilots often start out in well-resourced schools in an attempt to establish a proof of concept, but it follows that the solution for these schools 'may not work quite so well' in resource-poor settings (Truncano, 19 October 2011). Truncano argues for the need to begin by looking at, and working in, the most challenging environments. Scaling is an issue that has been identified across educational interventions that have been 'demonstrably effective in improving children's learning'—the issue is how they become 'effective in improving children's learning' and 'become increasingly taken up, ultimately leading to actors across the system changing their policies or practices' (Robinson and Winthrop, 2016).

The approach of placing computers in classrooms as the priority has seemingly in many cases yielded 'few useful educational outcomes'—the reason for this is the 'trap' of choosing technology first and 'then looking for an educational problem to solve with it, rather than the other way around' (Robinson and Winthrop, 2016). As for energy access, just providing ICT alone is not enough to reap the full extent of benefits. An integrated solution is needed that takes into account other factors such as 'effective teacher training and appropriately linking ICT usage to sound pedagogy' (UNESCO, 2014). Teachers are key to successful deployment.

2.3.9 Emerging trends

In terms of rural, off-grid contexts, newer 'battery-operated ICTs are emerging, in addition to mobile devices that may be recharged off-site' (UNESCO, 2014). This would enable the use of ICT for education without energy supply in the household/school, for a limited amount of time, provided there is a charging point nearby. However, for the most part, for the optimal use of such ICT access to a 'stable energy source' is required (UNESCO, 2014).

A particularly prevalent trend in recent years has been the emergence of the tablet. Tablets are the focus of the moment and the key trend for education, being used for interactive teaching programmes as well as encouraging children to read. PCs and laptops are slowly being eclipsed by tablets in the consumer space, and indeed in educational programmes (Truncano, 31 July 2013). Tablet programmes have been announced or begun in Brazil, Indonesia, Malawi, Colombia, and Senegal, amongst numerous others (Truncano, 28 July 2015).

The following section therefore concentrates on the use of this technology in particular, focusing on a selection of more established tablet programmes and their track records. However, the appropriate technology for each context should still be evaluated, and this is not to say that tablets are the only way forward for expanding ICT access effectively in rural contexts.

2.4 ICT deployment case studies: Challenges and opportunities

Section 2.4 summary:

This section focuses on a series of case studies that exemplify some of the challenges and opportunities in ICT for schools and education. There have been numerous initiatives in recent years in this field internationally, notably the 'One Laptop Per Child' initiative (using tablets) that has been trialled in a selection of countries. At the end of the section opportunities for the use of mobile phones for educational purposes are explored.

There have been numerous ICT initiatives and projects in the developing world in recent years. For example, 'Bangladesh – with support from the non- governmental development organization, BRAC – introduced 17 mobile ICT laboratories containing laptop computers, cameras, multimedia projectors, etc. to cover 1,000 schools in remote areas' (UNESCO, 2014). 'Sri Lanka – through its Nensala Project – established over 700 rural tele-centres or "Nensalas", which are managed and supervised by the Nensala Community Development Task Force to build ICT skills and impart ICT education in school curricula' (UNESCO, 2014).

The challenges of creating a tablet educational programme that is complementary to other teaching, useable and context-specified are numerous. The theory behind such initiatives is that giving each student a laptop or tablet 'allows students to bring the laptop into the home and thus provide computer and internet access to an entire family' that previously lacked it (Prusa and Plotts, 2011). This can draw not only students but also their families into the 'information economy, decreases social marginalization and increases inclusion' (Prusa and Plotts, 2011). In addition, the initiative is based conceptually on the idea that students can be empowered through laptops to become their own teachers as well as teaching others, such as their families (Prusa and Plotts, 2011).

Challenges and solutions vary depending on the context and technology. This section explores a selection of examples of initiatives and technologies that highlight key reasons for success and causes of failure.

The examples presented below point to the fact that the issues that are of concern, and the keys to successful deployment and design, may well depend on the context. Robinson and Winthop (2016) reviewed a number of ICT and education examples and found that many underscored 'how technology has to be appropriate for the context and the users, and that 'high tech' was not always the best solution, especially in the contexts of low resources or low literacy'. For example, Sesame workshop projects use a range of technology from high-end to low-end, utilising mobiles to remind teachers of videos/activities they should use each week, 'preloaded feature phones and pico projectors to bring content to classrooms in low-income communities; and interactive voice

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response systems to enable users to access radio episodes on their mobile phones' (Robinson and Winthrop, 2016).

In the case of CyberSmart Africa, they identified the need for batteries (particularly safer sealed AGM batteries), and to take technology to teachers and students in the classroom rather than segregating computers into another room—often there aren't enough computers for students, making it difficult to integrate their usage effectively (Truncano, 19 October 2011). Tools like projectors and interactive whiteboards can also be effective as they can 'impact as many students as possible at one time' (Truncano, 19 October 2011). Another context consideration is to look for local products to reduce costs, and maintain a local supply chain as far as possible (Truncano, 19 October 2011).

2.4.1 Thailand One Tablet Per Child Initiative

One of the most notable ICT for education programmes is 'One Laptop Per Child' (OLPC). The box below outlines the challenges of the OLPC initiative in Thailand.

In the case of Thailand it has been argued that the initiative served to distract attention from the real problems in Thai education and the deterioration of quality, despite growth in the proportion of children attending school (Economist, 2012a). Again, we must highlight that energy and ICT are not a quick fix for other and deeper problems in different education systems. The Thailand scheme has notably now been scrapped by the new government, along with plans to build computer rooms at some schools (Bangkok Post, 2015). However, money from such programmes is being put into distance learning initiatives and a project to create 'smart classrooms' (Bangkok Post, 2015).

Case Study: The Challenges faced by Thailand One Tablet Per Child Initiative

From Viriyapong and Harfield, 2013

1. Tablet software and programs need to be able to 'take into account the learning abilities in different regional areas across Thailand'—competencies and literacy levels varied. Cultural and language difference also need to be taken into account.

2. 'A number of studies have reported that the usability of mobile technology can be a factor in the success of educational activities'. In the case of Thailand, features such as 'battery life, screen brightness and button defects' were seen to have a negative impact. In addition to hardware, software usability is important. One concern in this area is whether educational programs give sufficient depth. An element of progression is needed. The interface for tablet education can mean a passive style of interaction 'whereby students watch and then click next'. To maintain attention there needs to be active engagement and interactive content.

3. Teacher training is key; indeed improved teacher training more broadly is a concern for many countries. In the Thailand example, problems included teachers lacking a tablet (hampering class preparation) and the tablet being used as an 'alternative to teaching' rather than a complementary aid. Software should engage both teachers and pupils, and allow teachers visibility of the students' interaction with the program.

4. Learning outcomes should be addressed by linking tablet activities to curricula, as well as having data collection and analysis that enables teachers/schools to assess outcomes.

2.4.2 Aakash Tablet: The Aakash tablet in India was ground-breaking due to its low cost. Often for price reasons 'low end phones predominate in most developing country markets' (Truncano, 9 December 2011). The suspicions that emerge around such low-cost devices is that low cost equates to low quality (Truncano, 9 December 2011). The danger lies in making an assumption that poorer communities 'will put up with substandard user experience simply because they are poor and/or don't know any better and/or have no other options' (Truncano, 9 December 2011). The Aakash tablet project was wound down in 2015 (The Wire, 2015). The first prototype had significant issues with battery life (Forbes India, 2012). Even the second version had a battery only lasting three hours, insufficient for a school day of seven hours (The Wire, 2015).

Commentators have noted that the assumption that a tablet would solve everything contributed to the programme's failure (The Wire, 2015). It was thought the need for children to carry textbooks would be eliminated, but there was no communication on when these books would be digitised, if at all (The Wire, 2015). In addition, although the project targeted low-income households, these households would often lack the regular electricity and internet connection needed to make full use of them (The Wire, 2015). The infrastructure needs to be in place first, as well as a battery life that reflects the possibility of unreliable electricity.

Infrastructure was also an issue in the Azim Premji Digital Learning Resources library project, with a very limited number of schools having computers (driven by lack of good electricity supply and an inability to fix technical problems) (Livemint, 2010).

2.4.3 Slate2Learn: To get around problems of infrastructure, technology and online learning developers have taken new approaches, and consider the context in the design. Slate2Learn—which aims to improve basic literacy and numeracy skills in India at the elementary level—takes one such approach (Slate2Learn, no date). In this case, the tablet syncs with a local server over Wi-Fi to send data regarding student progress and receive content. The server then syncs to the cloud and gets updated 'learning paths' for the student. Importantly, the tablets and the server can run for hours without electricity and 'only occasional access to a low-bandwidth internet connection, e.g. over a 2G mobile network' is required for the sync to the cloud. In addition, the local server allows teachers to monitor student progress in 'real time'.

2.4.4 BRCK: Another example of context-appropriate design is the Kio tablet by BRCK, which was designed with Africa in mind, with an eight-hour battery life to cope with intermittent power in rural areas. The tablets are able to run multimedia content which is locally cached on the BRCK, and the tablet enables access to educational content for teachers and students as part of the Kio kit (BRCK, no date).

2.4.5 Computer Aid: Empowering rural areas continues to be a priority. One notable operator in the area of ICT is Computer Aid, operating in various countries and regions, and focusing on the provision of ICT. One of its projects looks at rural development in Nepal, providing computer suites for remote schools and libraries (Computer Aid, no date). Nepal's Committee for the Promotion of Public Awareness and Development Studies believes ICT has a 'crucial role to play in narrowing the wealth divide' between rural and urban.

The project has built 400 computer suites (each with a minimum of five computers, a printer and 'networking equipment to allow access to the web') powered by solar power. As part of this initiative investment has been made in providing technical training to local people: this creates jobs and ensures the local community has the skills needed to maintain the computer suites and provides an ongoing resource centre for the community. By investing in training, this can have a positive impact across the community, and even aid economic development. Consideration of training is a key element of success (Computer Aid, no date).

2.4.6 Peru OLPC: In the case of Peru OLPC, problems included internet connectivity, lack of technical support and training, as well as students often not being allowed to bring laptops home (Prusa and Plotts, 2011). Decreasing use of the computers was also witnessed as time went on, potentially suggesting a need for longer-term 'teacher support and lesson planning' (Prusa and Plotts, 2011). Ongoing training and engagement for teachers appears to be a key element.

The Peru OLPC XO laptop initiatives (distributed since 2008) were subject to an evaluation by the inter-American Development Bank (Truncano, 23 March 2012). They used randomised control trials and found that the programme 'dramatically increased access to computers' and had 'some benefits on cognitive skills', but, 'no evidence that the programme increased learning in math or Language' (Truncano, 23 March 2012). However, we should note that there was criticism of the methods of evaluation and the testing approach (Truncano, 23 March 2012). The lack of positive results could also be due to timeline, or poor implementation (Truncano, 23 March 2012).

Positive impacts observed included 'evidence of better attitudes among teachers and parents; students were more critical of school-work and their own performance; and a greater development of technological skills among the students' (Prusa and Plotts, 2011). Although the study had a short time frame from implementation (there was little difference between children with and without laptops), 'a test of ICT ability showed computer use increased scores' (Prusa and Plotts, 2011).

2.4.7 Worldreader: Aside from more complex educational tablet programmes, which are intended to form part of the new way of teaching, technology can be used at a simpler level to promote reading, with potential literacy outcomes. Worldreader combines 'context-appropriate technology' access (low-cost e-readers and mobiles) with in excess of 31,000 books in 43 languages, 'teacher support and community engagement' (Robinson and Winthrop, 2016). Data from 'an evaluation of Worldreader's early grade reading programme in Ghana demonstrated improvements in oral reading fluency and reading comprehension, as well as the development of positive reading habits, among student users' (Robinson and Winthrop, 2016).

In Kenya, rural areas struggle with accessing books, with no local library; many students share textbooks (Kilgoris, no date). Kilgoris partnered with Worldreader to bring Kindles to primary school students and teachers (Kilgoris, no date). Since the inception, teachers have seen 'more engagement and excitement around reading, as well as improved test scores' (Kilgoris, no date). 'Improved reading comprehension skills speak for themselves when Intimigom students proudly placed near the top (if not at the very top) of all primary schools in region on academic testing' (Kilgoris, no date).

2.4.8 Plan Ceibal (Uruguay): Uruguay was the first country in the world to 'provide all primary school students with free laptops' (Truncano, 31 July 2013). Whilst it enjoys widespread community support, the concept is 'no longer novel, but rather part of the educational and cultural landscape' (Truncano, 31 July 2013). The trick with plan Ceibal is maintaining the excitement and momentum, particularly as it moves to help 'to catalyse and enable change as part of larger efforts' for whole system reform (Truncano, 31 July 2013).

Plan Ceibal, according to a 2011 study, succeeded in recusing the 'digital divide among those in the lowest socioeconomic strata' (Prusa and Plotts, 2011). In terms of education there was anecdotal evidence of improved reading and writing, although there was no baseline to measure impact against (Prusa and Plotts, 2011). However challenges included the need for teacher training and issues with hardware/software—high breakage rates and limited hard drive space (Prusa and Plotts, 2011). Again, much of the data on successes were anecdotal; for example, anecdotal evidence of better communication between parents and children 'within families separated by distance' (Prusa and Plotts, 2011).

2.4.9 eLimu: A project run by eLimu in Kenyan schools (a for-profit venture) aims to show 'digital content can be cheaper and better' (Economist, 2012b). At Amaf school in Kenya, where eLimu did its pilot project, 'average marks in science, for instance, went from 58 to 73 out of 100 in a single term, says Peter Lalo Outa, the headmaster' (Economist, 2012b). However, this is anecdotal and as we have seen data is still needed to connect educational outcomes with tablet deployment.

2.4.10 Mobistation: Mobistation in Uganda works to address huge educational challenges such as teacher absenteeism, 'poor quality instruction, and lack of textbooks' (UNICEF, 2014). Its portable format allows it to be effectively deployed in emergencies for temporary school or communications set-ups—this applies even where electricity and internet are lacking (UNICEF, 2014). Mobistation is a 'solar-powered multimedia kit built around a laptop, projector, document camera, speaker and other peripherals, all contained in a portable suitcase' (UNICEF, 2014).

2.4.11 One Mouse per Child: Due to the expense of computers, different solutions are being explored to enable access. One of the solutions that has been pitched is the 'One mouse per Child', which is aimed at 'working simultaneously with an entire class using an interpersonal computer' (Nussbaum, 2010). In terms of affordable solutions, such approaches can be viewed as 'promoting more equitable access to ICTs' (Truncano, 3 September 2010). However, some critics argue the opposite: that it short-changes children in the developing world who have one mouse rather than a laptop (Truncano, 3 September 2010). Efforts like One Mouse are 'enabled where technologies are available to help transform simple projectors into low-cost versions of digital whiteboards' (Truncano, 22 July 2014).

2.4.12 Opportunities for mobile phones

In the developing world mobile phones are often the primary computing method; therefore there needs to be more software targeted at these devices (Nye, 2013). Certainly, in the case of education the trend is focused very much on tablets. However, mobile software would be beneficial to expand access to children in rural areas, who may have access to mobiles but are not beneficiaries of a tablet programme. With regards to students' basic IT skills, 'On mobile platforms, community support such as libraries and schools may be pivotal to help install and setup ITS for home use'—often users can learn to use Intelligent Tutoring Systems (ITS) but may have difficulty setting up a device (Nye, 2013).

Mobile phones are 'helping to support teachers in small but meaningful ways by providing access to education content' (in Tanzania) and 'regular prompts and tips on how to utilize this content' (in Papua New Guinea) (Truncano, 22 July 2014). In addition, in Pakistan students have been sent 'short quizzes via SMS to their mobile phones to help them… gauge how well they are understanding topics being discussed in class' (Truncano, 22 July 2014).

In the context of limited electricity access, mobile phones are important—particularly low-end phones that require little power, and can function for a long period on a single charge (Truncano, 10 January 2014).

In Afghanistan, Paiwastoon looked at the local context, saw what was widely available locally—low-end phones—and created the Ustad mobile, an application which can be used to complement existing teaching methods (Truncano, 17 January

2014). Ustad Mobile Literacy has been approved by the Ministry of Education and 'takes users from the first letter of the alphabet through grade 3 literacy and numeracy and includes hours of narrated instruction, reading comprehension exercises, quizzes, educational games, and video clips for visual learners' (Truncano, 17 January 2014). By not requiring high-end devices or smartphones, education content can be developed locally by 'low-skilled local staff, in accordance with local resource constraints' (Truncano, 17 January 2014).

2.5 Teachers and ICT:

Section 2.5 key points:

- *Teachers need to be familiar with the technology and willing to integrate it with traditional teaching practices for successful ICT deployment.*
- *Teachers have resisted the integration of ICT into schools in the past, particularly where teachers are ageing or underpaid and where there has been inadequate training.*
- *Teachers' beliefs about ICT are important as well as their skills when it comes to integrating ICT into the classroom. Teachers need to understand how and why it should be integrated as well as acknowledge the new approach needed to lesson planning and teaching, and the benefits.*
- *Teacher training needs to be ongoing and not just 'one-off'*
- *There have been urban-rural disparities when it comes to training teachers to teach using ICT.*

At a very superficial level, teaching styles 'across the world appear to vary very little' (Unwin, 2009). However, 'cultural beliefs about teaching and learning' as well as 'lack of experience and knowledge of how traditional instruction interfaces with web-based teaching materials', play important roles in how teaching is carried out (Unwin, 2009). Traditional teaching techniques can often involve a one-way flow of information, except when a question is asked to the class; this can limit interaction with students, activities, creativity, and so on (Munienge and Muhandji, 2012). ICT can be used as a tool to engage.

Often one of the fears may be that ICT will replace traditional teaching methods and cause issues with teacher motivation, engagement and connection with class members. In the case of Vietnam, the use of ICT in teaching had remained limited, tending to actually replace traditional teaching practices (Peeraer and Petergem, 2011). However, the factors determining the use of ICT were ICT skills as well as computer confidence (Peeraer and Petergem, 2011).

We need to bear in mind, as noted by a commentator in plan Ceibal in Uruguay, that the technology itself does not 'resolve the complex task of teaching', and teachers still need to be engaged to ensure devices are integrated with a 'specific educational purpose' to limit wasted teaching time (UNESCO, 2011). Teachers themselves need to be familiar with the technology to optimise its use in line with teaching content; technology must make a real contribution to learning progress and not be 'time-fillers' (UNESCO, 2011). In an Azim Premji project in India, school culture determined how digital learning resources and computers were used ('new toy', furniture or 'crown jewel' (Livemint, 2010). The use of digital learning resources was 'only as good as the teacher in the classroom'. With a few exceptional teachers, it became a useful tool, whereas with an ordinary teacher, it was just a means of entertainment (Livemint, 2010).

We cannot underestimate the influence that teachers themselves have on classroom learning. In some cases a lack of motivation for change and learning new skills is exacerbated by a fear that newer forms of ICT will be better understood by the students than the teachers (UNESCO, 2014). 'The integration of ICT into education is frequently resisted by teachers and their unions, particularly in countries with an aging, underpaid teaching workforce, and where there has been inadequate training and preparation' (UNESCO, 2014).

Capacity for change is, consequently, a concern. For example, in one project in Thailand there were concerns not only about poor quality instruction (particularly in poor or rural areas), but also the ability to change traditional teaching methods (OECD, 2000). The case here was that 'teachers were accustomed to lecturing without being questioned… although they desired change, there were worries that it would need years of re-training, or new teachers' (OECD, 2000). In this particular case teachers and learners actually 'adopted the technologies fast and reliably enough to use them confidently and effectively' (OECD, 2000).

Findings from a 2007 study suggest that 'teachers' ICT skills and beliefs about ICT are of great importance with regard to their intentions to use ICT in everyday classroom practices' (Jimoyiannis and Komis, 2007). In the Brazil OLPC initiative, 'researchers found that teachers underutilized the laptops, or used them as a substitute' (Prusa and Plotts, 2011). In addition, the extent to which ICT contributes to pupils' attainment is dependent (according to evidence) on 'the way in which the teacher selects and organises ICT resources, and how this use is integrated into other activities in the classroom and beyond' (Cox et al, 2003). The technology alone is not enough; the social actors implementing it determine its ultimate success. 'There is growing and widespread awareness that the pedagogical and technical expertise of the teacher is absolutely critical' (Hennessey et al., 2010).

'Teachers need extensive knowledge of ICT to be able to select the most appropriate resources' as well as understanding how to incorporate it (Cox et al., 2003). How teachers integrate ICT can range from small enhancements to traditional teaching methods to fundamental changes in their approach (Cox et al., 2003). For example, interactive whiteboards may be used to show content and enable class discussion in a traditional format (Cox et al., 2003). Teachers need to appreciate that ICT requires a new approach to teaching, lesson planning and the curriculum (Cox et al., 2003).

Teacher training in ICT is an issue; in Kenya one study found that most schools 'did not have enough staff competent in ICT and therefore were not able to effectively implement ICT' (Mingaine, 2013). The teachers themselves are central to the effective deployment of ICT and need to be employed and trained on this basis for the benefits of ICT to be realised. Regular training should occur so that the necessary skills are acquired to implement ICT as part of teaching and learning (Mingaine, 2013).

Exact guidance and research is limited concerning the amount of training needed, how often it should be, what is appropriate or affordable and what it should cover, in order to produce teachers motivated to use ICT (UNESCO, 2014). 'Professional development of teachers' needs to be provided 'to facilitate adoption of teaching methods that meet the demands of a new educational model as well as ensuring that ICT and other skills are sufficient to improve the quality of student learning' (Unwin, 2009). Training needs to be accessible and not overwhelming. Guidelines, such as the UNESCO ICT Competency Framework for Teachers, help to inform teachers of the need for ICT competency, and emphasise the need to maximise the benefits of ICT for students (UNESCO, 2014).

Teachers need continued support with integrating ICT rather than simply initial one-off training (Unwin, 2009). In 2008 UNESCO launched an ICT competency framework for teachers 'aimed at supporting governments to design ways in which to improve teachers' practice, particularly in developing countries' (Unwin, 2009). The framework aims to help teachers improve skills and develop professionally, aiding them to embed ICT resources to improve their teaching (Unwin, 2009).

The key with integrating ICT is balance; not completely dispensing with traditional teaching approaches but empowering the teachers themselves with the skills to be able to effectively integrate ICT into their teaching approach, aligning it with their own style. 'The great advantage of ICT is not to substitute for teachers, but to enable teachers to enrich their teaching and their access to information' (OECD, 2000). Teachers should be actively encouraged to 'generate new content and processes in their own language, thereby participating in the creation of global knowledge' (OECD, 2000). What is not needed is a static classroom scenario where pupils carry out their work entirely autonomously without teacher input.

However, there are still issues regarding staff retention that may impact training considerations. In the EURO-SOLAR programme in Latin America, 'despite the fact that training in handling computer equipment has been developed on line with national digital inclusion policies, the mission noted on the ground that the high turnover of teaching staff is a serious problem, as this makes it difficult to secure the acquired knowledge and training' (Canessa et al, 2014).

Governments in developing countries, for example in sub-Saharan Africa, are emphasising 'teacher development as the key to effectively implementing policy and curricula, to using ICT to enhance teaching and learning, and to raising educational standards' (Hennessey et al, 2010). However, when it comes to such training, urban/rural disparities exist. For example, such disparities are common in several countries in Asia when it comes to teachers being trained to teach subjects using ICT (UNESCO, 2014). However, China has made significant 'strides in eliminating this gap by furnishing ICT and the requisite teacher training to schools in western and rural areas of the country' (UNESCO, 2014).

Chapter 3: Education, Productive Enterprise and Employment

Chapter 3 summary:

This section outlines how the improvement of the quality of education, or access to education through electrification and ICT, can contribute to employment and productive enterprise for students in later life. However, further research is needed to ascertain the links between energy and educational outcomes and, subsequently, employment. Evidence is currently conflicting in some cases.

ICT skills are identified as key for young people to integrate into the modern workplace and there are significant skills gaps between the capabilities of youth and the needs of the labour market in multiple areas. Energy and ICT could help to close this gap by contributing to improvements in the quality of education. ICT skills can also help to empower those groups traditionally excluded from certain sectors, such as women. By looking beyond school electrification we can also harness energy and ICT for employment and productive enterprise by helping to enable training in various vocational areas (for example, online certifications and so on).

'All countries need an education system with a strong focus on capacity development programmes to provide citizens with those skills necessary to make the most of their resources for economic prosperity' (Unwin, 2009). As such, energy and ICT in the full continuum of education, from primary through to 'secondary, higher and vocational education' as well as non-formal education from capacity building, have a key role to play in this development to facilitate employment and enterprise (Unwin, 2009).

'Information and communication technology (ICT) is a principal driver of economic development and social change, worldwide. In many countries, the need for economic and social development is used to justify investments in educational reform and in educational ICT' (Kozma, 2005). Particularly in developing countries affected by poverty, whilst education may play a role in breaking out of poverty, the role that ICT may play is unclear (Kozma, 2005). However, this is not to suggest there is no link.

In a study by Solar Aid on some of their work in Africa, they found that, in addition to benefits such as increased study time and educational attainment, longer-term impacts may be the ability to progress to further education and/or secure better employment (Eckley et al, 2014). Evidence from Nepal shows that electrification 'strengthened community adaptive capacity by raising incomes, diversifying economic opportunities, and reducing migration' (UNDESA, 2014). One study noted that, 'village electrification not only upgraded the education system for students, but also has profound impact in regard to raised literacy, awareness, self-confidence, independence, and increased income-generation opportunities among illiterate populations' (UNDESA, 2014).

However, electrification could work against education by working in favour of productive enterprise and employment. Contrary to the educational attendance and attainment benefits expounded in this paper, a study by Tim Squires in Honduras found that electrification 'reduces educational attainment'. The reduction was 'accompanied by an increase in childhood employment, suggesting that improved labor market opportunities, due to electricity access, led to the increased drop out rates' (Squires, 2015). Additionally Squires found that increased adult employment was 'driving children to stay home to compensate for parents going off to work' (Squires, 2015). In this case we are talking about community-wide electrification more generally (which is the preference for full educational benefits) rather than just school focused.

The relationship between electricity, energy, and education is not straightforward, and additional research is needed on educational outcomes and the relationship with employment when considering community-wide electrification (as this is the ultimate goal). Electricity alone may not be enough to get children back into school; other initiatives may be required to extol the benefits and facilitate children to stay in education in the long term (although, as we have seen, different communities will of course react differently).

Of course, in a 21st century society integrating ICT is key for students to gain opportunities to operate in today's society or be productive in the modern workplace (Munienge and Muhandji, 2012). ICT skills have been viewed by the creators of Plan Ceibal (for example) as enabling students to become more globally competitive by reducing the digital divide; with increasing 'reliance on science, technology, and new forms of global communication… students must develop the primary ICT skills required to profit from ICT innovations and revolutions' (Prusa and Plotts, 2011).

'Employer surveys, labour market analyses, and academic studies all find that across the board there is a significant skills gap between the capabilities of youth and the needs of the labour market, and improvements to technology will only widen this gap' (Robinson and Winthrop, 2016). Robinson and Winthrop, drawing on World Bank research, note that the 'future workforce will need to be equipped with a robust skill set, including literacy and numeracy plus communication, collaboration, and critical thinking skills, to contribute to the economy and lead prosperous lives'. Education needs to provide a balance of academic and 'current' skills, and to integrate skills that are relevant for the future workforce into the curriculum. Energy and technology are at the centre of this, not only as an enabler of education but as a key part of learning to prepare children, and indeed adults, for the working world.

ICT skills can also help to empower those groups traditionally excluded from certain sectors, such as women. For example, Computer Aid has a project in Liberia where 90% of employed women work in agricultural or informal sectors, with limited earnings and exposure to exploitation (Computer Aid, no date). Computer Aid is working with local partners to establish a 'vocational ICT technician's training course especially for women' in order to challenge gender boundaries of an often male-dominated industry like ICT. The unique opportunity we have in establishing ICT in developing countries and remote areas is that the 'industry' or sector is in its infancy and gender norms in terms of labour division can be challenged before they are entrenched. Computer Aid hopes women gaining new skills will encourage others 'to follow paths of vocational training in fields that they otherwise might have considered impossible or inappropriate' (Computer Aid, no date). Vocational classes in areas like engineering, welding, metalwork and carpentry are also enabled through electrical appliances and tools (UNDESA, 2014).

However, the potential for training is not limited to ICT skills. Programmes focused on skills development for income generation can enable youth to raise their standards of living (UNDESA, 2014). Successful harnessing of energy for education, as UNDESA argues, needs not just to supply energy but also teach communities 'how to put that energy to productive use through classes, education, or apprenticeships' (UNDESA, 2014).

By looking beyond school electrification and considering what it can lead to and its productive uses, we can better contribute to the economic and social development of the wider community by integrating training in these areas into project planning.

An example of employment-related training is how apprenticeships can be used alongside 'formal training procedures like classes or certificates' (UNDESA, 2014). In sub-Saharan Africa, apprenticeships account for most of youth training. For example, 'In Senegal, young people were 40 times more likely to be trained through informal apprenticeships than through formal technical or vocational education' (UNDESA, 2014). When considering the benefits of energy and education it is also worth considering the benefits of ICT for vocational training and online certification, helping to supplement such apprenticeship programmes. Schools could also utilise lighting to provide such classes outside normal school hours.

One Laptop per Child/Children and XOs in Mongolia/CC BY 2.0

Concluding Remarks

Concluding remarks and key points:

- *Electrification and ICT can contribute to improved teaching and school performance, with less absenteeism and higher enrolment amongst other potential benefits.*
- *The system and technology alone are not enough: training and capacity building of teachers, and household access alongside other development initiatives, need to be enacted to reap the benefits.*
- *A multifaceted and integrated approach is needed that considers the full local context and the challenges in education more broadly for electrification and ICT projects to be implemented successfully in the long term.*
- *The use of ICT in schools helps equip children for the future workforce.*
- *By enabling productive enterprises, energy could, in parallel with improving educational quality, contribute to reducing rural-urban migration.*

'In aggregate, the benefits from electricity-based lighting, ICT, and improved teaching lead to better outcomes in school performance—less truancy and absenteeism, higher enrolment rates, higher graduation and completion rates, and the achievement of higher test scores' (UNDESA, 2014). It appears to be a combination of factors that maximises the impact of energy and technology. The system and technology alone is not enough; training, capacity building, and household access alongside other development initiatives need to be enacted to reap the benefits.

Education is essential to reducing poverty, and a lack of electricity access in schools can create 'considerable obstacles towards escaping poverty' and correlates 'with many factors that contribute directly towards it' (UNDESA, 2014). It is this correlation that has trigged the key theme that has run throughout this report—that of integration and the interrelatedness of issues—and the need for a multifaceted approach that carefully considers the full context, as well as the knock-on effects of electrification and ICT throughout the project journey and long-term planning (for example, teachers' burdens).

The full context of educational challenges needs to be considered, and the impacts and effects on teachers, wider educational staff and communities have to be at the centre of deployment planning. Enabling household access as well as the schools', can also help students gain the full benefits of electricity for education through educational TV, increasing their parents' awareness, and increasing study time.

The use of ICT in rural education equips children (the future workforce) with the skills to interact more effectively with an increasingly 'networked world and the emerging knowledge economy' (Mingaine, 2013). When it comes to ICT there is immense opportunity for this to be harnessed to improve educational quality, reduce burdens on teachers and enable their professional development, and increase student engagement and attainment. What appears to be the key takeaway when it comes to ICT for development is the importance of engaging and training teachers, and working to ensure that ICT acts as a value-adding supplement to teaching and is integrated effectively, rather than replacing traditional teaching altogether.

We can speculate that improved education access and quality (partly facilitated through electrification and ICT) could contribute in the long term to lessen rural-urban migration. One thing that we could consider is that increased education could lead people to seek out opportunities in urban centres with more advanced qualifications and ICT skills.

However, energy provision in general, when applied to the whole community, can enable the start-up of productive enterprises—even within the field of energy provision itself. This in turn creates employment opportunities for rural community members. It is not simply a straightforward, direct connection through from education to rural productive enterprise, but the benefits of education in tandem with other benefits of energy for development and other initiatives can help to stem migration and create rural opportunities in the longer term.

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Bibliography

1. Sonia, A, Diniz, A, França, E Câmara, C, Morais, P, Vilhena L. (2006). 'The Important Contribution of Photovoltaics in a Rural School Electrification Program, Transactions of the IEEE' *Photovoltaic Energy Conversion, Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy*, pp. 2528-2531.

2. ADB (2010). 'Asian Development Banks's Assistance for Rural Electrification in Bhutan- Does Electrification Improve the Quality of Rural Life?' *ADB Impact Evaluation Study ref number IES: BHU 2010-27* available at: http://www.oecd.org/countries/bhutan/46757667.pdf

3. Alazraki, R and Haeslip, J (2007). 'Assessing the uptake of small-scale photovoltaic electricity production in Argentina: the PERMER Project' *Journal of Cleaner Production* 15(2): 131-142

4. Azim Premji Foundation (2004) 'The Social Context of Elementary Education in Rural India' available at: http://www.azimpremjifoundation.org/pdf/TheSocialContextofElementaryEductaioninRuralIndia.pdf

5. Bangkok Post (2015) 'Schools ordered to take back tablets' 30th June 2015, available at: http://www.bangkokpost.com/learning/learning-news/608188/schools-ordered-to-take-back-tablets

6. Barkat, A et al, 2002. 'Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh' *NRECA, HDRC and USAID Impact Evaluation Study*, available at: http://pdf.usaid.gov/pdf_docs/PDABZ138.pdf

7. Sovacool, B (2013). Energy Poverty and Development in Papua New Guinea: Learning from the Teacher's Solar Lighting Project, Forum for Development Studies, 40:2, 327-349

8. Bhattacharyya, S and Palit, C, eds. (2014). 'Mini-Grids for Rural Electrification of Dveloping Countries: Analysis and Case Studies from South Asia' *Springer International Publishing*

9. Bourgeois, T, Gerow, J, Litz, F and Martin, N (2013). 'Community Microgrids: Smarter, Cleaner, Greener' *Pace Energy and Climate Center, Pace Law School and Pace University,* available at: http://energy.pace.edu/publications/community-microgrids-smarter-cleaner-greener

10. BRCK (no date) 'Education: Kio' available at: http://education.brck.com/kio/

11. Canessa, R, Santome, J and Buss, N, (2014). 'Ex-post evaluation of the EURO-SOLAR Programme: Executive Summary' *The European Union's DCI-ALA Programme for Latin America,* available at: https://ec.europa.eu/europeaid/sites/devco/files/eurosolar-executive-summary_en.pdf

12. Center for Education Innovations (no date) 'Nafham' available at: http://www.educationinnovations.org/program/nafham

13. Computer Aid (no date) 'Our Projects' available at: http://www.computeraid.org/our-projects.html

14. Cook, P (2011). 'Infrastructure, rural electrification and development' *Energy for Sustainable Development,* 15: 304-313 available at: https://www.dmu.ac.uk/documents/technology-documents/research-faculties/oasys/project-outputs/peer-reviewed-journal-articles/pj2--paul-cook-paper.pdf

15. Cox, M, Webb, M, Abbott, C, Blakeley, B, Beauchamp, T and Rhodes, V (2003). 'ICT and Pedagogy: A review of the research literature' *ICT in Schools Research and Evaluation Series- no.18,*

produced for Department for Education and Skills, available at: https://wiki.inf.ed.ac.uk/twiki/pub/ECHOES/ICT/ict_pedagogy_summary.pdf

16. Davies, G, Currie, C, Young, E, (2015). 'Impacts of Solar PV on Teacher Satisfaction' *University of Strathclyde,* available at: https://www.dropbox.com/sh/m2wgfi7ev4wyet2/AAB5PZ9AX-3dLPu7rZFIWIWK2a?dl=0

17. Díaz, J (2015). 'Energy and ICT for educational inclusion in Latin America' in Heap, R (ed) (2015). *Smart Villages: New Thinking for Off-Grid Communities Worldwide* Banson/Smart Villages Initiative

18. E4SV (2016a). 'No one left behind: Smart Villages / EASAC at European Development Days 2016' available at: http://e4sv.org/no-one-left-behind-smart-villages-easac-european-development-days-2016/

19. Eckley, L, Harrison, R, Whelan, G and Timpson, H (2014). 'The social value of solar lights in Africa to replace the use of kerosene: Scoping Report' *Solar Aid and the Centre for Public Health (Liverpool John Moores University)* available at: http://www.cph.org.uk/wp-content/uploads/2014/06/SolarAid-scoping-report-FINAL.pdf

20. Economist (2012a). 'Let them eat Tablets' June 16th 2012, available at: http://www.economist.com/node/21556940

21. Economist (2012b). 'Digital Education in Kenya: Tablet Teachers' 8th December 2012, available at: http://www.economist.com/news/business/21567972-schools-africa-are-going-digitalwith-encouraging-results-tablet-teachers

22. EFA (2015). 'Global Monitoring Report- Education For All 2000-2015: Achievements and Challenges' *UNESCO Publishing*

23. ERC-IFC (2015). 'Kenya Market Assessment for Off-Grid Electrification: Final Report' available at: http://www.renewableenergy.go.ke/asset_uplds/files/ERC%20IFC%20mini-grids%20-%20final%20report%20-%20Final(1).pdf

24. Ezor, Z (2009). 'Power to the People: Rural Electrification in Uganda' *School for International Training, Uganda* available at: http://digitalcollections.sit.edu/cgi/viewcontent.cgi?article=1675&context=isp_collection

25. Faustino, N and Medina, M (2014). 'Impact Evaluation of the School Electrification and Education (SEEd) Project of the Alliance for Mindanao Off grid Renewable Energy Program (AMORE): A Utilization of Propensity Score Matching (PSM)' *Presented at the 'Making IE Matters Conference', ADB Headquarters, Metro manila, Philippines, Spetember 3-5, 2014,* available at: http://www.3ieimpact.org/media/filer_public/2014/09/18/52impact_evaluation_of_the_school_electrification_and_education_faustino_medina.pdf

26. Firefly(no date) 'Hybrid Power for Aid and International Development' *Firefly Clean Energy,* available at: http://www.fireflycleanenergy.co.uk/pdf/Firefly_Clean_Energy_Hybrid_Power_Aid_International_Development.pdf

27. Forbes India (2012). 'What Went Wrong With the Aakash Tablet' *25th June 2012,* available at: http://forbesindia.com/article/real-issue/what-went-wrong-with-the-aakash-tablet/33218/1

28. Furedi, F (2014). 'How the Internet and Social Media are Changing Culture' *Aspen Review*, 4, available at: http://www.aspeninstitute.cz/en/article/4-2014-how-the-internet-and-social-media-are-changing-culture/

29. Furukawa, C (2013). 'Do Solar Lamps Help Children Study?: Contrary Evidence from a Pilot Study in Uganda' available at: https://www.brown.edu/academics/economics/sites/brown.edu.academics.economics/files/uploads/Furukawa%20thesis.pdf

30. Gaible, E and Burns, M (2005). 'Using Technology to Train Teachers: Appropriate Uses of ICT for Teacher Professional Development in Developing Countries' *Information For development Programme (InfoDev)*, available at: http://files.eric.ed.gov/fulltext/ED496514.pdf

31. Guardian (2016). 'Spread of Internet has not conquered 'digital divide' between rich and poor-report' *13th January 2016* available at: https://www.theguardian.com/technology/2016/jan/13/internet-not-conquered-digital-divide-rich-poor-world-bank-report

32. GNESD (2014). 'Renewable energy-based rural electrification: The Mini-Grid Experience from India' New Delhi: Prepared by The Energy and Resources Institute (TERI) for the Global Network on Energy for Sustainable Development (GNESD).

33. Gollwitzer, L, Ockwell, D and Ely, A (2015). 'Institutional Innovation in the Management of Pro-Poor Energy Access in East Africa' *Science Policy Research Unit, Working Paper Series*, available at: https://www.sussex.ac.uk/webteam/gateway/file.php?name=2015-29-swps-gollwitzer-etal.pdf&site=25

34. Gurumurthy, A (2006). 'Promoting Gender Equality? Some Development-Related Uses of ICT by Women' *Development in Pratice* 16(6): 611-616

35. Gustavsson, M (2007). 'Educational benefits from solar technology — access to solar electric services and changes in children's study routines, experiences from Eastern Province Zambia' *Energy Policy*,;35:1292–1299.

36. Hennessey, S, Harrison, D and Wamakote, L (2010). 'Teacher Factors Influencing Classroom Use of ICT in Sub-Saharan Africa' *Itupale Online Journal of African Studies*, 2: 39-54 (Hennessey et al. 2010): https://www.researchgate.net/publication/228399541_Teacher_factors_influencing_classroom_use_of_ICT_in_Sub-Saharan_Africa

37. Herselmen, M (2003). 'ICT in Rural Areas in South Africa: Various Case Studies' *Informing Science, June 2003* available at:http://proceedings.informingscience.org/IS2003Proceedings/docs/120Herse.pdf

38. Holmes, J (2016). 'The Smart Villages Initiative: Interim Review of Findings' *Smart Villages* available at: http://e4sv.org/wp-content/uploads/2016/04/TR05-The-Smart-Villages-Initiative-Interim-Review-of-Findings.pdf

39. IADB (2014). 'Interactive Education using technology in Amazonas, Brazil: Expanding coverage of high quality education to remote areas' *Seminar of the Education Division of the Inter-American Development Bank and the Mobiles for Education (mEducation) Aliiance, 16th July 2014,* available at: http://events.iadb.org/calendar/eventDetail.aspx?lang=En&id=4344

40. IEG (2008). 'The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits' *World Bank Independent Evaluation Group* available at: http://siteresources.worldbank.org/EXTRURELECT/Resources/full_doc.pdf

41. IRFOL (2004). 'Improving the quality of primary school through distance education' *Paper commissioned for the Education for All Global Monitoring Report 2005: The Quality Imperative*

42. Jiminez, A and Lawand, T (2000). 'Renewable Energy for Rural Schools' *National Renewable Energy Laboratory* available at: http://pdf.usaid.gov/pdf_docs/PNACK616.pdf

43. Jimoyiannis, A and Komis, V (2007). 'Examining teachers' beliefs about ICT in education: implications of a teacher preparation program, Teacher Development', *An international journal of teachers' professional development*, 11 (2): 149-173

44. Khennas, S and Barnett, A (2000). 'Best Practices For Sustainable Development Of Micro Hydro Power In Developing Countries: Final Synthesis Report' for *Department for International Development and the World Bank* available at: https://practicalaction.org/docs/energy/bestpractsynthe.pdf

45. Kilgoris (no date) 'Education and Technology' *The Kilgoris Project,* available at: http://www.kilgoris.org/education-technology/

46. Kilmov, B (2012). 'ICT Versus Traditional Approaches to Teaching' *Procedia- Social and Behavioral Sciences* 47: 196-200

47. Kirubi, C, Jacobson, A, Kammen, D and Mills, A (2009). 'Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya' *World Development* 37(7): 1208-1221

48. Kozma, R (2005). 'National Policies That Connect ICT-Based Education Reform to Economic and Social Development' *An Interdisciplinary journal on humans in ICT Environments* , 1 (2): 117-156

49. Lambrou, Y and Piana, G (2006). 'Energy and Gender in Rural Sustainable Development' *FAO (Food and Agriculture Organization of the United Nations)* available at: ftp://ftp.fao.org/docrep/fao/010/ai021e/ai021e00.pdf

50. Livemint (2010). 'Limits of ICT in Education' *16th December 2010,* available at: http://www.livemint.com/Opinion/Y3Rhb5CXMkGuUIyg4nrc3I/Limits-of-ICT-in-education.html

51. Lung, M, Moldovan, I and Alexandra, N (2012) 'Financing Higher Education in Europe' *Procedia-Social and Behavioral Sciences* 51: 938-942

52. Maithani, P and Gupta, D (2015). 'Achieving Universal Energy Access in India: Challenges and the Way Forward' *SAGE Publications India*

53. Mfune, O and Boon, E (2008). 'Promoting Renewable Energy Technologies for Rural Development in Africa: Experiences of Zambia' *Journal of Human Ecology* 24(3): 175-189

54. Mingaine, L (2013). 'Challenges in the Implementation of ICT in Public Secondary Schools in Kenya' *International Journal of Social Science and Education* 4(1): 224-238, available: http://ijsse.com/sites/default/files/issues/2013/v4i1/paper/Paper-20.pdf

55. Munienge, M and Muhandji, K (2012). 'The use of ICT in Education: a comparison of traditional pedagogy and emerging pedagogy' *Proceedings of the 2012 World congress in Computer Science, Computer Engineering, and Applied Computing,* available at: http://worldcomp-proceedings.com/proc/p2012/FEC2651.pdf

56. Nussbaum, M (2010). 'One Mouse Per Child: Simultaneous participatory Educational Interaction' *Educational Technology Debate,* available at: http://edutechdebate.org/low-cost-ict-devices/one-mouse-per-child-simultaneous-participatory-educational-interaction/

57. Nye, B (2013). 'ITS and the Digital Divide: Trends, Challenges and Opportunities'

58. O'Reilly, S (2014). 'MREAP Baseline to develop a contextual understanding for renewable energy in Malawi' *IOD PARC, University of Strathclyde,* available at: https://www.dropbox.com/sh/m2wgfi7ev4wyet2/AABf28q4XDAR-bmrsLo4pY8Xia/Other%20Reports/IOD%20PARC%20MREAP%20Baseline%20report.pdf?dl=0

59. OECD (2000). 'Learning to Bridge the Digital Divide', *OECD Publishing, Paris.* Chapter 2 available at: http://www.oecd.org/site/schoolingfortomorrowknowledgebase/themes/ict/41284104.pdf

60. OECD (2015). 'Students, Computers and Learning: Making the Connection', *PISA, OECD Publishing.*

61. Osao, S (2016). 'The Impact of Mobile on rural Internet Users in Papua New Guinea' *APNIC*, available at: https://blog.apnic.net/2016/04/29/impact-mobile-rural-internet-users-papua-new-guinea/

62. Panjwani, A (2005). 'Energy as a key variable in promoting gender equality and empowering women: A gender and energy perspective on MDG 3' *Discussion Paper*, available at: http://r4d.dfid.gov.uk/PDF/Outputs/Energy/R8346_mdg_goal3.pdf

63. Pavlik, B et al. (2013). 'Solar Energy for Rural Madagascar Schools: A Pilot Implementation by University of Nebraska Engineers Without borders-USA' *International Journal for Service Learning in Engineering,* 8(2): 24-42

64. Peeraer, J and Petergem, P (2011). 'ICT in teacher education in an emerging developing country: Vietnam's baseline situation at the start of the year of ICT' *Journal of Computers & Education* 56: 974-982

65. Practical Action (2014). 'Poor People's energy outlook: Key messages on energy for poverty alleviation' Practical Action Publishing Ltd.

66. Practical Action (no date). 'Sustainable Energy 4 Rural Communities (SE4RC) 2015-2019' available at: http://practicalaction.org/sustainable-energy-for-rural-communities-se4rc

67. Prusa, A and Plotts, E (2011). 'Uruguay's Plan Ceibal: Can Laptops in the Hands of Primary School Students Reduce the Digital Divide, Improve Education, and Increase Competiveness?' *Capstone Project, The George Washington University,* available at: https://elliott.gwu.edu/sites/elliott.gwu.edu/files/downloads/acad/lahs/uruguay-potts-prusa-2011.pdf

68. Ramani, S (2015). 'Internet and Education in the Developing World- Hopes and reality' *Smart Learning Environments* 2:8

69. Robinson, J and Winthrop, R (2016). 'Millions Learning: Scaling up Quality Education in Developing Countries' *Center for Universal Education at Brookings,* available at: http://www.brookings.edu/~/media/Research/Files/Reports/2016/04/millions-learning/FINAL-Millions-Learning-Report.pdf?la=en

70. Roy, N (2012). 'ICT-Enabled Rural Education in India' International Journal of Information and Education Technology' 2(5): 525-529

71. Sabaliauskas, T and Pukelis, K (2004). 'Barriers to integration of information and communication technologies into the teaching and learning process' *Paper presented at the European Conference on Education Research, University of Crete, 22-25 September 2004* available at: http://www.leeds.ac.uk/educol/documents/00003861.htm

72. Skelton, A (2014). 'Leveraging funds for school infrastructure: The South African 'mud schools' case study', *International Journal of Educational Development,* 39: 59-63

73. Slate2Learn (no date) 'Our Technology', available at: http://slate2learn.com/vision/#technology

74. SOGERV (2015). 'SOGERV Policy Briefing 2015' *University of Strathclyde*, available at: https://strathclydee4d.files.wordpress.com/2016/08/sogerv-policy-briefing_2015.pdf

75. Solar Aid (2015). 'Impact Report: Autumn 2015' available at: http://www.solar-aid.org/assets/Uploads/Impact-week-2015/SolarAid-IMPACT-REPORT-2015.pdf

76. Squires, T (2015). 'The Impact of Access to Electricity on Education: Evidence from Honduras'

available at: http://economics.ucr.edu/seminars_colloquia/2014-15/applied_economics/Squires_JMP_Electricity.pdf

77. Tanzsolar (2012).'Tegaruka School' available at: http://www.tanzsolar.org/tegaruka.html

78. Tembo, Kand Mafuta, M (2015). 'Solar PV Strategic Energy project in Southern Malawi: Development, Design and Impact: Case Study' *University of Strathclyde*, available at: https://www.dropbox.com/sh/m2wgfi7ev4wyet2/AAB-5PZ9AX3dLPu7rZFIWIWK2a?dl=0

79. The Wire (2015) 'Instead of Reaching the Sky, Aakash Ends Up Six Feet Below' *15th July 2015,* available at: http://thewire.in/6473/instead-of-reaching-the-sky-aakash-ends-up-six-feet-below/

80. Todaro, M and Smith, S (2012). 'Economic Development' *Addison-Wesley: Boston, 11th Edition*

81. Truncano, M (2015). 'Innovative educational technology programs in low-and middle-income countries' *World Bank EduTech Blog,* available at: https://blogs.worldbank.org/edutech/innovative-educational-technology-programs-low-and-middle-income-countries

82. Truncano, M (10th January 2014). 'In search of the ideal educational technology device for developing countries' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/ideal-educational-technology-device

83. Truncano, M (12th Feburary 2014). 'Interactive Educational Television in the Amazon' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/interactive-educational-television-amazon

84. Truncano, M (17th January 2014). 'A model for educational technology development from… Afghanistan?' *World Bank EduTech Blog,* available at: https://blogs.worldbank.org/edutech/model-educational-technology-development-afghanistan

85. Truncano, M (19th October 2011). 'Using ICTs in schools with no electricity' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/off-the-grid

86. Truncano, M (22nd July 2014). 'Promising uses of technology in education in poor, rural and isolated communities around the world' *World Bank EduTech Blog*, available at: http://blogs.worldbank.org/edutech/education-technology-poor-rural

87. Truncano, M (22nd October 2010). 'Stuffing the Internet in a box and shipping it to schools in Africa' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/egranary

88. Truncano, M (23rd march 2012). 'Evaluating One Laptop Per Child (OLPC) in Peru' *World Bank EduTech Blog*, available at: http://blogs.worldbank.org/edutech/olpc-peru2

89. Truncano, M (26th June 2012). 'Ten trends in technology use in education in developing countries that you may not have heard about' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/some-more-trends

90. Truncano, M (28th July 2015). 'Tablets in education' *World Bank EduTech Blog,* available at: https://blogs.worldbank.org/edutech/tablets-education

91. Truncano, M (30th April 2010). 'Worst practice in ICT use in education' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/worst-practice

92. Truncano, M (31st July 2013). 'Big Educational laptop and tablet projects – Ten countries to learn from' *World Bank EduTech Blog*, available at: http://blogs.worldbank.org/edutech/big-educational-laptop-and-tablet-projects-ten-countries

93. Truncano, M (3rd September 2010). 'One Mouse Per child' *World Bank EduTech* Blog, available at: http://blogs.worldbank.org/edutech/one-mouse-per-child

94. Truncano, M (9th December 2011). 'The Aakash, India's $25 (?) Tablet for Education' *World Bank EduTech Blog,* available at: http://blogs.worldbank.org/edutech/aakash

95. UNDESA (2014). 'Electricity and education: The benefits, barriers, and recommendations for achieving the electrification of primary and secondary schools' available at: https://docs.google.com/gview?url=http://sustainabledevelopment.un.org/content/documents/1608Electricity%20and%20Education.pdf&embedded=true

96. UNDP (no date). Sustainable Development Goals- Goal 4: Quality Education' available at: http://www.undp.org/content/undp/en/home/sdgoverview/post-2015-development-agenda/goal-4.html

97. UNESCO (2011). 'Plan Ceibal in Uruguay: From Pedagogical Reality to an ICT Road Map for the Future' *UNESCO* available at: http://www.anep.edu.uy/anep/phocadownload/Publicaciones/Plan_Ceibal/plan%20ceibal%20in%20uruguay.pdf

98. UNESCO (2014). 'Information and Communication Technology (ICT) in Education in Asia: A comparative analysis of ICT integration and e-readiness in schools across Asia' *UNESCO Institute for Statistics, information Paper no. 22,* available at: http://www.uis.unesco.org/Communication/Documents/ICT-asia-en.pdf

99. UNESCO (no date). 'Telesecundaria, Mexico' available at: http://www.unesco.org/education/lwf/doc/portfolio/abstract8.htm

100. UNICEF (2014). 'MobiStation' *unicefstories,* available at: http://www.unicefstories.org/2014/05/20/mobistation/

101. Unwin, T (2009). 'ICT4D: Information and Communication Technology for Development' Cambridge University Press: Cambridge

102. Van Hoorik, P and Mweetwa, F (2007).Use of Internet in rural areas of Zambia, LinkNet Multi-Purpose Co-operative Society. Retrieved July 13, 2013, fromhttp://www.link.net.zm/.

103. Viriyapong, R and Harfield, A (2013). 'Facing the challenges of the One-Tablet-Per-Child policy in Thai primary school education' International Journal of Advanced Computer Science and Applications 4(9): 176-184 available at: https://thesai.org/Downloads/Volume4No9/Paper_28-Facing_the_challenges_of_the_One-Tablet-Per-Child.pdf

104. Wang, Y (2000). 'The China Experience: Providing Teacher Training through Educational Television' *Asian Development Bank Institute,* available at: http://pdf.usaid.gov/pdf_docs/PN-ACH453.pdf

105. Welland (2014). 'Smart Villages: The Gender and Energy Context' *Smart villages,* available at: *http://e4sv.org/wp-content/uploads/2015/08/03-Technical-Report.pdf*

106. Winrock International (2005). 'Alliance for Mindanao Off-grid Renewable Energy Project: Final Project Performance Report' available at: http://pdf.usaid.gov/pdf_docs/Pdacf122.pdf

107. World Bank (2016). 'Digital Dividends' *World Development Report 2016,* available at: http://documents.worldbank.org/curated/en/896971468194972881/pdf/102725-PUB-Replacement-PUBLIC.pdf

108. Zim Solar (no date). 'ZimSolar Rural Solar Systems | Rural School Systems' available at: http://www.zimsolar.co.uk/L2_rural_school_systems.htm

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SMART VILLAGES

New thinking for off-grid communities worldwide

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