Computer Aided Planning, Engineering and Management for Minigrids in Developing Countries

Amjad Umar, Ph.D.
Director, United Nations Partnership on ICT for Small Islands Developing States (ICT4SIDS)
Director and Professor of ICT, Harrisburg University of Science and Technology
umar@amjadumar.com

***Abstract*— This working paper shows how an extensive computer aided environment can be used to plan, engineer and manage a large number of minigrids in developing countries. The idea is based on the lessons learned from a United Nations Partnership that is focusing on computer aided planning for Smart Collaborating Hubs. These hubs provide inexpensive and highly specialized services in health, education, public safety, public welfare, energy and other vital sectors for rapid and massive implementation of UN Sustainable Development Goals (SDGs). We are applying our knowledge and experience to launch a large number of smart hubs that focus on solar energy. A detailed example is used to illustrate the main points.**

I. Introduction and The Challenge

The United Nations Sustainable Development Goals (SDGs) establish a major 2030 agenda that has been agreed by all 193 countries and numerous businesses around the globe. However, rapid implementation of SDGs at a massive scale is very challenging for the almost 3.5 Billion people who live in developing countries, rural areas, small islands and isolated communities. This paper presents a vision and a solution approach that is based on smart collaborating hubs and a smart global village for rapid implementation of SDGs to serve these underserved populations. An attempt is made to answer the following questions:

- What exactly are smart hubs and how can these hubs collaborate with each other to form a smart global village to support the United Nations SDGS (Sustainable Development Goals) [1]
- What are the key challenges faced in planning, engineering and management of smart collaborating hubs and what is the computer aided methodology and associated toolkit adopted to overcome these challenges
- How can this methodology be specialized to launch a large number of smart hubs that focus on solar energy.

II. The Overall Vision and Basic Definitions

Our vision is a *Smart Global Village for the Underserved Populations* that consists of smart collaborating hubs located in small islands, small towns and isolated communities, as shown in Figure1. *The basic definition of a smart hub is that it must provide most appropriate location specific services of high value to its users.* A smart hub may be totally virtual (i.e., located on a handset or in the cloud) or a physical location (i.e., a small room with access to the hub portal) but it must:

- Provide highly specialized region and population specific low cost and high impact services in health, education, public safety, public welfare and energy (for example provide a hypertension telemedicine clinic in areas with high incidents of hypertension and offer micro-entrepreneurship training in areas with high unemployment).
- Collaborate with each other for a region wide impact through information exchange and cooperation between various smart hubs (for example, a hypertension hub collaborates with another specializing in diabetes).
- Be aware of the local information technology and energy constraints and be customized accordingly (for example, do not offer cloud-based services to small islands that do not have access to the cloud).
- Be supported by a powerful portal that has prefabricated plug-ins for collaboration, business intelligence, decision support, and security so that a smart hub located in the remotest possible locations can equally participate in the government decision making and citizen engagement processes.

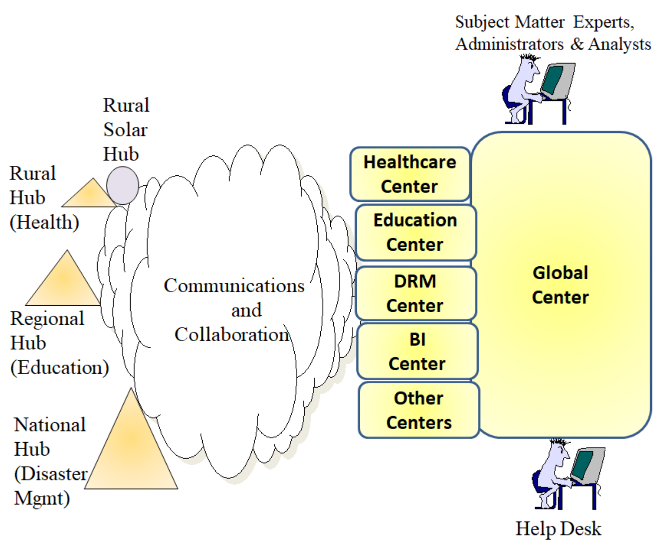

Figure 1: Overall architectural vision for Smart Hubs and the Smart Global Village

Due to our experience so far, we strongly believe that this *distributed collaboration* approach is very effective for rapid implementation of the 17 SDGs that span health, education, public safety, public welfare, energy, agriculture, food safety, and other vital areas [1,2].

III. Challenges Faced and the Methodology Adopted to Overcome the Challenges

Given the massive scale and the ambitious vision presented in Figure 1, our major challenge is how to materialize this vision quickly, economically, and globally so that no one is literally left behind. *Our main objective is to quickly identify and launch low cost but high impact services in health, education, public safety and other vital sectors for any location anywhere in the world.* Specifically:

- Where exactly should a hub be located?
- What type of service(s) should be provided for the area?
- What type of energy and communications will be needed for these hubs?
- What type of ICT infrastructure will be needed?
- What are the security, privacy and policy issues?
- How can the funding and capacity building issues be handled?
- How can the skill shortages in remote areas be addressed?
- What are the project management and governance issues?

Due to these and other complex issues repeatedly mentioned in extensive studies, the failure rates of ICT projects of this nature are very high – around 80% in developing countries [3]. To address these challenges, we used the computer aided methodology displayed in Figure 2. This methodology relies heavily on a powerful computer aided planning and decision support environment, called SPACE (Strategic Planning, Architecture, Controls and Education).

The SPACE environment [7] addresses the aforementioned challenges and produces a highly customized portal to support different smart hub configurations within an hour. Most importantly, SPACE supports individual services that can be combined into complex "*service bundles*" to represent offices, clinics, community centers, corporations, neighborhoods, and even cities. This allows us to plan and architect very simple to very large and complex scenarios for smart hubs. This methodology is based on the insights gained by implementing more than 40 smart hubs in pilot projects that span more than 12 countries. The pilot projects have been launched and managed by the United Nations ICT4SIDS Partnership [6]. The recent version of the methodology, displayed in Figure 2, consists of the following phases:

- Phase 1: We invite potential users to join a smart pilot project that implements smart hubs to support health, education, public safety, public welfare, and other SDGs for the community. We ask the interested users to use the SDG Advisor tool (part of SPACE) to help them assess their needs and determine which SDGs should be addressed in the pilot project.

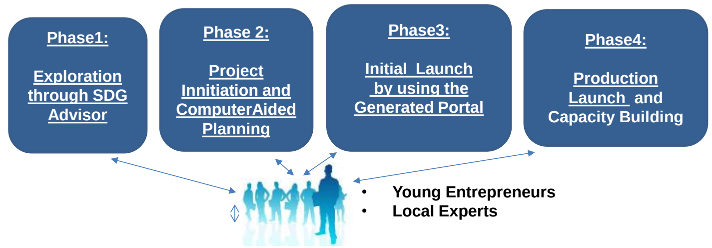

Figure 2: Computer Aided Planning and Implementation Methodology for Launching Pilot Projects

- Phase 2: A hub vision is proposed and a pilot project is initiated by a user and a *Point of Contact (POC)* is appointed by the target community. The POC is trained to use the SPACE Extensive Planner to conduct an extensive feasibility study and produce a strategic plan, a funding proposal and a working prototype of the selected smart hub(s) – all within 2-3 hours.
- Phase 3: The results of the feasibility study are analyzed/revised and a final smart hub is created in collaboration with the POC and local experts. The final hub is "registered" in the Collaboration Matrix and also in the appropriate Global Center (e.g., a hypertension hub is registered in the World Hypertension Center). The POC goes through intensive training, available through SPACE, and is responsible for refining and expanding the hub portal based on local needs.
- Phase 4: The produced portal is refined for a production version and is added to the collaboration matrix of the Global Village – this makes the new hub a collaborating hub. The new hub is also published in a Donor Portal for attracting funding sources and business partners. Funding models accessible by this process include public, private, or even "crowd sourcing" which allows individuals to contribute to specific projects. A production version of the smart hub is launched at the end of this phase.

It can be seen that SPACE is at the heart of this methodology. Initially developed as a computer aided planning tool for small businesses, SPACE has now matured into a powerful computer aided planning, engineering and management environment due to repetitive use and research since 2010 [9, 10, 11, 12]. Figure 3 shows a conceptual model of SPACE as it exists at the time of this writing. As shown, SPACE covers the entire Learn-Plan-Do-Check cycle to address the aforementioned challenges. SPACE uses an extensive array of capabilities that include patterns, games, decision support and planning tools, and specialized tools that invoke different capabilities for different types of situations. Specifically, SPACE consists of the following capabilities [7]:

- *Patterns and Knowledge Repositories* (the innermost circle) contain an extensive library of business and technology patterns and expose the users to educational materials, case studies, and examples needed throughout the cycle. These patterns and case studies span 11 sectors that include agriculture, education, health, public safety, public welfare and other vital sectors and are used throughout the aforementioned methodology. For example, healthcare patterns are used to create healthcare hubs.

- *Games and Simulations* (the next circle) that support decisions in strategic analysis, mobile services planning, interagency integrations and health exchanges, application migration versus integration tradeoffs, risks and failure management, and quality assurance. For example, disaster recovery (DR) games are used to populate DR hubs.
- *Decision Support Tools* (the outer circles) contain strategic and detailed planning tools that systematically guide the users through various decisions in strategic planning, architectures, integration, acquisition, security, controls and project management activities. An example is the Extensive Planner (ePlanner) that is used in Phase2 of our medethodology to produce a strategic plan, a funding proposal and a prototype of the selected smart hub(s).
- *Specialized Tools* (the outermost circle) that present and customize special views of the inner capabilities for specific large scale projects. An example is the SDG Advisor that is used in Phase1 of our methodology.

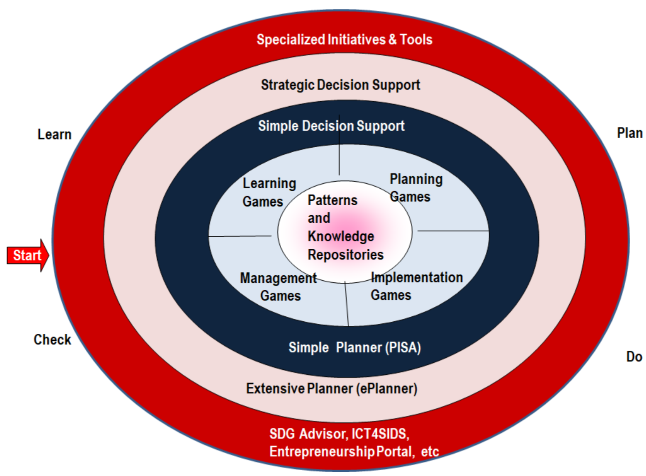

Figure 3: Conceptual Model of SPACE Capabilities

All SPACE capabilities are integrated with each other and collectively support numerous practical planning scenarios. For example, a health clinic for Haiti is first created by customizing the health clinic pattern for Haiti (the innermost circle) and then uses the higher level planning capabilities (the outer circles) that leverage other capabilities to build a smart collaborating clinic for Haiti. Big data, deep learning, and ontologies may also be used to launch a final hub.

IV. Main Results and Lessons Learned

We are implementing our vision of a Smart Global Village through pilot projects that have deployed several smart hubs for underserved populations in Small Islands, Africa, Asia, South America and the United States. A snapshot of our projects at the time of this writing is displayed in Table 1. This sample table displays how different hubs (columns) are being implemented in different countries (rows). Community Centers and Smart Towns provide multiple services to a small population. The cells of the table show the specific topics being addressed and illustrate the diversity of our approach. The computer aided methodology, explained previously, is being used to implement this plan by employing local youth and other individuals as Point of Contacts (POCs) who are given tangible entrepreneurship opportunities in different rural and urban areas. For example, young nursing school graduates in some developing countries are running Hypertension Telemedicine Centers as “Hub Masters”.

To operate these hubs, we are partnering with social enterprises such as Ikdar.org, UN agencies such as UNESCAP, healthcare organizations such as the World Hypertension League, and local NGOs and agencies. We have learned the following key lessons so far:

- The approach of highly focused pilot projects (about 2 months) works very well -- we quickly learn what really works and also provide educational and entrepreneurship opportunities for the youth. For example, young entrepreneurs in Maldives, Rwanda and Pakistan have developed business opportunities in health informatics by working on telemedicine hubs.
- In Tanzania, we launched an educational hub for educating high school teachers in ICT (a highly valued skill in extremely short supply). This hub exceeded our expectations by becoming financially independent in just 2 months because of much higher than expected enrollments. This hub has now started collaborating with nursing education to support telemedicine hubs.
- The POCs of each hub are *required* to communicate and collaborate with at least 3 other hubs as part of the training program. They initially exchange educational materials and lessons learned but later start exchanging other vital information such as evacuation procedures in case of a disaster and digital marketing approaches and experiences for cottage industries.
- Even in its formative stages, the collaboration matrix in Table 1 is an extremely interesting playground for horizontal collaborations between different hubs in the same country (e.g., all hubs of the Solomons), vertical collaborations between different countries but on the same topic (e.g., telemedicine hub in Haiti collaborating with the one in Peru), and diagonally (e.g., micro-entrepreneurship and micro financing in Pakistan and Sri Lanka serving as connector hubs for each other).
- The collaboration matrix in Table 1 is a realization of the Smart Global Village for underserved populations vision. This is giving us unprecedented opportunities to collect, combine, and analyze highly valuable data from very diverse populations from different sectors living in different parts of the world. For example, we have combined hypertension data from Seat Pleasant, a small town in Maryland (USA), with data from Haiti, Peru, and Jamaica. According to the World Hypertension League such data has *never* been collected before.
- The Global Center of the Village, located in USA, can remotely monitor the disaster resilience capabilities of smart hubs located anywhere in the world.

Table 1: Snapshot of implementation plan of the Smart Hubs and the Evolving Smart Global Village

	Health (Telemed Hubs)	***Education & Capacity Building Hubs***	***Entrepreneur-ship & eCommerce***	***Food and Agriculture Services Hubs***	***Business Intelligence (BI) Hubs***	***Disaster & Energy Hubs***	***Community Centers & Smart Towns***
Haiti	General						
Jamaica	Hyper-tension		Tech-Preneurship		Data Mining		Health and Agriculture
Solomon Island		Business Management	Digital Marketing		Data Mining	Storms	Health and Education
Tanzania		ICT4Teachers	Tech-Preneurship				
Nigeria	General	ICT4Teachers				Energy	
Rwanda	General		eConsulting				
Maldives	Hyper-tension			Food Distribution			
Sri Lanka	General Telemed		Digital Marketing	Farming & Fisheries	BI4Small Firms	Storms	Plastic Waste
Pakistan	General		eConsulting		BI4Health	Energy	Smart Town
Peru	General						
USA	Hyper-tension	Entrepreneur-ship Education	Tech-Preneurship		BI and Analytics	Remote Monitoring	Smart Towns

V. Detailed Example: Smart Energy Hubs for Minigrids

After some discussions and analysis, we decided to develop smart hubs for energy as emarketplaces that support entrepreneurs to buy, sell, design, and learn about solar energy installations. Figure 4 shows screenshot of a Smart Hub for Solar Energy Marketplace that we have planned and designed for a location in Yaba, Nigeria, by using the SPACE Environment. This hub is a starting point for several more energy marketplaces that we are planning to plan, engineer and manage in Africa, Southeast Asia and Small Islands and Developing States (SIDS). This simple emarketplace provides the following capabilities for the users at the time of this writing:

- Shop and purchase a wide variety of inverters, solar power panels and other solar equipment through direct sales and/or auctions and reverse auctions.
- Registration of vendors for participation in the educational, trading and solar system design aspects.
- Load calculations and other easy to use tools that can be used to quickly estimate the solar power needed in a house or a community of users. We will extend and enhance these tools into a comprehensive computer aided decision support environment for the end users.
- Educational and training materials that include technical guidance about how to install, repair and maintain solar panels and also business skills about developing funding proposals, locating funding sources, and other materials through a powerful Entrepreneurial Hub that is part of the Smart Global Hub.
- Extensive collaboration and communication capabilities with other smart hubs that we have developed as part of the Smart Global Village.

We have been able to quickly generate the Solar eMarketplace hubs similar to the ones shown in Figure4. However, we are in the process of extending the following capabilities of SPACE to greatly improve the process as well as the resulting solar emarkets:

- *Patterns and Knowledge Repositories* to enhance the educational materials, case studies, and examples about solar power.
- *Games and Simulations* to better support planning, design and project management, and quality assurance decisions.
- *Strategic and Detailed Planning* tools to better guide the users through various decisions in strategic planning, architectures, integration, acquisition, security, controls and project management activities of the aforementioned methodology.
- *Specialized Tools* that present and customize special views needed specifically for solar energy. For example, we are extending the SDG Advisor to include solar energy specific considerations in determining best locations for minigrid emarkets based on energy shortages and vicinity of the main grid [13].

Please see [8] for more information on the Solar eMarket.

VI. Summary and Conclusions

Under the umbrella of the UN ICT4SIDS Partnership, a small team of 6 people in a startup, with some help from advisors from the UN and other agencies, has launched more than 40 smart collaborating hubs that span more than 12 countries. Based on the insights gained through the hands-on pilot projects, we feel that our computer aided methodology and the SPACE environment can be easily customized and extended to plan, engineer, and manage the rapid deployment of minigrids in many countries.

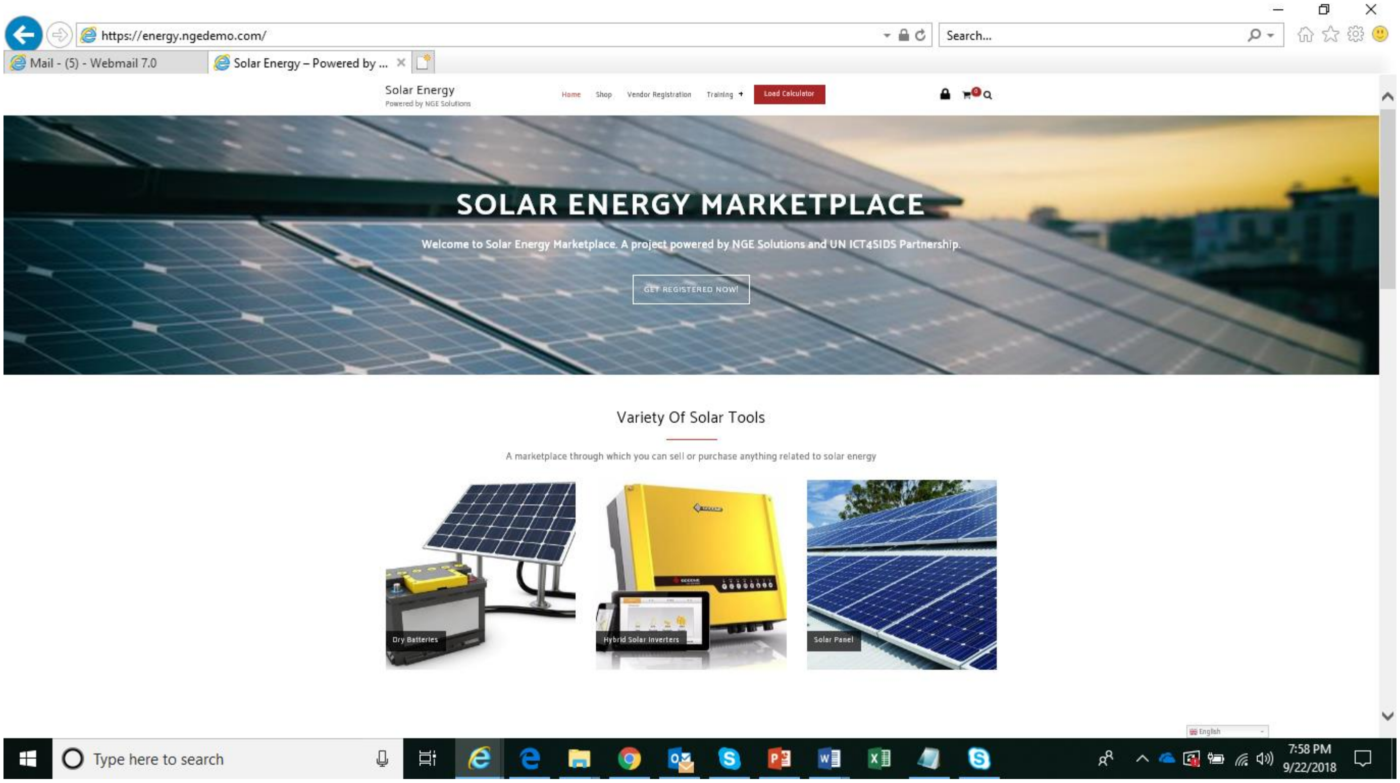

Figure 4: Screenshot of a Smart eMarket Hub for Solar Energy

Note: Please view a 3 minute video clip at https://youtu.be/zlesFECTzK0 and visit the sample eMarket Hub at http://energy.ngedemo.com

We are far from done and intend to pursue several areas of practical research and development to further improve the computer aided planning, architecture, integration, implementation, operation and management aspects of the smart global village (SGV) concept. In particular, we are further improving the SPACE Environment by taking advantage of the latest advances in deep learning, AI, block chains, IoTs, cloud computing, drones, and distributed intelligence. The objective of SPACE is to continue recommending low cost but high impact digital innovations for the poorest populations.

ACKNOWLEDGEMENTS: The SPACE Environment is being developed by the NGE Solutions Team (Kamran Khalid, Adnan Javed, Nauman Javed, Hannan Dawood, Abdul Qadir, and Arslan Dawood). The work in energy hubs is being led by Mr John Quigley (Director of Energy, Environment and Economy Center at Harrisburg University) with help from Dr Festus Odubo (Public Utility and Energy Advisor, the Commonwealth of Pennsylvania Public Utility Commission), Arslan Dawood and Hannan Dawood (both from NGE Solutions, Inc).

REFERENCES

[1] UN Sustainable Development Goals, Report 2016, http://unstats.un.org/sdgs/report/2016/

[2] UN Fast Forward Report on ICT4SDGs – July 17, 2017. Weblink: http://www.itu.int/en/sustainable-world/Documents/Fast-forward_progress_report_414709

[3] Dada, D., "The Failure of e-Government in Developing Countries", EJIDSC, Vol 26, no. 7, 2006

[4] World Hypertension Action Group Telemedicine Center, Link: www.whag4all.org

[5] Infodev, a World Bank initiative on Innovation and Entrepreneurship, site http://www.infodev.org/

[6] ICT4SIDS Partnership, UN Registered Partnership No:8005, Website: http://ict4sids.com

[7] SPACE – A Computer Aided Planning, Engineering & Management Environment, developed by NGE Solutions. Website: www.space4ict.com

[8]Solar Energy eMarket video at https://youtu.be/zlesFECTzK0 and the sample hub site at http://energy.ngedemo.com

[9] Umar, A., and Zordan, A., "Enterprise Ontologies for Planning and Integration of eBusiness", IEEE Transactions on Engineering Management, May 2009, Vol. 56, No. 2.

[10] Umar, A., "Computer Aided Planning, Engineering and Management of IT Services", IEEE International Technology Management Conference, Dallas, June 2012.

[11] Umar, A., "Computer Aided Strategic Planning for the United Nations Sustainable Development Goals", International Journal of Engineering and Applied Sciences, ISSN: 2394-3661, Volume-4, Issue-12, December 2017

[12] Umar, A "Smart Hubs and a Smart Global Village for SDGs", *IEEE Technology & Engineering Management Conference, Chicago, June 2018* .

[13] Tenenbaum, B. et al., World Bank (2014). "From the Bottom Up: How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa", URL: *https://openknowledge.worldbank.org/handle/10986/16571*