17th International Conference on Renewable Energies and Power Quality (ICREPQ'19)
Tenerife (Spain), 10th to 12th April, 2019
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.17 July 2019

Global Solar Energy availability model and use in relationship to Ecological Human imprint: Economic Sustainability Impact and Assessment

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ABSTRACT

The present study is to assess the solar-energy extraction from the global Earth land, the continuation demands and the availability use in relation to human population growth in the world through the modeling of different scenarios. For the last few years, global energy becomes the most important commodity for the continuation the life on this Earth. This is due to the decreasing the non-renewable resources such as oil. According to our model, the human population growth in the world will be between 9.5 to 11.00 billion people living on this earth by year 2050 at the current trend of human population growth rate, and we may be facing with shortening of availability of energy. It is important to stress that the energy should be replenished through non-tradition energy supply, but we have to concentrate on the renewable energy, which we can develop to the extent of harvesting this energy in efficient ways. An example for the needs of energy from the land is to calculate how much the Earth can be supporting the human beings. For this regard, if each human being is required to live daily is in need for 2000 calories/per day on an average from the food. This means that the global Earth size has to produce about 15000 billion calories/day and 5475000 billion calories per year as the current estimate of human population of the earth (i.e. 7.5 billion people in year 2017). The question is the Earth can produce these calories to support 7.5 billion people, and we need more calories when the human population grows to be more than 9.5 billion people in the year 2050 in this Earth. This is only for the food that we are consuming and what about another required energy necessity for our continuation of life for production of other commodities that we are in need such as energy for fulling our cars, trucks and other factories. Therefore, solar engineering harvesting from the Earth should be important, and we have to think how we accomplish it. Additionally, we need to sustain our environment by conserving our water resources, and keeping our global climate environmentally in best condition to sustain the land economic and social standards. Further, in this paper, we are discussing the impacts of changing different parameters that affect global energy in this Earth, and what are the useful lessons that we can learn from it. Furthermore, we assess the availability of solar-energy and how to harvest and economic aspects of it. This will lead to sustainability of non-renewable resources such as oil.

Keywords

Global Solar Energy, Ecological Human Imprint (E_{HI}), Modeling Scenarios of Solar Energy, Earth-Sustainability-Human Population.

Introduction

Considering the aims of sustainable development, renewable-energy wins over fossil or nuclear energy sources in regard to the limitations of resources and the negative impacts on environmental factors in sustainable cities (Shukla, Sudhakara, & Prashant, 2017; Shukla, Manish,& Barve, 2017).

World population is reaching 7.7 billion people [1] (http://www.worldometers.info/world-population/ Accessed on December 30, 2018).

Solar power "rose to record prominence" in 2017, according to the Global Trends in Renewable Energy Investment report released Thursday by United Nations Environment, the Frankfurt School-UNEP Collaborating Centre, and Bloomberg New Energy Finance. While adoption of renewable energy grew overall—and skyrocketed in China—investment from big markets like the US, the United Kingdom, and Germany dropped off.

In 2017, the world installed an unprecedented amount of solar-energy technology—98 gigawatts—more than the net addition of all coal, gas, and nuclear power plants combined. Solar power also attracted far more dollars than any other type of energy—$160.8 billion, up 18 percent from the year before. Investment in new coal and gas projects generated about $103 billion [2] (https://www.motherjones.com/environment/2018/04/solar-energy-set-a-global-record-last-year-mostly-thanks-to-china/ Accessed on December 30, 2018).

Solar-energy is very important source of energy because it comes directly from the Sun. However, the harness this energy is the most useful technology to get benefit from this source of abundant energy. Solar-energy in 2011 has produced less than one tenth of one percent of global energy demand (National Geographic (https://www.nationalgeographic.com/environment/global-warming/solar-power/ accessed on January 1, 2019) [3]. With an average level of solar radiation between 2,000 to 3,200 kWh per square meter a year in some countries such as Egypt has significant potential for solar energy. To date, however, uptake of solar projects has been slow because of high capital costs, but Egypt has recently moved to expand its solar capacity (http://www.solargcc.com/egypt-solar/ Accessed on January 1, 2019) [4].

The world now uses energy at a rate of approximately 4.1 × 1020 joules/yr, equivalent to a continuous power consumption of 13 trillion watts, or 13 terawatts (TW). Even with aggressive conservation and energy efficiency measures, an increase of the Earth's population to 9 billion people, accompanied by rapid technology development and economic growth world-wide, is projected to produce more than double the demand for energy (to 30 TW) by 2050, and more than triple the demand (to 46 TW) by the end of the century. The reserves of fossil fuels that currently power society will fall short of this demand over the long term, and their continued use produces harmful side effects such as pollution that threatens human health and greenhouse gases associated with climate change. Alternative renewable fuels are at present far from competitive with fossil fuels in cost and production capacity. Without viable options for supplying double or triple today's energy use, the world's economic, technological, and political horizons will be severely limited (Solar-energy science workshop -workshop 2005)[5].

The present paper is discussing the following points: 1) the status of using solar-energy in world; 2) Solar-energy availability model and use in relationship to Ecological Human imprint globally; and 3) the economic sustainability impact and assessment globally related to use of solar-energy.

Material and Methods

Solar-energy data were collected from different sources and organization in the world. These organization are: 1) Enerdata Energy Statistical Yearbook, 2018[6], 2) Units of solar-energy as cited in American Physics Society (ABS) https://www.aps.org/policy/reports/popa-reports/energy/ units.cfm [7], 3) US Department of Energy, 4) World Bank Data information[8], 5) United Nation FAO[9a&9b], and 6) Union of Concerned Scientists https://www.ucsusa.org/clean-energy/renewable-energy/how-solar-panels-work#. W7F QsmhKhPZ [10]. Further, data set of series available on the websites of World Research Institute (WRI) -Earth-Trends [11], United Nation Environmental Program (UNEP)[12], United Nation Development Program (UNDP)[13], World Wildlife Fund (WWF)[14], Global Footprint Network[15], and World Bank [8].

The data were analyzed using the regression, Correlation and statistical methodologies using Sigma Plot Software[1] Version 8 [16]), STELLA software [[17]]. Additionally, the Solar-energy the Ecological Human Index (E_{HI}) can be calculated as an index of human impacts on the solar-energy consumption, demands and the availability of solar-energy resources globally. The Ecological Human of solar-energy, the construction of the model of Ecological Human Imprint (E_{HI}) and solar-energy globally has been developed using Stella Software Version 10.06. The model developed to predict the solar condition globally and what are the predictions of solar-energy globally for the next century.

Accordingly, Krenz[18] had estimated that reflectivity and emissivity constants are averaged to the values that depend on the cloud coverage and atmospheric composition at 227 Watts/ m^2 of the Earth. However; Rancourt [[19&20]] found out that the global mean surface emission intensity is between 269 Watts/m^2, and 341.5 Watts /m^2. From the conversions of the Earth Watts of energy per m^2 to calories, the Earth will receive and emit in the range of 26.1- 28.0 million trillion (i.e. Quintillion) calories annually. This will be translated to the availability of energy in calories for each person on this Earth is 8.49 billion calories / capita in year 1961 and it reached to 3.91 billion calories in year 2008 as calculated by the author. This is an indication of lower the per capita share in the global calories that can be produced by the Sun sources of energy as the main source of energy in this Earth as the result of the increasing human population in an alarming rate. However, this type of energy is not usable by human beings. In this respect, the most important part of this energy is that one absorbed

[1] www.spssscience.com/sigmaplot version 8 2002

and converted to fossil fuel or converted to useful available energy to flow in the ecosystems or in the ecosphere and recycled between its components and not the lost heat energy. It is estimated that the energy used to form the Net Primary Production (NPP), which is the main source of energy transformed, is about less than 1% of the Sun energy. Furthermore, the solar-energy, we should harvest this energy through different technologies and make storage of this energy to be available to other uses.

Construction of Ecological Human Imprint-Solar-energy Globally (E_{HI}-SEG) Model

Description of the Model

Ecological Human Imprint-Solar-energy Globally (E_{HI}-SEG) has been designed to predict the solar-energy availability globally and use for the human population in globally. This model has been written using STELLA [17] modelling software package version 8.0. (EHI-SEG) predicts the status condition of the solar-energy globally and predicts the needs for energy from year 2000 to year 2100 for almost one hundred years to come according to different scenarios. These scenarios are: 1) The relaxed estimates are considering the global net human population which is increasing annually at 1.13 rates annually; 2) Moderate estimates are considering the global net human population is increasing at 0.85 % increase annually; and 3) On the very conservative estimates that the global net human population is increasing at 0.50% annually and this conservative estimate is due to the natural condition of resources availability. Further, the model has been developed according the use of energy and solar-energy and its pathways through the global ecosystems of the Earth and calculated in global meter square. Further, global human population were about 3068.4 million in year 1960, and will reach 7632.8 million people in year 2018. The Global population trend is increasing by about 1.1% annually in average. However, the different estimates as pointed out in this paper are due to the calculations from different formulas such as regression analysis. In this respect, there is some considerable uncertainty and these are related to: 1) The fertility of human population in different regions of the Globally, 2) The level of education, 3) The political systems, 4) Social and economic developments ideologies concepts including the people wealth's, and 5) The technological advances including medical that allows the increasing life expectancy.

The model used annually time step with the fourth order Runge–Kutta integration method STELLA [11] Modelling System. The simulation period could be from one year to several years and could be used for a short time period of stimulation. Background data and literature parameters were used to initialize the model and a short-term data collected from different sources and data sets of series available on the websites of World Research Institute (WRI) -Earth-Trends , World Bank, Food and Agricultural Organization (FAO)[8], US Energy Information Administration, 2018)[21], International Energy Agency (IEA, 2010)[22]. United Nation Development Program (UNDP)[11], World Wildlife Fund (WWF) and Global Footprint Network.

Results and Discussion

Global solar-energy is very important to reduce the impacts of using fossil fuel and the recent Paris Agreement on climate change provided the significant insights on the governments' intentions to reduce greenhouse gases (GHG) emissions. This is through inclusion in the agreement of nationally determined contributions (NDCs). This only will happen through the adoption of policies to NDC. This will impact in the reduction of supplies and use of energy across the societies. The only way to meet the demands is to use solar-energy which is the clean energy.

To support economic progress and make substantial progress on the climate goals identified in the Paris Acord, the policies should be transparent that weigh the cost and benefits without impacting climate change, while enabling the societies to look for other priorities such as water resources, better and clean energy and better progress for clean energy and economic progress for all the people. This will be achieved through the technological advances in green and clean energy use and conversion and storage of solar-energy to useful energy.

Survey and Use of Solar-energy Globally

The entire earth receives 164 Watts per square meter over 24 hour/day. Therefore; the entire planet will receive 84 Terra-Watts of power. This will be the solution for the increasing demands for energy -as human population increased annually- which is calculated at 12 Terra-Watts at the current worldwide consumption for energy (zebu. uoregon. edu/ disted/ ph162/l4.html Accessed January 3, 2019 [23]). The use of solar-energy can be presented in the Figures 1&2&3. In this figure the extraction of solar-energy and conversion of energy by **Photovoltaics** cells to electricity.

The solar-energy globally is measured by energy intensity which it is defined as a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP. The relationship between global human population and solar-energy intensity can be represented in (Figure 4). This graph shows that the efficiency uses of global energy. This means with increasing human population; the technologies have improved the efficiency of using global energy. However global solar-energy will lead to more efficiency of energy as we use the solar-energy (Figures 5& 6).

Accordingly, the solar-energy will play significant important role in the human development specially for energy intensity when the technological advances support the efficiency of use of solar-energy which it is plenty of resources that the world can use and can support the existence of human beings. (Figure 7).

The importance of solar-energy is considered to be the best option for the people and the industrial technologies. This is because the renewable energy can reduce the use of fossil fuels. The increase of the disappearance of the fossil fuels from the planet and their rising costs has forced countries to switch over to a sustainable energy source.

Major scientists in the field of solar energy indicated that in order to produce 10 TW energy using fossil fuels without affecting the environment, we need to find secure storage for 25 billion metric tons of CO_2 produced annually will be equal to the volume of 12500 km^3 or the volume of Lake Superior! [24]. However other scientists {25&26&27&28] indicated the magnitude of using fossil fuel in production of energy.

Figure 1 . The relationship between global solar energy and human Sustainability

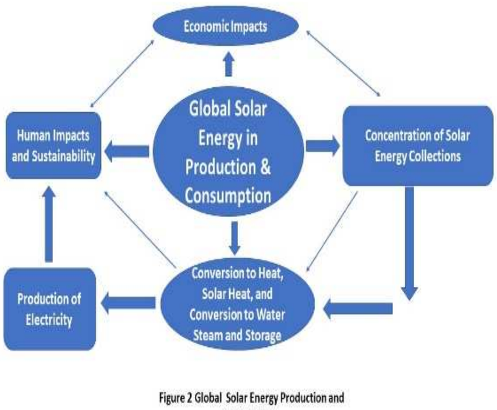

Figure 2 Global Solar Energy Production and Consumption

Model Formulas and the Scenarios

The data analyses that have been collected about global solar-energy indicated that the solar-energy extracted from one-meter square of the Earth can show the following results (Figures 4-13).

1) The relationship between world population in million and world energy intensity as Y= 0.32-0.00002 X r^2=0.99 (Figure 4).

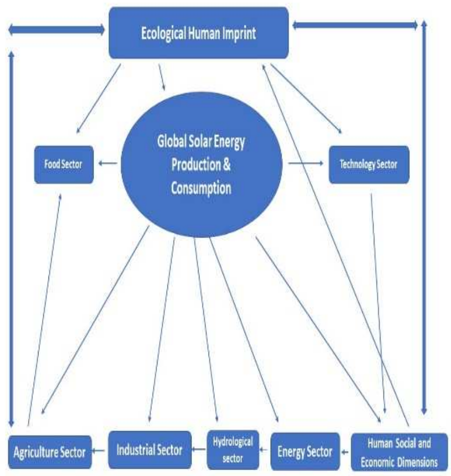

Figure (3) Impact of Ecological Human Imprint in Relationship with Solar Energy and Other Sectors Globally

2) The relationship between per capita global solar-energy and global solar intensity as Y=-0.02+ 0.00000004 X r^2 = 0.99 (Figure 5).
3) The relationship between energy intensity and total GDP in current trillion US$ where Y= 204.18-1077.57X r^2 =0.91 (Figure 6).
4) Th relationship between world human population in million people and GDP per capita in US$ where Y= -8302 +2.4 X r^2 0.95 (Figure 7)
5) The relationship between per capita GDP n US$ and solar-energy in megawatt per year where Y=8253.02 – 0.46X r^2=0.82 (Figure 8).
6) The relationship between per capita megawatt solar-energy extracted from square meter / year and global GDP in trillion US$ where Y=105.68 -0.013X r^2 0.74. (Figure 9)
7) The relationship between global human population and megawatt per capita availability from solar-energy when the Earth square meter of surface land receives solar is equal to 0.164 kW/m^2 per day where Y= 12731.77 - 1.24X r^2=0.95 (Figure 10).
8) The relationship between world human population and per capita world solar-energy produced from Earth surface in billion tones oil equivalence (Btoe) where Y=54098.90 – 5.26 r^2= 0.96 (Figure 11).
9) The relationship between total energy production in million tons equivalence in oil and solar-energy megawatt per year extracted from Earth surface where Y=7794.77-0.27X r^2=0.96 (Figure 12).

10) The relationship between global total energy production in million tons of oil equivalence (Mtoe) and world human population where Y= -6117.74 +2.68X r^2=0.98 (Figures 13).
11) The relationship between global total energy consumption in million tons of oil equivalence (Mtoe) and world human population where Y= -6139.85 +2.68 r ² = 0.98 (Figure 14).
12) The relationship between global GDP per capita and per capita megawatt as 0.164 kw/day that extracted from the Earth from one square meter solar-energy where Y=3012352.091-169.52 X r ²0.82 (Figure 15).

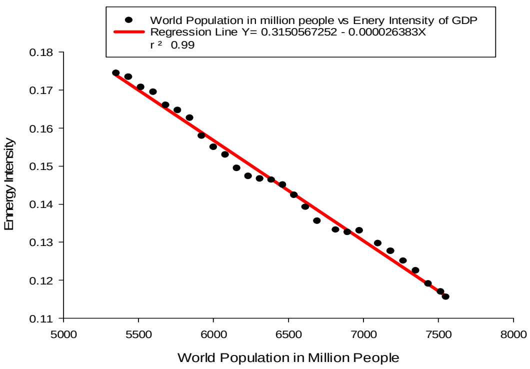

Figure 4 Relationship between world population in millon and world energy intensity (data since year 1990)

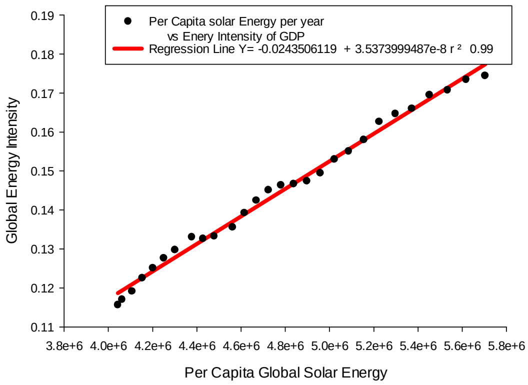

Figure 5. Relationship between per capita global solar energy and global energy intensity

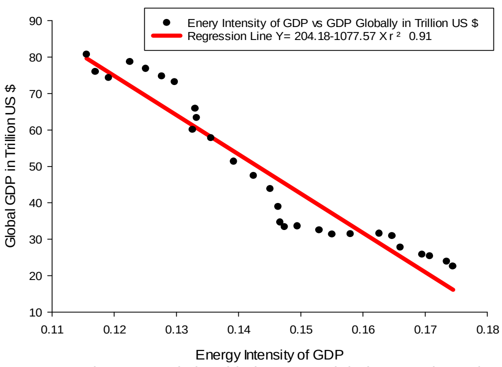

Figure 6. Relationship between global energy intensity and global growth domestic product (GDP) (data since 1990)

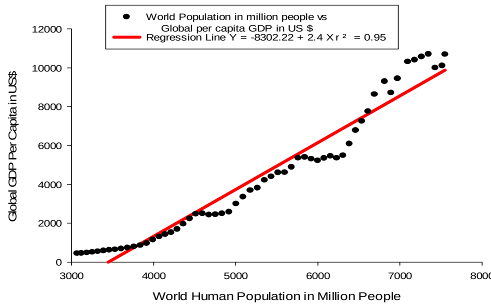

Figure 7 Relationship between global human population in million and GDP Per capita in US$ (Data since year 1960)

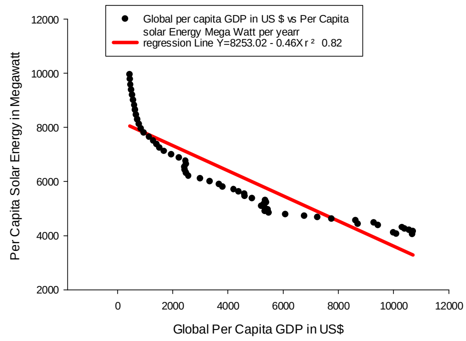

Figure 8 Relationship between per capita GDP in US$ and solar energy in megawatt per year

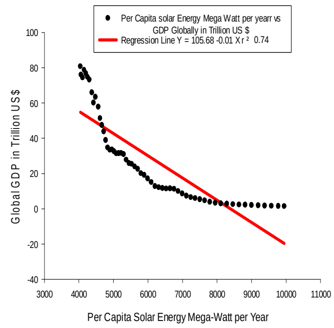

Figure 9 Relationship between per capita megawatt solar energy extracted from square meter / year and global GDP in trillion US$ (Data Since Year 1960)

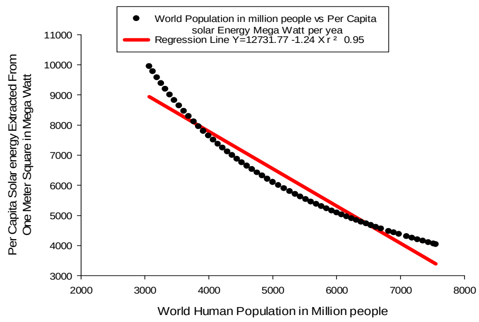

Figure 10 Relationship between per capita solar energy per year extracted from Earth surface land and world population in million people (data since year 1960)

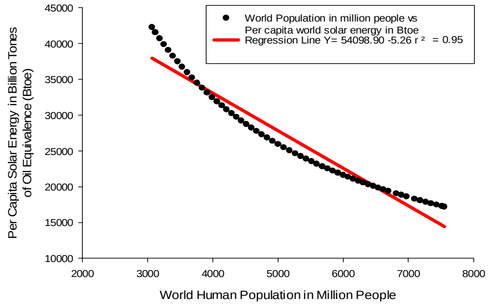

Figure 11 Relationship between world population and per capita world solar energy produced from Earth surface in billion tones of oil equivalence (Btoe) (Data Since 1990)

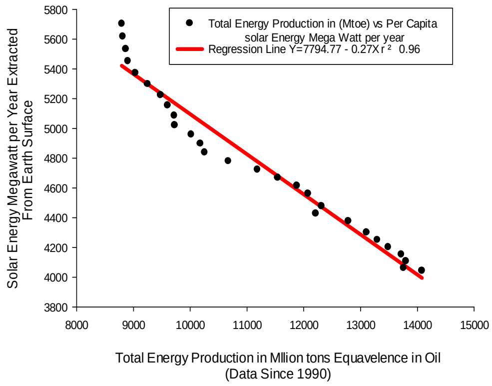

Figure 12 Relationship Between total energy production in million tons equivalence in oil and solar energy megawatt per year exatracted from Earth surface

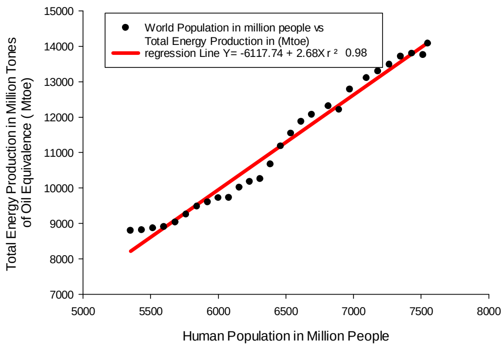

Figure 13 Relationship between global total energy production in million tones of oil equivalence (Mtoe) and world human population (Data since 1990)

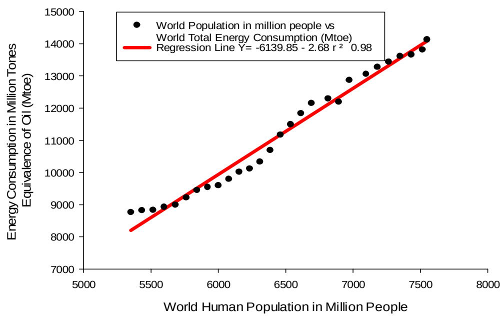

Figure 14 Relationship Between world human population in million and world total energy consumption in Mtoe

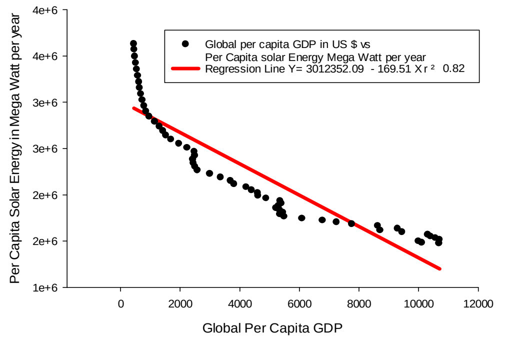

Figure 15 Relationship between global per capita GDP in US$ and Per Capita Solar Energy in Megawatt per year

Model Simulation and Analysis

The simulation model of global Ecological Human Imprint-Solar-energy (E_{HI}-SEG) indicated that with increasing human population, the growing demands for energy is increasing, then the solution is toward the explore the use of new energy sources. The solution is to invest in the extraction of solar-energy which it is in abundant in Earth coming from the Sun. However, Figure 3 shows that the per capita share from the solar-energy from one square meter of land is shrinking and declining on the assumption that one-meter square of the Earth land will receive solar-energy equivalent to 0.164 kw/day and to be 60 Kw per year from one square meter. Additionally, energy intensity (Figures 4 &5 & 6) is showing declining and this measure explains that the economy of the world is growing. The energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP. Many factors influence an economy's overall energy intensity. It may reflect requirements for general standards of living and the climatic change information. Further, as the global population increase the, GDP per capita increases (Figures 7 &8&9).

This can be interoperated as the increasing population the more people will be involving in the energy sector and this sector in the economy will increase the exploration and investments will be increasing. In consequence, the increasing the efficiency in this sector of economy for discovering the natural resources and using green technologies such as the solar-energy will lead to solve world economy problems. In consequence the trade balances in economy. In Figure 13 the trend in energy consumption is increasing and surpassing the energy production. This will lead to the more investment in energy sector especially in solar-energy.

Using Stella modeling system in prediction of status of solar energy production with all the parameters that involving in this research, we have developed several scenarios including the current human population growth rate between 0.5% and 1.13 % as representing the natural growth of human population in the word between the highly growth rate per year and the lowest growth rate as that what should be happening. These are presented in the Tables ( ) and Figures (16-18).

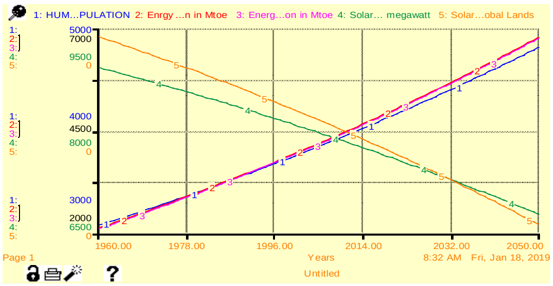

Figure 16 Output of simulation of E_{HI}-SEG) including 1) Human population; 2) energy production in Mtoe; 3) energy consumption in Mtoe; 4) Solar-energy production per capita; and 5) Solar-energy intensity from global lands on the bases of conservative assumption at the human growth of 0.5%

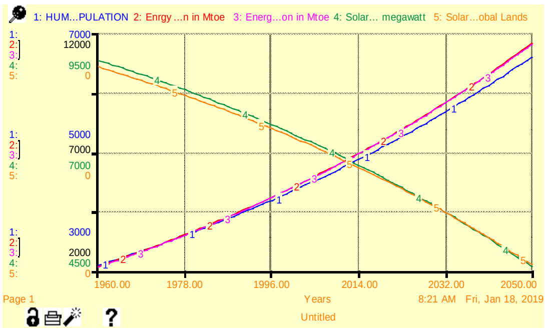

Figure 17 Output of simulation of E_{HI}-SEG) including 1) Human population; 2) energy production in Mtoe; 3) energy consumption in Mtoe; 4) Solar-energy production per capita; and 5) Solar-energy intensity from global lands on the bases of moderate assumption at the human growth of 0.85%

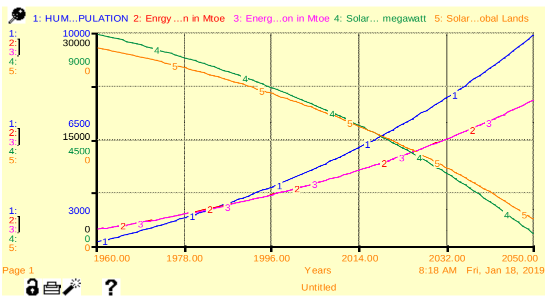

Figure 18 Output of simulation of E_{HI}-SEG) including 1) Human population; 2) energy production in Mtoe; 3) energy consumption in Mtoe; 4) Solar-energy production per capita; and 5) Solar-energy intensity from global lands on the bases of relaxed assumption at the human growth of 1.13%

The simulation analysis output from the presented from (E_{HI}-SEG) model showed that the main interaction in the model is between energy availability at any point in time and estimates of average global per capita consumption. According to the (E_{HI}-SEG), the human population is expected to reach 9.8 billion people by 2050 on the Earth at human growth rate at 1.1% (i.e. The Relaxed assumption), and might reach between 4.8 at the 0.5% human population growth rate (i.e. The optimum estimates or conservative estimates) and 6.6 billion people at the 0.85% human population growth rate (i.e. The moderate assumption).

The solar-energy that the Earth will be able to produce is about 3.052672262279200e+16 / KW per day from Earth surface. This huge energy per day could make the universe produce enough production of energy to cover the needs of the energy for generation to come on this Earth. However, the main problem for using the solar-energy is to have the technology for storage of this huge energy during the night when the sunset be in different places in the world. In this respect, the world should concentrate on the solar-energy because it is the most important source for energy for the whole world. Basically, the energy that we are using since the early ages is from sun radiation and it is transformed originally from the conversion of solar-energy by plants and forest to green vegetation and green vegetation died, their storage of energy in their mass is converted to oil over years. So the solar-energy from the sun is the most important source on this planet Earth.

According our model in spite of the per capita solar-energy converted to megawatt the Earth will provide sufficient megawatt per capita as predicted by model it will be sufficient for the humanity to continue do their activities on this Earth. For example the model predicted that the solar-energy produced from the surface of the Earth will be 474 megawatt in year 2050 on the relaxed assumption of human population growth stays on 1.13 % rate annually. However, at growth rate of human population at 0.50% the per capita is 6764 megawatt in year 2050.

The factors affecting conversion of solar-energy to usable energy are 1) Temperature solar cells generally work best at low temperatures, 2) Wavelength and energies. The sunlight that reaches the earth's surface has wavelengths from ultraviolet, through the visible range, to infrared; 3) A cell's efficiency can be increased by minimizing the amount of light reflected away from the cell's surface, 4) Recombination—One way for electric current to flow in a semiconductor is for a "charge carrier," such as a negatively-charged electron, to flow across the material. Another such charge carrier is known as a "hole," which represents the absence of an electron within the material and acts like a positive charge carrier.

The main conclusions of this paper are 1) the Earth can support humanity in life with the needed energy; 2) the universe has plenty of energy that can be use but the storage of the solar-energy is most important issue for useful energy for humanity; 3) the model predict the decreasing availability of energy per capita if the human population continue to increase unless we can solve the issue of storage of solar-energy as renewable energy.

Acknowledgments

The Authors are thankful to Prairie View A&M University and specially, Professor James Wilson, the Associate Vice President for Academic Affair for Faculty Development for funding the trip to Tenerife, Spain.

References

[1] http://www.worldometers.info/world-population/ Accessed on December 30, 2018).

[2] https://www. motherjones.com/ environment/ 2018/ 04/solar-energy-set-a-global-record-last-year-mostly-thanks-to-china/ Accessed on December 30, 2018.

[3] https://www.nationalgeographic.com/environment/ global -warming/ solar-power/ accessed on January 1, 2019).

[4] http://www.solargcc.com/ egypt-solar/ Accessed on January 1, 2019).

[5] Solar-energy science workshop -workshop 2005.

[6] https://www.aps.org/policy/reports/popa-reports/ energy/ units.cfm.

[7] World Bank (2011) Global Strategy To Improve Agricultural and Rural Statistics. Report No. 56719-GLB. 1818 H Street, NW Washington, DC 20433. 55 Pages.

[8] Enerdata Energy Statistical Yearbook 2018.

[9a] FAO, "The state of food insecurity in the world. Economic crises - impacts and lessons learnt," *United Nations Food and Agriculture Organization, Rome.*, 2009 a.

[9b] FAO.). *How to feed the world in 2050*, (2009b, accessed January 18, 2019.

[10] https://www.ucsusa.org/clean-energy/renewable-energy/ how-solar-panels-work#. W7F QsmhKhPZ

[11] WRI, 1960-2005 Series. EarthTrends Environmental Information, World Resource Institute(WRI). World Resource Institute:WRI http://Earthtrends.wri.org/.

[12] UNEP (2009). A Planet in Ecological Debt, Arendal Maps and Graphics Library: UNEP http://maps.grida. no/go/graphic/a-planet-in-ecological-debt.

[13] UNDP Human Development Data (1990-2017). http://hdr.undp.org/en/data.

[14] WWF (2012) Living Planet Report 2012. Biodiversity, biocapacity and better choices. Editor in chief: *Monique Grooten.*, Lead editors: *Rosamunde Almond and Richard McLellan.* Editorial team: *Nigel Dudley, Emma Duncan, Natasja Oerlemans and Sue Stolton.*

[15] Global Footprint Network (2008). Calculation methodology for the national footprint accounts. Edited by Ewing, B., A. Reed, Rizk, M.S., Galli, A., Wackernagel, M. and Kitzes, J., Global Footprint Network. , Oakland, CA 94607-3510, USA.

[16] SPSSSCIENC,"SigmaplotVersion8."www. spssscience. com/sigmaplot , 2002.

[17] B. Richmond., "STELLA An Introduction to System Thinking " High Performance Systems, Inc. The System Thinking Company. ISBN 0-9704921-1-1, 165 p., 2001.

[18] J. H. Krenz., "Energy conversion and utilization.," p. 359 pp., 1976.

[19] D. G. Rancourt, "Radiation physics constraints on global warming," p. 15, 2011.

[20] D. G. Rancourt, "Radiation physics constraints on global warming," p. 22, 2008.

[21] US Energy Information Administration

[22] https://www.iea.org/ 2010.

[23] University of Oregon (2019) zebu. uoregon. edu/ disted/ph162/l4.html.

[24] Kamat, P. V. 2007. Meeting the Clean Energy Demand: Nanostructure Architectures for Solar Energy Conversion. *J. Phys. Chem. C. 111*, 2834-2860.

[25] Kalogirou, S.A. 2014. Solar Energy Engineering Processes and Systems. Second Edition Academic Press is an Imprint of Elsevier 819pp.

[26] Kalogirou, S.A. 2014. Solar Energy Engineering Processes and Systems. Second Edition Academic Press is an Imprint of Elsevier 819pp.

[27] Mohandes, M., Rehman, S. and .Halawani, T.O. 1998. Estimation of global solar radiation using artificial neural networks. Renewable Energy, Vol 17: 179-184.

[28] Steffen, W., Grinevvald, J., Crutzen, P, and MeNeil, P. 2013. The Anthropocene: conceptual and historical perspectives. Phil. Trans. R. Soc. A (2011) 369, 842–867. doi:10.1098/rsta.2010.0327.

Table (1) Global Population, Energy Production, Energy Consumption, and Solar Energy per Capita fromYear 1961 to Year 2010 - Data are in 10 years intervals *

Year	Global Population in billion	Energy Production In 1000 Mtoe	Energy Consump-tion in 1000 Mtoe	Solar Energy per capita in 1000 megawatt
1961	3.08	2.21	2.19	8.88
1970	3.70	3.25	3.22	8.39
1980	4.44	4.56	4.52	7.80
1990	5.27	6.03	6.00	7.11
2000	6.10	7.71	7.69	6.33
2010	6.69	9.63	9.61	5.44

* Data Sources are World Bank- Entrade 2018 at the current growth rate 1.1% for Human population

Table (2) Global Population, Energy Production, Energy Consumption, and Solar Energy per Capita from Year 2020 to Year 2050 - Data are in 10 years intervals *

Year	Global Population in billion	Energy Production In 1000 Mtoe	Energy Consump-tion in 1000 Mtoe	Solar Energy per capita in 1000 megawatt
2020	6.78	12.05	12.03	4.32
2030	7.62	14.31	14.29	3.28
2040	8.68	17.14	17.12	1.97
2050	9.88	20.38	20.35	0.473

* Data Predicted by the Model at the current growth rate 1.1% for Human population