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Integrated assessment of renewable energy potential: Approach and application in rural South Africa

Bastian Winkler[a,*], Stefanie Lemke[b,c], Jan Ritter[a], Iris Lewandowski[a]

[a] *Department of Biobased Products and Energy Crops, Institute of Crop Science, University of Hohenheim, Fruwirthstrasse 23, 70593 Stuttgart, Germany*
[b] *Centre for Agroecology, Water and Resilience, Coventry University, Ryton Gardens, Wolston Lane, Coventry, Warwickshire, CV8 3LG, United Kingdom*
[c] *Department of Societal Transition and Agriculture, Institute of Social Sciences in Agriculture, University of Hohenheim, 70593 Stuttgart, Germany*

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ABSTRACT

This paper presents the development and application of the Integrated Renewable Energy Potential Assessment (IREPA), employing a three-pronged approach: (i) literature review of renewable energy potential assessment methodologies, renewable energy technology (RET) selection factors and impact assessment methods; (ii) discussions with academic peers from natural and social sciences, and the private energy engineering sector; (iii) evaluation of the IREPA methodology through case-study research in a rural community in South Africa. Locally relevant social, institutional, environmental and techno-economic factors were explored through mutual knowledge exchange with smallholders and subsequently applied for appropriate RET selection. Three barriers to participatory decision-making were revealed: i) lack of knowledge ofrenewable energy among smallholders; ii) insufficient practical information dissemination in IREPA; iii) abstract nature of the analytical hierarchy process. The adaptions recommended by this research would render IREPA a suitable bottom-up approach for the assessment and effective implementation of RET, stimulating socio-economic development in rural areas.

1. Introduction

Improving access to clean and modern energy is high on the policy agenda of many developing and emerging economies (Hailu, 2012) and essential to the post-2015 development agenda (UNECOSOC, 2014). Extension of the electricity grid to rural areas where most of the energy-poor households live is technically challenging and often not economically viable due to the low density and dispersed structure of rural settlements (Cherni et al., 2007). Decentralized, renewable energy (RE) systems (solar-, wind-, hydro-, geothermal and bioenergy) can increase access to modern energy in rural areas, (Cherni et al., 2007; Kaygusuz, 2012). By the end of 2015, 146 countries had adopted RE support policies. More than two thirds of these countries are developing countries or emerging economies (REN21, 2016).

* Corresponding author. Postal address: Bastian Winkler, Fruwirthstrasse 23, University of Hohenheim, 70593 Stuttgart, Germany.
E-mail addresses: b.winkler@uni-hohenheim.de (B. Winkler), stefanie.lemke@coventry.ac.uk (S. Lemke), janr84@hotmail.de (J. Ritter), iris_lewandowski@uni-hohenheim.de (I. Lewandowski).

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The highest technical potential for solar, wind and biomass energy (about 983 EJ) has been found for the African continent (De Vries et al., 2007). This is almost twice the 2013 total global annual primary energy consumption of 533 EJ (BP, 2014). Currently, modern RE accounts for only 1.5% of the total African primary energy supply, which is based to 51% on fossil fuels and nuclear power and to 47% on solid biofuels such as wood and charcoal (IRENA-DBFZ, 2013).

In South (Africa energy is mainly generated from coal (87.5%). Solid biofuels account for 9.4%, while other RE have a share of 1.3% (OECD/IEA, 2016). Since the abolishment of the Apartheid various electrification programmes have been implemented, e.g. *White Paper on Energy Policy* (estd. 1998), *Integrated National Electrification Programme* (estd. 2001) and *Integrated Resource Plan* (estd. 2011) (DoE SA, 2013). Between 1996 and 2014 5.7 million households were connected to the grid. This transformed the electrification rate in the Transkei (Eastern Cape) from more than 80% un-electrified households in 1996 (DoE SA, 2013) to 82.3% electrified households in 2015 (Stats SA, 2015). For further rural electrification off-grid renewable energy technologies (RET) are proposed, in particular in the former homeland areas in KwaZulu Natal and the Eastern Cape, the two provinces with the highest off-grid potential in South Africa (DoE SA, 2013).

Currently, RE development in South Africa is directed by the *Renewable Energy Independent Power Producer Procurement Programme (REI4P)* (DoE SA, 2015). The REI4P is based on a competitive bidding process for RE supply contracts, focusing on large-scale RE-production (> 1MW). In the first three years, the programme has had considerable success. The number of electricity producers has increased from one to 64 and RE electricity prices have decreased. However, the socio-economic development targets of the REI4P, including human capital building as well as job and enterprise creation in rural areas, have not been achieved (Walwyn and Brent, 2015). This shows the limitations of centralized, top-down approaches to reaching remote rural areas and stimulating socio-economic development. In rural areas, RET planned according to techno-economic considerations by external experts often fail to meet the expectations of a long-term and sustainable energy supply (Hailu, 2012; Wang et al., 2009).

The implementation of RE depends on the complex interaction of social, institutional, environmental, technical and economic factors that determine the adaptability of a technology to the local socio-cultural context (Barry et al., 2011; García and Bartolome, 2010; Kaygusuz, 2012). The involvement of stakeholders is therefore an important condition for successful RE implementation.

Smallholder farmers - defined here as farms with less than 10 ha, often less than 1 ha (Jayne et al., 2010) - manage more than 80% of the natural resources in rural areas (IAASTD, 2009). Therefore smallholders are the stakeholders that should primarily be addressed in RE potential assessments (REPA) and RE implementation programmes in rural areas.

This study presents an innovative methodology to REPA in smallholder farming systems. The "Integrated Renewable Energy Potential Assessment" (IREPA) was developed with the purpose of integrating the above-mentioned factors in a participatory, bottom-up approach to select locally appropriate RET for the assessment of the renewable energy implementation potential (REIP). For the methodological development, a three-pronged approach was applied. First, current methodologies used for REPA were analysed with emphasis on social, institutional, environmental and techno-economic factors. In addition, appropriate methodologies for participatory research, impact assessment and decision-making were reviewed. Second, IREPA was developed based on the results from the previous step, additionally informed by discussions with academic peers and the private energy sector. Third, findings from case-study research in the Eastern Cape Province of South Africa are presented, testing whether IREPA is applicable in this specific context.

2. Methodology

2.1. Development of the IREPA approach

2.1.1. Literature review

Current approaches for REPA were analysed, taking only methodologies into account that assessed the *theoretical*, *geographical*, *technical*, *economic* and *implementation* potential categories as defined by Hoogwijk (2004) and Resch et al. (2008).

In addition, literature on RE case studies was reviewed to explore the social, institutional, environmental, technical and economic factors considered important for RET selection. For the identification of these factors at the local level *Participatory Learning and Action* (PLA)[1] research methods are essential and are therefore included in the literature review (Chambers, 1994; Hart, 2008).

Further, social and environmental impact assessment as well as multi-criteria decision analysis (MCDA) methods were reviewed, drawing on the MCDA reviews of Hailu (2012), Taha and Daim (2013) and Wang et al. (2009), to identify a suitable methodology for assessing the impacts of RET on people's livelihoods and to select locally appropriate RETs in the IREPA.

2.1.2. Discussions with academic peers and the private sector

The results of the literature review were discussed with academic peers from the disciplines agricultural sciences, agricultural economics and social sciences, and with energy engineers from the research and development department on future renewable power technologies of ALSTOM (Schweiz) AG. This enabled an inter- and transdisciplinary research perspective.

[1] PLA comprise a wide range of approaches including *Participatory Rural Appraisal (PRA), Rapid Rural Appraisal (RRA), Participatory Learning Methods (PALM), Participatory Action Research (PAR), Farming Systems Research (FSR), and others* (Hart, 2008).