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A Three Level Research Gateway for African Renewable Energy Collaboration

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Abstract: This paper reports on the long-term objectives and current research results of the on-going Renewable Energy to Africa (REAfrica) project. The purpose of the REAfrica project is to increase knowledge of renewable energy solutions and markets in Sub-Saharan Africa in order to support Finnish renewable energy sector companies in entering the African market. Entry into a new geographical area also involves entry into a new business culture. This paper considers the potential for collaboration and networking with local partners in both business and research as a means of fostering business innovation. To achieve this, it is proposed that research collaboration needs to evolve as ecosystem-level collaboration on three levels – business, research and governmental – in order to create a 'piloting gateway' for new technologies.

Keywords: renewable energy, Africa, business networking, business innovation

1. Introduction

Energy is at the heart of most critical economic, environmental and developmental issues facing the world today. Clean, efficient, affordable and reliable energy services are indispensable for global prosperity. Developing countries, in particular, need to expand their access to reliable and modern energy services if they are to reduce poverty and improve the health of their citizens while at the same time increasing productivity, enhancing competitiveness and promoting economic growth [4].

At the same time, climate change is a major threat to wellbeing, sustainable growth and economic development in Africa. Although Africa is the continent least responsible for climate change, it is particularly vulnerable to its effects, including reduced agricultural production and food supply, increased incidence of both flooding and drought, increased disease spread, and increased risk of conflict over scarce land and water resources [1].

Worldwide, approximately 3 billion people rely on traditional biomass for cooking and heating, and about 1.5 billion have no access to electricity. Up to a billion more have access only to unreliable electricity networks. Countries with underperforming energy systems lose up to 1-2% of their growth potential annually as a result of electric power outages, over-investment in backup electricity generators, energy subsidies and losses, and inefficient use of scarce energy resources [5]. Extending and reinforcing the electricity grid in these countries is very costly, and progress is slow due to lack of resources. Backup electricity generators are mostly run on diesel oil, which is expensive and produces carbon dioxide (CO2) and other harmful emissions. A typical diesel generator produces over 50,000 kg of emissions per year [8,7].

Using renewable energy for local independent grids and for small user communities is a viable alternative in many developing countries and, especially, in East Africa. For example, in Tanzania and Kenya only half of the urban population has access to grid-based

electricity. In rural areas the figure is less than 10%. Renewable energy offers opportunities to improve the living standards of a huge share of Africa's current and future population. Access to electricity boosts ICT uptake and enables near-universal access to the Internet. To achieve these things, knowledge must be transferred to research and technology partners in Africa in collaboration and cooperation with a wide range of existing research actors. Uptake of renewable energy in Africa can be successfully advanced only if much of the research, prototyping, demonstration and large-scale deployment are done by Africans themselves [6].

2. Business environment

2.1 African energy generation outlook

Total industrial energy use in Africa is estimated to grow at an average annual rate of 1.8% until 2035, and GDP in the sub-Saharan Africa region is estimated to grow by an average of 3.7% annually. A substantial portion of this growth will come from primary commodities, i.e. material in raw or unprocessed state, such as ore and fresh fruit, which are extracted or harvested and require minimal processing before use. Demand for electricity in Africa is estimated to grow at an average annual rate of 3.0%. Fossil-fuel-fired generation supplied 81% of the region's total electricity in 2008, and dependence on fossil fuels is expected to continue until 2035 [10], as Figure 1 shows.

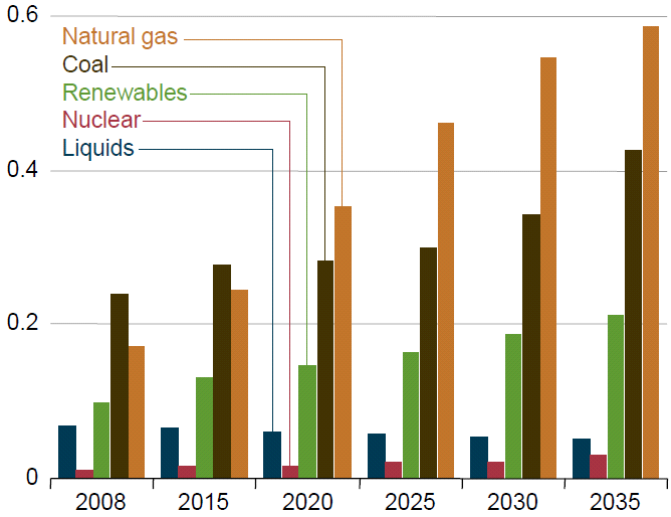

Figure 1. Forecasted African electricity generation, Peta(10^{15})Wh [10].

Africa's coal consumption is growing. South Africa currently accounts for 93% of all coal consumption on the continent and is expected to continue to account for the majority of this consumption in the future. Increasing demand for electricity in South Africa in recent years has led to a severe shortage of electricity. The country's state-owned electricity supplier, Eskom, is proceeding with the construction of two new coal-fired power plants with a combined generating capacity of 9.6 GW. The units at the Medupi and Kusile plants are scheduled to be fully operational by the end of 2017. Power shortages and a general lack of spare generating capacity in southern Africa have also led to increased interest in new coal-fired power projects in countries other than South Africa. Of particular significance are major investments being made by several international energy companies to develop coal reserves in Mozambique and Botswana for the purpose of supplying both domestic coal-fired generating plants and international markets.

Electricity generation from hydropower and other marketed renewable energy sources is expected to grow relatively slowly in Africa. Plans for several hydroelectric projects in the region have been advanced recently, which would help boost supplies of marketed

renewable energy. Ethiopia, for example, has constructed three hydroelectric facilities in recent years, the 300 MW Takeze and the 420MW Gilgel Gibe II, completed in 2009, and the 460MW Tana Beles plant, in 2010, and has additional plans for a plant in the Nile River basin that would generate as much as 5250 MW.

The Democratic Republic of Congo has enormous potential for hydroelectric power generation. The Inga Dams alone, on the Congo River, have the potential capacity to generate 40000 to 45000 MW of electric power, sufficient to supply the electricity needs of the whole Southern Africa region. Currently, the two hydroelectric dams, Inga I and Inga II, operate at low output due to poor maintenance and political instability. The currently proposed Inga III and Grand Inga power stations would generate an additional 4500 MW and 39000 MW, respectively, although it is uncertain how or when these projects will be realized.

2.2 World renewable energy consumption

Africa's share of other (non-hydro) renewable energy (including wind, geothermal, solar, biomass and waste) consumption was only 0.6% in 2011. Total consumption of other renewables in the same period was 5.5TWh. The share of renewable energy consumption of all primary energy (comprising commercially traded fuels, including modern renewables used to generate electricity) consumption in Africa was 1.3% in 2011. Figures 2 and 3 show no significant growth in other renewable energy consumption in Africa during the last decade [10].

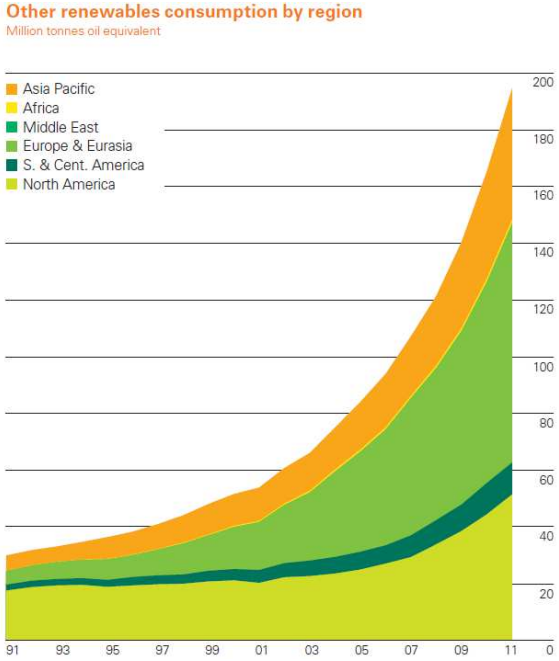

Figure 2. World other renewable energy (including wind, geothermal, solar, biomass and waste) consumption during the last decade [10].

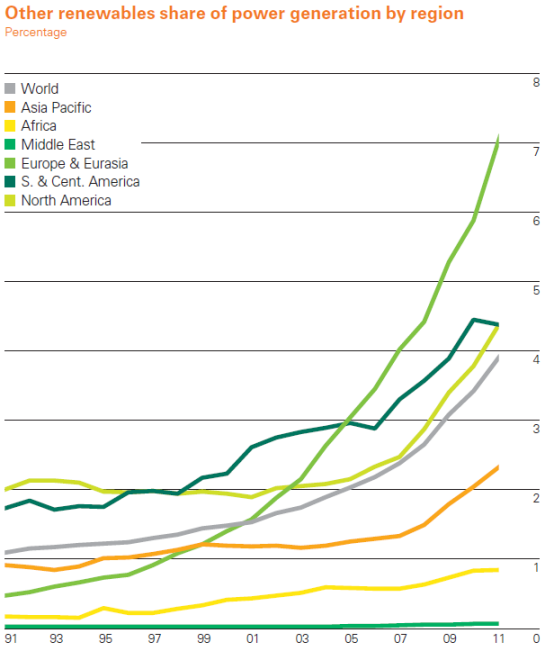

Figure 3. World other renewable energy share of power generation [10].

The increase in hydropower and the rapid expansion of wind and solar power have positioned renewable energy as an essential part of the global energy system [12]. By 2035, renewable energy will account for almost 30% of total electricity output. This forecasted rapid growth in renewable energy use is based on falling technology costs, mass production and government subsidy measures.

2.3 Population and business environment in the REAfrica target countries.

The Republic of South Africa, the Republic of Kenya and the United Republic of Tanzania were selected by the project's industrial partners as the main target countries of the REAfrica project. In addition, Uganda, a member of the East African Community (EAC), was also selected as a country of key interest. Of the selected countries, South Africa is by far the most developed in terms of business environment. South Africa is the largest national economy in Africa. Although in population terms the project countries are roughly similar in size, South Africa's GDP is roughly 20 times bigger than each of the other target countries. As a sign of its business environment maturity, South Africa officially joined the BRIC (Brazil, Russia, India and China) group of major emerging markets in December 2010. The group was duly renamed BRICS to reflect its expanded membership.

Table 1 Overview of target country energy markets

Country	Population [M persons]	GDP [US$ billion]	Energy market size [TWh]	Renewable electricity generation [TWh]
South Africa	50	408	1675	1.7
Kenya	41	33	217	3.7
Tanzania	47	24	228	2.7
Uganda	35	16	130	1.7

Table 1 gives an overview of the target countries' energy markets in relation to population. South Africa's dominance in market size terms, due to higher industrial energy consumption and access to grid-based electricity, is evident. However, with respect to electricity generation from renewable sources (primarily hydropower), the countries are relatively evenly balanced.

Figure 4 provides an overview of the REAfrica target countries' current energy market and business environment, and potential renewable energy project size. The horizontal axis shows the level of business maturity, ranging from social programmes and donor-based funding through to a fully competitive market. The vertical axis indicates the potential size of renewable energy project.

From the perspective of the Finnish small and medium-sized enterprise (SME), these are largely unfamiliar business environments with equally unfamiliar associated risks. South Africa is a potentially large, mature market, but with established international operators – including the Chinese – and competition is tough. The East African market, on the other hand, is still developing. Funding for renewable energy projects must mainly be south for from external sources and donors.

The African market represents a huge opportunity for Finnish companies to expand their market and service offerings. However, it is extremely difficult for an SME to establish itself in the market. There is a need for close cooperation with local actors. Local users and investors need proof of technology before investing in new renewable energy technology.

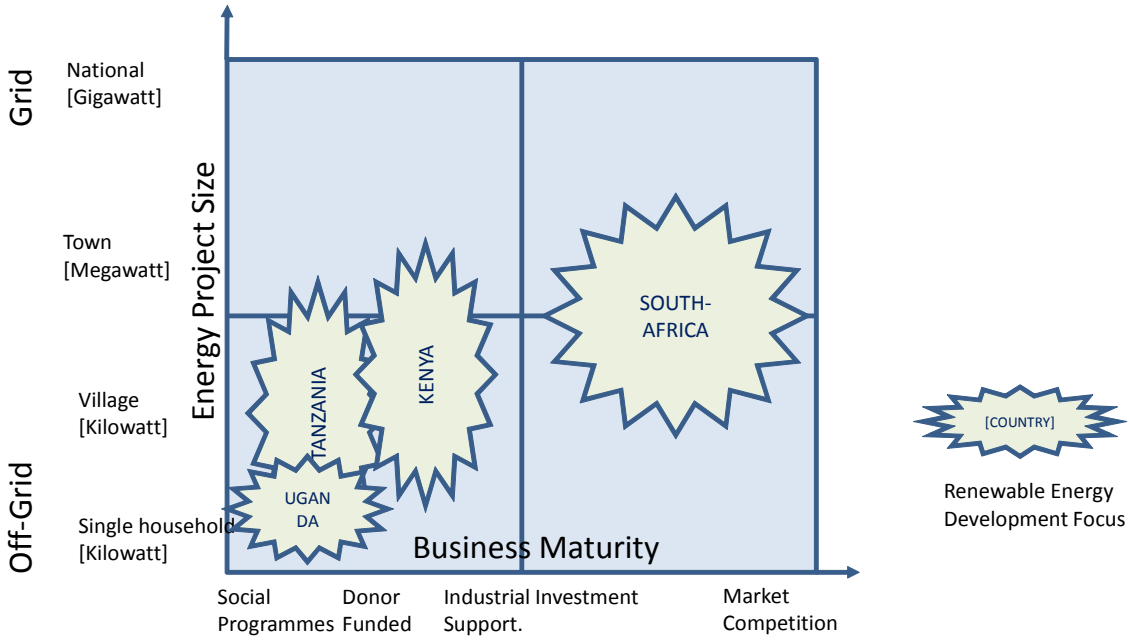

Figure 4. Energy market overview for the target countries and potential renewable energy project size

The few large multinational Finnish companies that are present in Africa have similar requirements – they need proven technologies and capable partners to provide a versatile portfolio of technological solutions and services. For an SME, partnering with large companies that have decades of knowledge and customer relations and existing networks can be of immense benefit. In return, the SME's access to new emerging markets and local SMEs can bring unique value, innovation and a dynamic solution supply to large partner companies. This requires communication, business model development, and time and resource investments that SMEs often struggle to deliver on their own. In Finland, research organisations and enablers play a key supportive role in this respect – a similar locally-adjusted 'gateway' model could also be implemented in Africa.

Sustainable innovation and business also means value transfer at the local level. Here value means not only money, but also business models, network structures and understanding of relations between key economic elements. In the short-term, the availability of reliable electricity enables the use of tools, lighting, running water and mobile ICT. In the long-term, changes and improvements are also enabled in the areas of sanitation, healthcare, waste management, and on community level the regional role of the village changes. Supporting this change and understanding future business opportunities requires diverse knowledge, which can be provided only by a heterogeneous network of companies and professionals participating in the process right from the beginning.

3. Objectives

The overall objectives of the REAfrica project are to increase knowledge of renewable energy solutions and markets in Sub-Saharan Africa and to support Finnish companies in the renewable energy sector in entering the African market through collaboration and networking with local partners.

Entering a geographically remote and unfamiliar business culture is not easy for any company. For an SME with limited resources, the challenge of entering an entirely new business environment is even greater. Success depends on the ability to adapt and modify existing business models and innovation processes with respect to local customers, products, suppliers, authorities, legislation, financing and funding, human resources, culture, and location.

Cooperation and collaboration with local partners is the key. The REAfrica project takes a practical approach, exploring different forms and levels of collaborative networking. The objective is to examine new forms of partnership and associated business and development opportunities at the national and international level. The knowledge needed to implement business process innovations is available, or can be generated, on different levels and in different dimensions, such as local–national–regional, private–public, enterprise–research–academic.

3.1 Industrial participation

The REAfrica project is managed and coordinated by VTT and involves 11 partner companies, all, except two (Vaisala and Hifab), of which are SMEs. The company descriptions are presented below in brief. In addition, a detailed case description is presented of a typical company (Darrox) searching for new markets in Africa for a hybrid renewable energy solution for telecom applications. The REAfrica project partners are:

M&S Power – Delivers containerized small-scale hydropower stations. The power stations can be built almost entirely in a workshop and rapidly installed in remote locations.

Vaisala – Leading supplier of observation and measurement products and services for meteorology, weather-critical operations, controlled environments, and industrial measurement. Services include, e.g., wind resource assessment, weather sensors for wind turbines, wind power forecasting, hydrological measurement systems, solar radiation measurement systems.

Darrox – Hybrid renewable energy solutions for telecom operators (see case description below).

GreenStream Network – Leading Nordic developer and manager of green investment vehicles. GreenStream's award-winning trading services include brokerage and portfolio management services covering environmental products in the carbon and renewable energy markets. Key growth areas beyond Northern Europe include China and Southern Africa.

Mervento – Global provider of multi-megawatt direct drive wind turbine power plant solutions for onshore, near-shore and offshore applications. Mervento turbines use a medium voltage direct drive permanent magnet generator to transform mechanical energy into electric power. The turbine hub and generator structure are integrated, enabling a gearbox-free design.

Höyry ja Lämpö – Delivers wood pellet plants as greenfield and/or turnkey projects. Wood pellets are technically suitable for domestic heating in wood fire places, pellet heating units and, after minor modification, oil boilers; and in industrial-scale power generation, e.g., for co-firing in coal-based power plants.

Wello – Wave Energy Solution. Wello Penguin vessels convert kinetic wave energy into electric power. The Penguin converters vessels float on the surface. The up to 1600 tonne vessel, approximately 30 meters in length, is held in place by with only minimal anchoring attached to the bottom. A single Penguin vessel/unit can produce between 0.5 and 1 MW of power. A Penguin fleet can consist of 1 or more units, depending on the desired energy production capacity.

Hifab – Management of electrical network projects. Hifab provides comprehensive services in the design and management of electrical network projects in order to facilitate optimal use of client resources and assets. Services cover the whole project cycle, from identification and feasibility studies to implementation planning and construction supervision.

One1 provides renewable heat as a service to households and businesses. By centralising renewable energy technologies to be implemented locally the company is able to supply the most economical and pleasant heating and cooling by using the most efficient

heat source available. The One1 service is based on geothermal, wind, solar and other natural sources of energy and their easy and reliable transfer to the client by always using the most efficient source available.

Elcon Solutions – Customized Power Supply System Solutions. Provider of customer- and application-specific battery-backed power supply systems for industrial and telecommunications applications based on efficient integration of advanced solar, wind and fuel cell technologies.

Simosol – Optimization of sustainable use of biofuel resources. Simosol helps forest owners make better resource management decisions by providing decision-support software that adapts to the client's needs to help reduce operating costs and increase the value of their forest investment. Simosol also provides forest resource planning consultation services.

3.2 Case: Hybrid renewable energy solutions for telecom applications

Darrox designs and manufactures hybrid wind and solar photovoltaic renewable energy solutions for telecom operators. The company's revolutionary Darrox DD6-3DCS system combines the benefits of wind and solar energy in a small-scale vertical axis wind turbine incorporating the electronics and components required for professional telecom operator usage. The product's cutting-edge design, robust construction and high efficiency, together with optional solar power panel attachment, enable decentralized energy production in areas without power grid access. The system is designed to meet global telecom operator needs in powering and backing up radio base station (RBS) masts, and for reliable performance with regard to demanding environmental, maintenance and long lifetime requirements. The turbine incorporates several innovations combining high-tech materials such as carbon fibre, high-strength aluminium and weather-resistant steel, and exploits state-of-the-art technology in its permanent magnet generator and embedded intelligent control unit. The unit enables extremely fast plug-and-play installation, with green energy production up and operational in less than a day. The product has a high power/weight ratio and an advantageous efficiency/price ratio. The system has been designed closely with Finnish telecom operators and thoroughly tested in Arctic conditions in temperatures ranging from -35 °C to +35 °C. Key features include bird-safe design, wind capture from any direction, silent and vibration-free operation, robust construction withstanding hurricane-force winds, cut-in wind speed of 5 m/s, nominal power 3.5 kW, engineered for virtually maintenance free and long lifetime, as well as online monitoring capability [14].

4. Methodology

The project is based on an action research approach. Action research involves the researchers actively participating in an organization change situation whilst conducting research. The research objective is to define a successful bilateral or multinational business partnership model, i.e., 'gateway model'.

4.1 Research hypothesis

A successful bilateral or multinational business partnership can be established if there is a high level of conformance between innovation systems in the respective source and destination environments. In addition to private enterprise partnership, supportive public partnerships are also needed.

A three-level collaborative and networked organisational model can act as an active enabler of renewable energy business networks in Africa. The model levels are business, research and governmental. A technology piloting approach supported by collaboration

networks on these three levels offers an efficient means of both speeding up and reducing the resources needed for entry to local markets. The model serves as a gateway to practical large-scale implementation of renewable energy technologies and business innovations by Finnish SMEs.

4.2 Research progress

The REAfrica project operates on three levels; 1) the company level, 2) networking level, and 3) facilitation level. VTT acts as the project facilitator, with the role of ensuring the project progresses and that all relevant information is passed between the corporate, networking and facilitation levels. Without this latter function, information essential for successful collaboration would be available only to the facilitator and the participating researchers. The facilitator thus also serves as a gatekeeper, filtering company-specific confidential information and transforming it into anonymous common information to be shared with all members of the group [3].
Project progress is according to the following partially overlapping steps:

- Individual company interviews to identify objectives, challenges and priorities. All participating companies were interviewed about their products and services, customers, current operations and operations models in Africa, networking and funding.
- Fact finding and networking trips to selected target countries, so far to South-Africa, Kenya, Tanzania, Uganda and Zambia.
- Industry- and country-specific seminars to promote information sharing and discussion, with presentations by invited experts on country-specific economic environments and local business cultures.
- Training workshops and lectures.
- Networking with local actors. Company delegation visits selected high-priority target countries.
- Dissemination of knowledge

5. Research framework

Figure 5 illustrates the research framework used in the REAfrica project using the Tanzania case as an example. Individual projects create collaboration between individual local partners both in research and in company ecosystems (in Finland and in Africa). Local projects ‘push’ for bilateral research collaboration and bilateral company networking. In the research networking dimension, VTT ‘pushes’ for closer collaboration with universities and research organisations in the target country (Figure 5, bottom left upwards). The participating REAfrica companies need local partners and ‘push’ for practical collaboration with target country companies (Figure 5, bottom left to right).

Research collaboration needs to evolve into ‘ecosystem’-level collaboration to create enough ‘push’ or momentum to initiate the formation of an active ‘three-level collaboration ecosystem’ (towards the top right, Figure 5). This model is similar to the successful innovation ecosystem in place in Finland. This then creates ‘pull’, drawing companies into the ‘three-level collaboration ecosystem’ and enabling a better informed, more secure and effective business environment.

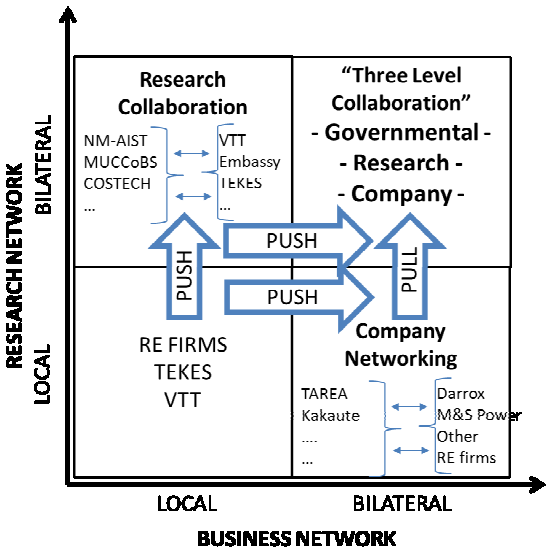

Figure 5. Research framework; case Tanzania.

To enable this evolution, research and business must access each country and market area in close cooperation. This enables faster networking, learning and business execution. Through research collaboration in an active research ecosystem where participants from both countries are present, learning and knowledge transfer is bilateral.

6. Developments – the Gateway Model

The REAfrica project is based on a Finland–Africa 'piloting gateway' model (Figure 2), according to which the proposed three-level collaborative and networked organisational approach serves as an active enabler of renewable energy business networks in Africa. The model levels are business, research and governmental. The gateway model is used as a means of piloting different technologies and services and gaining direct experience of local operating environments. The collaborative gateway model ensures that innovation and learning take place on all levels – i.e., learning by doing.

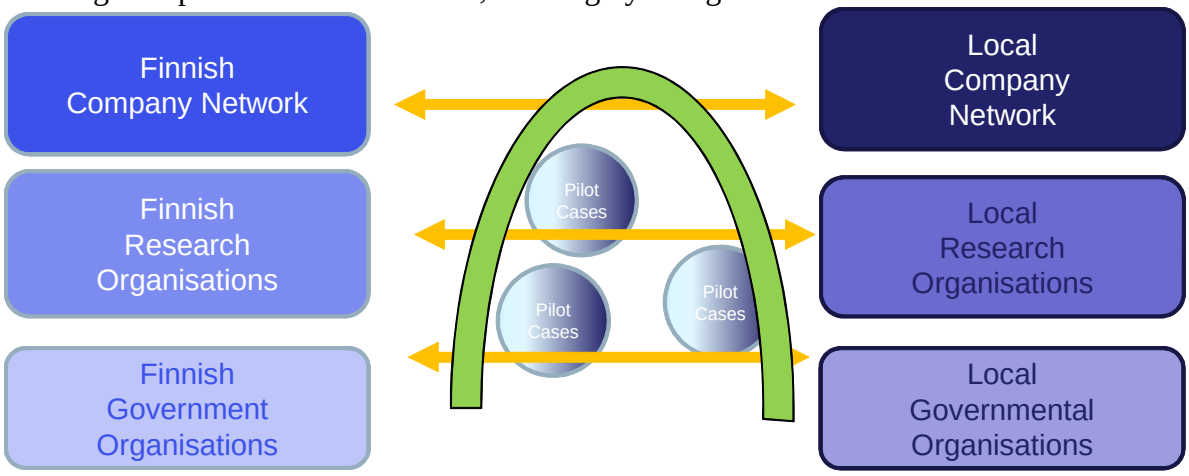

Figure 6. The Piloting Gateway – three-level collaboration ecosystem.

For the activities on different levels to effectively cross-support each other, they need to take place at the right time and to communicate necessary information from one level to another. Therefore, a further 'gate' element with the role of synchronizing the progress between research and business implementation is defined for the model. The gates serve as checkpoints and help in monitoring and controlling progress. The gates can also be

seen as a decision points, where available information from all levels can be shared and informed decisions made.

7. Results

In the on-going REAfrica project, VTT has started to build an operational research network in East Africa (Tanzania and Kenya) as well as South-Africa. The established collaboration provides a stable starting point and a good foundation on which to build further. Table 1 lists the Tanzanian Gateway partners.

Table 3: Partners in the Tanzania Gateway Model

Organisation.	Role / Task
TAREA, Tanzania Renewable Energy Association	**Business** partner. TAREA promotes sustainable development of renewable energy in mainland Tanzania. TAREA cooperates with all important enterprises in Tanzania, as well as (inter-)national organisations.
REDCOT, Renewable Energy Development Company Tanzania Ltd.	**Business** & Industrial partner
Kakute Limited	**Business** & Industrial partner
Tanzania Commission for Science and Technology (COSTECH)	**Research**. Leading organisation in Tanzania.
The Nelson Mandela African Institute of Science and Technology (NM-AIST)	**University.** Leading University
Moshi University College of Cooperative and Business Studies(MUCCoBS)	Leading **College** in cooperation research
Rural Energy Agency (REA)	Tanzania **Governmental**, Ministry of Energy and Minerals.
Energy and Water Utilities Regulatory Authority (EWURA)	Tanzania **Governmental** Authority
Tanzania Investment Centre (TIC)	Tanzania **Governmental** investment promotion.

8. Impact

Implementation of the three-level models will have long-reaching societal impact in the target countries. The delivery, installation and operation of renewable energy solutions will have a range of positive effects, such as:

- Provision of electricity to rural areas
- Reduced urbanisation
- Job creation
- Reduced deforestation and greenhouse gas emissions
- Boosted ICT uptake and Internet access

Interviews with the participating companies identified the following five key needs:

- Finding partners
- Market information
- Networking
- Funding
- Risk management

There are several means open to accessing the information needed to understand and overcome these challenges. However, the path from information to impact is challenging, not least for SMEs. It is also important to understand the individual information needs of different companies and offerings. An action research approach to collaboration between researchers and companies is therefore needed to ensure the effectiveness of research.

9. Conclusions

Conclusions: SMEs need to focus on off-grid and small-scale systems.

There is a huge shortage of electricity in the REAfrica target countries. Uptake of modern renewables will continue, but at a slow pace. Development plans are allegedly in place for large-scale photovoltaic solar energy parks both in South Africa and Tanzania, although these are showing slow progress.

Fossil fuels will be used to meet demand for large-scale electricity energy generation. In South Africa, growth will be based mainly on coal-fired power stations. Large off-shore natural gas reserves have recently been found in Tanzania. Exploitation of the gas fields has already started, raising the potential for increased LNG-based diesel power generation. Kenya is a forerunner in the field of geothermal electricity generation. Plans are also now in place for the Lake Turkana Wind Power project, the single largest private investment in Kenya's history. The project will provide 300MW of wind power to the Kenya national grid, equivalent to approximately 20% of the current installed electricity generating capacity. In addition, the expected increase in hydroelectricity generation in neighbouring Ethiopia represents a potential source of imported renewable energy for Kenya.

Although governments recognise the need for expansion and improvement of transmission capacity, there are no signs of large-scale electrification investments. Much of the grid expansion, especially in Tanzania, is based on donors and international development aid, and therefore no dramatic increases in national electricity grid coverage are expected. Expansion and reinforcement of the grid would provide viable business opportunities for large companies.

In their strive to find new African markets, Finnish SMEs will have to focus on off-grid, small-scale systems. Solutions and technologies for special conditions (telecom) and non-standard environments are currently needed in Africa. This offers niche market opportunities for SME companies to provide modern renewable energy technologies and innovative solutions. One key consideration is to design off-grid systems with readiness for future grid connection. There is a local need for professional expertise in building robust renewable energy systems. Companies with local experience in expanding existing grid solutions can benefit from expertise in smaller renewable energy systems and from partnership with smaller companies.

Through the REAfrica project VTT has successfully established personal working relationships with local industrial, governmental and research partners in each of the target countries as a result of networking and fact-finding trips. These initiatives must now be followed up with practical pilot-based business ventures.

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