



University of Pretoria

## **RESEARCH REPORT:**

**Contributions to the Theory and Practice of Technology Selection:  
The Case of Projects to Ensure a Sustainable Energy Base for Africa**

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## Abstract

Energy is essential for economic development in Africa. The current electrification figures show that countries in sub-Saharan Africa are facing major challenges in reaching positive economic growth and supplying basic energy services to rural communities. Sustainable energy technologies are available and can be used to great effect in Africa to alleviate this problem. Sustainable energy technologies can contribute to job creation and economic development. The implementation of renewable energy technologies in sub-Saharan Africa to date however has not always been successful due to both technical and non-technical factors. Prior to this study a comprehensive framework of factors to select renewable energy technologies did not exist. The purpose of this research was to develop such a framework and to validate it by means of empirical research.

Triangulation of methodologies was used to determine the framework of factors. The analysis of the literature investigated renewable energy technologies and their application, the challenges in renewable energy technologies for implementation in Africa and the selection methods in the fields of project, portfolio, programme and technology management. This was followed by a focus group with three experts in which thirty eight factors that need to be taken into account during the selection of renewable energy technologies in Africa were identified. The factors identified by the focus group were confirmed and the eleven most applicable factors were selected during a two-round Delphi study. Finally case studies on the implementation of renewable energy technologies were undertaken in three countries. These case studies confirmed the eleven factors identified during the Delphi study and identified a further two factors which needed to be added to the framework.

The final framework proposed in this study consists of thirteen factors that need to be considered before deciding on the technology appropriate for a specific implementation. For the implementation of the technology to succeed, it must be ensured that the technology can be maintained and supported on site over the life cycle of the technology, and that sufficient skills and resources exist to implement and maintain the technology. Sites for implementation of the technology must be selected in places where local champions exist to continue supporting the technology after the implementing agency has left, the community has the will to adopt the technology in the long term, sites are available for implementing pilot sites and sufficient sites with the correct characteristics are available for long term implementation. The technology must also contribute to economic development by creating jobs or improving the economic situation of households, and financing must be made available to ensure large scale adoption. Local businesses which aid with implementation need to have business management and technical skills as well as the financial capacity to implement the technology. Government support of the

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implementation of the technology is essential and the environmental benefits of the technology must be clear from the outset.

This report presents a framework that includes both the criteria and measures to be used for the selection of renewable energy technologies in Africa. Further work is required to implement these criteria and measures in a selection methodology.

*Keywords:* Renewable energy technology selection, developing countries, sustainable energy, selection criteria, framework of factors

## Acknowledgements

**'The fear of the LORD is the beginning of wisdom;  
all who follow his precepts have good understanding.  
To him belongs eternal praise.' - Psalm 111 vs 10**

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## List of Acronyms/Definitions/Abbreviations

AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
CO <sub>2</sub>	Carbon dioxide
ESMAP	Energy Sector Management Assistance Program
kgoe	Kilogram oil equivalent
IEA	International Energy Agency
MININFRA	Ministry of Infrastructure Rwanda
Mtoe	Millions of tonnes of oil equivalent
NAPA	National Adaption Program of Action
NDBP	National Domestic Biogas Program
NEPAD	New Partnership for Africa's Development
SNV	Netherlands Development Organisation
TWh	Tera Watt hour
UN	United Nations
UNEA	United Nations Energy Agency
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organisation

## Definitions

Climate change	All forms of climatic variations, especially significant changes from one prevailing climatic condition to another.
Carbon intensity	The amount of carbon by weight emitted per unit of energy consumed.
Co-generation	A form of energy recycling where a power station or heat engine are used to produce both electricity and useful heat.
Developing countries	Countries which fall within a given range of GNP per capita, as defined by the World Bank.
Emissions	Flows of gas, liquid droplets or solid particles released into the atmosphere.
Energy demand	The amount of modern energy required by various sectors of (millions toe) a country.
Energy imports	The total cost of energy brought from foreign countries into (US\$ million) the domestic territory of a given country.
Energy production	The amount of modern energy produced within the country. (million toe)
Energy reserves	Estimated quantities of energy sources that have been demonstrated to exist with reasonable certainty on the basis of geologic and engineering data (proven reserves) or that can reasonably be expected to exist on the basis of geologic evidence that supports projections from proven reserves (probable or indicated reserves).
Energy services	The end use ultimately provided by energy.
Energy sources	Any substance or natural phenomenon that can be consumed or transformed to supply heat or power.
Energy supply	Amount of energy available for use by the various sectors in a country.
Energy use per capita	The average amount of energy consumed (Kgое) per inhabitant in a given country.

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Fossil fuel	An energy source formed in the earth's crust from decayed organic material, e.g. petroleum, coal, and natural gas.
Geothermal energy	Natural heat from within the earth, captured for production of electric power, space heating or industrial steam.
Geothermal Plant	A plant in which the prime mover is a steam turbine that is driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The fluids are extracted by drilling and/or pumping.
Global warming	An increase in the near surface temperature of the earth due to increased anthropogenic emissions of greenhouse gases.
Greenhouse effect	The effect produced due to certain atmospheric gases that allow incoming solar radiation to pass through to the earth's surface, but prevent the radiations which are reradiated from the earth, from escaping into outer space.
Greenhouse gas	Any gas that absorbs infrared radiation in the atmosphere.
Gross domestic product	The total output of goods and services (US\$ million) produced within the territory of a given country.
Gross domestic product	The annual rate of increase/decrease in the gross domestic growth rate (per cent) product.
Gross national product	The total output of goods and services (US\$ million) produced within the territory of a given country (GDP), plus the net receipts of primary income from investments outside the country.
Gross national product	The average income per inhabitant of a country, derived by per capita (US\$) dividing the GNP by the population.
Household energy	The total amount of funds spent on energy consumed in, or expenditures delivered to, a housing unit during a given period of time.

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Household stoves	Household heating and cooking devices.
Household	A group of people who share a common means of livelihood, such as meals, regardless of source of income and family ties. Members who are temporarily absent are included and temporary visitors are excluded.
Hydro turbine	A device used to generate electricity using kinetic energy from moving water.
Improved household	Household heating and cooking devices that have been altered in design to improve their efficiency.
Institutional stoves	A heating and cooking device commonly used in medium and large institutions.
Kenya ceramic jiko	An improved household stove that uses charcoal and has a ceramic lining to improve efficiency. Widely disseminated in Kenya, and adopted in many African countries.
Less developed countries	Countries that are below a given level or threshold of per capita GNP as defined by the World Bank.
Micro hydro	Small-scale power generating systems that harness the power of falling water (above 100kW but below 1MW).
Modern energy	Refers to high quality energy sources e.g. electricity and petroleum products, as opposed to traditional energy sources such as unprocessed biofuels.
National budget	Estimated government expenditure on goods and services, (US\$ million) including expenditure on national defence and security.
National debt	The direct liabilities of the government owed to debtors. (US\$ million)
Petroleum consumption	The sum of all refined petroleum products supplied.
Photovoltaic cells	Devices used to transform solar energy into electrical energy.
Pico hydro	Small-scale power generating systems that harness the power of falling water (less than 100 kW).

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Population (millions)	The total number of people living within the borders of a country, whether citizens or not.
Primary energy	Energy sources in their crude or raw state before processing into a form suitable for use by consumers.
Small and micro	An enterprise that generates income up to a certain preenterprises defined limit.
Small hydro	Small-scale power generating systems that harness the power of falling water (1-15 MW).
Solar collector	A device which is capable of absorbing solar radiation and converting it into some other form of energy.
Solar thermal	Devices that use the sun as the primary source of energy for technologies heat appliances, e.g. solar water heaters, solar dryers.
Solar water heaters	Devices that use solar energy to heat water for domestic, institutional, commercial and industrial use.
Sub-Saharan Africa	The term used to describe the area of the African continent which lies south of the Sahara. All African countries south of the North African countries Algeria, Egypt, Libya, Morocco, Tunisia.
Sustainable energy	Sustainable energy supplies energy in a way that meets the needs of the present generation without compromising the ability of future generations to meet their energy needs. Sustainable energy usually includes technologies that improve energy efficiency.
Traditional energy	Low quality and inefficient sources of energy, predominantly biomass in nature and not often traded (e.g. wood fuel, crop residues and dung cakes).
Traditional stoves	Inefficient heating and cooking devices that use firewood, charcoal and other biomass based fuels.
Wind pumps/mills	Devices that use wind energy to lift water from underground sources.
Wind turbines	Devices used to generate electricity using kinetic energy from wind.
Wood stoves	Heating and cooking devices that use firewood as the main fuel.

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