Sustainable Options for Alleviating Energy Poverty in Sub-Saharan Africa: A Theoretical Evaluation of Community-led Renewable Energy Development

By

Keith Krosinsky

Energy poverty is an issue that affects billions of people around the world. It can be linked to a variety of other development issues, including economic poverty and environmental degradation, making it a critical issue on the development agenda. Sub-Saharan Africa experiences some of the highest rates of energy poverty, which is especially prevalent in rural areas where extending access to existing electrical grids is prohibitively expensive. Mainstream energy development strategies generally focus on either grid-extension or on technology transfers. These strategies have mostly failed at expanding energy access in rural areas. The ineffectiveness of current policy is largely due to a failure by energy development planners to account for local resources, needs, and cultural preferences. This dissertation will argue that a community-led approach to energy development that focuses on renewable energy technologies provides an alternative option that is more viable and sustainable. It will do so by evaluating this approach using theories from the field of science and technology studies, providing a novel insight into a topic that has been the subject of many previous works.

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1. Introduction

"Energy is the convertible currency of technology. Without energy the whole fabric of society as we know it would crumble."

-Ibrahim Dincer[1]

Access to energy in all of its myriad forms is an essential element to a modern standard of living and is the cornerstone of economic growth and progress throughout both the developed and developing world.[2] Yet, universal access to energy remains a distant prospect. This is an issue that divides the world; access to modern energy among the poorest people lags far behind that of the wealthiest. The prevalence of energy poverty is so pervasive that, according to the International Energy Agency (IEA), in 2009 approximately 1.3 people in the world lacked access to electricity (about 19% of the global population), and over 2.7 billion (approximately 40% of the global population) continue to rely mainly on traditional forms of biomass combustion for heating and cooking.[3]

Energy poverty is a broad concept; but the following definition by Indian scholar Amulya K.N. Reddy encompasses nearly all the elements relevant to this dissertation. He finds energy poverty to be "the absence of sufficient choice that allows access to adequate energy services, affordable, reliable, effective and sustainable in environmental terms to support the economic and human development."[4] What constitutes access to energy is sufficiently described by the International Institute for Applied Systems Analysis (IIASA). They find it to include access to clean energy for cooking and heating in the household, electricity for lighting and appliances in both houses and public facilities and efficient mechanical power that improves the productivity of labour. It must also take into account not only the intended recipient and type of energy but also the characteristics of access, including affordability, reliability, and quality as well.[5]

Awareness of these issues has reached the highest levels of international governance with the United Nations (UN) General Assembly declaring 2012 "the International Year of Sustainable Energy for All'." This declaration, though not binding, calls on Member States to publicize this issue while continuing progress on internationally agreed development goals.[6] Concrete action over the last two decades has complemented political rhetoric, —especially in Latin America, the Middle East, and East Asia— where access to electricity has been improved

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[1] Ibrahim Dincer. *"Renewable Energy and Sustainable Development: A Crucial Review."* Renewable and Sustainable Energy Reviews, Vol. 4, Issue 2, (June 2000), p. 157.

[2] Xilin Zhang, & Ashok Kumar. "*Evaluating Renewable Energy-Based Rural Electrification Program in Western China: Emerging Problems and Possible Scenarios*." Renewable and Sustainable Energy Reviews, Vol. 15, Issue 1, (January 2011), p. 774.

[3] Arno Behrens, Glada Lahn, Eike Dreblow, Jorge Núñez Ferrer, Mathilde Carraro & Sebastian Veit. "*Escaping the Vicious Cycle of Poverty: Towards Universal Access to Energy in Developing Countries."* CEPS Working Document, no.363, (March 2012), p. 3, 5-6.

[4] Nadia S. Ouédraogo. "*Bioenergy for Africa: An Illusion or a Sustainable Option to Reduce The Vulnerability to Energy and Poverty."* Université Paris-Dauphine, Centre Géopolitique de l'Energie Et des Matières Premières, (May 2009), p. 4.

[5] Behrens, *et al*. p. 4.

[6] U.N. General Assembly, Sixty-fifth Session. "Resolution 65/151 (2011) [International Year of Sustainable Energy for All]" A/RES/65/151. (16 February 2011), p. 2-3.

for over 2 billion people. But progress has not been universal and large parts of Sub-Saharan Africa (SSA) and South Asia have failed to keep up with increasing population growth and an exploding demand for energy.[7]

SSA is an especially vivid example of the unequal progress made in improving energy access, with nearly 70% of the total population lacking access to electricity and almost 80% of the total population relying on traditional biomass for cooking and heating.[8] Energy poverty is even more pronounced in rural areas of SSA. Here the average level of electricity access reaches only 14%,[9] and many states fail to provide access to even 5% of rural populations.[10] Endemic energy poverty in rural areas of developing countries is the result of many factors, ranging from poor governance, to lack of financing, as well as socio-cultural constraints.

The existence of successful rural electrification programmes demonstrates that these impediments can be overcome. A prime example is the progress witnessed in China over the last three decades. During this time energy access has been expanded to at least 98% of the population as of 2002,[11] making China the largest gross contributor to global energy access improvements.[12] However, much of this progress has been a result of the expansion of electrical grids and the utilisation of hydroelectric resources. This has been contingent on a number of factors that are lacking in many energy-poverty hotspots around the world. These include the previously mentioned availability of financing, the presence of a strong central government, as well as the feasibility of extending existing electricity grids.[13]

The high cost of extending access to existing electrical grids in remote areas is one of the primary roadblocks to reducing energy poverty throughout the developing world, and especially in SSA where at least 66% of the population lives in rural settlements.[14] This has created an opportunity for the deployment of decentralized, small-scale, renewable energy technologies (RETs) that provide an opportunity for a cost-effective, sustainable and environmentally friendly solution to improving energy access that can function in lieu of traditional grid infrastructure.[15] Focusing on the deployment of RETs over fossil fuel-based systems is especially critical due to the dual factors of volatile fossil fuel prices and the predicted consequences of anthropomorphic climate change; both of which are likely to disproportionately affect developing states and their poorest residents.[16]

The construction of coal-fired power plants and large-scale hydroelectric facilities to supply national grids with energy has been the focus of most government policies in SSA, as

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[7] Behrens, *et al*. p. 5.
[8] Ibid. p. 5-6.
[9] Chiyembekezo S. Kaunda, Cuthbert Z. Kimambo & Torbjorn K. Nielsen. "*Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa*." International Scholarly Research Network Renewable Energy, Vol. 2012, (June 2012), p. 2.
[10] Stephen Karekezi & Waeni Kithyoma. "*Renewable Energy Strategies for Rural Africa: Is a PV-Led Renewable Energy Strategy the Right Approach for Providing Modern energy to the Rural Poor of Sub-Saharan Africa?"* Energy Policy, Vol. 30, Issue 11-12, (2002), p. 1072.
[11] Wang ZhongYing, Gao Hu, & Zhou Dadi. "*China's Achievements in Expanding Electricity Access for The Poor*." Energy for Sustainable Development, Vol. 10, Issue 3, (September 2006), p. 5.
[12] ZhongYing, Hu, & Dadi, p. 5.
[13] Zhang & Kumar, p. 774-775.
[14] Kaunda, *et al*. p. 2.
[15] Karekezi & Kithyoma, p. 1071.
[16] Ogulade Davidson & Youba Sokona. "*A New Sustainable Energy Path for African Development: Thank Bigger Act Faster."* Energy and Development Research Centre & Environment Development Action in the Third World, (2002), p. 5-7.

well as being the recipient of much of the international aid directed to energy development projects.[17] However, nearly every state in SSA has also experimented with the deployment of small-scale RETs in rural areas over the last two decades; unfortunately these pilot programmes have generally failed to provide major improvements to modern energy access in rural areas.[18] A leading issue behind the lack of success in these initial programmes has been the failure of both government energy planners and international donors to take account of local social, cultural, and economic circumstances when planning decentralized energy projects.[19] This failure is ultimately a result of a government-led, supply-oriented approach that exemplifies energy development programmes in SSA and around the world.[20]

Considering the above-mentioned failures of energy development to provide universal access, this dissertation will endeavor to answer the question of how energy development can be better targeted to meet the needs of the rural poor in SSA. Ultimately it will demonstrate that the needs of the rural poor can be better met by a community-led approach that focuses on a decentralized energy infrastructure. Specifically this infrastructure should employ small-scale RETs that are suitable to both the geography and demographics of the locale in which they are deployed, as well as being acceptable to the societies and cultures that will utilize them. It is hoped that the findings of this dissertation will demonstrate the need to reevaluate energy development strategies so as to create a more democratic and transparent process of deployment; and as a result a more effective and sustainable outcome, that provides environmental and health benefits while ensuring an avenue for economic growth that can alleviate the crushing cycle of poverty that grips much of the developing world.

Much of the literature on this topic focuses on policy issues such as technical aspects of the proposed technologies, the cost-effectiveness of deploying them and the economic and social benefits that they can bring to areas where they have been deployed.[21] However, there exists a dearth of literature on the prerequisites required for social acceptance of, and the optimal conditions needed for, the adoption of new technologies in developing states.[22] This dissertation will thus depart from the traditional focus on policy analysis and will instead focus on these otherwise neglected factors by applying a theoretical framework drawn from the fields of science and technology studies, (also known as science, technology and society or STS), and specifically the philosophy of technology. SSA will be the main region of focus due to the previously discussed issues of endemic energy poverty that exist there, although examples from other regions will be cited in order to make comparisons and support conclusions.

The theories that will be used in the evaluation of community-led development will primarily fall under Andrew Feenberg's critical theory of technology, as well as the social construction of technology (SCOT). E.F. Schumacher's concept of appropriate technology will be linked to these theories, especially for evaluating small-scale RETs. These theories provide a

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[17] Ibid. p. 9-12.
[18] Karekezi & Kithyoma, p. 1073.
[19] James T. Murphy. "*Making the Energy Transition in Rural East Africa: Is Leapfrogging an Alternative?"* Technological Forecasting and Social Change, Vol. 68, Issue 2, (October 2001), p. 174-175.
[20] Davidson & Sokona, p. 12.
[21] Pablo Del Río, & Mercedes Burguillo. "*Assessing the Impact of Renewable Energy Deployment on Local Sustainability: Towards a Theoretical Framework*." Renewable and Sustainable Energy Reviews, Vol. 12, Issue 5, (June 2008), p. 1330-1331.
[22] Erik Paredis. "*Sustainability Transitions and the Nature of Technology*." Foundations Of Science, Vol. 16, no. 2-3, (May 2011), p. 198.

way of explaining the relationship between societies and technology, the interactions that govern their development, as well as the very nature of technology. They will provide insights into the effectiveness of a community lead approach and the merits of small-scale RETs that a policy analysis cannot.

The remainder of this dissertation will be structured as such; Chapter 1 will examine the topic of energy poverty, providing an overview of the subject material. It will argue that energy poverty is not only a critical development issue but also that mainstream efforts at energy development are ineffective at providing universal access. It will conclude by examining the concepts of sustainable development and renewable energy. Chapter 2 will introduce the theoretical framework. It will provide a synopsis of the wider fields of study and will specifically see how the theories of instrumentalism and substantivism explain the current form of mainstream energy development. It will then provide an interpretation of critical and social constructivist theories and demonstrate their link to community-led development. Chapter 3 will evaluate small-scale RETs and community-led development using the theoretical framework from Chapter 2. The dissertation will conclude with a summary of the findings and a brief discussion about their implications for energy development in rural areas of the developing world.

2. Setting the Scene: The Critical Issue of Energy Poverty

Chapter 1 will provide an overview of the complex topic of energy poverty so as to demonstrate its relevance. It will argue that energy poverty is linked to multiple development criteria and that current energy development approaches are inadequate at providing universal access. This will lay the groundwork for the theoretical evaluation of community-led energy development. Section 1 will begin with a focus on energy poverty and access to energy and will examine some of the relevant statistics on the subject. Section 2 will elaborate on the negative consequences of energy poverty to society, the economy and the environment and argue that these links make energy poverty a critical development issue. Section 3 will then examine the driving causes behind lagging improvements to energy access and argue that mainstream energy development strategies are to blame. Section 4 will conclude by briefly examining the topics of renewable energy and sustainable development.

2.1 Access to Energy & Energy Poverty

A qualitative assessment cannot fully reveal what constitutes access to energy nor energy poverty, and as such some relevant statistics will help create a more complete picture of this topic. As stated in the introduction, approximately 1.3 billion people lack access to electricity and approximately 2.7 billion rely on traditional biomass fuel sources for cooking and heating. 99% of those without access to electricity are located in the developing world while 80% of those people are located in either SSA or Southern Asia. The situation in the former is especially dire.[23] SSA consumes only 2.7% of all commercial energy produced globally with an average per capita energy consumption of fewer than 300 kilograms of oil equivalent (Kgoe) compared to the global average of 1431 Kgoe.[24] The IEA provides a benchmark to conceptualize what a

[23] Behrens, *et al*. p. 3, 5-6.
[24] Ouédraogo, p. 4-5.

minimum standard of access to energy should be. They suggest an initial target of 50-100 Kilowatt-hours (kWh) of electricity and 50-100 Kgoe for cooking and heating fuels per capita on an annual basis. (Appendix A Table 1.).[25]

The average per capita energy consumption in SSA not only includes the more developed economy of South Africa (which is often excluded as a more advanced economy), but also has lumped together the very different consumption patterns of urban and rural consumers. Overall consumption of modern energy sources is drastically less in rural areas then in urban areas,[26] with over four fifths of those without access to modern energy living in rural areas.[27] (Appendix A Table 2. for more details). As stated before, an estimated 66% of the population of SSA lives in rural areas, bucking the global trend towards urbanisation and further exacerbating traditional efforts of improving energy access by extending a centralized electricity grid.[28]

While many states in SSA have abundant fossil fuel and renewable energy resources,[29] they generate a comparatively small amount of energy. In total, all SSA states (excluding South Africa) collectively produce just 30 gigawatts (GW) of energy, an amount comparable to the generation capacity of Argentina. The average rural electrification rate in SSA (at 14%) is drastically less than that of other developing regions; with average electrification rates of 98.4% in North Africa, 60% in South Asia, 74% in Latin American and 72% in the Middle East, far surpassing even the most electrified states in SSA (Appendix A Table 3. for more information on electricity access by region). Electrification rates in SSA vary quite a bit from state to state with South Africa and Gabon being the only states reaching a rate of at least 50%. Many states including Mali, Eritrea, Tanzania, Uganda, Malawi, Mozambique, Liberia and Togo provide access to only 2% of rural populations.[30] Overall, the regional rate of electrification falls to 28% when South Africa is excluded from the statistics.[31] SSA, and in particular rural SSA, is the focus of this article due to this incomparable depth of energy poverty.

Energy poverty is a widespread problem affecting billions of people around the world. The following will examine how it affects states and societies, including slowed economic growth, detrimental health effects,[32] and environmental damage.[33] These issues interrelate and create feedback loops that perpetuate one another, with energy poverty acting as a sort of nexus between them.[34]

2.2 Economic Poverty, Health Risks and Environmental Damage

Lack of access to modern and reliable energy sources is related to numerous development challenges, with energy poverty almost always linked to economic poverty.[35] A variety of other issues, including health effects, environmental damage, gender disparity, and increasing

[25] Behrens, *et al*. p. 4.
[26] Laurent Raspaud. "*Sustainable Energy and The Fight Against Poverty*." Field Actions Science Reports, Issue 6, (2012), p. 3.
[27] Kaunda, *et al*. p. 2.
[28] Ibid. p. 2.
[29] Davidson & Sokona, p. 16.
[30] Kaunda, *et al*. p. 3.
[31] Behrens, *et al*. p. 5.
[32] Ouédraogo, p. 1-2.
[33] Davidson & Sokona, p. 27-28.
[34] Ibid. p. 27.
[35] Ibid. p. 4.

urbanisation can all be directly linked with energy poverty. For these reasons reducing energy poverty is often linked to achieving the UN Millennium Development Goals (MDGs) despite it not being one of the eight specific goals.[36]

The dependence on traditional biomass fuels in lieu of modern energy sources that predominates across much of SSA is one of the main causes of these negative effects.[37] Traditional biomass accounts for almost 90% of final energy consumption in SSA, excluding South Africa.[38] These traditional biomass fuels include mainly firewood, charcoal, animal wastes, as well as agricultural and forestry residues and are generally unprocessed when used. Most of this biomass is used in the household and over 90% is used for cooking. The remainder is used for lighting and heating, although kerosene or candles often supplement biomass in this context.[39] This intensive use of traditional biomass fuels has in many areas lead to over-harvesting beyond what can be sustainably renewed.[40] The simultaneous dominance of biomass as a fuel source and its increasing scarcity due to overuse further compounds the negative effects of its use.

Lack of access to modern energy impacts the agricultural sector in particular, which in many SSA states makes up over 20% of gross domestic product (GDP). This often means a lack of access to markets due to the difficulty of transporting perishable products. Lack of access also inhibits rural populations from processing agricultural goods, using more efficient means of irrigation, operating more advance agricultural equipment, and other activities that could help improve economic growth. Without access to modern energy many small farms still rely primarily on human labour, which is less productive and detrimental to the health of those toiling in the fields.[41]

The economic detriments of energy poverty can also stifle non-agricultural activity, as many small businesses such as workshops, stores, restaurants and guesthouses require reliable energy sources to function properly.[42] Energy poverty can thus severely restrain the income generating abilities of people, especially in rural areas, where options for income-generation are already limited. Access to a centralized energy grid in rural areas does not provide a solution to these problems due to the inability of many rural households to afford the cost of centrally supplied energy.[43] Additionally, the frequency of energy shortages due to aging infrastructure means that grid-supplied energy is generally unreliable and as such a dependence on it can lead to losses in productivity. The IEA has estimated that on average, states in SSA experience the equivalent of three months of lost service per year, leading to economic costs equaling close to 7% of GDP.[44]

The reliance on traditional biomass fuels also entails direct and indirect effects on economic performance. This is primarily due to the inefficient manner in which most biomass is used, which leads to an increased demand for fuel and a corresponding increase in the amount of

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36 Behrens, *et al*. p. 3.
37 Karekezi & Kithyoma, p. 1073.
38 Ouédraogo, p. 2.
39 Karekezi & Kithyoma, p. 1073.
40 Parfait Tatsidjodoung, Marie-Hélène Dabat, & Joël Blin. "*Insights into Biofuel Development in Burkina Faso: Potential and Strategies for Sustainable Energy Policies.*" Renewable and Sustainable Energy Review, Vol. 16, Issue 7, (September 2012), p. 5320.
41 Karekezi & Kithyoma, p. 1073, 1077.
42 Ibid. p. 1073, 1077.
43 Kaunda, *et al*. p. 2-3.
44 Behrens, *et al*. p. 6.

income spent on acquiring it. The gathering of agricultural residues and animal waste for combustion can also have an indirect effect on agricultural productivity by removing would-be fertilizers from agricultural lands that in many cases are already over utilized and stripped of nutrients.[45] Additionally, the time spent gathering biomass fuels, especially once they become scarce due to overexploitation, limits the amount of time that can be spent on income generating activities.[46] This is especially true for women and children, who can spend anywhere from two to twenty hours a week collecting fuel.[47]

Energy poverty is also linked to negative impacts on the socio-cultural level as well as health risks associated with improper diets and air pollution. Access to a reliable source of energy is an essential requirement for the functioning of numerous communal institutions, including schools, clinics, pharmacies, and hospitals. Lack of energy access or unreliable connections to central grids can reduce the quality of services provided, leading to diminished academic achievements for students and restricting the level of medical care that can be provided.[48] The collection of scarce biomass fuel by women and children also has dimensions of gender inequality and reduces the time available for children to seek an education. Indirect health risks are also associated with scarce or expensive fuel supplies as families may attempt to conserve fuel by undercooking meals, cooking less nutritious foods and opting to not boil drinking water.[49]

A number of direct health risks are linked to the inefficient combustion of biomass, kerosene,[50] and diesel fuels. The latter has been widely used for the processing of agricultural products and for transport when it is available and affordable.[51] The inefficient use of biomass and fossil fuels, especially when used indoors or in poorly ventilated areas, can cause dangerous levels of exposure to carbon monoxide, benzene and formaldehyde, among other dangerous particles. Findings from the World Health Organization (WHO) link this exposure to 1.6 million deaths per year from pneumonia, chronic respiratory diseases, and lung cancer, as well as to increased incidences of asthma, bronchitis, tuberculosis, and many other chronic illnesses which reduce quality of life and economic productivity.[52] Illness from indoor air pollution causes more annual fatalities than malaria or HIV/AIDS,[53] leading to an estimated one death every twenty seconds from what the WHO has termed "the killer in the kitchen." Once again this burden disproportionately affects women, as they bear primary responsibility for fulfilling the cooking and heating requirements of their families.[54]

The link between environmental degradation and energy poverty is an especially important issue in SSA where much of the economic activity is reliant on natural systems that in many cases are already overexploited. The variety of environmental issues both directly and indirectly linked to energy poverty is staggering; it includes deforestation, desertification, land degradation, loss of biodiversity, water security, air pollution, and the release of greenhouse

[45] Behrens, *et al.* p. 3.
[46] Murphy, p. 176-177.
[47] UNDP. "*Gender Mainstreaming: A Key Driver of Development in Environment & Energy.*" United Nations Development Programme. (2007), p. 2.
[48] Karekezi & Kithyoma, p. 1073.
[49] Murphy, p. 177.
[50] Karekezi & Kithyoma, p. 1072-1073.
[51] Byrne, *et al.* p. 4391.
[52] UNDP. "*Gender Mainstreaming.*" p. 2.
[53] Behrens, *et al.* p. 3.
[54] UNDP. "*Gender Mainstreaming.*" p. 2.

gases (GHG). The expected continuation of economic development in SSA poses a number of challenges, as this growth is likely to be predicated on an increasing utilisation of non-renewable resources and delicate eco-systems.[55]

The reliance on traditional biomass fuels is one of the leading contributors to environmental degradation in SSA. Overexploitation of biomass, especially in areas with little forest-cover, often leads to deforestation or desertification and has been linked to declines in the quality and quantity of soil, water shortages, biodiversity loss, and changes in weather patterns.[56] The burning of biomass contributes to air and water pollution through the release of lead, sulfur, and particulate emissions, contributing to health risks and environmental damage.

Deforestation and the combustion of biomass and diesel fuels also contribute to anthropomorphic climate change; specifically from the direct release of GHG emissions and indirectly due to the destruction of carbon sinks. While the share of global GHG emissions from the African continent is less the 3%,[57] it has seen an increase in carbon dioxide emissions (a major contributor to overall GHG emissions) of almost 37% since 1990.[58] This growth is likely to continue in the future as major changes in land use continue and with many of the national energy development strategies focused on carbon-intensive forms of energy generation; such as coal and oil.[59]

Addressing anthropomorphic climate change should be a major concern for the states of SSA as many experts, including the Intergovernmental Panel on Climate Change (IPCC), predict that developing countries will weather the worst effects of a changing climate while also being the most vulnerable to the disruptions it may cause. SSA is especially vulnerable, with even a slight increase in average global temperatures predicted to cause losses to agricultural productivity of up to 30%. This is just one of a number of climate change related challenges that may arise in the near future.[60]

As the preceding pages have demonstrated, the impact of energy poverty on economic growth, society, public health, and the environment contributes to poverty across the developing world, especially in rural areas. The linkages between these issues demonstrate the critical need to address energy poverty. This importance has not gone unnoticed by government authorities and development officials, and many programmes are dedicated to energy development. However, these energy development strategies are inadequate for providing energy access to rural areas, as the next section will argue.

2.3 Mainstream Energy Development Strategies

Energy development projects in the developing world received investments of over $9 billion in 2009.[61] This level of financing indicates awareness by policy makers and energy

[55] Davidson & Sokona, p. 27.
[56] Murphy, p. 177.
[57] Davidson & Sokona, p. 27.
[58] Michael Jefferson. "*Sustainable Energy Development: Performance and Prospects.*" Renewable Energy, Vol. 31, Issue 5, (April 2006), p. 580.
[59] Murphy, p. 177.
[60] Noreen Beg. Jan Corfee Morlot, Ogunlade Davidson, Yaw Afrane-Okesse, Lwazikazi Tyani, Fatma Denton, Youba Sokona, Jean Philippe Thomas, Emilio Lèbre La Rovere, Jyoti K. Parikh, Kirit Parikh, & A. Atiq Rahman. "*Linkages Between Climate Change and Sustainable Development*." Climate Policy, Vo. 2, Issues 2–3, (September 2002), p. 132.
[61] Behrens, *et al*. p. 11.

officials of the need to address energy poverty and to improve the reliability of already existing energy infrastructure. Most of these efforts have been ongoing since the 1970s and 1980s and generally began as a response to the oil crises and subsequent volatility of fossil fuel prices. These efforts have been a mix of government programmes and projects financed by international donors,[62] and as such they have generally been marked by either large-scale, supply-oriented strategies or by technology-led approaches. In general these have failed to take into account local socio-economic and cultural conditions.[63] The overall lack of progress in reducing energy poverty indicates that these strategies are not effective in providing universal energy access, especially in rural areas.[64] The following will show why current energy development programmes have been so ineffective, focusing on a lack of proper financing, poor or misguided governance, and energy projects that do not fulfill the needs of those lacking access to energy.

Although over $9 billion was invested in energy development projects in 2009, most experts agree that it is only a fraction of the overall amount needed to achieve universal access to energy. The IEA estimates that investments of up to $48 billion per year will be needed, with a total cost of $1 trillion during the period 2010-2030 required to provide universal access to energy and clean cooking facilities. The IEA also finds that 60% of this funding would be needed in just SSA, where it would be used for conventional energy programmes as well as the dissemination of RETs. The individual states of SSA will each have different requirements and needs depending on their individual circumstances. A study undertaken by the UNDP in 2006 can provide a benchmark. It estimated the costs of providing universal energy access in Senegal (a relatively small SSA state) at 1.7% of GDP per capita, which is a manageable amount, although not a negligible sum to developing states with limited budgets.[65] Such a large level of financing requires the existence of proper governance and knowledgeable institutions. Unfortunately this feature is generally lacking in most SSA states.[66]

The energy sector in SSA has generally followed global models that concentrate on large-scale energy sources and supply-oriented strategies and has been heavily influenced by the energy sector in Europe. Most of these energy institutions were inherited from colonial governments and evolved over time into independent departments and utilities. Some became state-owned, vertically integrated enterprises, and others developed more commercial aspects while still remaining under state control. However, European-style energy institutions cannot adequately address many of the issues confronting the energy sector in developing states and poor performance has generally marked their operations.[67]

One major issue has been a lack of effective governance at the national and local level. While investments in energy development are often made, the capacity to properly utilize them is lacking. For example, in many areas the grid has been extended to remote regions at great cost, yet a lack of accounting and technical know-how has meant that the intended recipient households were never connected.[68] Another issue is the lack of national institutions capable of energy policy analysis, and a corresponding lack of the type of complete and relevant data that is essential to properly implementing energy development projects. Other issues include

[62] Davidson & Sokona, p. 25-26.
[63] Murphy, p. 175, 178, 184.
[64] Davidson & Sokona, p. 26.
[65] Behrens, *et al*. p. 11-12.
[66] Davidson & Sokona, p. 25.
[67] Davidson & Sokona, p. 25.
[68] Behrens, *et al*. p. 13.

competition for funding by competing development priorities, and a lack of skilled professionals at both the local and national level.[69]

These shortcomings have led to a reliance on international institutions and donor countries for both technical assistance and financing. This has resulted in much of the energy policy in SSA being externally planned without the input of local communities or governments.[70] Some of the largest contributors of technical and financial assistance include the World Bank, the Asian Development Bank, the US Export-Import Bank, as well as many other development and finance institutions.[71] They have generally shown a preference for multi-billion dollar projects focused on fossil fuel and hydroelectric-based power generation that are usually aimed at improving power supplies and increasing reliability of existing grid networks.[72]

Two examples of this are the 4800-megawatt (MW) coal-fired Medupi plant in South Africa and the 39,000-MW hydroelectric plant on the Inga River in the Democratic Republic of the Congo (DRC), neither of which will expand access to those without grid connection. Each will also carry environmental and social costs, including GHG emissions, land degradation, and acid rain, in the case of the Medupi plant;[73] and issues of water security, population displacement, and methane emissions, in the case of the Inga River Dam.[74] While occasionally successful, the large-scale projects have generally failed to address the key issues behind energy poverty in SSA and tend to further exacerbate social and environmental issues where they are located.

Small-scale RETs provide an alternative option for energy development that avoids many of the shortfalls of large and centralized energy projects. However, the same issues of external planning,[75] as well as a reliance on the technology-led approach, has meant that many previous efforts at renewable-based energy development have failed to provide the expected results.[76] Promotion of small-scale RETs by international development agencies began in the 1970s and 1980s and between 1980 and 2000 over $3 billion was invested in renewable energy development (including large-scale hydroelectric), according to data from the Organization for Economic Co-Operation and Development (OECD).[77] These numbers do not take into account the multitude of projects also implemented by non-governmental organisations (NGOs) and private sector-led community initiatives, which will be the focus of Chapter 3.[78]

The reasons behind the failure of many donor-led renewable energy development projects are numerous, but tend to rely mainly on issues relating to a lack of sustainability and ease of replication in their design. The bulk of previous efforts have been focused on technical demonstrations. They have generally been plagued by lackluster performance and have failed to create proficient technical expertise at the local level, so as to ensure proper maintenance and dissemination of the technologies. Some studies have estimated that on average less than 10% of donor funding is allocated to local capacity building. Awareness of these problems has existed

[69] Davidson & Sokona, p. 20, 26.
[70] Davidson & Sokona, p. 26.
[71] Behrens, *et al.* p. 12.
[72] Murphy, p. 178.
[73] Behrens, *et al.* p. 12.
[74] Kaunda, *et al*. p. 2.
[75] Davidson & Sokona, p. 26.
[76] Murphy, p. 184.
Eric Martinot, Akanksha Chaurey, Debra Lew, José Roberto Moreira & Njeri Wamukonya. "*Renewable Energy Markets in Developing Countries.*" Annual Review of Energy and the Environment, Vol. 27, (2002), p. 313
[78] Behrens, *et al.* p. 12.

since at least the 1980s with the German aid agency (GTZ) finding in a review of its own energy projects that:

> [T]here has not been a single project that was designed expressly to disseminate the technology . . . . Rather, the bulk of activities have taken the form of pilot projects or testing and demonstration projects . . . frequently characterized by the diffusion of a small number of systems . . . and public-sector counterpart institutions which showed little interest in promoting a commercial dissemination process.[79]

This demonstrates that proper action has not been taken despite awareness of this issue at the institutional level.[80]

The majority of previous efforts have also suffered due to the fact that they failed to consider local conditions and the needs of those receiving the aid. This has occurred primarily as a result of the previously discussed technology-led approach to energy development, as well as the failure to involve relevant, local stakeholders in the process.[81] Most types of RETs proposed for energy development in SSA were designed outside of the region and do not meet the complex economic, social and cultural needs that are required for easy adoption. A technology-led approach also dampens participation by excluding non-experts and those lacking technical knowledge, which invariably includes the majority of those living in isolated rural areas affected by energy poverty.[82] The researcher Benjamin Sovacool published excerpts of a particularly insightful interview of a village leader in SSA which explains this issue more adeptly,

> [C]lassically, energy planners have seen the access question as one involving 'givers' and 'takers': the utility giving electricity or donors giving technology, and the consumers taking it. This completely places the energy services provider and consumer into a false dichotomy.[83]

Examples of successful projects such as the development of a market for solar home systems in Kenya, the expansion of small hydroelectric power in Nepal, and the spread of wind-powered water pumps in Argentina can all be attributed to the fact they were designed to require little change to the users behavior and attitude while also fitting their individual needs and practices.[84] A further discussion of appropriate technologies, participation, capacity building and alternative development strategies will resume in Chapter 3.

The failure of these development strategies cannot, in most cases, be linked to the technologies being used but on the conditions surrounding their deployment, especially the top-down approach that is currently favored by international development institutions and donors. Decentralized, small-scale RETs still provide the best option for alleviating energy poverty in

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[79] GTZ. "*Basic Electrification for Rural Households: Experience with the Dissemination of Small-Scale Photovoltaic Systems*." Deutsche Gesellschaft für Technische Zusammenarbeit, (1995), p. 49.
[80] Martinot, *et al*. p. 313.
[81] Ibid. p. 313.
[82] Murphy, p. 184-185.
[83] Benjamin K. Sovacool. "*Deploying Off-Grid Technology to Eradicate Energy Poverty*." Science, Vol. 338, no. 6103, (October 2012), p. 47.
[84] Martinot, *et al*. p. 313-314.

SSA while taking into account environmental and socio-economic concerns. The next and final section of Chapter 1 will briefly discuss renewable energy and sustainable development.

2.4 Renewable Energy & Sustainable Development

This section will examine the topics of sustainable energy development and renewable energy so as to demonstrate why the types of small-scale RETs that this article proposes for energy poverty alleviation are an appropriate option. Meeting the criteria for being a renewable energy source and meeting the standards of sustainability are key traits that differentiate these technologies from traditional large-scale methods of generating energy.

Sustainable development is a concept that has been applied with increasing frequency over the previous decades. It is an essential element of effective energy development and is therefore pertinent that a working definition be provided for the purposes of this article.[85] One of the most commonly cited is from the 1987 Brundtland Commission's report *Our Common Future*, which found it to entail "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[86] (Appendix B Figure 1. for alternative definitions). This was elaborated on by providing four essential components of sustainable energy; including energy that meets the needs of those using it, minimizes waste through efficiency, addresses issues of public health, and that prevents and protects from environmental damage.[87] However, other parameters should be considered to ensure that sustainable energy development does not occur to the disadvantage of other development goals. These include economic sustainability that ensures affordability, social sustainability that ensures that the poor benefit equally, and administrative sustainability that ensures that energy programmes can be maintained and expanded.[88] Effective energy development that accounts for all of these aspects will inevitably involve renewable energy.

But why is it the case that sustainable development and renewable energy sources are linked? The main cause is that renewable energy sources are by their very essence sustainable due to the fact that they are a non-exhaustible resource.[89] All energy sources on Earth are originally derived from the sun and specifically solar energy, which heats the planet, provides energy for photosynthesis, drives the wind, waves and produces the hydrological cycles that provide rainfall.[90] On an annual basis the sun sends the equivalent of $5.6 \text{ X } 10^{24}$ joules of energy to the earth, which in turn leads to an estimated production of $2 \text{ x } 10^{11}$ tons of organic material via photosynthesis.[91]

Over billions of years this process has produced the hydrocarbon-based fossil fuels that are the cornerstone of energy production for modern societies. While technically all resources are renewable, those that require a geological timeframe for renewal such as fossil fuels are regarded

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[85] Jefferson, p. 571.

[86] World Commission on Environment and Development (WCED). "*Our Common Future*." Oxford University Press, London, (1987), p. 41.

[87] Jefferson, p. 573.

[88] I.M. Bugaje. *"Renewable Energy for Sustainable Development in Africa: a Review."* Renewable and Sustainable Energy Reviews, Vol. 10, Issue 6, (December 2006), p. 604.

[89] Harald Winkler. "*Renewable Energy Policy in South Africa: Policy Options for Renewable Electricity.*" Energy Policy, Vol. 33, Issue 1, (January 2005), p. 27-28.

[90] Dincer, p. 158.

[91] Naim H. Afgan, Darwish Al Gobaisi, Maria G. Carvalho, & Maurizio Cumo. "*Sustainable Energy Development.*" Renewable and Sustainable Energy Reviews, Vol. 2, Issue 3, (1 September 1998), p. 236.

as non-renewable,[92] especially since their consumption has outpaced the geological processes that create them. Truly renewable forms of energy such as solar, wind, and hydro cannot be exhausted within a time frame relevant to human needs and as such they could provide an indefinite supply of energy.

However, renewable energy is not always sustainable. Large-scale hydro, as previously mentioned, is linked to a number of environmental issues and socio-economic impacts.[93] Industrial-scale production of biomass for fuel can lead to shortages of water and food, conflicts over land rights, and deforestation.[94] While large-scale solar and wind energy farms can impact biodiversity and lead to changes in land-use.[95] Thus the scale and location of a RET is key, supporting the argument that the flexibility of small-scale RETs make them best option for rural energy development.

Renewable energy, if utilized correctly, can meet nearly all the criteria of sustainable development. In fact the World Energy Assessment 2000 (a collaborative report from the UNDP, United Nation Department of Social and Economic Affairs, and the World Energy Council) found renewable energy to be, "highly responsive to overall energy policy guidelines and environmental, social, and economic goals."[96] The fact that renewable energy is abundant, clean and well suited for the type of decentralized energy scheme that can most benefit poor and rural users indicates a strong link between it and sustainable development.[97] An analysis of the specific renewable energy technologies best suited for serving the rural poor of SSA will be provided in Chapter 3.

This chapter has served to provide an overview of the complex issue of energy poverty and its effects on SSA. It has made an argument for its relevance as a development issue and has claimed that mainstream energy development strategies have failed to provide universal energy access, especially to rural areas in SSA. This information will serve to provide context to the theoretical evaluation of community-led energy development and small-scale RETs that will occur in the proceeding chapters.

3. A Theoretical Framework: Interpreting Technology Studies

Chapter 2 will introduce the theoretical framework of this article, which is to be used in Chapter 3 to evaluate the effectiveness of a community-led approach to energy development using small-scale renewable RETs. It will interpret theories from STS, with a focus on the philosophy and sociology of technology and how their development has reflected a changing conception of the role and place of technology in society. Section 1 will situate the philosophy of technology and will examine Andrew Feenberg's categorisation of technology theories. This will be followed in Section 2 by an interpretation of the theories of technological instrumentalism and substantivism. They will then be applied to the case of mainstream energy development strategies so as to demonstrate their relevance as a framework for this topic. Section 3 will introduce the critical and social constructivist theories of technology. Elements

[92] Ibid. p. 236.
[93] Kaunda, *et al*. p. 2.
[94] Ouédraogo, p. 20-22.
[95] Afgan, *et al*. p. 260-261, 267-269.
[96] UNDP, UNDESA, & WEC. "World Energy Assessment." United Nations Development Programme, United Nations Department of Economic and Social Affairs & World Energy Council, New York, (2000), p. 221.
[97] Winkler, p. 28.

from these three theories will make up the theoretical framework for the evaluation of community-led development in Chapter 3.

3.1 STS and the Philosophy of Technology

STS is a separate field from the study of the philosophy of technology, although the two are intrinsically linked by both the subject that they study and by the scholars that contribute to them. There is much crossover in what these fields demonstrate, although they differ in the methods that they use. STS tends to be a purely empirical study, with a research tradition more grounded in case studies. It includes the sub-school of the sociology of technology to which the theories of SCOT are usually attributed. The field of study that these theoretical traditions belong to is mostly irrelevant for the purpose of this article; as a result the wider field of study will be referred to simply as technology studies when appropriate. Understanding what these theories explain and how they can be applied to the case of energy development is what is essential and will be the focus of this section.

Andrew Feenberg has argued that as technology becomes an ever more present element of society it starts to shape the ways in which individuals think and the form that cultures takes. He finds that culture is based on “scientific-technical rationality.” The replacement of traditional cultures, which are based on unjustifiable customs and myths, with those based on a culture of rationality, has become widespread and in many places taken for granted. Contemporary studies of technology are more interested in understanding how our modern technological society is formed.[98]

Specifically they search for an understanding of the relationship between technology and society, exploring how technology affects society and in turn how societies influence the development of technology.[99] The most modern theories of technology studies offer a multilayered mode of analysis that takes into account multiculturalism and gender inclusion, thus departing from the Enlightenment-based and inherently Western models that have dominated the understanding of technology in the past.[100] Contemporary scholars of technology studies such as Feenberg and Philip Vergragt have also explored the role of technology in achieving what they call “the good life” or the fulfillment of basic human needs and self-realisation.[101]

As such, the findings of this field of study can contribute to an evaluation of how developing societies adopt technology and how the development of technology can better meet the needs of its users and lead to a better standard of living. Both of these aspects will contribute to the evaluation of community-led energy development and small-scale RETs in the next chapter.

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[98] Andrew Feenberg. “*What is Philosophy of Technology*.” In Conferência pronunciada na Universidade de Komaba, Oliveira NR [org.]; Apaza A [trad.], (2003), p. 1.

[99] Pitch Sutheerawatthana, and Takayuki Minato. “*The Relation of Technology to Politics in Infrastructure Development: The Chain Phenomenon and Its Relation to Sustainable Development*.” Sustainable Development 17, no. 4, (2009), p. 200.

[100] Clifford G. Christians “*The Philosophy of Technology*.” Journalism Studies, Vol. 12, no. 6, (December 2011), p. 727.

[101] Philip J. Vergragt. “*How Technology Could Contribute to a Sustainable World*.” GTI Dissertation Series, no. 8, (2006), p. 2.

The three main schools of theory within technology studies today are instrumentalism, substantivism and the group of critical and social constructivist theories.[102] According to Feenberg they can be categorized by how they interpret the relationship of technology to values and human power. Technology can be interpreted as either value-neutral or as value-laden, whereby the properties of a technology extend beyond the physical and hold their own value as an entity within society. Technology can also be interpreted as being controlled by humans or as being autonomous; the latter referring to the idea that while human beings are involved in the process of technological development, they do not control how it develops.[103] (Appendix A Table 4. for chart). Each of the main theories draws on a different combination of these relationships.

How these relationships are understood is key to one's conception of the role and place of technology in society and the way they interact with one another. This is central to the premise of this article as different interpretations of technology can justify different types of energy development, some of which may inadvertently exclude the critical issues of sustainability and universal access due to an overreliance on the promise of technological progress.[104] In fact, the importance of one's understanding of technology is a common theme throughout the literature and is exemplified by the scholars Deborah Johnson and Jameson Wetmore, who believe that "understanding this relationship is the key to building a better world."[105] The next section will demonstrate how the mainstream interpretations understand the place and role of technology in the world.

3.2 The Era of Instrumentalism

The critical and social constructivist theories of technology are most relevant for understanding the adoption of small-scale RETs at a local level but they do not adequately explain the energy development strategies that have been in vogue for much of the second half of the twentieth century. These can be better explained through the theories of instrumentalism and substantivism, which have dominated the discourse for much of this time. This section will examine these two theories and apply them to the top-down, technology-led energy development that was discussed in Chapter 1, Section 3.

The most popular conception of technology is the instrumentalist view, as it is the most straightforward of the theories and adheres to commonsense. Instrumentalists interpret technology as a tool that is controlled by humans in both use and design.[106] Technology does not condition what it means to be human; on the contrary, humans control it to meet their needs.[107] Technology does not have an innate purpose; it can only fulfill the intended goal of a user. In other words instrumentalists see the means as independent from the ends. Feenberg has used the example of the American phrase, "Guns don't kill people, people kill people" to demonstrate this.

[102] Paredis, p. 196.
[103] Feenberg, "*What is Philosophy of Technology*." p. 5-6.
[104] Paredis, p. 196-197.
[105] Deborah G. Johnson & Jameson M. Wetmore. (Eds.). "*Technology and Society. Building our Sociotechnical Future*." Cambridge, MA. MIT Press, (2009), p. 441.
[106] Paredis, p. 201.
[107] Christians, p. 78.

This phrase shows how people tend to see the means (guns) as separate from the ends (murder), which is instead accredited to the actions of the user.[108]

They also view technology as being value-neutral and as such it is applicable in any context, regardless of societal, economic or cultural factors.[109] This view is inherited from Aristotle and has evolved into technology being viewed as purely mechanical, as an engineered object separated from value. In this context efficiency and power become the universal norms of technology in lieu of specific values. Social and cultural factors become irrelevant when technology is considered as universal,[110] and it can thus be viewed as decontextualized in it application and use.[111] As a result the misuse of technology cannot be blamed on the intentions of those who created it, but by the way it is being used. Instrumentalists believe nearly all problems can be solved by a technical solution.[112] The dominance of this mode of thought is apparent in many fields, with Feenberg describing instrumentalism as a "spontaneous product of our civilisation" that is "assumed unreflectively by most people."[113]

The view of instrumentalists has strongly influenced debates around energy development and continues to do so today, especially in connection to climate-change mitigation strategies. The reliance on a technological fix for issues relating to poverty, social inequality and the environment is prevalent in practice and throughout much of literature is symptomatic of this influence. Within academic circles the instrumentalist view is marked by technological pragmatism and a belief that the convergence of proven and theoretical technologies such as large-scale solar, nuclear fusion, the Internet, nanotechnology, and bioengineering will lead to a zero-carbon future of equitable economic growth. At the institutional level this is exemplified by the IPCC's recommendations for adaptation and mitigation to climate change. These recommendations rely on the development and diffusion of new technologies from the developed to the developing world, or what is known as technology transfer. In the instrumentalists' view the transfer of energy technology from developed to developing countries is only a problem in relation to its costs, with social and cultural factors being largely irrelevant.[114] Many policy-oriented papers on energy development have adhered to this view and focused specifically on the cost of installing and maintaining specific types of technology.

Mainstream energy development strategies in SSA, particularly those that are technology-led can also be interpreted as influenced by an instrumental interpretation of technology. Large-scale hydro projects and the expansion of grid networks based on energy development models from the developed world are emblematic of the decontextualisation of technology, and can be viewed as a form of technology transfer. Efforts at disseminating RETs in SSA, in particular solar-photovoltaic (PV), have been implemented with the assumption that these technologies are beneficial to communities regardless of local economic and cultural factors. Energy development that focuses on renewable energy is also considered a form of technology transfer, although at smaller scale.[115] The failure of so many of these projects to

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[108] Feenberg, "*What is Philosophy of Technology*." p. 4-5.
[109] Paredis, p. 201.
[110] Feenberg, "*What is Philosophy of Technology*." p. 5.
Andrew Feenberg. "*From Essentialism to Constructivism: Philosophy of Technology at the Crossroads*." Technology and the Good Life, (2000), p. 12.
[112] Christians, p. 728-729.
[113] Feenberg, "*What is Philosophy of Technology*." p. 5.
[114] Paredis, p. 201.
[115] Murphy, p. 313.

fulfill their intended purpose (as discussed in Chapter 2, Section 3) can be seen as a viable critique of the instrumentalist's interpretation of technology.

This critique has more or less coalesced into the substantivist interpretation of technology. Substantivism is the minority interpretation, but still highly influential, and is often associated with the work of the preeminent philosophers Martin Heidegger and Jacques Ellul. This interpretation finds technology to be autonomous, meaning that its development follows its own logic free from human control or intentions. Technology is also considered to be value-laden, meaning that its development introduces new values that shape culture and dictate social interactions.[116]

The title of substantivism is derived from the idea that substantive values are inherently ascribed to a technology. These values are constrained by their relation to the maximisation of efficiency and power, and as a result the use of technology cannot be modified to fit the needs of a specific society. In other words, the use of a technology is not merely a means of extending human capabilities but is an embrace of a new way of life guided by a maximisation of efficiency. Substantivists usually have a pessimistic understanding of the autonomous and value-laden development of technology, and predict that its outcome will lead to the destruction of cultures, human free will, and the environment. Feenberg provides a fictitious example of this dystopian outlook by pointing to Aldous Huxley's *A Brave New World*, in which humans have been overtaken by technology and relegated to being mere "cogs in the machinery."[117] Ultimately, substantivism focuses on hermeneutic questions regarding the meaning of technology, departing from the practical approach of instrumentalism, which is more concerned with understanding what technology is.[118]

The substantivist position is not nearly as present as instrumentalism in the energy development debate although it can be argued that it influences some of the more radical positions of the Deep Ecology movement, the New Left and the EcoSocialists. Their ideas have mostly been relegated to the academic sphere and as result many of them have not been tested in practice. These ideological views tend to perceive modern technology as being inherently biased by its roots in European modernity and their solutions rely on developing new power structures, values, and social innovations instead of relying on technology as solution to all problems.[119]

Radical concepts such as deindustrialisation and a move away from large-scale agriculture and advanced chemical compounds are derived from the substantivists position. They also tend to be dismissive of technology transfers to the developing world, arguing the advanced technologies cannot be generalized and will lead to environmental exploitation and cultural decline. At the more radical end of the spectrum, exemplified by the scholar Otto Ulrich, they are even dismissive of transferring renewable technologies because they can "force their laws upon society in such a way that cultural self-definition and autonomy cannot be maintained for long". Substantivists should exclude any possibility of a technological solution to these issues. Yet many of its proponents still argue that a solution to these problems lies in the development of alternative and appropriate technologies.[120] This shifts them to instrumentalism as they interpret technology as being controlled by humans, thus diluting the purity of their original position that humans cannot influence technological development.

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[116]Paredis, p. 201-202.
[117]Feenberg, "*What is Philosophy of Technology*." p. 7-8.
[118] Feenberg. "*From Essentialism to Constructivism."* p. 11.
[119] Pardeis, p. 205.
[120] Ibid. p. 205-206.

It is important to dwell for a moment on appropriate technologies so as to demonstrate their connection to the types of small-scale RETs that Chapter 3 will evaluate. While the concept is technically based on substantivist assumptions, it can also be linked to the critical and social constructivist theories of technology. The economist E.F. Schumacher developed appropriate technology in the early 1970s as a critique of large-scale industrial development.[121] In particular, he is critical of the transfer of advanced technology from the developed to the developing world. Proponents of appropriate technology argue that the labour-saving technology of developed states is an ill fit for the labour-abundant economies of developing states. They also find that these technologies to be too costly, especially for the poor, as well as lacking cultural appropriateness. Furthermore, they find that advanced technologies tend to require infrastructure and technical expertise that are generally non-existent in developing countries.

These proponents argued instead for scaled-down, decentralized technologies that could be sustained using local resources and knowledge, thus the moniker of appropriate technology. The most important criteria for being considered an appropriate technology are that it takes into account physical and social conditions at a local level. RETs were of particular interest, especially once the criteria of ecological sustainability were included in designating what technologies could be considered as appropriate.[122] Small-scale RETs meet nearly all the criteria of appropriate technology, especially in their application as a decentralized, relatively simple technological fix for energy poverty that causes minimal harm to the environment. This will tie into the next chapter.

Having examined the instrumental and substantive interpretations of technology and demonstrated their relevance to the energy development debate, this section has showed how particular interpretations of technology can be linked to varying outcomes. Specifically it linked instrumentalism to mainstream energy development strategies and substantivism to more radical alternatives including that of appropriate technology. These theories provide a framework for understanding the mainstream strategies that currently dominate energy development but they are incapable of indicating a viable alternative. The next section will focus on the diverse set of critical and social constructivist theories and will argue that they are relevant to the evaluation of community-led energy development.

3.3 A Critical Turn

The final and most relevant category of technology studies that will be examined is the group of critical and social constructivist theories. This group includes some of the newest theories of technology, many of which were until recently considered to be in an embryonic stage of development and lacked coherent research traditions.[123] They tend to offer some of the most diverse interpretations of the relationship between technology and society, and as a result they are invaluable for understanding alternative technologies and strategies for energy development. This section will first analyse Feenberg's critical theory of technology and what differentiates it from the mainstream theories. It will then interpret Trevor Pinch and Wiebe

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[121] Pardeis, p. 206.

[122] M.J. Peterson. "*Appropriate Technology*." International Dimensions of Ethics Education in Science and Engineering, (2008), p. 1-4.

[123] Trevor J. Pinch, & Wiebe Bijker. "8 ''The Social Construction of Facts and Artifacts''." in *Technology and Society: Building our Socio-Technical Future, MIT Press,* (2009), p. 202.

Bijker's SCOT theories and indicate which elements are most relevant for understanding and evaluating energy development.

Instrumentalism prevails in public debates and substantivism remains influential in the academic arena, but they have generally fallen out of favor in contemporary technology studies. A grouping of theories that includes critical and social constructivist ideas has largely replaced it. A key element of these theories is that they depart from studying an abstraction of technology in general and instead focus on specific technologies that can be independently analysed using empirical case studies. This has led to a further convergence of the philosophy of technology and STS, reinforcing the link between the two. It should be noted that Feenberg's categorisation of technology theories does not lump together critical and social constructivist theories, and in fact omits constructivism entirely. However, subsequent scholarly works have demonstrated links between these two theories, which will be the reference point for this article.[124]

Feenberg's critical theory of technology is different from the approach of social constructivist in that it departs from the descriptive method used in SCOT. It instead explains why technologies develop a certain way while also prescribing alternatives for future development. Simply stated, the critical theory of technology interprets the relationship of technology and society as one of co-evolution and mutual influence.[125] It is linked to the substantivist position in that is recognizes the negative consequences associated with technological development. Critical theory also allows for the development of technological alternatives, although without the theoretical trap that many substantivists create for themselves. Technology is considered as value-laden in critical theory however these values extend beyond the traditional abstractions of efficiency and power that lead to the substantivist interpretation of technology as autonomous. Instead they are specific to the particular social condition under which a technology is being used. Efficiency remains as an influential value inherent to all technologies but does not determine the other values imbued within a technology by its user. Furthermore, technology does not dictate a single way of life but provides for a wide variety of outcomes depending on particular designs and uses as dictated by its creator.[126]

Thus critical theory is also influenced by instrumentalism in that it retains a belief in human-control over technology. This control is manifested in the socially specific values that are imbued into the design and use of a technology by its user. This control is not instrumental but is situated at a higher (meta) level. Technologies are not tools but act as a framework for different ways of living. The means and ends are connected in critical theory, which Feenberg again exemplifies with the refrain that, "Guns don't kill people, people kill people;" he argues that a world in which people have weapons creates a different social contract then one in which people are disarmed, and that the existence of weapons increases the possibility of violence. We choose through laws and personal decisions whether or not to allow the possession of weapons and as such our control is on a meta-level in which we determine which values to include in the technical framework of our societies.[127]

Critical theory argues that the problems that have been associated with technology in the past can be overcome by extending democratic principles to the development and application of technologies. This does not mean an ill-informed public voting on the types of technology that

[124] Paredis, p. 202.
[125] Paredis, p. 202, 209-210.
[126] Feenberg, "*What is Philosophy of Technology*." p. 9.
[127] Feenberg, "*What is Philosophy of Technology*." p. 9-10.

they wish to have, but instead increasing their participation in the process by vocalizing their needs and concerns during the design and development phase. Feenberg uses the examples of popular protest against nuclear energy and the development of email as a popular medium for personal communications to demonstrate that the public can become increasingly involved in technical issues that were previously the domain of experts.[128]

The idea of extending democratic principles to technological development by increasing participation in the public sphere fits with the concept of community-led development. It helps to explain how a society can shape a technology to fit particular needs as long as they are involved in the initial phases of design and development and shows that technologies should not be considered as a "one size fits all" option, especially in areas that still retain elements of traditional society or which are mostly isolated from the socio-technical culture that is dominant in much of the developed and urban world.

One can look at the process of designing and deploying improved cookstoves (ICSs) throughout the developing world, and especially in East Africa, as an example of democracy in technological development. Local people were intricately involved in the design and production of these devices and as a result there deployment has faced fewer hurdles for social acceptance then other energy efficiency measures.[129] A more detailed discussion of this will follow in the next chapter. The appropriate technology movement also includes elements that can be interpreted as endorsing the extension of democratic principles to technological development, especially in their capacity to be controlled and designed by local communities.[130] This also demonstrates the connection of appropriate technology to critical theory.

The final group, the social constructivist theories of technology, is often related to sociological studies and as such they are often descriptive in nature, which differentiates their approach from that of the Critical Theories. SCOT is one of the most influential of the social constructivist theories and is also the most relevant to this article. At its core it is a repudiation of the popularly held linear model of technological innovation (Appendix B Figure 2.), which held a deterministic view that scientific discovery inevitably led to technological development and commercial acceptance. This model, which interpreted technology as autonomous, has fallen out of favor in technology studies, but like instrumentalism it has remained popular with the public.[131] While this linear model minimizes the role of values as well as social and economic factors, SCOT embraces them, interpreting technological innovation as being driven by pertinent social groups who imbue meaning within technology. This part of the process often leads to the development of design related problems, leading to an adjustment of the technology that is conditioned on local context.[132] As such, SCOT interprets technology as human-controlled and value-laden, with the values depending on the local context where a technology is developed. In other words, it interprets the development of technologies as a social process contingent on the idea that technologies are not restricted to one form or function but can be utilized by different groups of users depending on their needs and values.[133] This supports the critical theory of extending democratic principles to technological development by arguing for the central role of human influence on the design process.

[128] Ibid. p. 9-11.
[129] Murphy, p. 182-183.
[130] Vergragt, p. 12.
[131] Vergragt, p. 5.
[132] Ibid. p. 5.
[133] Paredis, p. 210.

At the heart of SCOT is Pinch and Bijker's concept of interpretive flexibility. This concept demonstrates that technology is constructed and interpreted by cultures due to flexibility in how it can be designed. A single "best" design does not exist, and ultimately the development of a technology (which they characterize as multidirectional) depends entirely on the circumstances around its development. Gradually the design of a technology becomes stabilised through a series of socially relevant constructions and deconstructions.[134] Pinch and Bijker demonstrate this with the case of the development of the bicycle; showing how a variety of designs (i.e. the bicycle with a larger front wheel) used by relevant social groups eventually coalesced into the design that most people recognize today. They define relevant social groups as an organized or unorganized group of individuals that attach a shared meaning to a specific technology, which can include consumers, users, and even those opposed to the technology.[135] This concept is central to social constructivism and is the rationale for the interpretation of technology as human controlled and driven by values derived from its designers and users.[136]

The relevance of SCOT for evaluating energy development strategies can also be demonstrated by applying it to the case of an ICS programme. Of specific interest is a programme in the Purhépecha Region of Mexico in which a locally designed and constructed ICS called a Patsari was disseminated and monitored for success. The design of the Patsari stove was based not only on meeting local needs and social factors but also on fixing problems that arose with an ICS model called the Lorena that has been disseminated there in the past.[137] This case demonstrates a number of the principles of SCOT in practice including interpretive flexibility of a stove design, and the development of a new stove as a social process by relevant stakeholders instead of as a donor driven imitative.

Having introduced the theoretical framework of this piece, this chapter has demonstrated how pertinent theories from the field of technology studies can be applied to the case of energy development. While instrumentalism and substantivism provide a theoretical foundation, it is the critical and social constructivist theories, and the specific concepts of appropriate technology, interpretive flexibility, and extending democratic principles to technological development that are the most relevant for the evaluation of a community led energy development strategy that is based on RETs. The final chapter of this article will provide this evaluation and discuss the results.

4. Evaluating Alternatives: Renewables & A Local Approach

The final chapter of this article will evaluate small-scale RETs and a community-led approach to energy development using the highlighted theories and concepts from the previous chapter. It will do so while envisioning an optimal scenario for sustainable energy development in rural areas of developing countries and will base its conclusions both on empirical evidence as well as by its applicability to the theoretical concepts of appropriate technology, interpretive flexibility and the extension of democratic principles to technological development. This will

[134] Wiebe E. Bijker. "*Do Not Despair: There is Life After Constructivism*." Science, Technology & Human Values, Vol. 18, no. 1, (1993), p. 119.
[135] Pinch & Bijker, p. 118, 123.
[136] Bijker, p. 118.
[137] Karin Troncoso, Alicia Castillo, Omar Masera, & Leticia Merino. "*Social Perceptions About A Technological Innovation for Fuelwoo Cooking: Case study in Rural Mexico*." Energy Policy, Vol. 35, Issue 5, (May 2007), p. 2801.

bridge the gap between the theoretical and practical and will provide a novel justification for alternative energy development strategies. Section 1 will evaluate small-scale RETs. The chapter will conclude with Section 2, which will evaluate community-led energy development.

4.1 Small-Scale Renewable Energy Technologies

The following will evaluate whether small-scale RETs are an applicable technology for energy development in rural areas of SSA. This will be based on the conclusions of the first chapter, which found that an energy development strategy that constitutes centralized and large-scale energy generation is neither capable of delivering universal access nor is it sustainable at an environmental and/or socio-economic level. It will focus on four types of small-scale RETs, including solar, wind, hydro, and biomass. It will test their applicability as appropriate technologies while also examining them for their openness to interpretive flexibility.

Small-scale solar power technology, especially solar-PV, is one of the most commonly deployed types of RET in SSA and has been the recipient of large amounts of international funding. Systems designed for use at the household can generally provide between 15-75 watts of electricity,[138] and up to 60 kilowatts (kW) for slightly larger systems designed for agriculture and industry (Appendix B Figure 3. for examples). They are generally used to replace kerosene for lighting,[139] and to power small appliances such as radios, TVs, and mobile phones.[140] They have also been successfully used to power refrigeration for vaccines.[141] However, they are less successful as a power source for water pumps and a number of other uses related to agriculture and industry. Published research has demonstrated that predicted improvements to energy access from solar-PV have not materialized, despite its promise of providing a decentralized alternative to diesel generators.[142]

The reason for this failure becomes apparent when solar-PV is evaluated using the criteria of appropriate technology as well as its ability to be flexibly interpreted. Karekezi and Kithyoma have found the main factors to be the relatively high costs of purchasing and installing the technology, a reliance on components that cannot be manufactured domestically and a mismatch in what the technology offers versus what local communities need.[143] Other studies have also indicated that a lack of durability plagues many of the designs that have been disseminated throughout SSA, which requires a level of technical expertise that is generally not available in rural areas.[144] These factors demonstrate that in most contexts solar-PV does not constitute an appropriate technology; it fails to meet the criteria of being affordable, reliable, and does not fulfill local needs and is not developed from endogenous resources and knowledge.[145] The rigidity of how and in what context it can be used also demonstrates that its design has stabilised and it can no longer be flexibly interpreted.[146]

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[138] Martinot, *et al.* p. 315.
[139] Karekezi & Kithyoma, p. 1073, 1075.
[140] Martinot, *et al.* p. 315.
[141] Stephen Karekezi. "*Renewables in Africa – Meeting the Energy Needs of the Poor.*" Energy Policy, 2002, Vol. 30, Issue 11-12, (2002), p. 6.
[142] Karekezi & Kithyoma, p. 1073, 1079.
[143] Ibid. p. 1075-1082.
[144] Murphy, p. 182.
[145] Peterson, p. 1-3.
[146] Bijker, p. 119.

In most cases Solar-PV should be discarded as an option for rural energy development. However, a variety of different solar-powered devices (especially solar-thermal) do not suffer the same problems as solar-PV, including solar dryers for the processing of crops, solar pasteurizers for the purification of water,[147] and solar lanterns, which provide a cheap and durable alternative for household lighting.[148] These devices are much cheaper, tend to be more durable and are of a simpler design, meaning they can be constructed with local resources. Most importantly, they meet the specific needs of local communities and provide socio-economic benefits as a result.[149]

Small-scale wind power technology is also popular with many energy development programmes. They tend to provide between 100-5000 watts of electricity and can be used for many of the same purposes as solar-PV, including lighting, powering small appliances, and communications (Appendix B Figure 3. for an example). They are most commonly used to power water pumps for irrigation, as is the case in a number of states in SSA, including South Africa and Namibia, and this has proven to be its most effective application.[150]

Unfortunately, like solar-PV they are held back by the high cost of the technology, a reliance on imported components, and the need for complex technical maintenance, which has hampered adoption. A lack of information at local level about the availability of wind resources has also been a hindrance.[151] While some forms of utilizing wind power meet the criteria of an appropriate technology (i.e. wind-driven water pumps), it generally encounters the same problems as solar-PV. However, they do show a greater degree of interpretive flexibility as they can be designed and deployed to perform a variety of mechanical processes. Designs that harness mechanical power are much simpler and can be constructed from local resources as a result.[152] Wind power technology can also be integrated into a hybrid wind/solar-PV system, which provides a more reliable source of energy as well as providing more power. This increases the number of applications for which it can be used.[153] Small-scale wind power technology should be considered for energy development programmes in areas with adequate wind energy resources however, they are only appropriate for a limited number of uses.

Small-scale hydroelectric power (SHP), also known as a run-of-river system, is one of the most promising decentralized RETs that can be deployed to rural areas. These systems can provide upwards of 10 megawatts (MW) of electricity as well as mechanical power while avoiding many of the problems related to large-scale hydroelectric systems (Appendix B Figure 4. for an example). Such a robust level of electricity generation means that SHP can provide energy to decentralized micro-grids, powering small industries as well as serving a variety of other purposes. The practicability of utilizing SHP is dependent on the availability of a suitable site. Fortunately many states in SSA have ample hydroelectric potential.

SHP meets nearly all of the criteria of being an appropriate technology, including being relatively affordable, and reliable. Most importantly it can be designed and constructed using local resources and labour. SHP also demonstrates a high level of interpretive flexibility as it can

[147] Karekezi, p. 6.
[148] Martinot, *et al.* p. 315.
[149] Karekezi & Kithyoma, p. 1075, 1078.
[150] Martinot, *et al.* p. 318-319.
[151] Karekezi p. 7.
[152] Annabel Yadoo, & Heather Cruickshank. "*The Role for Low Carbon Electrification Technologies in Poverty Reduction and Climate Change Strategies: A Focus on Renewable Energy Mini-Grids with Case Studies in Nepal, Peru and Kenya.*" Energy Policy, Vol. 42, (March 2012), p. 596.
[153] Martinot, *et al.* p. 318-319.

be designed to work in a variety of settings and for a large number of purposes. These designs can also be modified so as to allow integration with a variety of other RETs, creating a more diverse and reliable energy supply.[154]

The final type of RET is small-scale biomass production in addition to the related technology of ICS. While the previously evaluated renewable energy technologies are intended to produce electrical and mechanical power, they do nothing to serve heating, cooking or transport needs. Modern biomass technologies can serve all of these needs while building on a pre-existing base of local experience and knowledge.[155] They also differ from the previously mentioned RETs in that they can be powered by a variety of different feedstock. Two types of modern biomass technologies will be evaluated. The first is biogas technology, which has been heavily promoted as a means of providing fuel for electricity and cooking to the rural poor. It can be scaled for a household or a community depending on local conditions, and it relies on animal dung as a feedstock.[156] It is also of a relatively simple design, and requires a low-level of investment. Additionally, the production of biogas produces a byproduct that can be used as fertilizer, leading to agricultural benefits.[157]

The second type is biodiesel technology, which produces fuel that can be used for transportation. This technology requires vegetable oil as feedstock, which is readily available across much of SSA. Sustainable production relies on numerous factors; in particular ensuring that food crops are not diverted for production of energy crops.[158] Second-generation fuels that use agricultural waste as feedstock will alleviate issues of sustainability however they are still in a developmental phase.[159] The cultivation of specific types of plants for production can help to avoid sustainability issues in the meantime. The Jatropha plant for example can be cultivated on the edge of fields dedicated to growing food and requires little attention. In addition to biodiesel it also produces a number of useful byproducts, including animal feed, fertilizer and bio-oil. The latter is an alternative to hydrocarbon diesel for powering generators, thereby creating a locally produced fuel for electricity in addition to transport. (Appendix B Figure 5. for example of Jatropha supply-chain).[160]

Both biogas and biodiesel technology can meet the criteria of appropriate technology, although this depends on where they are deployed and the type of feedstock they use. Under the right circumstances they can be affordable, reliable, and can be built and operated using local resources.[161] Additionally, a variety of designs requiring different fuels and producing different products are feasible, demonstrating interpretive flexibility. However, both of these technologies face problems. There is a risk that the cultivation of biodiesel feedstock can result in the same negative effects as traditional biomass use.[162] Problems relating to acquiring enough feedstock for biogas have arisen as well, especially in sparsely populated areas where collecting sufficient quantities of dung is often impossible.[163] As such, their utilisation requires a focus on small-

[154] Kaunda, *et al*. p. 4-5, 8.
[155] Raspaud, p. 4-6.
[156] Martinot, *et al*. p. 319.
[157] Karekezi, p. 5.
[158] Raspaud, p. 5-6.
[159] Ouédraogo, p. 10.
[160] Raspaud, p. 5-6.
[161] Karekezi, p. 5.
[162] Ouédraogo, p. 20-22.
[163] Karekezi, p. 5.

scale development, careful planning, and an awareness of local capacities; although they do hold much potential if sustainably developed.

A related but separate technology from modern biomass production is ICSs. While biogas and biodiesel technologies produce fuel, ICSs are an end-use technology meant to reduce fuel consumption and the health risks that occur from traditional methods of biomass combustion (Appendix B Figure 6. for example). It is arguably the most appropriate technology for energy development as it can be designed and produced by local people using entirely endogenous resources.[164] Most importantly it is open to interpretive flexibility. Designs can be modified so as to reflect local values, including preferences for taste, type of fuel used, as well as other cultural preferences. ICSs are most effective at reducing fuel consumption and negative health effects when designed to use modern fuels such as biogas. However, they can be designed to use fuels like firewood if a sustainable supply of more efficient fuels is not available,[165] or if local values imply a preference for traditional fuels. The adoption of ICSs in rural communities benefits women in particular, by eliminating the economic burden of traditional biomass collection, as well as reducing health risks.[166]

No single type of RET can provide a means for eliminating energy poverty. Each type has its own positive and negative aspects, and successful adoption of a technology depends entirely on local conditions and the manner in which it is deployed. Technology alone does not provide a solution; the final section of this article will evaluate the missing element of successful rural energy development.

4.2 A Community-led Approach to Energy Development

If technologies alone could end energy poverty then the billions of dollars spent on energy development each year would have a greater effect. While on paper, technologies can be portrayed as holding all the answers; in reality this is not the case. A government or international donor-led approach that leads with technology has proven its ineffectiveness numerous times, especially in rural areas of SSA. A top-down approach will inevitably fail in understanding the technological capabilities of people in rural areas, will fail to expand their participation, and will base the design of its development programme on inaccurate assumptions about the needs and complexities of rural communities. An alternative does exist to the asymmetric technology transfers that have dominated energy development in SSA.[167]

The alternative is a community-led approach to energy development that is based on local values, capabilities and resources. This approach allows for the process of interpretive flexibility in designing and adopting the types of RETs that will be utilised. It also implements Feenberg's call for the extension of democratic principles to the development and use of technology. Successful efforts of deploying ICSs provide an example of the efficacy of a community-led approach. This can be demonstrated by the adoption of the ceramic jiko-stove in Kenya, where almost one million locally designed stoves have been installed and maintained through the combined efforts of local businesses, entrepreneurs and community organizations.[168]

[164] Murphy, p. 182-183.
[165] Behrens, *et al*. p. 11.
[166] Troncoso, p. 2800-2801.
[167] Murphy, p. 184.
[168] Martinot, *et al*. p. 318-324.

The success of programmes like this are built on local knowledge and capabilities and through widespread participation of the local community (who would be considered the relevant social group in a SCOT interpretation of this case). Perhaps the most important element of a community-led approach is that it develops a local market for a product, thus generating economic growth and other related benefits that can increase early participation of the community.[169] The existence of local stakeholders can lead to improvements in the viability of an RET project, as local people have more to lose from its failure then they would from a project that was financed and deployed by outsiders.

A good example of this is the implementation of a SHP project in the community of Thiba, Kenya. Community leaders conceptualized and organized the construction of this project, which was funded by local shareholders and constructed by local people using local resources. Once completed, the project paid dividends to those who originally invested in it, and was open to anyone in the community willing to pay for access to the energy it produced. Furthermore, it is managed by a democratically elected committee of local people and maintained by locals who were trained by a local NGO. However, this project has faced some difficulties, including technical issues related to the design of the SHP system, and the maintenance of transparency within the management committee. This demonstrates that community-led development does face hurdles to success, especially in relation to the availability of local technical knowledge and the capacity for legitimate management and governance. However, building local capacity in these areas could become the focus of international donors if funding is diverted away from unsuccessful efforts at technology dissemination and transfers.[170]

Providing an optimal model of community-led development is a fool's errand. Local needs and capacities will dictate the shape that endogenous development takes and the types of technologies that can be used. Even the management structure of these projects can vary; with private ownership and cooperatively managed energy projects both offering advantages and disadvantages depending on local values and capabilities. This article cannot definitively state which options are the most likely to produce progressive results. It can merely indicate the direction from which these efforts should begin.

5. Conclusion

This article set out to discover how energy development could be better targeted to meet the needs of the rural poor in SSA, and by extension the developing world. It has demonstrated the critical need to address energy poverty, unveiled how it is linked to other development issues, and demonstrated that mainstream efforts at energy development have been ineffective at providing access in rural areas of SSA. It has also established the need for energy development to abide by the criteria of sustainability, thus focusing on RETs as the technology of choice.

The evaluation of these technologies and a community-led approach to energy development using insights from the critical theory of technology and SCOT supports the original claims of this article; that the needs of the rural poor can be better met by a community-led approach that focuses on a decentralized energy infrastructure. Specifically this infrastructure should employ small-scale RETs that are suitable to both the geography and demographics of the

[169] Yadoo & Cruickshank, p. 595.
[170] Yadoo & Cruickshank. p. 599, 601.

locale in which they are deployed, as well as being acceptable to the societies and cultures that will utilize them.

Further research on this subject is required to develop best practices for community-led development, and to better understand the economic benefits that it can provide. Furthermore, a deeper analysis into the efficacy of RETs as an appropriate technology could expand the number of options available for sustainable energy development. Given more time and space, this article would have developed an in-depth case study of community-led development so as to further demonstrate these concepts in practice. Further work could also be performed within the field of technology studies so as to directly connect it to the design and development of RETs.

This article has provided a comprehensive introduction to the complex topic of energy poverty; and has done so using a novel approach that has unveiled a new way of understanding alternative options for development. Progress in reducing energy poverty over the second half of the twentieth century has demonstrated that there is a way forward. It is hoped that these alternatives can provide a path to universal energy access in the near future.

Appendices

Appendix A: Tables

Table 1. Minimum Threshold for Access to Energy

Energy service		Minimum standard
Lighting	1.1	300 lumens for a minimum of 4 hours per night at household level
Cooking and water heating	2.1	1kg wood fuel or 0.3kg charcoal or 0.04kg LPG or 0.2l of kerosene or biofuels per day, taking less than 30min per household per day to obtain
	2.2	Minimum efficiency of improved solid fuel stoves to be 40% greater than a three-stone fire in terms of fuel use
	2.3	Annual mean concentrations of particle matter (PM2.5) < 10μg/m3 in households, with interim goals of 15μg/m3, 25μg/m3 and 35μg/m3
Space heating	3.1	Minimum daytime indoor air temperature of 18°C
Cooling	4.1	Households can extend life of perishable products by a minimum of 50% over that allowed by ambient storage
	4.2	Maximum apparent indoor air temperature of 30°C
Information and communications	5.1	People can communicate electronic information from their household
	5.2	People can access electronic media relevant to their lives and livelihoods in their household

Source: Behrens, et al. *Escaping the Vicious Cycle of Poverty: Towards Universal Access to Energy in Developing Countries."* pg 4

Table 2. Urban and Rural Electricity Access in Selected SSA States (2000)

Country	*Percentage of households electrified*	
	Urban	*Rural*
Malawi	11.0	0.32
Tanzania	13.0	1.0
Lesotho	14.0	4.0
Mozambique	17.05	0.66
Zambia	17.85	1.39
Namibia	26.0	5.0
Botswana	26.48	2.09
Swaziland	42.0	2.0
Zimbabwe	64.72	0.6
South Africa	74.6	27.2
Côte d'Ivoire	73.1	12.7
Ghana	61.7	4.3
Average	**25.78**	**1.7**

Source: Davidson, Ogulade., & Youba Sokona. "*A New Sustainable Energy Path for African Development: Thank Bigger Act Faster."* Pg 62

Table 3. Lack of Energy Access by Region (2009)

	Rural	Urban	Total	Share of Population
Africa	466	121	587	58%
Sub-Saharan Africa	465	121	586	69%
Developing Asia	595	81	676	19%
India	268	21	289	25%
Developing countries*	1,106	208	1,314	25%
World**	1,109	208	1,317	19%

Source: Behrens, et al. "*Escaping the Vicious Cycle of Poverty: Towards Universal Access to Energy in Developing Countries.*" pg 5

Table 4. Theories of Technology

Technology is:	Autonomous	Humanly Controlled
Neutral (complete separation of means and ends)	Determinism (e.g. modernization theory)	Instrumentalism (liberal faith in progress)
Value-laden (means form a way of life that includes ends)	Substantivism (means and ends linked in systems)	Critical Theory (choice of alternative means-ends systems)

Source: Feenberg, Andrew. "*What is Philosophy of Technology.*" pg 5

Appendix B: Figures

Figure 1. Alternative Definitions for Sustainable Development

(a) for the World Commission on Environment and Development (Brundtland Commission) [26]: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

(b) for Agenda 21, Chapter 35 [27]: "the development requires taking long-term perspectives, integrating local and regional effects of global change into the development process, and using the best scientific and traditional knowledge available".

(c) for the Council of Academies of Engineering and Technological Sciences [28]: "it means the balancing of economic, social environmental and technological considerations, as well as the incorporation of a set of ethical values".

(d) for the Earth Chapter [29]: "The protection of the environment is essential for human well-being and the enjoyment of fundamental rights, and as such requires the exercise of corresponding fundamental duties".

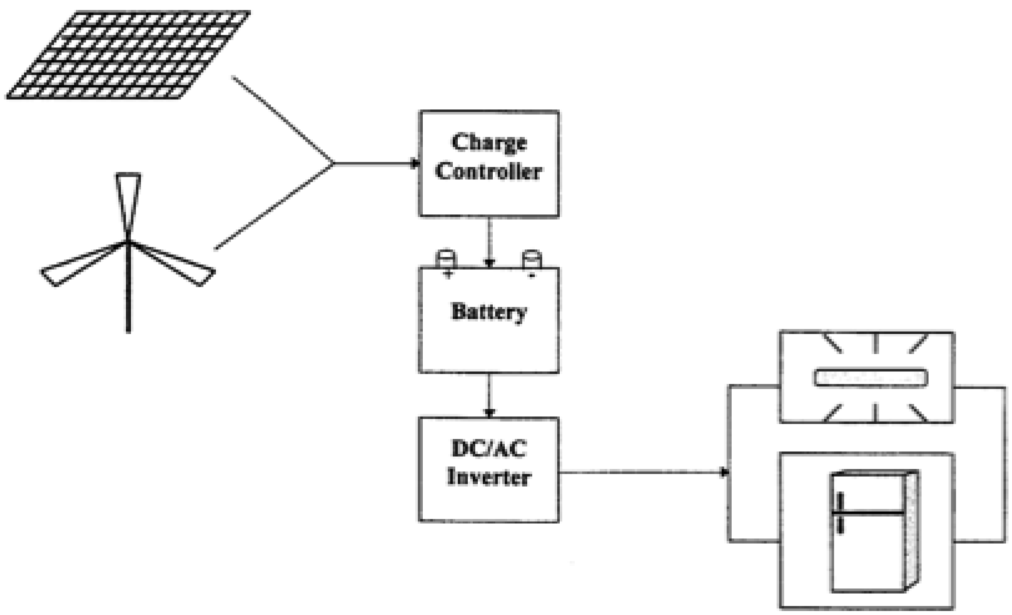
(e) Thomas Jefferson, Sept. 6 1889 [30]: "Then I say the Earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence".

Source: Afgan, Naim H., Darwish Al Gobaisi, Maria G. Carvalho, & Maurizio Cumo. "*Sustainable Energy Development.*" pg 245

Figure 2. Linear Model of Technological Innovation

Source: Vergragt, Philip J. "*How Technology Could Contribute to a Sustainable World*." pg 5

Figure 3. Conceptual Design of Small-Scale Solar/Wind Renewable Energy System

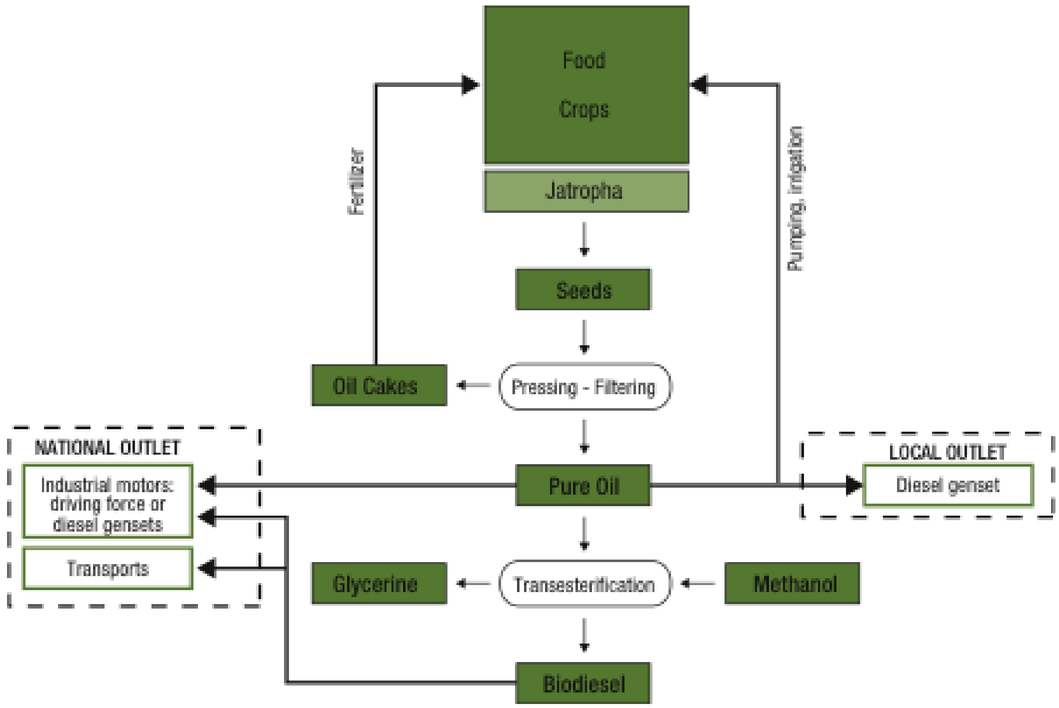


Source: Byrne, John., Bo Shen, & William Wallace. "*The Economics of Sustainable Energy for Rural Development: A Study of Renewable Energy in Rural China."* pg 46

Figure 4. Conceptual Design of A Small-Scale Hydroelectric System

Source: Kaunda, Chiyembekezo S., Cuthbert Z. Kimambo & Torbjorn K. Nielsen. "*Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa*." pg 5

Figure 5. Hypothetical Applications of Jatropha for Biofuel



Source: Raspaud, Laurent. "*Sustainable Energy and The Fight Against Poverty*." pg 4

Figure 6. Example of an Improved Cookstove

Source: Troncoso, Karin., Alicia Castillo, Omar Masera, & Leticia Merino. "*Social Perceptions About A Technological Innovation for Fuelwood Cooking: Case study in Rural Mexico*." pg 2802

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