The current issue and full text archive of this journal is available at
www.emeraldinsight.com/1065-0741.htm

Solar power generation for ICT and sustainable development in emerging economies

Damasen I. Paul
Faculty of Science, Technologies and Environmental Studies, The Open University of Tanzania, Dar es Salaam, Tanzania, and
James Uhomoibhi
Faculty of Computing and Engineering, University of Ulster, Londonderry, UK

Abstract

Purpose – The purpose of this paper is to systematically examine and draw attention to the potential benefits of solar power generation for access to and use of information and communication technologies (ICT) aimed at sustainable development in emerging economies.

Design/methodology/approach – Electricity plays a crucial role in the development and use of ICT and in the process of striving to achieve sustainable development in emerging economies. It has been shown that electrical energy is intrinsically linked to economic, environmental and social dimensions of sustainable development. An extensive analysis of the major contribution of solar electricity in various sectors such as economic, social and environmental benefits is provided. The paper concludes with a discussion on current status of solar electricity in major emerging economies, their planning policies and strategies for promoting solar power generation for increased access to ICT by people and sustainable development of society.

Findings – The demand for electricity in residential, commercial and industrial sectors in developing countries (emerging economies) is likely to increase, both as a result of increase in population and expanding industrialization. It remains amongst others, a growing challenge for these nations to obtain and put in place reliable and secured electricity supplies, for accessing ICT and to work towards achieving sustainability. The important issues that must be considered and addressed for the successful implementation of solar electricity programs for sustainability and wellbeing in developing nations are pointed out.

Practical implications – The paper shows that the problems of lack of qualified solar technicians and established Photovoltaic (PV) markets and business modes, renewable (solar) energy education have to be addressed. Other issues include appreciation of solar electricity as one of the major energy component, lowering initial cost of the PV technology, availability of finance mechanisms for customers, import tax exemption and regarding electricity as one of the basic needs like food, shelter and clothing. Overhaul of existing systems needs to take place in order to provide the means to deal with some of these issues.

Originality/value – Availability of power remains crucial for development in emerging markets. Solar electricity is of major interest for the energy sector in developing or emerging economies because it offers the possibility of generating renewable electricity using sunlight – a resource that is widely and freely available in most, if not all, developing countries. This paper raises awareness about this in a unique way and identifies problems faced by the sectors. To address some of these challenges without compromising the goal of sustainability and development, it is important that low carbon emitting electrical energy sources such as solar electricity are given high priorities by policy makers, industries and research and development institutions in emerging countries. Some innovative suggestions are provided for achieving this.

Keywords Sustainable development, Solar power, Information technology, Communication technologies, Emerging economies

Paper type Research paper

Campus-Wide Information Systems
Vol. 29 No. 4, 2012
pp. 213-225

1065-0741
DOI 10.1108/10650741211253813

1. Introduction

Apart from land, capital and labour, electrical energy is a crucial input in the process of sustainable development in emerging economies (Brazil, Russia, India, China and South Africa). It has been shown that electrical energy is intrinsically linked to environmental, social and economic aspects of sustainable development (United Nations (UN), 2010). However, for the past decades, the electrical energy demands in emerging economies have been met by non-renewable energy sources (specifically coal, thermal, oil and gas) which are pollution agent, not equally distributed and worse still, limited. On the other hand, the demand for electrical energy for technological use and sustainable development in emerging economies is likely to increase, both as a result of increase in population and expanding industrialisation. The need for emerging economies to address climate change and increase its reliable, affordable, clean and secured electrical energy supplies, in both urban and rural areas, is a key challenge which requires market penetration of low carbon emitting energy technologies. Solar electricity (from photovoltaic (PV)) is clearly one of the most promising prospects to these problems since it is non-pollutant, renewable and sunshine is available to all emerging economy countries, although with varying intensity.

2. Impact of information and communication technologies (ICTs) in advanced and emerging economies

By definition, ICTs include electronic networks, embodying complex hardware and software that is linked by a vast array of technical protocols (Mansell and Silverstone, 1996). It covers internet service provision, telecommunications equipment and services, information technology equipment and services, media and broadcasting, libraries and documentation centres, commercial information providers, network-based information services, and other related information and communication activities (United Nations Economic Commission for Africa (UNECA), 1999). It has been reported that the "new ICT" is about electronic means of capturing, storing, processing, sharing, displaying, protecting and managing information (Duncombe and Heeks, 1999).

For the past two decades, the role of ICTs in economic growth, social change and transformation in various developmental sectors has received considerable attention. The reason is that ICT enables the production of goods in a short amount of time with the assistance of computerised systems (Miles, 2001). ICT is regarded as a reliable vehicle for changing and modernising educational systems, a platform for communication, a means for improvement in health sector and a powerful tool for economic growth (Pigato, 2001; Punie *et al.*, 2006; Ngoma, 2010). It has been argued that extensive applications of ICTs creates "intangible assets" (in the form, e.g. of organisation or managerial improvements), which contribute to increasing the overall efficiency of all sectors of production, thus increasing the total factor of productivity (TFP) (Ngoma, 2010). Investment in ICTs is a capital input which contributes to overall capital deepening in other sectors, thus helping to increase labour productivity (Souter, 2004). The Organisation for Economic Co-Operation and Development (OECD) views ICT as a tool for increasing efficiency that provide access to new markets or services, create new opportunities for income generation, improve information and knowledge management inside the firm and reduces transaction costs and increase the speed and reliability of transactions for both business to business and business to consumer transactions (OECD, 2004). The use of e-mail, online banking and e-commerce have significantly cut down on the physical transportation involved in sending mail, banking and buying goods, which results in saving money and time; the production of

ICTs goods and services contributes significantly to economic growth (e.g. USA, Finland, China and India) and in a wider context, ICT is seen as a "gateway for successful economic and social transition" (Lake, 2004; Wangwe, 2007; UN, 2009).

In advanced economic countries such as USA and some European Union countries were significant investments in ICTs have been made; several studies have shown that such investments resulted in generous payoff (OECD, 2002; Kuppusamy *et al.*, 2009). For example, the ICT sector was a major source of employment growth for the 1995-2000 period were ICT services employment grew to 10.5 per cent in the UK, 10.2 per cent in the Netherlands, 9.8 per cent in Finland, 9.5 per cent in the USA, 7.3 per cent in the Czech Republic and 7.3 per cent in Spain. In addition, the ICT sector contributed significantly to the increase in the international trade. For example, in 1990, trade in ICT goods, defined as the average of imports and exports, accounted for over 12 per cent of OECD-wide trade in goods and by 2000, the share had reached almost 20 per cent (OECD, 2002). Other contribution of ICT includes the use of internet where users purchase goods over the internet and communication via e-mail to providing information about a company's products, services and technologies.

In 2001, the share of individuals using the internet to order products was about 38 per cent in Denmark, Sweden, UK and USA while in Canada and the Netherlands it was 24 and 20 per cent, respectively (OECD, 2002, 2004). The contribution of ICT in education varied significantly from one country to another. Report from "Education at a Glance" (OECD, 2002) showed that the percentage of students with access to a computer varies from 25 per cent in Italy to over 90 per cent in Canada, Finland and New Zealand (note: the average number of students per computer is an indicator of students' access to new technologies). The percentage contribution of ICTs to gross domestic product (GDP) growth for the period of 1995-2000 in selected developed countries increased as is shown in Table I (Daniele, 2006).

The World Bank often classifies the economy of a country by its gross national income per capita. Developing countries are characterised by low per capita income and considers this to be a statistical indicator for general unemployment, poverty, scarcity of highly paid jobs, low-level of personal income, energy crisis, insufficient capital resources and lack of investment in technology.

On the other hand, emerging economies are subgroup of developing countries that are characterised by fast economic growth, economic liberalisation and economic transition from controlled markets to more open markets while increasing transparency and accountability (Roztocki and Weistroffe, 2008). Countries classed as emerging economies are faced by demand for economic growth, climate changes, lack of affordable and sustainable electrical energy, insufficient capital resources, environmental degradation, lack of availability and investment in technology, insufficient food supplies in remote areas, high rate of unemployment, high population growth, lack of transport and communications (particularly in remotes areas), lack of education infrastructures, poverty and climate change (Meng and Li, 2002; Roeth and Wokeck, 2011). However, some of these large-scale problems can be addressed if education is promoted with access to and use of ICT made possible for the people in the public, private and voluntary sectors.

Furthermore, competing in the global market has become more challenging and complex and therefore attaining sustainable development is not only about liberalisation of the economy, but also entails how far ICT is being used in the country. It has been argued that the contribution of ICTs to economic growth and

Country	Labour	ICT	Non-ICT	TFP	GDP
Austria	−0.2	0.3	0.7	1.7	2.7
Belgium	−0.1	0.7	0.2	1.9	2.8
Germany	−0.3	0.3	0.3	1.4	1.7
Denmark	0.4	0.7	0.9	0.8	2.8
Spain	2.9	0.3	1.1	−0.3	4.0
Finland	1.0	0.7	0.1	3.1	4.9
France	0.2	0.3	0.7	1.6	2.7
Greece	0.7	0.3	0.6	2.2	3.8
Ireland	2.2	0.6	2.2	4.8	9.7
Italy	0.4	0.4	0.7	0.5	2.0
Luxemburg	1.0	0.2	1.6	1.0	3.9
Holland	1.0	0.2	1.6	1.0	3.9
Portugal	1.0	0.5	1.2	1.1	3.9
Sweden	0.7	0.8	0.4	1.7	3.5
United Kingdom	−0.8	0.4	0.6	1.4	1.7
USA	1.3	0.8	0.6	1.5	4.2

Source: Daniele (2006)

Table I.
The percentage contribution of ICTs to GDP growth for the period of 1995-2000 in selected developed countries

sustainable development in emerging economies depends on the way new information technologies are used by individuals and businesses (OECD, 2002). The authors pointed out that the greater use of ICTs in the production process may, for example, help raise the overall efficiency of the use of capital and labour, e.g. by reducing inventories and transaction costs. For technologies based on networks, such as the internet, the more people who are connected, the greater the potential benefits. In addition, the ICT sector has the potential to play a powerful role in tackling climate change in emerging economies by enabling other sectors (such as transport, construction, power and industry) to become more efficient (Roeth and Wokeck, 2011). According to a report published by the Climate Group and the Global e-Sustainability Initiative (GESI, 2008), ICTs could reduce global carbon emissions by 7.8 Gt CO_2e by 2020, an amount that is five times larger than its own carbon footprint.

3. ICT in emerging economies

Sustainable economic development requires a well-developed infrastructure and a substantial number of high-value-added industries. Thus in emerging economies, ICTs should be regarded as an enabler and catalyst for successfully shifting away from economic dependency on low-value-added industry sectors, such as agriculture and raw materials extraction. Many studies have identified various sectors where ICTs can make a great impact in emerging economies. These include economic growth (Meng and Li, 2002; Reddy *et al.*, 2004), good governance (Reddy *et al.*, 2004; Walsham, 2010), education improvement (Leblois, 2004; Reddy *et al.*, 2004), business growth (Pigato, 2001; Leblois, 2004; Reddy *et al.*, 2004), organisations (Leblois, 2004), human development (Reddy *et al.*, 2004), health sector (Reddy *et al.*, 2004; Chetley, 2006), social well-being (Reddy *et al.*, 2004; Walsham, 2010), employment (Reddy *et al.*, 2004), agriculture (Walsham, 2010), poverty eradiation (Pigato, 2001; Kshetri, 2005) and providing cheaper, quality and empowered communication to marginalised communities (Kuppusamy *et al.*, 2009). While the ICTs contribution still accounts for a relatively small share in these sectors, it can make a relatively large contribution if it

can be accessible and affordable by the majority in both urban and rural areas like in the developed countries. However, in order to make this technology truly available, accessible and affordable to the majority, especially in rural areas, there are number of important factors which should be tackled before the emerging economies can reap the benefits of ICTs. The major constraints facing the ICTs sector in emerging economies include:

- the digital divide due to imbalance of diffusion of ICTs infrastructure between urban and rural areas (Pigato, 2001; Wensheng, 2002; Reddy *et al.*, 2004);
- high cost of the technology such as high cost of bandwidth and high cost of ICT devices (Pigato, 2001; Meng and Li, 2002; Reddy *et al.*, 2004);
- lack of human resource capacity which limits the ICT implementation (Pigato, 2001; Meng and Li, 2002; Wensheng, 2002);
- lack of awareness about the benefits of ICTs (Reddy *et al.*, 2004);
- local content and language barrier (Pigato, 2001; Wensheng, 2002; InfoDev, 2010); and
- lack of sustainability, i.e. meeting the ongoing costs of maintaining equipment, staff training, connectivity and content materials acquisition (Meng and Li, 2002; InfoDev, 2010).

While all these are very important prerequisites conditions for ICTs development and implementation in emerging countries, they are insufficient conditions. Electricity availability and reliability is the major pre-condition due to the fact that all ICT devices use and need regular supply of electricity. Electricity is the engine for development, access and implementation of ICTs. It is impossible to operate any form of ICT in remote locations without electricity or urban areas without adequate and reliable grid electricity.

In fact, ICT would have no significant impact if the web site in the rural areas cannot be accessed because of lack of electricity or computers cannot be used in urban areas because of grid electricity rationing. Since ICT can make impact on all developmental activities, it is anticipated that as soon as ICT become accessible to most people in the public, private and voluntary sectors (both in urban and rural areas), new employment, economic growth, information on health, marketing assistance (using eBay-like auction exchanges), access to best practices to improve productivity, natural disaster warning and mitigation, life-long learning, education improvement, free flow of government information, increased government transparency, good price for food products, forecast and prediction, access to finance information (credit and payment), tourist information and entertainment information (TV show, sports, movies, music, newspaper and books) emerge. These will result in sustainable development in emerging economies.

4. Electricity scenario in emerging economies

All emerging economies are blessed by enormous non-renewable energy resources such as petroleum, natural gas, coal and uranium and renewable energy resources such as solar energy, wind, geothermal and hydropower (OECD/International Energy Agency (IEA), 2010). However, the status of electricity in both urban and rural areas in these countries does not reflect the enormous resources they have although the magnitude varies considerably from one country to another. Due to variation in

technology, economic growth and the type of energy sources, the dominant energy sources for electricity also varies from one country to another. For example the report from OECD/IEA (2005) indicates that in 2003, 66 per cent of total production of electricity in Russia came from natural gas while the share for hydro-electrical power and nuclear power was 17 and 16 per cent, respectively. In 2008, hydropower was the main source of electricity (72.6 per cent) in Brazil, followed by thermoelectricity generation (14.7 per cent) (OECD/IEA, 2010). In the remote isolated villages, electricity is supplied through decentralised small diesel plants (Andrade, 2009). However, the cost of electricity generated from diesel power plants in rural areas is high due to high costs of fuel and transportation (Goldemberg *et al.*, 2004). Access to electricity in rural areas has widened strongly throughout the past years.

By 2007, 55.35 million out of a total 56.34 million permanent residences were connected to electric energy. In 2009, the overall Brazilian electrification rate reached 97.8 per cent. The rate was 99.5 per cent in urban areas and 88 per cent in rural areas, which means that over 80 per cent of Brazil's population located in rural areas were without access to electrical power (USAID, 2009).

According to OECD/IEA, in 2008, China had a total electricity production amounted to 3.45 trillion kWh, an increase of 5.6 per cent compared to 2007 (OECD/IEA, 2010). Thermal electricity from coal accounted for about 81 per cent of total production, with hydropower accounting for about 17 per cent and nuclear energy for 2 per cent. The electrification rate in urban areas was 98 per cent. In late 2007, a total of 11.5 million people had no access to electricity, with wide variation among provinces (China mid- and long-term renewable energy development plan by 2020). Latest statistics from the National Energy Administration indicated that in 2008, 2 million rural households still lacked electricity (Tang, 2009). Through the deployment of decentralised power systems, the government aims to supply 10 million people with electricity by the end of 2020. The government however expects that beyond 2020 some Chinese households will still be lacking electricity, indicating that these people will also still lack ICTs.

As of mid-2009, 63.8 per cent of the electricity in India was generated from thermal power plants, 52.19 per cent by gas, 24.56 per cent by hydroelectric power plants, 10.90 per cent by gas, 8.82 per cent by renewable energies, 2.73 per cent by nuclear and 0.8 per cent by oil (Garcia-Valverde *et al.*, 2009). In 2005, a total of 412 million people in India had no access to electricity, with 380 million of them (92 per cent of total population) living in rural areas and 32 million in urban areas (OECD/IEA, 2007). According to OECD/IEA recent report, the electrification rate in India in 2009 was 64.5 per cent, with an urban electrification rate reaching 93.1 per cent and a rural rate of only 52.5 per cent (OECD/IEA, 2009). With the largest rural population in the world (OECD/IEA, 2010), India is facing a huge electrification challenge if the dream of achieving the predicted economic growth of over 5 per cent by 2030 has to be met.

In 2001, 93 per cent of electricity in South Africa was generated from coal, with nuclear energy and hydropower accounting for the remaining 7 per cent (Malzbender, 2005). In the same year, the national electrification level was about 66 per cent with an average electrification level of 46 per cent in rural areas and 80 per cent in urban areas (Davidson and Mwakasonda, 2004). According to OECD/IEA (OECD/IEA, 2009), South Africa achieved 75 per cent electrification; with 88 per cent urban and 55 per cent rural populations who gained access to electricity services. It has thus become evident that each country is facing challenges in providing universal access to clean and affordable electricity which requires more effort and strategies.

5. Solar electricity for ICTs and sustainable development

As shown in Section 4, with the exception of Brazil, high percentage of electrical energy demands in emerging economies have been supplied by non-renewable energy sources (mainly thermal, coal and gas) which are environmental pollutant agent, not equally distributed and worse still, limited and their prices are increasing tremendously. On the other hand, the demand for electrical energy for sustainable development is likely to increase in these countries, both as a result of increase in population and expanding industrialisation. Furthermore, a close attention should also be paid to the ICTs and electricity divide between urban and rural areas. In terms of electricity, it has been reported that extending grid electricity to many rural villages in most emerging economies would not be economically viable in the near future and in some villages not practically possible due low-load densities, low-capacity utilisation rates, high electricity line losses and requirement for accompanying infrastructure development such as roads (Liming, 2008). This suggests that the rural communities in these countries will continue to live without ICTs for several decades; a situation that not only deteriorates their economic growth but also threatens the process of climate change mitigation. To address these challenges, it is important that low carbon emitting electrical energy sources must be given high priorities in emerging economies. Solar electricity is clearly one of the most promising prospects to these problems since it is non-pollutant, renewable and available to all emerging economy countries, although with varying intensity.

Electricity from solar energy is obtained through stand-alone PV system which is defined as a small autonomous energy station, powered by a PV module, that provides electricity for basic services such as lighting, radio, television, computer, internet devices and operation of small appliances (Scheutzlich *et al.*, 2001). For a household or building with grid electricity, solar electricity acts as back-up electricity. Stand-alone solar system consists of a solar module which converts the solar radiation into electricity; rechargeable battery which stores the generated energy for use in the night and during cloudy days; charge controller which controls the charging of the battery; an alternative current (AC) inverter to covert direct current (DC) to AC current, switches, interconnecting wires and PV mounting rack (Robert, 1991). It may also include circuit breaker to prevent the cabling from overloading.

All emerging economies recognise the importance of expanding access to modern energy services for their rural areas through renewable energy sources, particularly solar electricity. For example, the largest existing markets for solar home systems are India (450,000), China (150,000), Kenya (120,000), Morocco (80,000), Mexico (80,000) and South Africa (50,000) (Martinot *et al.*, 2002). Kenya and China are the fastest growing markets, with annual growth rates of 10-20 per cent. Other notable emerging markets for solar electricity include Argentina, Bangladesh, Botswana, Bolivia, Brazil, Dominican Republic, Indonesia, Namibia, Nepal, Philippines, Sri Lanka, Tunisia and Zimbabwe (Martinot *et al.*, 2002). There is evidence that access to electricity services in rural areas in the developing world and emerging economies has significant impact on the standard of living of rural communities. Some of the benefits are summarised in Figure 1 (Obeng and Hans-Dieter, 2009) and also can be found in other sources (Martinot *et al.*, 2002; Gustavsson, 2004, 2007; Wamukonya, 2007; Bahauddin and SalahUdin, 2010). In addition, providing inexpensive charging solution through the use of solar electricity increases mobile phone access and improve social and economic situation in the rural areas. It has been found that solar charger extends service availability and boost average revenues per user by 10-14 per cent (GSMA Development Fund, 2010).

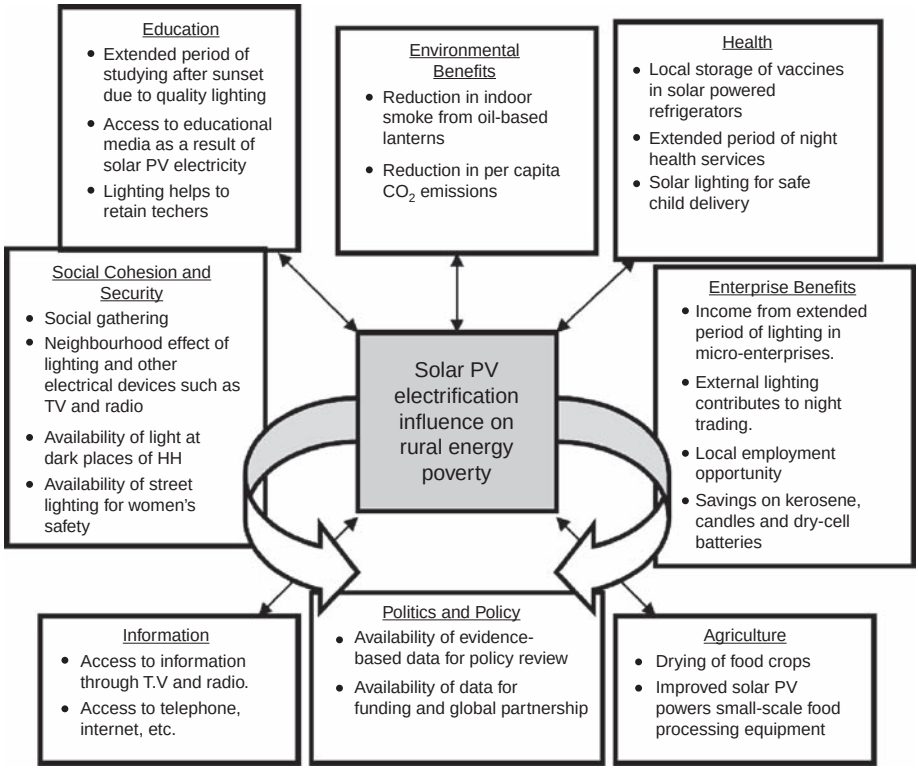

Figure 1.
Multi-sectoral linkages of solar electricity influence on quality of life in off-grid rural communities

Source: Obeng and Hans-Dieter (2009)

Despite these impacts, which will be the cases for ICTs and sustainable development, solar electricity in rural areas in emerging economies has not been utilised as much as it should have been due to:

- lack of qualified solar technicians which result into system failures leading to high cost for users, disappointment with the solar electricity and a strong negative about the technology (Nieuwenhout *et al.*, 2004; Chaurey and Kandpal, 2009);
- lack of established markets and establishes business modes (Chaurey and Kandpal, 2009; Martinot *et al.*, 2001);
- lack of renewable energy education at various levels (Nieuwenhout *et al.*, 2004; Chaurey and Kandpal, 2009). Studies have found that education systems in most emerging economies have been designed along established non-renewable energy sources (Hasnain *et al.*, 1998); the reason is that there is considerable uncertainty about the path of renewable energy sources as a major component in the energy sector (Ma *et al.*, 2010);
- uncertain or unrealistic grid expansion plans (Martinot *et al.*, 2001);
- high cost of the technology, particularly the cost of PV modules (Chaurey and Kandpal, 2009; Martinot *et al.*, 2001);

- lack of financing mechanisms for rural communities (Nieuwenhout *et al.*, 2004; Chaurey and Kandpal, 2009; Martinot *et al.*, 2001). Funding either from governments, domestic financing institutions or international organisations (through cooperation) have been seen as a driving force in rural solar electricity projects due to the fact that it is difficult for rural electrification projects to be accomplished by profit companies as there are no immediate returns; and
- other constrains such as subsidies, tariff structures and import duties (Martinot *et al.*, 2001).

6. Development of solar power generation

For significant penetration of solar electricity in rural areas and urban areas without reliable grid electricity, which will in turn, support extensive use of ICTs as well as accelerating sustainable development and reducing the effect of climate change, we therefore recommend the following:

- Training skillfully qualified solar electrical technicians, in both urban and rural areas, who will be able to design, install and provide timely solar system maintenance.
- Renewable (solar) energy courses should be introduced to all people, at all education levels and through all possible modes of education. The content of the courses and the mode of delivery should vary with the age of the learner.
- The government should put polices and programmes in place that will maximise private, community and public investment in rural solar electricity.
- The government should support policies that encourage community investment in stand-alone solar systems including community finance funds and training.
- Since stand-alone solar system can be built in phases, we also recommend the use of "modularity approach" for low income families. Modularity approach is the method of adding components (particularly the PV modules, inverter and storage battery) to the existing system depending on financial availability. It may also include a process of purchasing one component at a time, until the whole system is complete. This has not been done in the past due to lack of basic knowledge in solar electricity as most people regards stand-alone solar system as a "generator".
- For solar electricity to be available for use by everyone the government of each country must view electricity as a basic need the way water, air and roads are perceived. That means it has to be free or at marginal cost or provided as part of public infrastructure.

7. Conclusions

In emerging economies, ICTs is growing rapidly, but its effects to sustainable development have been heavily concentrated amongst the few due to fact that it is not accessible to many people who live in rural areas. In order to make ICT truly available, accessible and affordable to the majority, especially in rural areas, one of the important factors which should be tackled before the emerging economies can reap the benefits of ICTs is clean, reliable and available electricity. This has the potential to lead to

expanded and sustained use of e-learning for all sectors and at all levels of engagement with knowledge and skills acquisition, thereby promoting education for all and improving the workforce through life-long learning. Solar electricity has been identified as the best option to tackle these problems as well as accelerating sustainable development and reducing the effect of climate change. However, some constrains must be addressed properly before its effect can be clearly seen. These include qualified solar technicians, established PV markets and business modes, renewable (solar) energy education, appreciation of solar electricity as one of the major energy component, lowering initial cost of the PV technology, availability of finance mechanisms for customers, import tax exemption and regarding electricity as one of the basic needs like food, shelter and cloth.

References

Andrade, C.S. (2009), "Photovoltaic system for electrical power generation in remote rural areas of the Brazilian Amazon", RIO 9 – World Climate and Energy Event, Rio de Janeiro, 17-19 March.

Bahauddin, M.K. and SalahUdin, T.K. (2010), "Impact of utilization of solar PV technology among marginalised poor people in rural area of Bangladesh", Proceeding of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Kitakyushu, 4 September 2010.

Chaurey, A. and Kandpal, T.C. (2009), "Carbon abatement potential of solar home systems in India and their cost reduction due to carbon finance", *Energy Policy*, Vol. 37, pp. 115-25.

Chetley, A. (2006), "Improving health, connecting people: the role of ICTs in the health sector of developing countries", Grant No. 1254, Framework Paper, InfoDev Program, Washington, DC.

Daniele, V. (2006), "Information technologies and the Italian economic growth, 1980-2004", available at: http://w3.ced.unicz.it/upload/daniele/wp05.pdf (accessed 13 January 2011).

Davidson, O. and Mwakasonda, S.A. (2004), "Electricity access for the poor: a study of South Africa and Zimbabwe", *Energy for Sustainable Development*, Vol. 8 No. 4, pp. 26-40.

Duncombe, R. and Heeks, R. (1999), "Information, ICTs and small enterprise: findings from Botswana", Working Paper Series No. 7, Institute for Development Policy and Management, IDPM, Manchester, available at: http://unpan1.un.org/intradoc/groups/public/documents/nispacee/unpan015541.pdf (accessed 10 May 2012).

Garcia-Valverde, C., Miguel, R., Martinez-Bejar, C. and Urbina, A. (2009), "Life cycle assessment study of a 4.2 kWp stand-alone photovoltaic system", *Solar Energy*, Vol. 83, pp. 1434-45.

Global e-Sustainability Initiative (GESI) (2008), "Smart 2020: enabling the low-carbon economy in the information age", report by the Climate Group on behalf of the Global e-Sustainability Initiative, Belvedere Road, London.

Goldemberg, J., Rovere, E.L. and Coelho, S.T. (2004), "Expanding electricity access to Brazil", *Energy for Sustainable Development*, Vol. 8, pp. 86-94.

GSMA Development Fund (2010), "Green power for mobile: charging choices off-grid charging solutions for mobile phones", available at: www.lightingafrica.org/files/Green_Power_For_Mobile_Charging_Choices.pdf (accessed 7 March 2012).

Gustavsson, M. (2004), "The impact of solar electricity services on life styles: experiences from Zambia", *Journal of Energy in South Africa*, Vol. 15 No. 1, pp. 10-15.

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*, Vol. 35, pp. 1292-9.

Hasnain, S.M., Al-Awaji, S.H. and Elani, U.A. (1998), "Solar energy education a viable pathway for sustainable development", *Renewable Energy*, Vol. 14 Nos 1-4, pp. 387-92.

InfoDev (2010), "Essay V: ICT in non-formal education information and communication technology for education in India and South Asia", available at: www.infodev.org/en/Document.937.pdf (accessed 21 March 2012).

Kshetri, N. (2005), "The institution-ICT-economic development nexus: two cases", *Proceedings of the 2005 Americas Conference on Information Systems, 11-15 August, Omaha, NE*, pp. 491-9.

Kuppusamy, M., Raman, M. and Lee, G. (2009), "Whose ICTs investment matters to economic growth: private or public? The Malaysian perspective", *Electronic Journal of Information Systems in Developing Countries*, Vol. 37 No. 7, pp. 1-19.

Lake, A. (2004), "Time, mobility and economic growth: flexibility", available at: www.flexibility.co.uk/issues/transport/time-mobility.htm (accessed 1 February 2012).

Leblois, A. (2004), "The impact of information technology on business education in emerging markets", paper presented Occasion of the Business Education Systems and Emerging Markets Conference at the Georgia Institute of Technology, Atlanta, Georgia, 6 November, available at: www.ciber.gatech.edu/workingpaper/2003/04-001.pdf (accessed 13 February 2012).

Liming, H. (2008), "Financing rural renewable energy: a comparison between China and India", Working Paper, No. 44, ISAS, Singapore, available at: www.frankhaugwitz.info/doks/general/2008_05_23_China_RE_Finance_Comparison_India.pdf (accessed 3 March 2012).

Ma, H., Oxley, L., Gibson, J. and Li, W. (2010), "A survey of China's renewable energy economy", *Renewable and Sustainable Energy Reviews*, Vol. 14, pp. 438-45.

Malzbender, D. (2005), "Domestic electricity provision in the democratic South Africa", paper prepared for the Nordic Africa Institute's Conflicting Forms of Citizenship Programme, available at: www.acwr.co.za/pdf_files/01.pdf (accessed 15 March 2012).

Mansell, R. and Silverstone, R. (1996), *Communication by Design: The Politics of Information and Communication Technologies*, Oxford University Press, Oxford.

Martinot, E., Cabraal, A. and Mathur, S. (2001), "World bank/GEF solar home systems projects: experiences and lessons learned 1999-2000", *Renewable and Sustainable Energy Reviews*, Vol. 5 No. 1, pp. 39-57.

Martinot, E., Chaurey, A., Lew, D., Moreira, J.R. and Wamukonya, J. (2002), "Renewable energy markets in developing countries", *Annual Review of Energy Environment*, Vol. 27, pp. 309-48.

Meng, Q. and Li, M. (2002), "New economy and ICT development in China", *Information Economics and Policy*, Vol. 14, pp. 275-95.

Miles, P. (2001), "Globalisation-economic growth and development and development indicators", Planet Papers, available at: www.planetpapers.com/Assets/4302.php

Ngoma, S. (2010), "ICT in education: catalyst for economic growth in the Congo", available at: www.congovision.com/science/NGITLiteratureReview2.pdf (accessed 10 March 2012).

Nieuwenhout, F., Taric de Villers, T., Mate, N. and Aguilera, M.E. (2004), available at: www.taqsolre.net/doc/TaQSolRe%20WP1-year%201.pdf (accessed 9 March 2012).

Obeng, G.Y. and Hans-Dieter, E. (2009), "Solar PV rural electrification and energy-poverty: a review and conceptual framework with reference to Ghana", Working Paper, No. 36, Department of Political and Cultural Change, Centre for Development Research, University of Bonn, ZEF, Bonn, pp. 1-18.

Organization for Economic Co-Operation and Development (OECD) (2002), *OECD Information Technology Outlook: ICTs and the Information Economy*, OECD, Paris.

Organisation for Economic Co-Operation and Development (OECD) (2004), "ICT, e-business and small and medium size enterprises (SMEs)", report by Secretary-General of the OECD, No. DSTI/IND/PME(2002)7/Final, OECD, Paris.

Organization for Economic Co-Operation and Development/International Energy Agency (OECD/IEA) (2005), *Russian Electricity Reform, Emerging Challenges and Opportunities*, IEA, Paris, available at: www.iea.org/textbase/nppdf/free/archives/russianelec.pdf (accessed 27 February 2012).

Organization for Economic Co-Operation and Development/International Energy Agency (OECD/IEA) (2007), *World Energy Outlook, China and India Insights*, IEA, Paris, available at: www.iea.org/textbase/nppdf/free/2007/weo_2007.pdf (accessed 10 March 2012).

Organization for Economic Co-Operation and Development/International Energy Agency (OECD/IEA) (2009), *World Energy Outlook*, IEA, Paris.

Organization for Economic Co-Operation and Development/International Energy Agency (OECD/IEA) (2010), "Comparative study on rural electrification policies in emerging economies: keys to successful policies", working paper, OECD/IEA, Paris.

Pigato, M. (2001), "Information and communication technology, poverty, and development in sub-Saharan Africa and South Asia", Africa Region Working Paper Series No. 20, World Bank, Washington, DC.

Punie, Y., Zinnbauer, D. and Cabrera, M. (2006), "A review of the impact of ICT on learning", working paper prepared for DG EAC, European Commission Joint Research Centre, Institute for Prospective Technological Studies, Seville.

Reddy, R., Arunachalam, V.S., Tongia, R., Subrahmanian, E. and Balakrishnan, N. (2004), "Sustainable ICT for emerging economies: mythology and reality of the digital divide problem", a discussion note, available at: www.rr.cs.cmu.edu/ITSD.doc (accessed 8 March 2011).

Robert, S. (1991), *Solar Electricity: A Practical Guide to Design and Installing Small Photovoltaic Systems*, Prentice Hall Europe, London.

Roeth, H. and Wokeck, L. (2011), "ICTs and climate change mitigation in emerging economies", available at: www.niccd.org/RoethWokeckClimateChangeMitigationICTs.pdf (accessed 11 March 2011).

Roztocki, N. and Weistroffe, R.H.H. (2008), "Information technology investments in emerging economies", *Information Technology for Development*, Vol. 14 No. 1, pp. 1-10.

Scheutzlich, T., Klinghammer, W., Scholand, M., Wisniwsky, S. and Pertz, K. (2001), *Financing of Solar Home Systems in Developing Countries: The Role of Financing in the Dissemination Process*, Division 44, Environmental, Management, Water and Transport, GTZ.

Souter, D. (2004), "ICTs and economic growth in developing countries", Report No. DCD/DAC/POVNET(2004)6/REV1, Development Co-operation Directorate, Development Assistance Committee (DAC), DAC Network on Poverty Reduction.

Tang, A. (2009), "Window of China, China reports 2 million rural households without electricity", available at: http://news.xinhuanet.com/english/2009-10/02/content_12173548.htm (accessed 19 March 2012).

United Nations Economic Commission for Africa (UNECA) (1999), *An Overview of ICT Trends and Policy in Africa*, UNECA, Addis Ababa.

United Nations (UN) (2009), "Impact of ICT on community development in United Nations economic and social commission for western Asia (ESCWA) member countries", ESCWA Year Report No. GENERAL E/ESCWA/ICTD/2009/15, New York, NY.

United Nations (UN) (2010), "New and emerging technologies: renewable energy for development", report of the Secretary-General, Commission on Science and Technology for Development, Thirteenth Session, Geneva, 17-21 May.

USAID (2009), "Village goes online with solar power", available at: www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/success_stories/brazil_telecenter.pdf (accessed 4 March 2012).

Walsham, G. (2010), "ICTs for the broader development of India: an analysis of the literature", *Electronic Journal of Information Systems in Developing Countries*, Vol. 41 No. 4, pp. 1-20.

Wamukonya, N. (2007), "Solar home system electrification as a viable technology option for Africa's development", *Energy Policy*, Vol. 35, pp. 6-14.

Wangwe, S. (2007), "A review of methodology for assessing ICT impact on development and economic transformation", contribution to the AERC Project on the Impact of ICTs on Economic Development and Transformation, available at: www.aercafrica.org/documents/ICT_project_working_papers/WangweSAReviewofMethodologyonICT.pdf (accessed 8 March 2012).

Wensheng, W. (2002), "Bridging the digital divide inside China", paper presented at the 3rd Annual Conference of the Association of Internet Researchers, Maastricht, 13-16 October.

Corresponding author
James Uhomoibhi can be contacted at: j.uhomoibhi@ulster.ac.uk