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Universities can be the Social Innovation Engines that End Energy Poverty

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I. Universal access to clean and affordable energy: the quintessential sustainable development challenge

The United Nations Sustainable Development Goals (SDGs) are a set of aspirational global targets that envisage a world of equal individual and community well-being, opportunity and freedom, as well as global harmony with the natural environment.[1] The goals are also inextricably linked – meeting any one of the 17 targets requires progress on a number of others.

SDG 7 is such a goal – impossible to achieve on its own, yet foundational to achievement of the globally prosperous and sustainable future that the SDGs aspire to.[2] SDG 7 calls for universal access to sustainable, affordable, reliable and modern energy by the year 2030. At present there are more than one billion people on the planet with no access to electricity whatsoever.[3] While electricity is not the only form of energy that we use, its provision is the primary means through which clean electrons flow.

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[1] "The Global Goals for Sustainable Development". United Nations. http://www.globalgoals.org/
[2] McCollum D, Gomez Echeverri L, Busch S, Pachauri S, Parkinson S, Rogelj J, Krey V, Riahi K, et al. "Connecting the Sustainable Development Goals by their energy inter-linkages". *IIASA Working Paper*. IIASA, Laxenburg, Austria, 2017.
[3] "Access to Electricity (% of population)". *The World Bank*. http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS

Access to electricity for this massive segment of the global population – the 'base of the pyramid', concentrated primarily in sub-Saharan Africa and developing Asia – would provide a foundation on which to build economic independence and opportunity for poverty-stricken individuals, families and communities. Energy poverty – their current reality – is a productivity trap, a health trap, and an education trap, amongst others.

Energy poverty is a productivity trap because without access, the energy poor must rely on traditional fuel sources such as firewood to meet basic heating and cooking needs. The collection of these fuels can take upwards of 6 hours per day, often the job of women and children.[4] With electricity, their most valuable resource – time – becomes available for other uses, allowing for entrepreneurial and other productive activities.

It is a health trap because the burning of traditional fuels in the home is a leading cause of death worldwide – indoor air pollution leads to more premature deaths annually (about 4 million) than AIDS and Malaria combined.[5] In areas facing energy poverty, wood is burned indoors in homes that are unventilated, and a lack of electricity means that health centres to treat respiratory and other indoor air related illnesses are severely under-provided and ill-equipped.

Energy poverty is also an education trap. Children living in households that rely on traditional fuels often must spend time collecting these fuels instead of going to school or doing homework. They are also unequally affected by respiratory illness from fuels burned in the home and miss school as a result.[6] Beyond these two direct impacts on school attendance, when they do go to school their unelectrified classrooms lack heating, cooling and lighting. On top of this, a lack of electricity restricts access to the information technologies (computers) and global knowledge networks (the internet) that open up new worlds of discovery and learning.[7] Rote learning continues to dominate and critical thinking is stifled.

These examples illustrate the severely detrimental effect on human development that energy poverty can wreak. However, even if we are to provide universal access to electricity, we may yet fail to live up to the challenge of sustainable development. This is because it is not only reliable, affordable and modern energy that is required, but energy that is also clean. Serving a billion new electricity users will severely imperil our global greenhouse gas mitigation targets if it is accomplished through the use of primarily non-renewable sources. This is the dual challenge that makes SDG 7 the quintessential sustainable development issue facing our species. We must make good on both pillars – sustainability and development – or we will necessarily fail to meet other SDGs that are inseparable from SDG7.

How do we meet this immense challenge? Until recently the primary method of electrification has been through extension of central electricity grids. While recent estimates have pointed to

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[4] Agea J.G., Kirangwa D., Waiswa D., Okia C.A. "Household Firewood Consumption and its Dynamics in Kalisizo Sub-Country, Central Uganda" *Ethnobotanical Leaflets* 14 (2010): 841–855

[5] Plumer, B.. "The deadliest environmental problem today is indoor air pollution — killing 4 million a year" *Vox*. September 15 2014. https://www.vox.com/2014/9/15/6150713/the-deadliest-environmental-problem-today-is-indoor-air-pollution

[6] "Indoor Air pollution". *World Health Organization*. http://www.who.int/indoorair/en/

[7] Gulati, S. "Technology-Enhanced Learning in Developing Nations – a review". *International Review of Research in Open Distance Learning* (2009) 9-1.

this pathways as the most economical for meeting approximately half of the global need, the emerging promise lays in the area of off-grid electrification.[8]

Communities that have remained persistently unelectrified face three primary barriers of isolation: economic isolation (they don't have the money to pay for expensive grid-based electricity), geographic isolation (they live far away from existing electricity generation and transmission infrastructure), and political isolation (they don't have the ear of powerful decision-makers that can act in their interests).[9]

Off-grid electrification schemes are designed to dodge these barriers. What's more, they take advantage of new clean technologies that utilize distributed renewable resources such as the sun, wind and water that are available everywhere. While previously seen as second-class and too expensive, new technologies and business models are proving that off-grid electrification can succeed where grid extension has consistently failed.

This revolution and its attendant benefits for meeting a slew of SDGs will not however come without concerted global action. This is not only at the level of international power brokers and decision-makers but through a massive yet diffuse effort undertaken by an emerging class of social innovators and entrepreneurs that, under the right circumstances and with adequate support, have the power to make energy poverty and its human development traps a thing of the past.

II. Enabling environment: the role of national and international institutions in removing policy and finance barriers to energy access

The emergence of SDG7 as a key development target has raised off-grid electrification on the international development agenda globally. Existing actors concerned with renewable energy deployment and poverty alleviation have had an invigorated focus on energy access, and new actors have been ushered into the space as a result of this momentum. This is especially the case at the level of international policy support and finance institutions, especially those of the United Nations and collaborating organizations.

Increased knowledge sharing about the systemic barriers facing clean energy access initiatives has resulted in significant focus on the regulatory and finance constraints facing these initiatives. Policy and finance efforts such as those championed by the UN's flagship 'Sustainable Energy for All' (SE4All) campaign[10] are receiving the lion's share of attention from international institutions, which necessarily must be involved given the scope and scale of action required. The overarching goal is to create an enabling environment across jurisdictions affected by energy poverty that paves the way for affordable on and off grid solutions to become scalable, and where possible, profitable for private sector actors to deploy.[11]

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[8] "Energy access projections". *International Energy Agency*. http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessprojections/

[9] Alstone, P., Gershenson, D. and Kammen, D.M. "Decentralized energy systems for clean electricity access". *Nature Climate Change* 5 (2015): 305–314.

[10] "Sustainable Energy for All". *United Nations*. http://www.se4all.org/

[11] Brooks, M. & Moore, N. "OpenAccess Energy Blueprint". *Waterloo Global Science Initiative*, 2017.

International policy co-ordination efforts are concerned with reforming national energy policy conditions through actions including: [11]

1) development of long-term energy planning for off-grid electrification and ensuring transparency in decision-making on electrification plans and investments;
2) popularizing energy access metrics that go beyond the have/have-not dichotomy of electricity access through focussing on levels of service delivery;
3) encouraging co-ordination between public and private sector actors;
4) establishing appropriate duties, levies and quality standards for off-grid energy products; and
5) clearly delineating responsibility between government departments whose responsibilities cover some aspect of the electrification continuum.

Beyond ensuring appropriate policy and planning for the new energy access paradigm, access to finance is needed to enable the deployment of new business models and technologies for off-grid electrification that are being developed by private sector actors. The focus of large policy and finance institutions – both public and private – on delivering adequate access to finance for the sector has included: [11]

1) reaching out to a growing number and variety of finance institutions, from micro-lenders to large institutional investors about the opportunities emerging in the off-grid space;
2) de-risking investments through public-private partnerships that split risk between lenders according to their appetite; and
3) encouraging innovative financing mechanisms and new models for lending that are specifically designed for the energy access sector.

The policy and finance actions listed here are critical to ensuring that clean and affordable energy access solutions are in a position to scale quickly and to penetrate communities facing the greatest degree of energy isolation. However, the institutions involved in taking these actions are not themselves creating the next-generation solutions that are required – rather, they are laying the pathway.

The solutions themselves are not yet fully formed. While off-grid solar has reached hundreds of thousands of previously unelectrified individuals,[12] these successes are concentrated in places of the least energy isolation as compared with the most difficult and arguably most important for delivering enhanced well-being.[13] What's more, private sector actors and social enterprises who will be invaluable to reaching these markets have not yet shown, to any significant degree, the ability to profit and thus become financially sustainable and able to deliver millions of additional success stories. To get there, innovation in technologies and business models, as well as the creation of a more robust supply chain of expertise for the sector are necessary. Without the

[12] Orlandi, I. et al. "Off-grid Solar Market Trends Report 2016". *Lighting Global, Bloomberg New Energy Finance and GOGLA*, 2017.
[13] International Energy Agency (IEA) and the World Bank. "Sustainable Energy for All 2017—Progress Toward Sustainable Energy (Summary)". *World Bank*, Washington, DC. 2017.

solutions themselves, no amount of policy reform or finance innovation can fully pull one billion people out of energy poverty by 2030.

III. Developing robust solutions: the need for technology and business model innovation, and development of human capital for the energy access sector

The task of developing 'solutions' to energy access in isolated communities worldwide is non-trivial. Technologies must be robust, able to operate in harsh environments with little maintenance. They must be delivered through business models that allow for the poorest people on the planet to be able to afford them. Delivering them at scale, serving many millions of people over the course of the next decade, is a task that requires a massive infusion of human capital – the salespeople, the engineers, the entrepreneurs, those involved in every aspect of this new global supply chain – and this infrastructure of knowledge, skills and labour must be developed from the ground up in time to meet the exceedingly tight timeline for success laid out by SDG 7.

There will be no silver bullet solution. What works in Bangladesh may not work in Zambia or Haiti. At the very least the delivery models and price-points must vary to account for the intricacies of regulatory environments and ability of diverse customer segments to pay for their first step on the energy ladder. This task is utterly massive, yet profoundly diffuse. Below it is broken down into areas of innovation and capacity development that when jointly accomplished can produce what may rightly be called a 'solution'.

i. Technology and business model innovation

Solutions must meet a number of difficult criteria in order to meet off-grid energy needs in isolated communities. These include:

1) *Affordability*: achieving low cost is perhaps the most pervasive and important challenge for off-grid clean energy deployment. While costs have reduced significantly over the past decade – creating the present opportunity for scale-up – affordability bottlenecks continue to be a dominant barrier. This is especially the case when it comes to the most energy isolated regions.
2) *Controllability*: taking advantage of information and communications technology to allow both energy users and providers to monitor and control systems in real time can enhance system efficiency and resilience while at the same time reducing costs.
3) *Modularity*: many customers – whether they be at the individual consumer, institutional, commercial or community level – prefer to start with a system of minimal size and scale up over time. Modularity can therefore contribute to scaling at the customer level.
4) *Durability*: energy access products and systems must be able to withstand the environments in which they are deployed. Minimizing the size and complexity of systems, and therefore reducing transportation costs and overall ease of use is also an important consideration.
5) *Ease of maintenance*: a result of the remoteness and affordability constraints affecting many prospective consumers, the cost of maintenance and repair of systems must be minimized. This has the benefit of ensuring customer confidence in the systems they invest in.

Through a combination of technological and business model innovation, a host of social enterprises have emerged as the leading developers of workable energy access solutions that begin to meet the above criteria.

Integrating system components to allow for more efficient production, storage and use of electricity can reduce overall system costs and help stretch every dollar spent by end users. Taking advantage of existing infrastructure is also a low-cost opportunity. For example, *ME SolShare*,[14] which operates in Bangladesh, piggy-backs on the fact that millions of small rooftop solar panels have been sold to low-income Bangladeshis over the past decade through a government-sponsored program. Their solution is to interconnect these panels and install smart meters and battery storage in households, creating 'nano-grids' that can scale from the bottom up. The ability to share and store energy in this way makes much more efficient use of the energy generated by the panels, about 40% of which is otherwise wasted. Neighbors who are too poor to afford a solar panel can instead invest in a cheaper 'Solbox' meter and purchase clean electricity directly from others in the village.

Gram Power[15] has taken smart system integration to another level with its proprietary smart meter. This technology – which would seem futuristic even in the richest countries – is now being used to manage over 30 village-scale micro-grids in rural India. The smart meters resolve a number of common failure modes that have plagued renewable energy micro-grid deployment in the developing world to date. They can identify 18 different types of tampering as well as limit the use of electricity by selected loads to prevent overconsumption, grid failure, and damage to batteries. They also allow enhanced control by both system operators and consumers. Consumers can view their balance and consumption patterns in real time, and operators can prioritize access based on how much power is available, even setting different prices according to the source of electricity that is currently available on the micro-grid.

Beyond technology, social enterprises have also become adept at reaching energy poor customers through using innovative sales techniques, developing innovative customer tracking infrastructure, and leveraging ICT developments to make payments for clean energy products and services more manageable.

Organizations such as *Solar Sister*[16] and *Sunny Money*[17] leverage female entrepreneurs and grade school teachers to promote and sell solar products in rural villages, providing income generation and women's empowerment which benefit communities in myriad ways.

Solar home system market leaders *M-KOPA*[18] and *Mobisol*[19] on the other hand have been able to reach hundreds of thousands of customers in rural Africa by providing mobile payment solutions that allow customers to pay small monthly installments by SMS message, significantly reducing up-front costs.

To provide maximal benefit to energy users, a recent trend in the market has been to provide not only solar panels and batteries but also the end-use appliances that they power. Innovation on the energy efficiency of these appliances is allowing much more service to be squeezed out

[14] https://www.me-solshare.com/
[15] http://www.grampower.com/
[16] https://www.solarsister.org/
[17] http://www.sunnymoney.org/
[18] http://www.m-kopa.com/
[19] http://www.plugintheworld.com/mobisol/

of every watt generated. An increased focus on productive use applications such as solar irrigation systems and other agricultural and commercial appliances, including the sewing machines and solar projectors for schools being deployed in India by *Boond*,[20] are helping off-grid solar become a more effective lever on poverty alleviation, access to clean water and education, and other key development metrics.

ii. Human capital development

The examples above are heartening and demonstrate the potential of the emerging social enterprise space within the energy access sector. However, scaling these and other success stories to meet the target of universal energy access by 2030 will rely on more than good ideas and successful pilots. Accelerating deployment at the level required, across so many different regions, will require a massive infusion of human capital. While ICT is helping to automate a significant amount of the work required, a new generation of social entrepreneurs, researchers, innovators, advocates, financiers, technicians and salespeople must enter this sector en masse in the next decade if we are to reach the finish line. Locally appropriate solutions must be developed in diverse geographies by local champions, and thousands of new companies must be created along the energy service value chain in order to bring these solutions to market.[21]

A lack of skilled workers for the energy access sector – especially within rural areas where technicians and salespeople drive growth but are often hard to find and even harder to retain – has driven enterprises like *Mobisol* to create their own pipeline of fresh talent. Through their *Mobisol Akademie*,[22] they utilize an intensive learning program that is tailored to their company's needs and treats aspiring technicians and salespeople as entrepreneurs that are needed to help their products penetrate new markets and allow the sector as a whole to grow.

At the global level there is also a need for many more champions supporting the sector. The researchers and innovators who laid the groundwork for the many enterprises listed above through their pioneering work represent a minute proportion of the global energy sector's capacity for innovation. Research labs, business schools and others that contribute to knowledge creation in the energy and development sectors to date have focussed little on creating the next generation of solution providers and social entrepreneurs for the access challenge. A concerted effort on the part of a slew of global educational, research and advocacy institutions in creating this cohort of change-agents is severely needed if the challenge is to be met.

IV. Universities are well-suited to incubate solutions

While the role of the private sector to develop solutions is significant, a closer look points to the major role that Universities can and already have played in accelerating progress.

Each of the organizations described above have, to varying degrees, benefited from University collaboration and involvement. *ME Solshare* was spun out of a micro-energy systems research lab at TU Berlin.[23] *Gram Power* was developed at UC Berkeley's *Development Impact Lab* and

[20] http://boond.net/
[21] "Universal energy access: An enterprise system approach". *Miller Center for Social Entrepreneurship Santa Clara University, 2015.*
[22] "Mobisol Akademie". *Mobisol*. http://www.plugintheworld.com/mobisol/mobisol-akademie/
[23] "ME Scientific Research". *Microenergy International*. http://www.microenergy-international.de/index.php?id=633

still benefits from involvement of key personnel as both advisors and investors.[24] *Solar Sister* graduated from the *Global Social Benefit Incubator* at Santa Clara Univeristy's *Miller Center for Social Entrepreneurship*.[25] *Sunny Money's* parent organization *SolarAid* is partnered with Both Stanford and Berkeley.[26] *M-KOPA* was founded by Oxford MBA classmates.[27] *Mobisol* and *Boond* both work collaboratively with a number of Universities, especially to enhance and assess the social impact of their activities.[28]

There are a number of reasons why Universities are ideal incubators of energy access solutions. For one, they house expertise from a variety of disciplines and can bring this knowledge to bear on the complex interdisciplinary problems that define energy access and other development challenges. What differentiates social enterprise from traditional business development is its focus on the complex and interlinked social objectives that these ventures aim to address.[29] Navigating and developing strategies to meet entrenched social, environment and economic problems through social enterprise requires deep and nuanced understanding of them, and a large up front problem definition effort.

This is a challenge ideally suited to the kinds of inter- and transdisciplinary research that universities are capable of excelling at. While private enterprises often do not have the luxury of taking their time through painstaking problem definition processes, they can partner with Universities to help ensure that the solutions they develop are appropriate within the contextual landscapes that they aim to impact. University researchers also have the freedom to focus more on social and environmental issues, assessment of benefits and impacts, and identification of overlooked problems that could present opportunities for delivering positive development outcomes, as compared with enterprises.

Functionally, universities can deliver these knowledge support services within platforms for social enterprise incubation, which already exist at a number of leading institutions.[30] Incubators also provide invaluable financial, mentoring, advocacy, market research and other services that are critical to social enterprise development, especially at early stages. A number of the ventures mentioned above, and a host of others in the energy access sector, have benefited previously from university-based incubators.

On the human capital development side, the role of universities is also paramount. No other type of institution has as much existing capacity to scale up the training of individuals with the skills and knowledge to contribute to and lead the energy access sector over the coming decades.

Universities are not just ideal for incubating social enterprises, but for incubating the social entrepreneurs themselves, which may be an even more important role. The journey of a social

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[24]"About Us". *Gram Power*. http://www.grampower.com/about-us/
[25] "Solar Sister". *Santa Clara University Global Social Benefit incubator.* http://www.globalsocialbenefit.institute/portfolio/solar-sister13.html
[26] "More Partners". *SolarAid*. https://solar-aid.org/more-partners/
[27] "Oxford MBA graduates secure $20m funding to light up a million homes in Kenya." *Skoll Centre for Social Entrepreneurship*. https://www.sbs.ox.ac.uk/faculty-research/skoll-centre-social-entrepreneurship/news/oxford-mba-graduates-secure-20m-funding-light-million-homes-kenya
[28] "Participants". *Affordable Energy for Humanity Initiative*. https://ae4h.org/team
[29] "What is a Social Entrepreneur?" *Canadian Social Entrepreneurship Foundation*. http://www.csef.ca/what_is_a_social_entrepreneur.php
[30] Schroeder, L.F. "Kennedy School to Create New 'Social Enterprise Incubator'". *The Harvard Crimson*. March 31 2015. http://www.thecrimson.com/article/2015/3/31/hks-campaign-social-incubator/

entrepreneur consists of a number of stages, from learning about a problem or set of problems in the classroom, to deepening that knowledge through real-world experience, developing and testing pilot solutions, creating suitable business/deployment models around these solutions, and finally scaling up to the enterprise stage. Each of these can be offered to aspiring social entrepreneurs within university environments. Already today – from undergraduate courses on development issues, to graduate field placement programs in developing countries, to post-graduate social incubator support – universities have the shown that they can play a major role in assisting social entrepreneurs on every stage of their journey.[31]

Universities can also help strengthen the flow of knowledge, resources and expertise between institutions in the global North and South. Exchange programs, research collaborations and other knowledge sharing activities can help grow the number of engineers, policy-makers, social scientists, financiers and others around the world that are aware of and can actively contribute to the energy access sector. An example aimed at addressing critical gaps in the clean energy sector workforce is the Vocational Training and Education for Clean Energy (VOCTEC) program led by Arizona State University, which targets technicians, educators and policy-makers in Africa, Asia and the South Pacific, and is funded by USAID.[32]

Finally, many of the technological innovations that have been critical to the early successes of the off-grid renewables industry in the developing world – smart meters, mobile money, solar and storage – have emerged out of university laboratories. While great technological strides have been made, innovation continues to proceed at a rapid pace, providing new opportunities to deliver more powerfully on the criteria of affordability, controllability, modularity, durability and ease of maintenance. There is no reason to doubt that a concerted effort by academic institutions to accelerate the pace of this innovation and help researchers create business plans around them would usher in many more ground-breaking enterprises and entrepreneurs.

V. Benefits to academic institutions

By delivering on their promise as solution incubators and human capital development hubs for energy access, Universities can reap a number of benefits that are fundamental to their value proposition to students and other stakeholders.

As active participants in the energy access sector's development they benefit from the necessary internationalization of these activities – an objective that is increasingly prised by academic institutions and improves their reputation on the global stage in an increasingly globalized world.[33] Partnerships that span borders and sectors also open up opportunities for new sources of funding and institutional development.

Educating a new generation of global problem solvers, such as those that will contribute to affordable clean energy access, also creates opportunities for enhancing the educational

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[31] Belizaire, K. "Universities begin to unlock the potential of social enterprise". *The Guardian*. July 26 2013. https://www.theguardian.com/social-enterprise-network/2013/jul/26/higher-education-social-enterprise-innovation

[32] Razzouk, R. & Weis, C. "Vocational Training & Education for Clean Energy (VOCTEC) Program: Impacts and Lessons Learned." *Clean Energy Solutions Center* webinar presentation, 2016. https://cleanenergysolutions.org/training/vocational-training-energy-access

[33] Bothwell, E. "The world's most international universities 2016". *Times Higher Education.* January 14 2016. https://www.timeshighereducation.com/features/200-most-international-universities-world-2016

experience of students through hands-on problem solving, internship and fellowship program participation, and entrepreneurship.

These efforts will also attract students and professors to these institutions that have a combination of social conscience, entrepreneurial capacity and ability to conceptualize and develop workable solutions to complex development problems. These individuals make for compelling ambassadors that attract additional talent to their institutions, a positive feedback loop that has already benefitted first movers.

Taken together, these benefits promise to create dynamic institutional cultures of problem solving and humanitarianism that will benefit students, professors, staff and external stakeholders alike, and deliver on the promise of universities as not only sites of higher learning but also change-making.

VI. Affordable Energy for Humanity: a platform for university-led energy access innovation

At the University of Waterloo we aim to seize on this opportunity, and to bring others along with us. We have therefore launched a global-level collaboration of institutions with varying degrees of existing participation in the energy access sector. The Affordable Energy for Humanity Initiative (AE4H)[34] was formed to develop solutions to energy poverty with a focus on the aforementioned areas of technology and business model innovation as well as capacity building.

Comprising a diverse set of partners including enterprises that operate in locales from Haiti to Zambia to Bangladesh, and some of the world's leading energy research labs from Cambridge to Berkeley to Karlsruhe, our aim is to mobilize knowledge and resources on a global scale and thereby bring an unprecedented opportunity for innovation on energy access, and growth of sectoral capacity.

Our vision is to support the Universities within our consortium to strengthen and create new pathways for aspiring social entrepreneurs at their institutions to be successful, as well as to combine our efforts and incubate solutions globally, especially in regions that are presently isolated from global knowledge networks. Use-inspired basic research (linking what happens in the lab to insights from the field), social entrepreneurship support and incubation, extension service inspired activities that bring the latest scientific advances in technology to those implementing projects in remote environments, and a global exchange program to equip the next generation of change-makers with a broad knowledge base are all elements of the ambitious strategy that we are working with partners to put in place.

Through doing so, we hope to empower Universities to become the social innovation engines that are needed to deliver on SDG7 – which we believe to be the quintessential sustainable development challenge that faces our world today.

[34] http://AE4H.org