GLOBAL RESEARCH ALLIANCE (GRA) - SMART SUSTAINABLE ENERGY FOR RURAL COMMUNITY DEVELOPMENT

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ABSTRACT

There is a genuine opportunity for the developing world and rural areas to leapfrog the conventional Western paradigm of power. Where conventional electricity delivery is reliant on expensive, polluting and centrally controlled generation (with its spider web of infrastructure and dependence on decades-old technologies), the developing world can harness modern, low carbon, renewable, agile, smart and decentralised generation to rapidly deliver tailored, appropriate and sustainable energy, potentially with increased speed, reduced cost and better societal fit. The CSIR, together with two other members of the Global Research Alliance (GRA), TNO of The Netherlands and CSIRO of Australia and the University of Fort Hare have formed a core team to pool resources and know-how to develop a response to the Eastern Cape Provincial Government's Sustainable Energy Strategy's 9th Priority – universal access to energy. This paper will provide an overview of the comprehensively scoped energy initiative for rural community development and poverty alleviation. The scoping of this energy initiative is based on lessons learnt from extensive field work undertaken by the GRA members.

1. INTRODUCTION

It is generally recognised that access to energy services plays an important role in economic development. However, the linkages between the provision of energy and poverty alleviation through economic development are not fully understood and it can be argued that this lack of understanding contributes to the relatively slow pace of energisation of the African continent. Africa's economic priorities are strongly formed by the need to alleviate poverty. With more than 500 million people currently without access to electricity and with more than 600 million people dependent on traditional biomass for survival on the African continent, Africa has a dire need for safe, affordable and clean forms of energy to enable productive economic activities to generate much needed income.

The delivery of new energy services must be one based on an integrated and holistic approach where Africa's priorities such as potable drinking water, sanitation, food security and poverty reduction are included in any paradigm for development. Integrated thinking across the energy, water and carbon nexus is essential, as is the interplay between social, economic and environmental principles and policies. Even within the energy economy understanding the supply of energy and its use in a development context is complex, [1], as shown in Figure 1 that illustrates the linkages to various sectors of the economy and the associated cross cutting issues.

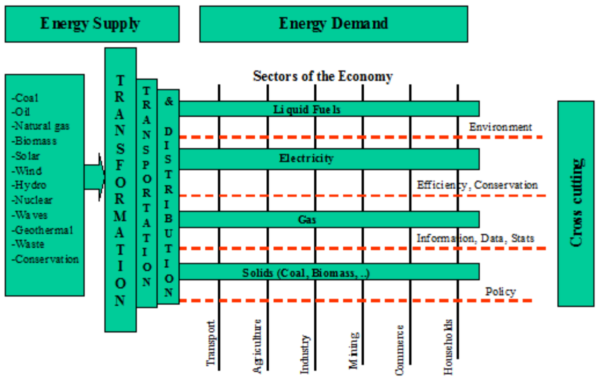

Figure1. Holistic nature of the energy economy

Two of the key crossing cutting issues within this landscape, namely access to good and validated information data and statistics, together with policy and how it intersects and implemented or exemplified through an integrated smart sustainable energy solution form the rationale behind the GRA energy initiative.

Conventional centralised generation and distribution energy solutions that prevail at the top of the pyramid are being rapidly transformed by the introduction of smart grid technologies and large-scale renewables. For remote and rural communities at the base of the pyramid, however, the transformation has little value. The financial overhead and slow deployment of long-distance electrical transmission, the expense of large-scale renewables and the ICT requirements of smart grid methodologies mean that many of the recent technical innovations in the energy space fail to yield impact where energy access is at its lowest.

To date, the South African electrification programme has been extremely successful from a policy, institutional, planning, financing and technical innovation perspective as described by Bekker et al, [2]. The focus on electrification and energisation, though, has moved from chasing numbers of connections mainly in the urban areas, to one of achieving sustainable economic and social benefits mainly in the rural areas. With approximately 80% of the urban areas and approximately 45% of the rural areas being electrified there are still approximately 3.4 million households without electricity – this being unevenly distributed amongst the provinces, and as mentioned between rural and urban areas.

2. DEVELOPMENT CONTEXT

"Widespread energy poverty condemns billions to darkness, to ill health, to missed opportunities. Energy poverty is a threat to the achievement of the Millennium Development Goals. It is inequitable and unsustainable. Children cannot study in the dark. Girls and women cannot learn or be productive when they spend hours a day collecting firewood. Businesses and economies cannot grow without power. We must find a way to end energy poverty. And with climate change a growing menace to all, we must also rethink conventional energy solutions. We can no longer burn our way to prosperity. Fortunately, providing sustainable energy to all offers benefits for developed and developing countries alike. It can enable developing countries to leapfrog over the energy systems of the past and build the resilient, competitive, clean energy economies of the future." Ban Ki-moon Secretary General UN

3. DECENTRALISED AND SMART ELECTRIFICATION

Increasingly, the technical opportunity for energising the developing world and in particular remote and rural areas is framed around the concept of mini-grids and decentralised power, as discussed comprehensively by Berry *et al*, [3]. The direction is well motivated, alleviating many of the encumbrances that have thus far inhibited the rapid, affordable, sustainable and reliable deployment of large-scale centralised energy systems. Indeed, at least to some extent, the notion of decentralised power has been embraced by the developing world, with Nepal, India, Vietnam and Sri Lanka each hosting between 100 and 1,000 schemes and the World Bank funding more than 30 off-grid projects between 1995 and 2008. There is an opportunity, then, to build on these important and pioneering first steps and move towards something bolder, more holistic and codified.

However it also needs to be recognised that many mini-grid and decentralised energy efforts in the developing world are often narrow in scope, focussing on delivering meaningful, though very specific, outcomes for a single community rather than a scalable, replicable and financially sustainable solution. Moreover, many such systems become derelict due to poor community fit, inappropriate business models and technical maintenance complexities.

Beyond decentralised electrification is smart electrification. There are truly impressive gains being made in the smart grids space that have not found optimal application in developing world mini-grids. Smart grid technologies that focus on dynamic demand management, automated battery control, low-cost solar forecasting, intelligent refrigeration, optimal grid planning and automated fault detection and diagnosis all have the potential to deliver significant savings, increased reliability and improved energy quality in a development and especially low carbon context. But integration of such technologies is non-trivial; it requires a reassessment of financial cost, an understanding of local energy needs, development of new business models and community engagement practices and an acknowledgement that many of the assumptions which hold in the developed or urban world are much less certain in a development context (i.e. communications availability and reliability; end-use appliances and behaviour patterns).

There is an opportunity here to not only explore and qualify the nature of existing systems (and lessons learned), but to plot a course for widespread, sustainable and fit-for-purpose smart mini-grid solutions in a South African context. Insight and trialling of innovative community engagement practices that are married to small-scale smart grid technologies and decision support tools that highlight smart mini-grid options across the South African landscape (from both an environmental, economic and demographic perspective) will deliver methodologies and documentation for driving technical and policy innovation in this space. Importantly, the GRA activities will draw on real-world community case-studies, but deliver direction and context that is national in scope.

4. ELECTRIFICATION FOR RURAL ECONOMIC DEVELOPMENT

The long term goal of the South African Government is also the establishment of a sustainable renewable energy industry with an equitable Black Economic Empowerment share and job market that will offer in future years a fully sustainable, non-subsidised alternative to fossil fuel dependence. Local manufacture of related technologies will need to be encouraged to limit the cost of imported equipment and to benefit from economies of scale as well as creating employment opportunities.

The rural electrification challenge also provides a major opportunity for industries, whose commercial drive can immensely speed up the process of rural electrification, and improve working and living conditions for workers, and generate more jobs in rural and remote locations. A good example comes from the mobile communications industry, which by its representative GSMA, has indicated that its members will jointly be operating 639,000 off-grid base stations in developing countries in 2012, [4]. (The GSM Association, GSMA, is an association of mobile operators and related companies devoted to supporting the standardising, deployment and promotion of the GSM mobile telephone system. The GSMA was formed in 1995).

Since base stations require electricity to function, off-grid base stations are generally equipped with either diesel generators or PV and wind turbines. Figure 2 encapsulates

GSMA's philosophy of access equality despite income inequality.

Income inequality 10,000:1

Access equality 1:1

Figure 2: Access equality, income inequality

Currently, the electricity generated by these base stations is not shared with its surrounding communities. However, operators are strategizing to grow mini-grids from these base stations into rural communities. In minimal scenario's this will offer enough energy for local households to charge LED-lantern batteries and cell phones (potentially increasing the use of cell phones locally and thus increasing revenue for the operators, or lowering the investment cost for cell towers, thus increasing rural coverage). In more extensive scenarios local mini-grids can be run by 3rd parties that use the steady energy supply from the cell tower as an 'anchor' in their mini-grid design, greatly reducing the cost for rural electrification, and creating local jobs.

Similar scenarios are currently being thought up in other industries that have off-grid electricity generation capacity (such as agri-processing, food processing plants, mining companies, beer brewers). Many of these industrial sites have extensive power backup generators on their premises, on stand-by to deal with power cuts. Can these generators be used as a similar 'anchor' in local mini-grids, running a more continuous operation, thereby providing power to the homes of the factory workers and their families? Or when installing wind or PV, can any excess energy generated be sold (or shared) with local villages? Any idealistic motive in sharing this (renewable) energy ("technical innovation") with local communities ("social innovation") always goes hand-in-hand with a solid business case on the side of industry ("business innovation") that in our vision greatly improves the chances for a sustainable, scalable solution.

5. REVIEW OF GRA LITERATURE

This energy initiative will look at the complex green economy policy landscape in the context of rural energy solutions. Within that landscape will be a network of actors and stakeholders and work such as that by CSIR and Risø DTU of Denmark (see Szewczuk et al, [5]) investigating the development of a wind energy industrial strategy for South Africa, provides an example of how an analysis of stakeholders and theirs roles was used by the intended target market (for instance the Department of Trade and Industry), as a reference document in the developments of its national wind and solar sector development strategy.

From a technical innovation perspective and in the area of mini-grids and micro-grids, prior work has focussed principally upon reviewing technologies, internal capability, developing fundamental science and gaining deployment and simulation experience. Outputs include works that describe the state and future of micro-grid systems and components (see Platt et al, [6] and Szewczuk et al,[7]), renewable resource availability in South Africa using geographic information systems (GIS) (CSIR et al, [8], the Wind Atlas for South Africa, Mortesen et al [9], software decision support tools for distributed generation (see Berry et al [10] and Kok et al [11]) and micro-grid experiments, case studies and simulations (see Szewczuk et al [12] and Berry et al [13]) including pilot hybrid mini-grid energy systems in Hluleka Nature Reserve and Lucingweni village in South Africa, and the work of the University of Fort Hare in Melani village on a biomass gasifier and the lessons learned on cooperatives versus community trusts in this context.

Socio-economic studies and reports have focussed upon identification of optimal tools for connecting poverty alleviation with energy availability, system dynamics modelling, Greben et al [14], the development of economic assessment tools for local energy supply (see TNO et al [15] and Montalvo et al [16]). The scope is principally focussed on identifying impact, acceptability and value for existing or traditional approaches to energisation.

The key to building upon the body of work out there is to move away from distinct and separated technical and socio-economic streams, as has principally been the case and to integrate, unify and extend prior work and then to present it in an engaging and thoughtful manner to a wide range of stakeholders

6. PROJECT DESIGN AND METHODOLOGY

The "Smart Sustainable Energy for Rural Community Development" Project (the Project) aims to capture, address and innovate around those challenges and perceptions regarding renewable and clean energy systems and their incorporation into a low carbon economy. With the dual challenge of alleviating poverty through establishing new economic activities based around energy access, the Project plans to make use of various social, business model and technological innovations.

The implementation of such innovation will be supported by good research, development and application, with an overarching objective being to gain insight and understanding of the linkages between energy, societal needs and the economy in developing communities with a view to replication into other communities.

Figure 3 provides an overview of the Smart Sustainable Energy for Rural Community Development project and its various components. The main components of the project relate in particular to Technical Innovation, Social Innovation and Business Innovation. The Innovation Application and Spin-in Innovation spheres represent more the environment within which the project is planned to operate.

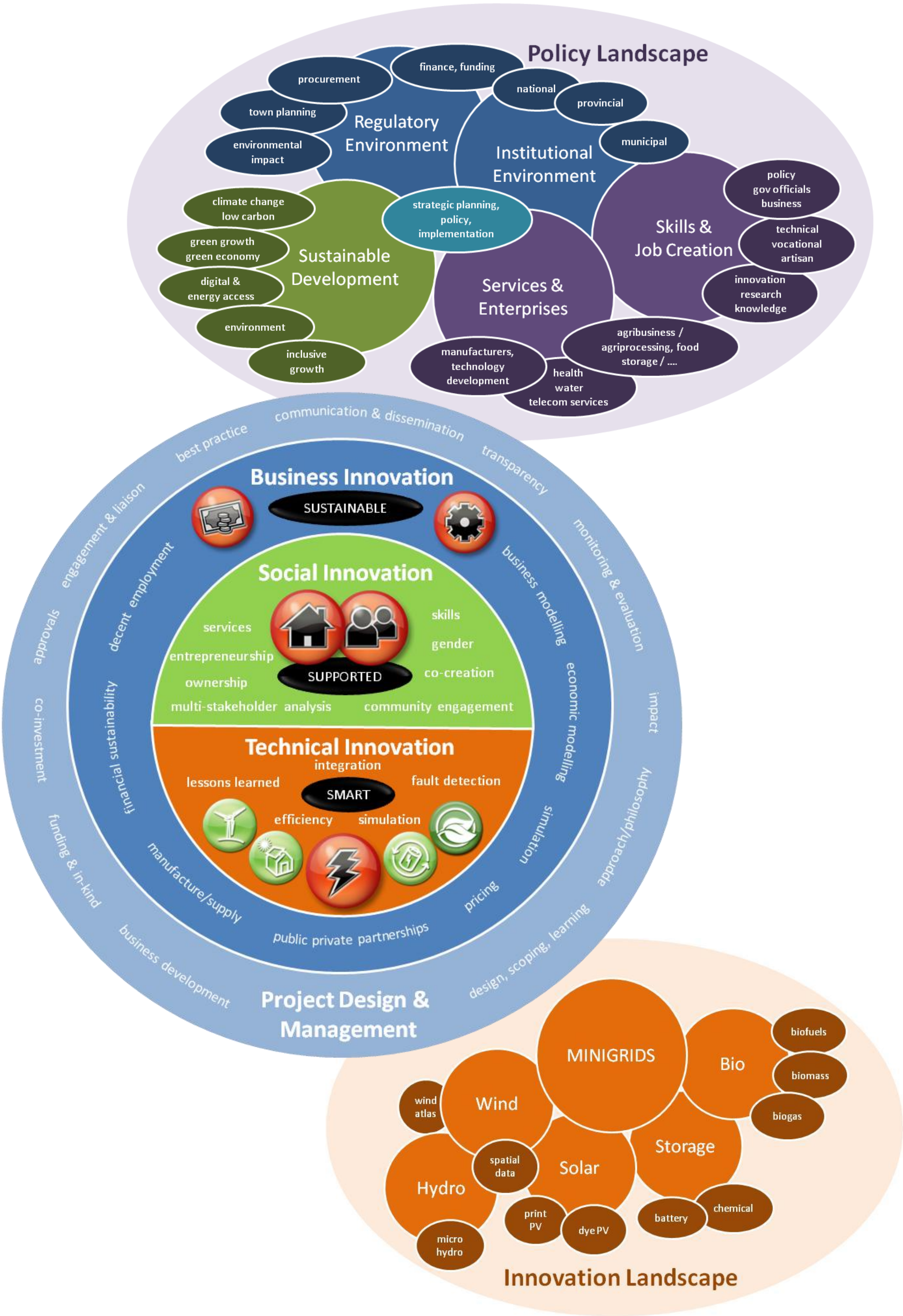

Figure3. Overview of project design

7. TECHNICAL, SOCIAL, BUSINESS SPIN-IN & APPLICATION INNOVATION

The introduction of Smart Sustainable Energy involves technical, behavioural, socio-economic and policy aspects. Successful innovations for the Base-of-the-Pyramid (BoP) have to be:

- **Affordable**: people with limited financial resources are able to purchase the innovation
- **Acceptable**: the innovation fits with the belief system of people at the BoP
- **Appropriate**: the innovation provides a suitable solution for a user need
- **Accessible**: the innovation is readily available for BoP users, in terms of distribution network and required knowledge to operate and maintain the innovation.

Smart Sustainable Energy will deliver impact through three streams:

- **Social Innovation**: all aspects related to users being able to adopt the innovation
- **Business Innovation**: all aspects related to the ecosystem of stakeholders that is involved in delivering the innovation to the user
- **Technical Innovation**: all aspects related to the development and application of technologies to enable sustainable and reliable power.

Spin-in Innovation

The other opportunities presented by the Project are those technical innovations or future developments to energy systems that could be added on or "spun-in" to the Project during its lifetime - recognising that the Project is not principally about developing new or cutting edge technologies on PV or battery storage for instance, but rather the smart integration of existing renewable technologies in a mini-grid context.

Innovation Application

On the periphery of the Project is the broader environment within which the Project operates, influences and is influenced by – namely what we have termed "Innovation Application". This includes the institutional and regulatory environments at different levels together with the services, enterprises, skills and job creation that electrification can benefit, as well as the broader sustainable development imperative of a nation – namely climate change, the green economy etc.

8. DISCUSSION

The foundation of the Project is essentially "smart electrification" and integrating technical, social and business innovation in the solution and journey of engagement – Figure 3 provides an overview. However it must be noted that Figure 3 is based on the combining of field experience based on previous projects that have been implemented. For example, CSIR's contribution is based on field experience in South Africa's first hybrid mini-grid energy systems at Hluleka Nature Reserve and Lucingweni village; (see Szewczuk, [17]). There is a genuine opportunity for rural communities to leapfrog the conventional paradigm of power. Where conventional electricity delivery is reliant on expensive, slowly deployed, polluting and centrally controlled generation (with its spider web of infrastructure and dependence on decades-old technologies), these communities can harness innovative, low carbon, renewable, agile, smart and mini-grid/decentralised generation to rapidly deliver tailored, appropriate and sustainable energy, potentially with increased speed, reduced cost and importantly better societal and economic fit and outcomes.

Such a marked paradigm shift requires technical, social, government and business innovation, engagement and buy-in. This Project will enable the corner-stones of such work to be established in the Eastern Cape, with an ultimate vision of application into broader South Africa and beyond. The components of this design led innovation will be:

- a living roadmap as a platform of knowledge and direction promoting universal energy access,
- supported by systemic modelling and simulation decision support tools that can assess the impact of different policy interventions,
- exemplified by real-world trialling of pilot smart sustainable energy for selected rural communities in the Eastern Cape and,
- deployment of smart sustainable energy solutions with modularity, scalability and associated business cases and livelihood development impact.

These components will be underpinned by an inclusive innovation engagement process with collaboration, cooperation, participation and co-creation across stakeholders at its core so as to engage and empower citizens, communities, private sector and local government. Together with mechanisms to strengthen the science-policy interface so that the Project can provide the necessary information for policies to be updated, implementation strategies to be developed and exemplified, and institutional capacity and decision making improved.

This is an ambitious and long-term programme with implementation anticipated to be over a three year period. The total cost of the Project is R59, 337,000.00 exclusive of 14% VAT, with the option of an additional R5-7million for an innovative distribution network facility.

The primary objective of executing the components of this project is to develop sustainable financing models.

9. GLOBAL RESEARCH ALLIANCE

The Global Research Alliance (GRA), Figure 4 is a collaboration of nine of the world's leading applied-research agencies – consisting of CSIR South Africa, CSIRO Australia, TNO The Netherlands, CSIR India, SIRIM Malaysia, Fraunhofer Germany, VTT Finland, DTI Denmark and Batelle USA. The GRA network has the ability to undertake research, create technologies, and leverage knowledge and expertise across virtually all fields of scientific endeavour from agriculture to advanced manufacturing, energy to environment. The GRA is designed to address national, global and future challenges.

Figure 4: GRA logo

Drawing upon its diverse membership, the GRA is able to mobilise the most targeted and effective, cross-cultural, and multi-disciplinary teams to deliver innovative and affordable solutions to improve the lives of people in developing countries. The GRA implements its solutions through partnership-based projects, combining the expertise of researchers with the local knowledge and understanding of communities, development partners, industry and the private sector.

Inclusive Innovation is central to the work of the GRA. Inclusive Innovation is any innovation that leads to affordable access of quality goods and services creating livelihood opportunities for the excluded population, primarily at the base of the pyramid, and on a long-term sustainable basis with a significant outreach.

The GRA believes Inclusive Innovation requires a holistic and new way of approaching demand-driven projects and co-creation with partners such as the end-users. The GRA aims to develop strong connections and transparent relationships with relevant local organisations and communities in developing countries to work in partnership and with shared commitment to identify needs and collaboratively create solutions to global challenges.

ACKNOWLEDGMENTS

Dr Adam Berry is a Research Scientist and Research Team Leader with the Demand Side Energy Systems Group at the CSIRO Energy Transformed Flagship and currently leads a team of researchers, engineers and PhD students focused on exploring solar intermittency, the deployment of data collection systems, the development of software and the analysis and simulation of mini-grid systems. Dr Berry has provided valuable inputs into the scoping of the Project.

Stephanie von Gavel, Executive Manager of the GRA, made the effort to travel to South Africa to obtain first-hand experience of the socio-economic developmental challenges facing the rural areas of the Eastern Cape Province. Consequently Stephanie von Gavel formulated the Project design as depicted in Figure 3.

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Stefan Szewczuk holds an MSc degree in Mechanical Engineering the University of the Witwatersrand and an MBA from the Herriot-Watt University in Scotland. He is a Senior Engineer at the CSIR and has worked on a wide range of projects around the world on behalf of the World Bank, UNDP, GEF and the EU. Stefan's primary interests are in wind energy, distributed generation and strategy development.

Co-author: Stephanie von Gavel is Executive Manager of the Global Research Alliance. Stephanie von Gavel has over 18 years' experience in technology transfer, business development and strategy development in the life sciences area, with a specific focus on biotechnology and agriculture and now a much broader perspective and experience in the field of research for development and inclusive innovation. Stephanie has strong interpersonal, strategic, project management and conceptual (design) abilities which can be applied to the development and implementation of strategic plans, arrangements and relationships in a collaborative and international context

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Co-author: Max Schreuder has 17 years' experience in telecommunication, innovation management and management consulting. Max combines business acumen, a broad interest in science and technology, a keen eye for emerging trends and innovations with excellent analytical and creative skills and an open-mind set. Max Schreuder currently works as Senior Business Consultant at TNO in the department of Performance of Networks & Systems and the TNO Theme Smart Energy Systems. Max's focus is on ICT and Energy, particularly on integrating renewables, resilience of communications networks and information systems for Smart Grids.

Co-author: Dr Sampson Mamphweli is a Researcher at the University of Fort Hare, Institute of Technology, he has 10 years' experience in the research field having worked for SANParks and the University of Cape. His area of research is biomass conversion and solar energy technologies and their applications. He conducts research on biomass gasification and co-gasification of biomass and coal for electricity generation. He also conducts research on active and passive solar systems. He has presented and published several papers in international and national conference proceedings. Dr. Mamphweli has also been awarded the prestigious University of Fort Hare Vice Chancellor's Emerging researcher medal for the 2012 academic year. He has also been invited as a guest speaker on renewable energy and energy efficiency issues in several functions held at the University of Fort Hare, and he reviews papers for publication in several international journals.

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Presenter: The paper is presented by Stefan Szewczuk.