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1. S. Kibaara, kariukisamuel2004@gmail.com
2. E. Muendo, eliud90.m@gmail.com

Techno-Economic Modelling Tool for Small Scale Utility Solar PV Technology for Quantifying Environmental Impacts

Highlights

- Ongoing research work identifies a need to develop a tool (Solar PV based Power and Environmental Costing Assessment tool (SPECA) which fully incorporates the variability of the environmental impacts of Solar PV, together with some key cost parameters to realize a more realistic LCOE.
- Incorporation of the environmental impacts of RETs in the cost modelling tool will permit for cost accounting evaluation of the indirect cost incurred while using solar PV for electricity generation.
- Sustainable energy development requires methods and tools for assessing impacts in order to associate them with conservation of ecosystem goods and services

Introduction

- Global attention always focused on the environmental impacts of NRETs
- RETs always regarded as clean. They haven't realized their full potential despite promotion through incentives from governments. Their penetration globally remains at 15-20% (PV @ 4.5%).
- Barriers towards full realization ranges from high initial cost ,Environmental and social impacts and Technological aspect
- Environmental impacts of Solar PV include ecosystem damage, human health and GHG emissions
- GHG emissions (such as carbon dioxide from hydro(3.6-11.6g/kWh),wind(7-9g/kWh),PV (98-167 g/kWh), CSTP(26-38 g/kWh)
- LCOE is the most convenient measure of the economic competitiveness/viability of RETS.
- This research work has found popular Techno-economic tools such as HOMER, HOGA, TRNSYS, SAM, HYDROGEMS, SOMES, INSEL, RAPSIM and SOLSIM etc. used for the economic evaluation and optimization of different Solar PV do not put enough emphasis on the environmental impacts
- Use of capital costs, operation and maintenance costs and the annual replacement costs to calculate the LCOE is inadequate.

SPECA Tool Modeling Approach

$$\text{LCOE} = \frac{\text{life cycle cost}}{\text{life time energy production}}$$

SPECA LTCOE

$$LCOE = \frac{IC - \sum_{n=1}^{N} \frac{DEP+INT}{(1+DR)^n} TR + \sum_{n=1}^{N} \frac{LP}{(1+DR)^n} + \sum_{n=1}^{N} \frac{O\&M}{(1+DR)^n}(1-ROI) - \frac{RV}{(1+DR)^n} + \sum_{i=k}^{k} \mathrm{EC} + RC}{\frac{\sum_{n=1}^{N} initialkWh*(1-SDR)^n}{(1+DR)^n}}$$

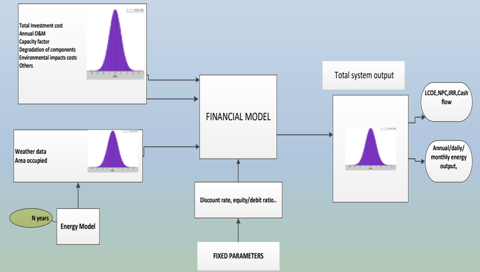
LTCOE,LCOE and LECOE

$$LECOE = \left(\frac{\sum_{t=0}^{T} \frac{C_0 + O\&M_t + RC_t + RV}{(1+r)^t} + \frac{\sum_{i=1}^{k} \mathrm{EC}}{(1+r)^t}}{\sum_{t=1}^{T} \frac{E_0(1-d)^t}{(1+r)^t}} \right) - \left(\frac{\sum_{t=0}^{T} \frac{C_0 + O\&M_t + RC_t + RV}{(1+r)^t}}{\sum_{t=1}^{T} \frac{E_0(1-d)^t}{(1+r)^t}} \right)$$

$$\sum_{i=1}^{k} \mathrm{EC}$$

Externalities of Solar PV

SPECA Model

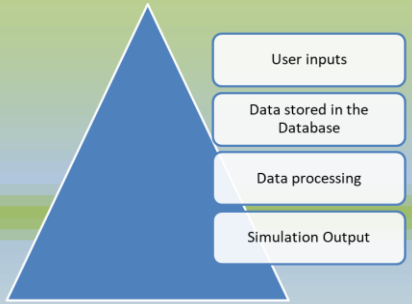


Monetary Valuation of Biodiversity Loss

Restoration costing (Value coefficient) will be used to estimate the damage cost attributed to USSE installation

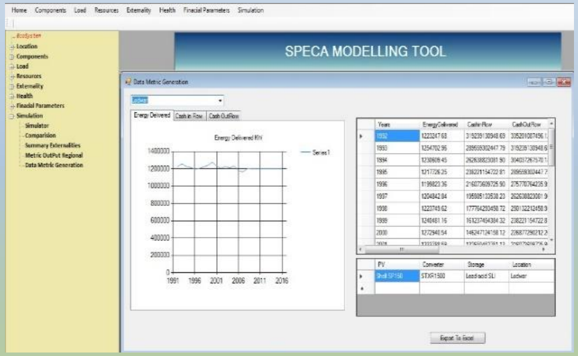
$$ESV = \sum A_k * VC_k$$

SPECA Tool Development



Visual Basic Programming
Graphical User Interface (GUI)
Standard Query Language (SQL) -Database

SPECA Tool



Conclusions

- Literature done revealed that majority of the tools do not quantify the environmental impacts (externalities) of Solar PV
- SPECA modelling tool was developed
- Incorporation of the Environmental Impacts of solar PV in the SPECA tool achieved
- Externalities of Solar PV were quantified through the restoration cost approach using the functions of ecosystem goods and services (Proxies)
- Ignored LECOE is what has rendered LCOE in other tools a crude estimate (5.51% for Lodwar)
- Global standard for hybrids (HOMER) among others fails to quantify the EI
- LCOE values of HOMER and SAM were 36.85% and 53.98 % lower as compared to that of the SPECA modeling tool

[1]S Kibaara; D K Murage;Petermoses Musau;M J Saulo, "Analysis of the Levelized cost of Electricity (LCOE) of Solar PV Systems considering their Environmental impacts on Biodiversity", 2020 6th IEEE International Energy Conference (ENERGYCon), October 2020, Tunis, Tunisia .
[2]S Kibaara; DK Murage;P Musau;M J Saulo "Comparative Analysis of the Implementation of Solar PV Systems using the ECOS Model and HOMER Software: A Kenyan Scenario", 2020 6th IEEE International Energy Conference (ENERGYCon), October 2020, Tunis ,Tunisia.
[3]S. Kibaara, D. K. Murage, P. Musau, and M. J. Saulo, "Internalisation of Externalities of Utility Scale Solar Energy using the ECOS Model", Proc. of IEEE PES Power Africa, August 2019, Accra , Ghana