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Research needs for meeting the challenge of decentralized energy supply in developing countries

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ABSTRACT

Scenarios imply that there will still be a considerable percentage of people (16%) without reliable access to electricity, especially in developing and emerging countries, in the year 2030, if ongoing efforts are not intensified. International governance and funding institutions like UNDP and the World Bank consider access to electricity as being fundamental for economic development and poverty reduction. Since the extension of centralized grids is often expensive, different forms of decentralized electricity supply options have gained importance for rural areas and informal settlements during the last 3 decades. Until now, there has been a lack of systematic evaluation of experience with decentralized electricity systems in different cultural and geographic contexts and the transfer of this experience. One reason for this deficiency is that the 'research community' for this field is not very clearly defined regarding disciplines and institutions and that there are few institutionalized occasions and forums which enable discussion and systematization of existing knowledge. This article gives a rough overview of the challenges linked to developing and implementing systems of decentralized energy supply under difficult context conditions and the research needs resulting from these challenges. Central means towards success in this domain include embedding the introduction of technical systems in a range of services (e.g. capacity building, maintenance, repair and disposal services, financing schemes), integrating users' needs in their development and implementation, enhancing productive use of electricity by linking energy supply to regional development programs. To be able to deal with the outlined questions, the perspective of decentralized energy supply as socio-technical systems can be helpful. Research desiring to adequately meet the challenges needs to integrate knowledge and perspectives from different disciplines as well as expertise from practitioners in the field in a reflective manner.

Introduction

Status quo: energy supply in developing countries

Worldwide, about 4 billion people live on less than $8 per day. Next to food and housing, energy often is the biggest expense for low-income households IFC and WRI (2007). Most energy expenses are spent for cooking, heating and lightning. Having no or only infrequent access to energy especially affects the poorest segments of society, which often have to diversify their energy sources and buy them in small, expensive units. This has severe consequences for their household spending: according to IFC and WRI (2007), they spend up to 30% of their household income on energy.

It is expected that the world population will reach 9.1 billion people by 2050. According to UNDESA (2009), the largest increase in population is to be experienced in the least-developed countries,[1] whose total population is projected to double from currently 0.84 billion in 2009 to 1.7 billion in 2050. All developing countries taken together will experience population growth from 5.6 billion in 2009 to 7.9 billion in 2050.

International organizations estimate that, in 2030, 1.3 billion people – or 16% of the world's population – will still not have access to electricity, compared to 1.5 billion in 2008 (OECD and IEA 2010). The greatest share of people without access to electricity will be found in Sub-Saharan Africa, where the numbers are estimated to increase (from 587.1 million in 2008 to 698.3 million in 2030), while they are expected to decrease in South Asia (from 613.9 million to 488.6 million) and China and East Asia (from 195.1 million to 72.5 million). At the same time developing countries will have to deal with the growing cost of importing fossil fuels.

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[1] The group of least developed countries currently comprises 49 countries, most of which are in Sub-Saharan Africa, followed by South East Asia and the Pacific.

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The majority of people without access to electricity – 85% – live in rural areas and informal urban settlements in developing and emerging countries (OECD and IEA 2010). In many countries the existing grid is not adequate to meet the demand and requires technical upgrades and rapid expansion. Especially poor households and small business owners who are highly dependent on reliable and cost-effective electricity access are affected by fluctuating electricity supply and frequent blackouts.

In its 'Special Report Renewable Energy Sources' the IPCC (2011) states that renewable energies are an affordable and economically viable option to react to the electricity needs of people in developing countries. Already now, tens of millions of households are being supplied by renewable energy from different sources. The 'Renewables 2010 Global Status Report' (REN21 2010) estimates that about 3 million households use small solar PV systems to generate electricity. For more than 3 decades, different types of decentralized electricity from renewable sources have been implemented by governments, development agencies, NGOs and, in a few cases, private-sector initiatives.[2] Besides a few success stories and best practice examples, there have also been many failures in introducing these technologies under difficult context conditions (Nieuwenhout et al. 2001).

Research in the field of decentralized electricity supply

As stated above, there has been much experience with decentralized energy supply in different continents during the last 3 decades. Many times, however, there has been no systematic evaluation of these experiences or sufficient transfer of the results of such evaluations between regions, countries and continents. Faced with the necessity of efficiently providing access to electricity for the poorest segments of society during the next decades, a more systematic evaluation and transfer of experiences seems to be essential.

Parallel to the decentralized character of off-grid electricity supply, research in this field seems to be scattered across disciplines and numerous institutions in various continents, without many institutionalized occasions and forums which allow systematic comparison of "lessons learnt" and drawing of joint conclusions about future strategies in this field.[3] Since research in this field is often done with few resources, case studies of applying certain technologies in a specific context are common. To be able to compare the results of case studies of decentralized energy supply in different countries of the developing world, it would be very helpful to be able to agree on minimum standards and an accepted framework for the evaluation of case studies in the international research community. This would include discussions about which type of methods and results are transferable to other regional and cultural contexts and which types of results cannot be generalized because they are context specific.

Another characteristic is that research in this field is seldom financed by public scientific funds, which would allow a transparent discussion of outcomes and results. Particularly evaluations are often financed by international or national development organizations. Since these organizations have to prove the success of their funding programs, it is often not easy to discuss difficulties or failures openly in these contexts or to publish critical results. These circumstances bear the risk that practitioners such as NGOs, funding institutions or implementers will get caught in the same traps over and over again.

Against this background, there seems to be a need for neutral scientific forums and formats, which would allow for addressing problems, questions, bottlenecks and difficulties openly and without negative impacts on future funding. This kind of forums could be a first step towards community-wide learning from previous experiences.

The international conference 'Micro Perspectives for Decentralized Energy Supply,' which was held in April 2011 at the Technische Universität Berlin, was attempting to provide such a forum.[4] It aimed at reflecting the state of the art of current scientific activities in the field of decentralized energy supply and starting an open discussion about difficulties and challenges. Presentations included research conducted in more than 30 different countries on all continents.[5] Various aspects of the main topics – "implementation and business models", "technology", "user experience" and "regulation" – were discussed in 17 thematic sessions with 120 participants.[6] The following section presents some of the challenges of implementing systems of decentralized energy supply in remote areas, based on the presentations and discussions of the conference. As most papers received for the conference were focused on decentralized electricity supply, the rest of this paper focuses on decentralized electricity supply. However, it is important to mention that research areas outside of this focus also merit attention due to their importance and pressing nature in development contexts.

Challenges of implementing systems of decentralized energy supply in remote areas

Remote rural areas in developing or emerging countries are often characterized by a lack of infrastructure such as transport, education and health facilities and – closely linked with these deficiencies – a lack of human capital. The difficulty of overcoming long distances between urban settlements and remote areas is intensified by roads, which are in bad condition. These circumstances make it difficult or expensive for service suppliers to guarantee regular visits and hinder local populations from participating in regional or national markets. They are also a barrier for attracting persons with higher education, like teachers and doctors, to these remote areas.

It is this context, which fosters typical difficulties in implementing systems of decentralized electricity supply, which will be outlined in this section.

The implemented technology often is not adapted to local conditions and users' needs

Many stakeholders consider decentralized electricity supply systems as being technologically mature. However, after more than 3 decades of implementation and with millions of decentralized systems in the field, frequent total failures or systems functioning only partially are well known (see Laufer & Schäfer in this issue, Lindner 2011, Nieuwenhout et al. 2001). The technical fundamentals of the conversion of solar energy into electricity might be well understood, but it seems that the technical systems often are not adapted to specific local conditions and the needs and skills of users. Various surveys show that the implemented technologies often are not protected against damage or reduced functionality through local weather conditions or animals: solar home systems are often undersized, their batteries become damaged during rainy seasons, charge controllers are not adapted to high temperatures and cables are often affected by mice and rats (see Laufer & Schäfer in this issue, Lindner 2011, Reinmüller & Adib 2003, Nieuwenhout et al. 2001). Additionally observable is that the users often have incomplete or false information regarding the capacities of the installed systems and are disappointed because they cannot use them for their intended purposes (Sandgren 2001).

[2] The first comprehensive evaluation dealing with the implementation of solar home systems on a large scale was done by Martinot et al. (2001) and evaluated the implementation starting 1993.

[3] The Journal for Energy for Sustainable Development is one of the few existing forums, another one is the UNDP Sustainable Energy Forum.

[4] http://www.microenergysystems.tu-berlin.de/conference2011/.

[5] The Conference was organized by the postgraduate program "Microenergy Systems" and funded by the Hans Böckler Stiftung as well as supported by DAAD and the Heidehof Foundation. The next conference is scheduled for 2012.

[6] http://www.microenergysystems.tu-berlin.de/conference2011/sites/default/files/mpdes_proceedings_web.pdf.

Professional installation and long-term functionality of the systems are not assured

Due to lack of information transfer between producers and technicians or users, it is often not assured that the components of a technical system like Solar Home Systems will be installed properly. Areas of a solar panel being in shade and installing wrong-size cables or inappropriate charge controllers are a few examples that reduce the capacities of such systems and result in functionality problems. The remoteness of many rural areas additionally makes it difficult to assure regular repair and maintenance services and to provide access to spare parts. Insufficient planning and reduced availability of spare parts leads to installation of inadequate components which, in turn, affect the capacities of the systems (Lindner 2011, Kristjansdottir 2003, Egido 2001, Fahlenbock & Haupt 2000). Moreover, users often are not informed about the limits of the systems and tend to overuse them (see Laufer & Schäfer in this issue). Systems that appear to work fine under laboratory conditions fail under "real-life conditions" due to incorrect handling, use and maintenance (see Tillmans & Schweizer-Ries in this issue and Schweizer-Ries 2004).

Technical design and quality management are not adapted to financing models

Implementation of systems of decentralized energy supply is increasingly linked to microfinancing models that especially enable households with lower incomes to invest in them. Recent studies show, however, that existing schemes for linking the provision of the technical systems with microcredits differ in their impact for users. One example is the financing schemes employed for Solar Home Systems: While the "one hand" model, which is implemented in Bangladesh, assures that functionality of the technical system is guaranteed during the period of paying the credit back (Wiese & Steidl 2011), this is not the case in the "two hand" model in Sri Lanka (see Laufer& Schäfer in this issue). In the latter, users are provided with a two year guarantee on system batteries, while the payback period for the credit is 3 years. In cases of battery failure after 1 or 2 years, which is very common, users are confronted with additional costs for a new battery or giving up on the Solar Home System and reverting to their previous energy supply (e.g. kerosene), while still needing to continue paying their credit installments. This can be a huge burden as in many cases additional income is generated for such users through savings of kerosene and not through increased productivity of related business activity, as is otherwise usual in microfinance (see Laufer & Schäfer in this issue, Rohatgi & Enright 2010).

Sketching some of the difficulties of implementing systems of decentralized energy supply in remote areas makes clear that the efficiency of implementation strategies should be increased. Based on the discussions at the international conference in Berlin, we now introduce some ideas regarding future approaches that could be taken in research and development. These theses are not meant to be complete and should be understood as an impulse for further discussion in the emerging community of researchers and practitioners who are dealing with decentralized energy supply.

R & D approaches which meet the challenges

Systems of decentralized energy supply need robust and adaptable technologies

The demands on technology of decentralized energy systems are especially high due to the difficult context conditions mentioned above (see Laufer & Schäfer, Tillmans & Schweizer-Ries in this issue as well as Lindner 2011, Müggenberg et al. 2011). Technology needs to be robust, maintainable and reparable with low-level technical skills. While a certain standardization is necessary to avoid high costs, it needs to be possible to adapt technologies to specific context conditions. "One size fits all" models cannot respond adequately to the diversity of needs and influential factors. Pilot models of new technical systems should be evaluated under different climatic conditions and in direct contact with those responsible for installing and maintaining them and/or their users. A "learning by implementing" approach does not seem to be adequate, considering the vulnerability of the target group, which is often confronted with livelihood problems. Availability of spare parts should be easier if systems are produced from regional resources and with regional know how; engineers should consider this fact in the development process.

User needs have to be integrated into strategies for developing and implementing systems of decentralized energy supply

Surveys show that the design of existing decentralized technologies often does not take the lifeworld conditions of users sufficiently into account. Tillmans and Schweizer-Ries (see article in this issue) explain this fact by pointing to the different "mental maps" of the technology-developing engineers and the end users. The contrasts between the lifeworld of a developing engineer and an end user is especially high if technologies are developed in industrialized countries. But also within the national contexts of developing countries, huge differences can exist between the daily lives of highly educated persons living in urban areas and low-educated poor households living in remote rural ones. The educational levels of end users (and those responsible for services) and their daily life routines need to be considered when designing energy systems, but also when developing informational material dealing with their installation or maintenance. The specifics of cultural backgrounds as well as the difference between decision making processes regarding investment in and actual use of such systems should also be taken into account. Especially with regard to providing energy supply systems that motivate productive uses, it seems to be essential to know more about user profiles, differentiated into consumptive and productive uses.

Decentralized energy supply systems have to be accompanied by a "service package"

As experience in many cases has shown, it is not enough to provide decentralized energy supply systems which can be installed by technicians or even by users themselves; of crucial importance is to assure their proper installation and regular maintenance. Parallel to ongoing trends of offering "Product Service Systems" in high-tech contexts, it seems to be crucial to assure quality management through a diverse range of services, depending on the specific technology (Sakao & Lindahl, 2009). Such a "package" should include installation, repair, maintenance, upgrading and disposal services (Müller et al. 2009). A neutral consulting session regarding the choice of a technology best fitting the users' profile and an adequate financing strategy which does not bear high risks for the household is of great importance. A switch from "providing technology" to "providing Energy Product Service Systems" bears great chances for regional economic development if the local population is integrated into offering components of these services. Providing services also assures direct contact between commercial or private end users and allows quick adaptation of technical systems according to users' needs (see Tillmans & Schweizer-Ries in this issue, Müller et al. 2009, Ericson 2007).

Productive use of decentralized energy supply systems should be the focus of future implementation strategies

As several surveys have shown, providing access to energy does not always lead to its being used for productive purposes that would result in considerably higher household incomes. Many households use the provided energy mainly for consumptive purposes and benefit from some savings on former energy expenses and better living conditions (see Laufer & Schäfer in this issue, Rohatgi & Enright 2010). Since the implementation of these technologies is in most cases dependent on household investments, this is a crucial point requiring urgent attention. So far, there is little known about the potential of different decentralized energy systems for different types of productive use (e.g. processing agricultural products, operating water pumps, offering services). A comparative analysis of different decentralized energy systems and their economic impact on the productivity of various micro-businesses and small-peasant farming activities could deliver important results regarding technical requirements and financing schemes. In this context, it is important to differentiate between the productivity of a single business and the productivity of a whole village or community. Analyses are needed about whether increased productivity on the individual level enhances the wealth of the whole community or rather deepens social inequalities.

Competition is also another important aspect in the context of productivity: Although decentralized energy supply might be cheaper in off-grid areas compared to the extension of the centralized grid, off-grid producers still have to compete on the national market with those who have access to cheaper centralized energy supply.

Providing energy supply has to be integrated into regional development programs and multi-level governance

Access to energy is a necessary, but not a sufficient, condition for setting up new businesses and enhancing productivity. Economic development in remote regions can only be encouraged through the joint efforts of different political sectors like education, health, agriculture and regional development. Providing systems of decentralized energy supply, therefore, should be embedded within regional economic development strategies (see Laufer & Schäfer in this issue). Furthermore, in order to allow investment planning for poor households in remote areas, it is very important that grid extension plans not be altered at short notice.

Last but not the least, R&D approaches in the field of decentralized energy supply should consider the interconnection between local and regional implementation strategies and forms of national as well as international governance. Whether systems of decentralized energy supply can be implemented often depends on national or international funding programs as well as on microfinancing schemes. New forms of international governance, such as in the field of climate protection (e.g. Clean Development Mechanism, Carbon Financing), can play a supportive or an inhibiting role.

Characteristics of an adequate research type

The former section has outlined some of the necessary approaches in research and development in the field of decentralized energy supply. It is easy to recognize that interdisciplinary cooperation is necessary in order to be able to answer most urgent questions and develop strategies which go beyond providing purely technical solutions. To elaborate concepts, like Product Services Systems, for different forms of decentralized energy supply requires knowledge from various disciplines. Expertise in areas such as financing schemes, capacity building, life cycle analysis, robust design, recycling and upscaling of technical systems as well as methods of analyzing users' needs will be helpful for embedding technical solutions into service systems.

Besides interdisciplinary cooperation, it seems to be just as important to carry out research in this field in close exchange with practitioners (e.g. funding institutions, administration, politics and engineers) in order to be able to integrate their expertise. Research which tries to explore socially relevant problem fields is called “transdisciplinary” or “mode 2” research in contrast to “mode 1” research, which in most cases has a disciplinary character and generates its research questions within the scientific context (Nowotny et al. 2001, Gibbons & Nowotny 2000). Science of the former type acknowledges the appearance of societal problems of a new quality over the last few decades that cannot be dealt with adequately solely via disciplinary science (Funtowicz & Ravetz 1993). During the last 2 decades, transdisciplinary research has gained importance in fields like sustainability, risk, health, innovation and environmental research (Schäfer et al. 2010, Pohl & Hirsch-Hadorn 2008).

Mode 2 research takes up societal problems, reformulates them as scientific problems and contributes towards solving them through exchange between scientific and lifeworld knowledge. However, in transdisciplinary research scientific quality standards also have to be adhered to and unbiased results need to be guaranteed. Integrating knowledge of lifeworld actors and transferring of results have to take place in a transparent and reflexive manner. Researchers in transdisciplinary projects aim towards attaining knowledge for problem solving in the lifeworld that goes beyond counseling. For this purpose, they also need to identify and systematize what can be learned from one case that may be relevant to other situations (Krohn 2008). In contrast to disciplinary knowledge that generalizes findings on the basis of standardized conditions, transdisciplinary research aims at validating abstract models in concrete lifeworld situations (Pohl and Hirsch-Hadorn 2008).

Research in the field of decentralized energy supply often takes place in close exchange with practitioners; context-specific case studies are very common. It seems, however, that the process of integrating scientific and lifeworld knowledge often is not sufficiently reflected upon and that the systematization of the findings is not yet assured.

The postgraduate program “Microenergy Systems”: one example of inter- and transdisciplinary research

This section seeks to briefly introduce a postgraduate program in the field of decentralized energy supply at the Technische Universität Berlin, highlighting its attempts at doing inter- and transdisciplinary research in a reflexive manner. Eight postgraduates from different disciplines (process and production engineering, electrical engineering, sociology, environmental psychology, landscape planning, political sciences) are cooperating in this program, all of them dealing with questions of decentralized energy supply in industrialized as well as in developing countries.[7] One problem of interdisciplinary research is that each discipline has evolved its own set of concepts and terms, making mutual understanding difficult. The postgraduates have therefore tried to develop a common understanding of central terms in a moderated process. By doing so, different perspectives, on for example the role of technology in society and its relations to other societal systems, have been clarified.

The term “Microenergy Systems” is the core of this postgraduate program, standing for a bottom-up view on systems of decentralized energy supply and looking from the perspective of the end user or of stakeholders close to the end users. Microenergy systems preferably use local renewable energy resources like sun, water, biomass or wind and convert them into heat, electricity, light or power. These products are either used by the producers themselves or sold to consumers in their vicinity. Microenergy systems are understood as systems with a high degree of efficiency that can be made accessible to households and small business operators on a sustainable basis through adequate financing and service models (Phillip & Schäfer 2009).

[7] The postgraduate program “Microenergy Systems for sustainable decentralized energy supply in structural weak areas” is located at Technische Universität Berlin and has been funded by the Hans-Böckler-Foundation since 2008. It has started with eight PhD students in 2008 and will enter into a second phase with another eight postgraduates in 2012:www.planen-bauen-umwelt.tu-berlin.de/microenergysystems.

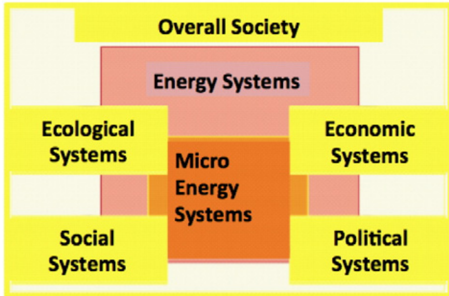

Fig. 1. Definition of microenergy systems.
(Source: Philipp & Schäfer 2009).

The interdisciplinary approach in dealing with microenergy systems is reflected in their being defined as socio-technical systems that, in a reciprocal process, are shaping society while also being shaped by it. A precondition for dealing with questions of efficient implementation of microenergy systems is the realization that such technical facilities are embedded within the energy system as a whole, which in turn is part of society with economic, social, ecological and political systems (see Fig. 1).

Referring to these common understanding in all of the PhD work of program participants has been one of the instruments to assure reflexivity in dealing with interactions between technology and society. Furthermore, the program provides methodological training, such as on the difficulties of carrying out research in a different cultural context or on standards for carrying out case studies. The individual PhD theses of participants have been focused on different microenergy systems and analyzed them in very different cultural contexts (Europe, Africa and Asia). Comparing their results in a systematic way is therefore a great challenge. Nevertheless, attempts have been made to generate transferable, abstract knowledge concerning questions of implementation models and financing schemes, the relation between providing technical systems and additional services, supporting governance strategies or the potential of microenergy systems to minimize impacts on natural resources.

Presenting and discussing the results at the "International Conference on Micro Perspectives for Decentralized Energy Supply" was another step in reflecting upon them in a broader context with a community of people who are dealing with similar topics.

Conclusions

The implementation of different systems for decentralized energy supply is not a new topic — much experience in this field has been gained in different cultural contexts during the last 3 decades. However, due to current discourses and global governance strategies, for example in the fields of poverty reduction (Millennium Development Goals) and climate protection (United Nations Framework Convention on Climate Change), the issue has gained priority. Various national and international development institutions, such as UNDP, UNEP, European Union, GIZ and the World Bank, agree that accelerated decentralized energy supply bears potentials to confront energy poverty in a climate-friendly way, if it is based on renewable resources. This background has led to the launch of various programs that support the implementation of decentralized renewable energy systems, such as Energizing Development (EnDev), the Global Alliance for Clean Cookstoves (United Nations 2011), the European Energy Facility, the Global Environment Facility and the like.

In this situation, it seems to be of crucial importance to accompany this strategic shift with neutral research which is able to evaluate experiences and lessons learnt systematically and draw transferable conclusions. Since research on decentralized energy supply has so far mostly taken place in a "niche" – as are the technical systems it is investigating – it has mostly been carried out with few resources and little (wo)manpower. Additionally, it has been difficult to define a "research community," because research in this field is being done by very different disciplines, deals with a variety of technologies and has been carried out in very different geographic and cultural contexts.

Nevertheless, contributions to forums like the Journal of Energy for Sustainable Development or at the International Conference on Micro Perspectives for Decentralized Energy Supply show that there is a rich stock of empirical data and analyses which can be referred to. Due to the current international relevance of the topic, a window of opportunity seems open that may allow for the enhancing of discussion about adequate methods and instruments for integrating different types of knowledge in this field.

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