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The Challenges and Capabilities of the Existing Techno-economic Modelling Tools for Renewable Energy Utilization

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ABSTRACT

Kenya is on the path of developing domestic renewable energy resources to reduce the overdependence on imported petroleum products and reduce carbon emissions. Presently, Kenya has increased the renewable energy penetration into the existing power systems for the purposes of reducing the overreliance on thermal power generation which stands at 36% and growing. Environmental conditions affect renewable energy generation thereby making energy supply to be intermittent and uncertain. To understand the potential use of renewable energy technologies and the Levelized Cost of Electricity (LCOE), there exist several techno-economic tools that offer great insights of the renewable power generation world over. These tools and methods categorized into financial analysis, impacts analysis and system analysis tools combine the capital costs, operation and maintenance costs, fuel costs and the energy output which when computed provide the necessary metrics which are indicators of project viability. LCOE is an economic assessment of the cost of energy generating system and should include all the life cycle costs, usually determined at the point where the sum of all the discounted revenues equalizes with the sum of all the discounted cost. However, there are certain aspects that are not covered by LCOE which includes damage from air pollution, energy security, transmission and distribution costs and the environmental impacts. This paper will present a review of these techno-economic modelling tools, identify their gaps, challenges and propose modifications to the LCOE calculations that will provide a more realistic value that encapsulates the externalities of renewable energy generation.

Key words: Levelized cost of electricity, Environmental Impacts, Life cycle cost, health impacts, Renewable Energy

INTRODUCTION

As the global population and living standards increase, so is the increase in energy demand. Kenya through its Vision 2030 and the Big 4 Agenda envisions an improvement of living standards to her population which will in turn demand an increase in electricity production to sustain the improved living standards and in turn reduce carbon dioxide gas emissions by 30% in 2030 [1-2]. Kenya is rapidly developing its RES to reduce its over reliance on fossil fuels. For example, the geothermal energy has contributed immensely to overall electricity capacity, moving from 13% in 2011 to 26% in 2015 while Hydropower and fossil fuel based power add 36% each to the energy system [1]. Wind energy, cogeneration and solar PV contribute the remaining 2% with an annual growth of approximately 2.25% [1, 3]. This increase in energy demand is to be met sustainably, that is without compromising the ecosystems and also be capable of meeting the energy needs for future generations. The immediate and future challenge has been and will always be meeting the energy needs of the ever-growing populations at the least cost possible, without affecting the environment and human health. To assess the viability of the energy resources before the power plant is constructed, techno economic assessment tools are used to estimate the performance of the plant, the likely pollutants that the plant will emit, the overall cost of the power plant and the ultimately the unit cost of power to determine the feasibility of the plant. Techno-economic tools selection subject to the objectives that one wants to achieve in an energy system [4]. The objective of this study is to assess and identify a tool among the many techno-economic assessment tools that is capable of incorporating the impacts of environmental effects in the calculation of LCOE. In the following section LCOE is discussed which a common metric applied in almost all techn0-economic modelling tools.

LEVELIZED COST OF ELECTRICITY

Many of the techno-economic tools use the levelized cost of energy LCOE as a comparative metric for assessing different energy power plants in relation to their lifetimes, cost structures, and capacity factors from an economical perspective [5]. LCOE is used by power producers as a utility factor to estimate the cost of power produced by any power plant [6]. The calculations to arrive at this factor takes into consideration all the expected lifetime costs of the power plant that includes all taxes, cost of fuel, capital expenditure for the project, incentives in form of grants, inflation rate, Operations and Maintenance costs and insurances, divided by the discounted energy production from the power plant [6]. The LCOE of power generation plants can be high or low. A low LCOE indicates a low unit cost of energy while a high LCOE indicates a higher unit cost of energy. Levelized Cost of Energy Cost (LCOE) is one of the famous indicators that can be used for economic analysis of an energy system. LCOE is calculated as shown by Equation 1 below [7]:

$$\frac{LCOE = TPV * CRF}{LAE} \tag{1}$$

Where TPV the total present cost of the entire system is, LAE is the annual load demand and CRF is the capital recovery factor.
CRF and TPV can be determined by [7-8] as shown by Equation 2 and 3 below:

$$CRF = \frac{r(1+r)^T}{(1+r)^T - 1} \tag{2}$$

$$TPV = IC + OMC + RC + FC - PSV \tag{3}$$

r is the net interest rate and T is the system lifetime in years, normally assumed to be 25 years.
is the initial capital cost of the power system (supply, installation/construction, testing and commissioning).
OMC is the present value of operation and Maintenance cost of the Energy system over its lifetime (salaries, insurances, inspections, all maintenance activities, etc). OMC can be assumed to be a fixed cost per capacity of each component of the energy system [7]. The total OMC cost can be determined using the following equations 4 and 5 [7]:

$$OMC = OMC_o \frac{(1+i)}{(r-i)} (1 - \frac{(1+i)^T}{(1+r)} \quad for\, r \neq i \tag{4}$$

or

$$OMC = OMC_o \, x \, T \quad for\, r = i \tag{5}$$

Where OMC_o is the operation and maintenance cost a the first year of the project
RC is the present value of replacement cost of components in the energy system that will be carried out throughout the lifetime of the energy system and is calculated as indicated in Equation 6 [7]:

$$RC = \sum_{j=1}^{N_{rep}} C_{RC} \, x \, C_U \frac{(1+i)^{T*j/(N_{rep}+1)}}{(1+r)} \tag{6}$$

Where *i* is the inflation rate of the replacement units which is around 5.7% in Kenya (Central Bank of Kenya). C_{RC} is the capacity of the replacement units, which is in kW for the energy system, C_U is the cost of the replacement units in Ksh/kW; N_{rep} is the number of replacement unit over the lifetime, T of the power system components. PSV is the present value of scrap. Calculation of PSV can be finalized as shown in Equation 7:

$$PSV = \sum_{j=1}^{N_{rep}} SV \quad \frac{(1+i)^{T*j/(N_{rep}+1)}}{(1+r)} \tag{7}$$

TRADITIONAL SOFTWARE TOOLS AND ENERGY MODELLING TOOLS

There exist quite a number of software tools that can be used to optimize and simulate energy systems [4] Amongst these tools employed for techno-economic analysis are the Hybrid Optimization for Modeling Electrical Renewables (HOMER) , RETScreen Expert, SAM, Aeolius, EnergyPLAN, EnergyPro, MARKAL/Times, ETEM, Modest, Sifre, LEAP, BCHP Screening Tool, HYDROGEMS, and TRNSYS16 and many more [4,9]. HOMER and RETScreen are the most popular Techno-Economic tools. HOMER has the capacity of simulating and optimizing renewable power systems in standalone or grid linked configurations for the purposes of determining the cost effectiveness of the power plant [9]. This tool can be used to evaluate stand-alone power generation systems as well as grid connected systems in remote areas, islands and buildings to summarize their environmental, technical and economic benefits with a main objective of minimizing Net Present Costs (NPC) [4,9]. HOMER optimizes the system components of the power system to provide energy cost but does not look at all the costs associated with civil and structural work, installation and operation [4]. RETScreen is a project analysis and decision support tool which does not provide RE optimization but only analyses the energy scenario provided that the energy mix input is provided by the user [4]. This tool provides detailed cost analysis, financial analysis and emission analysis [4].
Salehin et al., 2016 noted that HOMER omits costs like feasibility costs, development costs, civil engineering costs, system installation costs and operational cost thereby making the levelized cost of electricity to be less than the actual cost of energy. They further noted that Energy Pro can be used to carry out a combined techno-economic design for fossil based and biofuel based power generation [4]. It is to be noted that though the common approach in modeling energy systems is through the use of one techno economic tool, several modeling frameworks exist that use two or more tools have been used to complement each other for the purposes of capturing key parameters of the energy systems.
Techno-economic analysis of power generation systems gives great insights into the economic viability of the power system to be designed and constructed.

MODEL REVIEW OF TECHNO-ECONOMIC TOOLS

Due to the great importance of these tools in modeling, simulation and techno-economic analysis, there has been a number of studies that have attempted to assess the capability of these tools for the primary purpose of helping modelers identify the best tools for energy applications [10]. The reviewers have evaluated the features of the techno-economic tools highlighting the unique features that the tool has to meet specific objectives in techno-economic study of power generation systems [9]. Connolly *et al.*, [10] has reviewed 68 techno-economic tools based on their capabilities to simulate, create scenarios, create equilibriums, carry out top-down and bottom up analysis, optimize operations and energy investments. They further analyzed and described in detail, in collaboration with developers 37 of these tools for the renewable energy penetration into the grid. They noted that BCHP Screening Tool, HOMER, HYDROGEMS, and TRNSYS16 have their primarily focus on stand-alone energy systems while EnergyPro undertakes feasibility studies of power plants, WASP analyses capacities of new power plants, ProdRisk and EMPS are used for optimization of hydro-power plants while the AEOLIUS is highly beneficial in analyzing the intermittency and uncertainty effects of RE penetration in conventional power systems. They additionally noted that ORCED simulates the dispatch of electricity, and EMCAS simulates electricity markets while BALMOREL, GTMax, RAMSES, and SIVAEL are applicable mostly in district heating and in electricity generation. The study revealed that E4cast, EMINENT, and RETScreen have the capability of addressing all aspects of heat and electricity sector for the primary purpose of improving the penetration of intermittent RE by using CHP and thermal storage. In addition to the heat sector, PERSEUS, STREAM, and WILMAR Planning Tool also included the transport sector in the form of electric vehicles and MiniCAM and UniSyD3.0 analyse hydrogen and electric vehicles into the transport sector. The reviewers noted that Invert, H2RES, and SimREN tools are applicable in the modeling of the use of biofuels and hydrogen vehicles respectively while COMPOSE, EnergyPLAN, ENPEP-BALANCE, IKARUS, INFORSE, LEAP, MARKAL/TIMES, Mesap PlaNet, MESSAGE, NEMS, and PRIMES can account for all technologies in the electricity, heat, and transport sectors. However, they stated that only four of these, EnergyPLAN, Mesap PlaNet, INFORSE, and LEAP have previously simulated 100% renewable energy-systems.

In conclusion, they noted that though there is a wide range of these tools in use, they differ significantly in terms of the regions they analyse, the technologies they consider, and the objectives they fulfil and [10] there is no single computer tool that can meet all the requirements in an energy system but each tool is only able to meet a specific objectives for a specific energy scenario. Additionally, the economic capabilities of these tools as analyzed are limited since no single tool has the capabilities of incorporating environmental impacts to LCOE costing.

Ringkjøb *et al.*, [11] has reviewed, with the help of developers 75 computer-based techno-economic modeling tools by looking at the capabilities of these tools in terms of their general logic, spatiotemporal resolution as well as the technological and economic features for the purposes of aiding energy modelers identify the right tools for modeling. They assessed these tools based on their capabilities to analyse power systems, provide operation decision support, provide investment decision support, create scenario, to provide an engineering approach (top-down or bottom up approach), to create methodologies for energy and electricity models which deals with simulation, optimization, and equilibrium models. Additionally, the team analyzed the techno-economic tools based on their capability to model systems that have large percentage of variable renewable energy sources and also based on their capability to determine the technological and economic properties of grids and energy storage systems. Ringkjøb *et al.*, [11] noted that the current suite of modeling tools can address most but not all challenges in a power system. Challenges such as short-term variability, incorporating the effects of climate change in power systems with high levels of renewable energy penetration cannot be easily addressed by the current crop of modeling suites.

Jebaraj and Iniyan, [12] reviewed and classified energy models into energy planning, supply-demand, forecasting, emission reduction, optimization and modeling techniques. They observed that that the energy–economy models help in understanding the way in which energy–economy interactions work in a power system thereby enabling the prediction of future costing of energy. It’s also noted that there is no model that incorporates the impacts to the environment of power systems in LCOE costing thereby making the LCOE to be lower than required.

Yue *et al.*, [13] indicated that although energy system optimization models (ESOMs) have provided direction on how to handle energy policies and effects to the climate, the uncertainties within the model structures and the inputs these models have are not adequately addresses or ignored altogether. They compared other energy models to ESOMs and indicated that ESMs use scenarios to handle uncertainties or treat them as an elementary issue though they found out that model insights may be limited, lack robustness, and may mislead decision makers. They therefore provided an in-depth review of systematic in-depth review of the techniques that address uncertainties for ESOMs. We have identified four prevailing uncertainty approaches that have been applied to ESOM type models: Monte Carlo analysis, stochastic programming, robust optimization, and modelling to generate alternatives. For each method, we review the principles, techniques, and how they are utilized to improve the robustness of the model results to provide extra policy insights. In the end, we provide a critical appraisal on the use of these methods while Sinha and Chandel [14], focused their reviews on the optimization techniques of standalone hybrid renewable energy systems by reviewing of sixteen types of optimization techniques.

Lopion *et al.*, [15] looked at the customization of climate goals into techno economic models to be in line with Paris Agreement. In their reviews, they looked at the trends, challenges and future requirements in energy system models based on their methodology, analytical approach, time horizon and transformation path analysis, spatial and temporal resolution, licensing and modeling language for the purposes of aiding researchers and decision makers find appropriate energy system models.

Further studies on the capabilities of standalone tools like EFOM, MARKAL, MOREHyS (Based on BALMOREL tool), Invert and UREM were discussed by Cormio *et al.*, [16], Reza *et al.*, [17] , Almansoori and Betancourt-torcat, [18]/Robu and Bikova, [19], respectively. These studies looked at the strengths individual tools without looking at the weaknesses of these tools.

EXTERNALITIES RELATED TO UTILITY SCALE SOLAR ENERGY

Land use impacts

CSTP and solar PV need large tracks of land for installation and no reclamation can be done until the plant is decommissioned. The term land use has three meanings [20]. First, it means the physical nature of land being that will be affected by the installation of the project. The physical nature refers to the condition of the ground and the earth surface. The second meaning is a quantitative one and means the total area of land occupied by the installation. The third meaning refers to the alternative use of this land apart from solar installation. The impacts of solar plants on land depends on the topography of the landscape, area covered, type of land e.g.(cropland, forests etc.), distance from the areas of archaeological sites, types of sensitive ecosystems in that land and the biodiversity [21]. The size of land occupied by solar power plants also depends on the technology, topography of the site and the intensity of the solar resource availability. There are two ways to quantify the area impacted by solar energy technologies. The first is the total area which corresponds to all land enclosed by the site boundary which is characterized by fencing. The second one is the area directly occupied by access roads, solar arrays, substations, service buildings and other infrastructure. The direct impact area is contained within the total area boundaries [22].

The size of land occupied by PV or CSTP depends on the direct normal irradiation (DNI) in a given region. The ratio of the amount of energy generated to the size of land occupied is known as land use efficiency. On average utility scale solar energy has a land efficiency of $35W.m^{-2}$. Machinda et.al [23] in their study discussed CSTP as inefficient in terms of land usage in the sense that to achieve high electricity generation from them, more land is needed for more reflectors. The intensity of the solar radiation on the receivers is proportional to the number of concentrators used and therefore the more the concentrators the high he intensity and hence the electrical energy. Mathematical expressions for relating the solar efficiency and land use factor are described by equations (8), (9) and (10) respectively [23].

$$\boldsymbol{Solar\ electricity\ efficiency\ (SEE)} = \frac{\boldsymbol{Annual\ Net\ power\ generation}}{\boldsymbol{Annual\ DNI\ on\ Aperture}} \tag{8}$$

$$\boldsymbol{Land\ use\ factor(LUF)} = \frac{\boldsymbol{Aperture\ area\ of\ reflectors}}{\boldsymbol{total\ land\ required\ (m^2)}} \tag{9}$$

$$\boldsymbol{Land\ use\ efficiency\ (LUE) = SEE * LUF} \tag{10}$$

In Spain for example, the 50MW, 7.5-hour parabolic trough CSTP plant known as Andasol 1 occupies a direct area of $510{,}120m^2$ and a total area of 200ha. The 64MW Nevada Solar 1 plant in Mojave Desert in California, USA occupies a total area 400 ha of land. Plans are also underway to install a 100MW CSTP plant in a site near Uppington, South Africa which receives an annual DNI of approximately $2995kWh/m^2/year$ [24][23][25]. This plant will have an estimate of 4000-5000 heliostat mirrors, each heliostat occupying $140m^2$. This implies that the plant will occupy approximately 172 acres of land. According to a report [26], the monetary value of such cultivatable lands in South Africa is $667/ha/year, and therefore using it for electricity generation attracts a revenue loss of $114,724/ha/yr. It is noted that utility scale PV plants occupy approximately 3.5-10 acres per MW while that of utility scale CSTP ranges between 4-16.5 acres per MW [21, 27]. In the endeavor to promote solar PV, US has put aside 285,000 acres of public land for the solar projects. A summary of land use requirements for PV and CSTP projects in the United States is shown in Table 1 below.

The land cover change as a result of occupation of land for a number of years for installing and operating solar power plants is now raising concerns over land occupancy, damage to vegetation and soil and adverse impacts on ecosystem and biodiversity more than the concern over GHG emission. It has been seen that the application of solar technologies to cultivatable land or lands that can be irrigated causes soil infertility and potential food insecurity. It is estimated that in the US 97000ha of land have pending leases for the development of utility scale solar energy in which majority of this land is occupied by shrub-lands ecosystems. There are also some wetlands and glass lands that have been approved for the same purpose [28-29].

Hernandez et al. [30] report that there are over 20MW of utility scale solar power plants that are in operation, occupying 86000ha of agricultural and arid lands in California, USA. In California 28% of the utility scale solar energy systems are located on crop land and pastures and only 15% of the total installations are located in compatible areas [31]. Globally the monetary value of cropland and pastures is about $752/ha/yr while the total economic value of arid areas is $258/ha/yr [32]. Therefore, the total revenue lost as a result of installing a CSTP plant in a 86000 ha of crop land and arid areas would result in a lost value of $64.672 million and $22.118 respectively[31].In the South West United States [33], large areas of public land are reported to be on evaluation stage or have been permitted for utility scale solar energy development schemes including areas with high biodiversity and protected species of animals and plants.

Table -1 Summary of Land Use Requirements for PV and CSTP in the United States [22]

Technology	Direct Area		Total Area	
	Capacity-weighted average land use (acres/MW)	Generation weighted average land use Acres/GWh/yr	Capacity-weighted average land use (acres/MW)	Generation weighted average land use Acres/GWh/yr
Small PV(>1MW,<20MW)	5.9	3.1	8.3	4.1
Fixed	5.5	3.2	7.6	4.4
1-axis	6.3	2.9	8.7	3.8
2-axix flat panel	9.4	4.1	43	5.5
2-axix CPV	6.9	2.3	9.1	3.1
Large PV(>20MW)	7.2	3.1	7.9	3.4
Fixed	5.8	2.8	7.5	3.7
1-axix	9	3.5	8.3	3.3
2-axix CPV	6.1	2	8.1	2.8
CSTP	7.7	2.7	10	3.5
Parabolic Trough	6.2	2.5	9.5	3.9
Tower	8.9	2.8	10	3.2
Dish Sterling	2.8	1.5	10	5.3
Linear Fresnel	2	1.7	4.7	4

This has mainly been driven by the increasing costs and demand for the fossil generated energy and also the concerns about emission of the GHG gases.

The Deserts in South West which include Mojave and Sororan which are hosts to some potentially endangered species of animals and plants which are under stress already due to human encroachment and climatic changes. In this study the reported potential impacts include destruction and modification of wildlife habitat, direct mortality of wildlife, landscape destruction, water consumption effects by CSTP plants and pollution effects from spills [33]. Globally the USSE installations and the land cover type are as shown in Table 2 below.

Table -2 USSE installations and Land cover type [31]

Land cover type	Name Plate capacity (MW)		Area, kM	
	PV	CSP	PV	CSTP
Barren land	2102	1000	77	34
Cultivated land	3823	280	110	8
Developed areas	2039	50	70	1
Herbaceous Wetlands	60	0	1	0
Shrubland/ scrubland	6251	744	343	32

Impacts of ecosystems Goods and services

It is reported that the 10MW Solar 1 CSTP plant in Mojave Desert killed 70 birds for a period of 40 weeks which equates to a mortality rate of 1.9-2.2 birds per week [28]. The major cause of death of the birds (81%) was attributed to collision with the CSTP infrastructure while the rest (19%) died as a result of burning when the heliostats were oriented towards their eyes which impaired their visual ability. Additionally, there are changes in land surface temperatures as a result of their installations and thus killing some insects, birds, burrowing animals, and other sensitive plants which thrives in areas they are installed. Some of these plants have medicinal values [33].

The solar tower type of CSTP are seen to have the potential of concentrating light to high intensities that could impair the eyesight of wild animals and the birds. Other adverse impacts hazards from toxicants in the coolant fluids, soil erosion and compaction, destruction of habitats of some wild animals such as (antelopes, giraffes, zebras, lions, leopards etc.) [28, 31, 34, 35]. The fragmentation of habitats of both animals and birds can lead to low turnover in revenues collected from tourism.

Large scale solar power at their inception are reported to be more hazardous emitting greenhouse gases and respective environmental degradation than does a nuclear plant and other fossil energy generating systems [34]. The green gas emissions are 40-55 grams per Kilo watt of generation capacity for the standard silicon panels and 25-32 grams for the thin mirrored solar panel types [36].

Health Impacts of Renewable Energy Technologies

In each day across the world, chemicals of different toxic levels and varying human damage effects are released to the environment. The carcinogenic and non -carcinogenic (human toxicity), respiratory effects (organic and inorganic substances), ozone layer depletion and radiation ionization are contributory factors to the human health damage [37, 38]. The toxicity can be expressed in terms of Disability Adjusted Life Years (DALY per kg emission). Table 4 shows the characterization factors damage factors of different substances on the human health.

Table -3 Reference Damage factors for Human Health [37]

Category	**Damage factor**	**Units**
Carcinogens	1.45E-06	DALY/kg chloroethlyne
Non-carcinogens	1.45E-06	DALY/kg chloroethlyne
Respiratory inorganics	7.00E-06	DALY/kg PM 2.5
Ozone layer	1.05E-03	DALY/kg CFC-11
Respiratory Organics	2.13E-06	DALY/kg ethylyne
Radiation	2.10E-10	DALY/Bq carbon-14

The amount of toxic substances entering the human body, normally referred as the intake fraction, IF, is the incremental intake from a source such as power plants, refineries etc and summed over all individuals exposed for in a given time, per unit of emission as described by equation (11).

$$IF = \frac{mass\ \text{int}\, ake\ of\ \ pollu\ \tan t\, i\ by\ an\ individual}{mass\ released\ to\ environment} \quad (11)$$

The intake fraction is therefore the amount of pollutant that is absorbed by the target, for this case, human beings through inhalation, ingestion and dermal exposure. The following section discusses ways into which the health impacts emanating from energy generating sources can be accounted for.

Disability Adjusted Life Years

Crettaz et al [39], Goedkoop et al 2016 [40] and Goedkoop et al 2009 [41] described the disease burdens on human populations. A line was drawn between the mortality and morbidity was made in terms of Years of Life Lost (YLL) and Years of Life Disabled (YLD) as shown in Equation () below.

$$DALY = YLL + YLD \quad (12)$$

Crettaz et al discussed the DALY of cancer in the different parts of the human body as shown in Table 5 below using the world data.

Table -4 Disability Adjusted Life Years for Various types of Tumours in affecting the Human body across the World [39]

Type of cancer	**Disability**			**Death**			**Disability +Death**
	w	**D**	**YLD=w.D**	**L**	**N**	**YLL=L/N**	**DALY=YLL+YLD**
Mouth and oropharnyx	0.145	4.3	0.62	$3.2x10^6$	$1.1x10^6$	2.9	3.5
Oesophagus	0.217	1.7	0.37	$3.4x10^6$	$3.8x10^5$	8.9	9.3
Stomach	0.217	2.9	0.63	$7.0x10^6$	$1.1x10^6$	6.5	7.2
Colon and rectum	0.217	3.7	0.8	$3.9x10^6$	$9.9x10^5$	3.9	4.7
Liver	0.239	1.6	0.38	$6.3x10^6$	$5.4x10^5$	11.6	12
Pancreas	0.301	1.2	0.37	$1.5x10^6$	$1.9x10^5$	7.9	8.3
Trachea	0.146	1.8	0.26	$8.3x10^6$	$1.1x10^6$	7.9	8.2
Melanoma	0.045	4.2	0.19	$5.1x10^5$	$1.7x10^5$	3.1	3.2
Breast	0.069	4.2	0.29	$3.8x10^6$	$1.1x10^6$	3.6	3.9
Cervix uteli	0.066	3.8	0.25	$2.7x10^6$	$4.5x10^5$	6	6.2
Corpus uteri	0.066	4.5	0.3	$5.8x10^5$	$3.1x10^5$	1.9	2.2
Ovary	0.081	3.4	0.28	$1.3x10^6$	$2.0x10^5$	6.4	6.7
Prostrate	0.113	4.2	0.47	$1.1x10^6$	$6.8x10^5$	1.6	2.1
Bladder	0.085	4.2	0.36	$9.8x10^5$	$4.6x10^5$	2.1	2.5
Leukemia	0.112	3.1	0.35	$4.4x10^6$	$3.1x10^5$	14.3	14.6

Also

$$YLD = w * D \quad (13)$$

Where w is the severity factor of the disability/ disability weight which ranges between 0 for complete health and 1 for dead. D is the duration of the disease/disability.

YLL for an individual can not be predicted but assumed to conform to the reference population[27, 42]. Accordingly YLL is defined as shown in Equation (14).

$$YLL\ (c,a,s) = N(c,a,s) * L(a,s) \quad (14)$$

Where L is the standard loss function in (years) for age a and sex s

$N(c,a,s)$ is the total number of deaths (incidences) due to cause c for given age a and sex s

$YLL\ (c,a,s)$ is the years of life lost per affected person in a population (years/ incidence)

CONCLUSIONS AND RECOMMENDATIONS

Arising from the reviews, it can be concluded that Energy modeling suites are designed with different end uses, research problems in mind and they are diverse in terms of their structure, operation, and applications. Though the objectives of these tools vary, they are all used in one way or the other in the energy sector to model, simulate and optimize power systems to accommodate the fluctuations of renewable energy, or to provide a long-term report for 100% renewable energy system. It has also been noted from the reviews that there is no tool that integrates the impacts of environmental effects in LCOE costing. It has also been documented that there are health impacts arising from renewable energy technologies and not taken care of in the already existing techno-economic modelling tools. R& D should therefore be geared towards re-modeling the LCOE in order to address these challenges by incorporating the externalities for the purposes of upgrading energy modeling, simulation and optimization suite with enhanced LCOE calculations.

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