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Designing and Implementing Applied Rural Sustainable Development Model using Renewable Energies for the Purpose of Energy Saving in Iran

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ABSTRACT: In a glance, more than three billion people live in the rural areas of low and middle-income countries. In most cases, rural households have many unmet energy needs including cooking, lighting, heating, transportation, and telecommunication needs. Designing appropriate solutions to meet these needs requires an understanding of human, natural and engineered systems that drive village energy. The objective of this study is therefore to investigate energy demand patterns of households in rural communities and thereafter designing and Implementing Applied Rural Sustainable Development Model with the use of Renewable Energies in Iran.

Keywords: Iran, Conceptual Model, Regenerative energy, Rural, energy saving, renewable, Sustainable.

INTRODUCTION

In many parts of the world, lack of access to modern energy services continues to impede sustainable development. Recent assessments suggest that about 1.3 billion people still do not have access to electricity, and more than 2.6 billion people rely on traditional biomass for cooking and heating. Research accentuates that during 2013, people in remote and rural areas of the world (more than 47% of world population) have lived in the rural regions (Fig. 1). In order to improve access to electricity, modern cooking, heating and cooling along with installation and the use of distributed renewable energy technologies have significantly increased. This expansion was a direct consequence of improvements in affordability, inclusion of distributed energy in national energy policies, greater access to financing, increased knowledge about local resources, and more advanced technologies that can be tailored to meet customers' specific needs (Renewable global status report. 2014: 9).

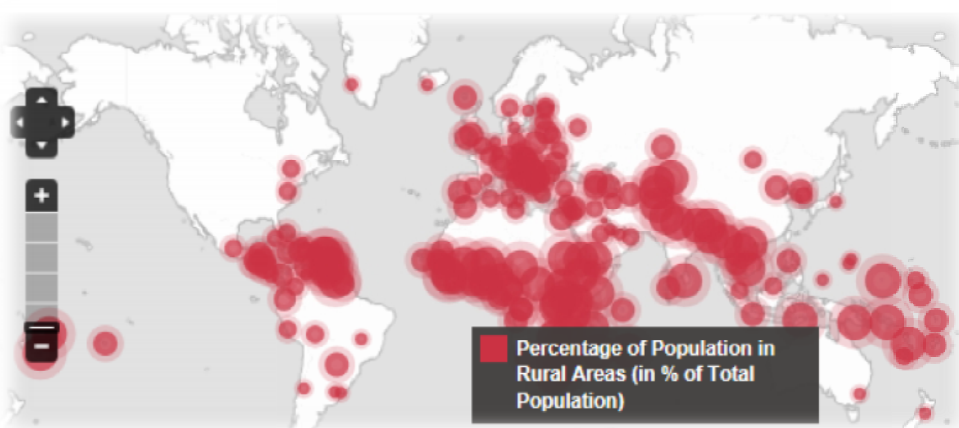


Fig. 1. Percentage of Population in Rural Area in the world.

Today, the energy of the world is mostly provided by different kinds of fossil fuels like coal, oil and natural gas (Hoeeini *et al*, 2013, Zhang *et al*, 2009). Around 66% of required electricity of the world is generated by fossil fuel utilization. For example, Iranian economy strongly relies on crude oil export and obviously oil price fluctuations significantly impact on country's development (Heshmatzadeh, 2000).

According to the most recent available data (as of early 2015), approximately 1 billion people, or 15% of the global population, still lack any access to an electricity grid. Approximately 2.9 billion people lack access to clean forms of cooking. As it is illustrated, the people live without electricity and clean cooking options are scattered around the world (Fig. 2 and 3). Unluckily, lack of electricity and clean cooking solutions still remains basically a rural issue. Confirming this fact is the presence of 941 millions in rural are as compared to 139 million inhabitants in urban areas, without any means of electricity. Similarly, there are 2.4 billion villagers in comparison with about 400 million citizens lacking clean cooking. Nonetheless, the raw numbers portray little about emerging trends. While figures look bleak, the situation of electrification is improving. Supporting this claim, it has been reported that from 1990 to 2012, the global electrification rate climbed from 75% to 85% (Fig. 2 and 3).

Regarding energy and its performance standards in developing and emerging economies, energy efficiency of cooking technology has become important and consequently several countries have begun to adopt related regulations and standards. For example, Iran implemented energy performance standards (EPS) for cook stoves and hobs/cooktops in 2013.Vietnam also adopted mandatory labeling and EPS for rice cookers in the same year. Other countries which are in the process of considering or developing similar instruments could be named as Bangladesh, Chile, Indonesia, and Mexico. Furthermore, several developing countries have programs for promotion of efficient cook stoves, including Burkina Faso, the Gambia, Ghana, Guinea, Mali, Niger, Senegal, and Togo (Renewable global status report. 2015: 27, Government of the People's Republic of Bangladesh. 2014, The Gambia from REN21, 2014, Khalili, 2015, Nigerian Ministry of Environment, 2013).

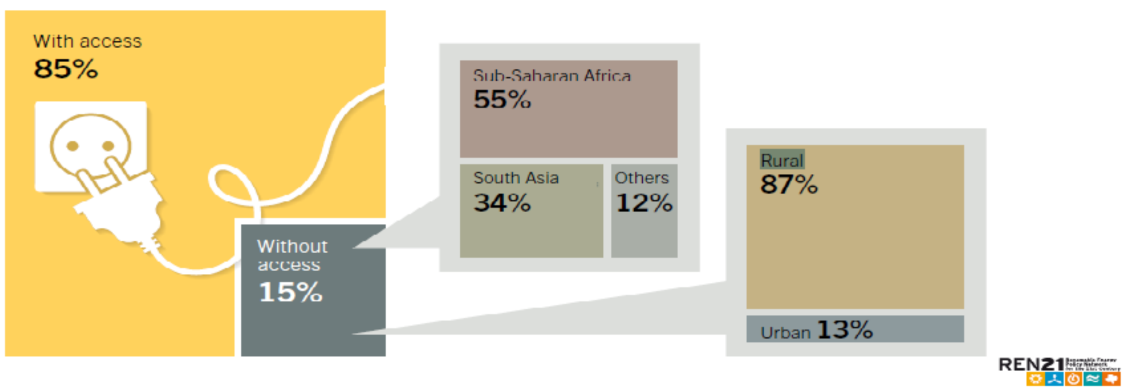


Fig. 2. World Electricity Access and Lack of Access report by Region, 2012.

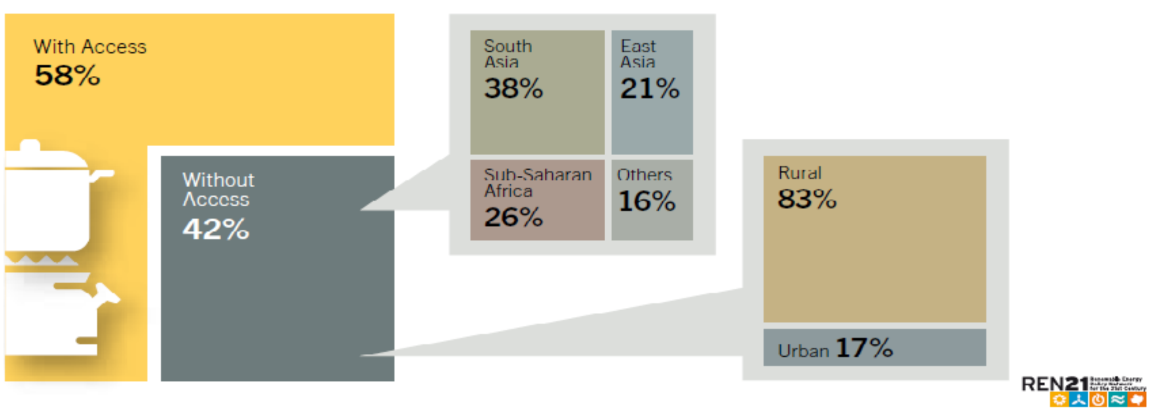


Fig. 3. World Clean Cooking Access and Lack of Access report by Region, 2012.

It is widely recognized that in terms of reducing poverty, improving human welfare and raising living standards, energy is linked in numerous ways to the achievement of virtually all millennium development goals. Furthermore, social and economic benefits of rural electrification have been researched for more than 30 years (Barnes, 2007). In traditional view, in rural development energy is perceived to have two distinguished usages: residential and productive. Productive uses are mainly presumed as motive power for agriculture-based industries and driveshaft power and lighting for other rural industries (Mustonen, 2010, Cabraal *et al*, 2005).

In previous decades, energy consumption per capita of villagers was very low and mostly for cooking and heating purposes (Zheng *et al*, 2010), and their energy requirements were supplied through traditional biomass fuels (Zheng *et al*, 2010 & Li and Hu, 2003). However, in recent years, biomass fuels' application has been decreasing with the ratio of 0.2% in 2006(Dai *et al*, 2015). In contrast, total primary energy consumption has increased mainly due to peasants' better living standards with a rapid growth of coal, natural gas, and electricity consumption (Dai *et al*, 2015).

Previous thinking about productive uses has been clearly updated with an enhanced understanding of the tremendous impact of energy services on education, health and gender equality. The reason is that improved health, education and social equality are the goals of human resource development and this does not happen unless the optimal use of energy by renewable sources is seriously taken into account (Mustonen, 2010).

Renewable energy technologies are on the one hand more and more being considered as a crucial element in countries' energy policies particularly meeting energy needs of villagers and remote communities. On the other hand, applying these energies is vital to help governments be able to materialize climate change mitigation and other policy objectives of future energy security (IEA, 2012).

Renewable energy employment has been growing in off-grid sectors. Solar home systems' installations in the country have been risen up to 3.8 million units as of early 2015.Consequently, new created employment possibilities has been expanded to an estimated of 115,000 jobs principally in sales, installations, and maintenance of these energies' instruments (Renewable global status report, 2015)

Over three billion people live in rural areas of low and middle income countries(World Bank, 2008).Rural households often have many unmet energy needs including cooking, lighting, heating, transportation, and telecommunication.

Rural households account for 85% of the1.4 billion people lacking access to electricity worldwide and 83% of the 2.7 billion people who rely on biomass fuels for cooking world wide (IEA, 2010). Because of this, rural energy development is a critical global need that can save time, improve health, and help to preserve the environment (Bond and Sun, 2005 & Sovacool and Drupady, 2011 & Johnson and Bryden, 2012).

With the rising awareness that off-grid, low-income customers can provide fast-growing markets for goods and services, and with the emergence of new business and financing models for serving them, rural energy markets are increasingly being recognized as offering potential business opportunities(Renewable global status report. 2014).

In studied village, a private enterprise is operating an off-grid hybrid power system to provide energy for adjacent community; nonetheless, if to have an optimal renewable energy combination in rural area; an optimal case is needed.

Iran possesses various substantial renewable energy resources (such as cultivation of energy generator plants on marginal lands and rural areas, animal and human waste, wind, solar as well as geothermal energy). All these energy resources could be beneficial in easing and addressing energy demands and also promoting environment and economy sustainable development.

Considering the availability of pre-requisites and suitable required environments for renewable energy use, this study provides estimates of renewable energy potential and a geographic analysis of rural renewable energy in order to design and implement an applied rural development model in terms of energy saving with the emphasis on renewable energies.

A. Sustainable energy development relying on the village

There is an urgent need to provide access to reliable and clean cooking energy for 2.8 billion and electricity for 1.2 billion people all over in the world (World Bank, 2013). Sustainable energy is defined as energy that is reliable, affordable, and accessible and that meets economic, socialand environmental needs within the overall developmental context of the society; but with equitable distribution in meeting those needs(Davidson, 2002 & ICSU, 2007). Providing sustainable energy has been apriority for governments throughout the world particularly since the UN Conference on Environment and Development held in Rio 1992, and the signature of the United Nations framework Convention on Climate Change (Carrera and Mack, 2010).

However, providing sustainable rural energy access remains one of the central political challenges form any developing countries (Mainali and Silveira, 2013).

Several studies have assessed energy sustainability using different sets of indicators and approaches (Mainali, 2012). Energy sustainability can be evaluated providing amore general sustainability indexthat could be used to inform policy makers, investors, and analysts from energy situation (Afgan *et al.*, 2005; Brown and Sovacool, 2007; Doukas *et al.*, 2012; Ediger *et al.*, 2007; WEC. World Energy Trilemma, 2012).

According to WEO (World Energy Outlook, 2012), International Energy Agency (IEA) has developed Energy Development Index (EDI)for 80 different countries to assist policymakers follow the progress made towards modern energy access provision. . However, this index only provides a snapshot at a country level and does not cover technical and environmental aspects of sustainability. The EDI analyzes data at the national level and comprises indicators related mainly to access to clean cooking fuels, and electricity at the household level and access to energy for community services and productive uses. The WEC (World Energy Dilemma, 2012) presents an energy sustainability index (ESI National) covering indicators related to energy equity, security and environmental sustainability at an aggregated national level. Information and assessments of rural energy sustainability are thus limited (Doukas *et.al.*, 2012).

There is typically a significant imbalance in socio-economic development between rural and urban areas. The majority of rural populations living in developing countries have insufficient access to energy in general. Thus, there is a need to analyze rural available energy separately, using indicators that can provide suitable insight into the sustainability of rural energy development (Mainali *et. al.*, 2014).

Considering negative effects of fossil fuels and conventional power generation systems on environment has necessitated application of renewable and sustainable energy systems for the next decade (Ahmadi *et.al.*, 2014).

Renewable energy technologies (RETs) can provide universal modern energy services which drive development and improve living conditions, particularly in rural communities. In addition, these modern and renewable sorts of energies can mitigate many of the impacts of traditional energy generation such as deforestation, unexpected climate change, and local air pollution (Ahmadi *et.al.*, 2014). Achieving universal modern energy access is a key objective in many developing countries in supporting economic and social development and this could be assumed as the real implication of their sustainable development (Gurung *et al*, 2011 from Ahmadi *et al*, 2014).

Unluckily, Iran is listed in a group of countries with the share of less than 0.5% renewable energy consumption percentage (Fig. 4). So, paying attention to this issue, any research in this field plays a crucial role towards sustainable development of the country.

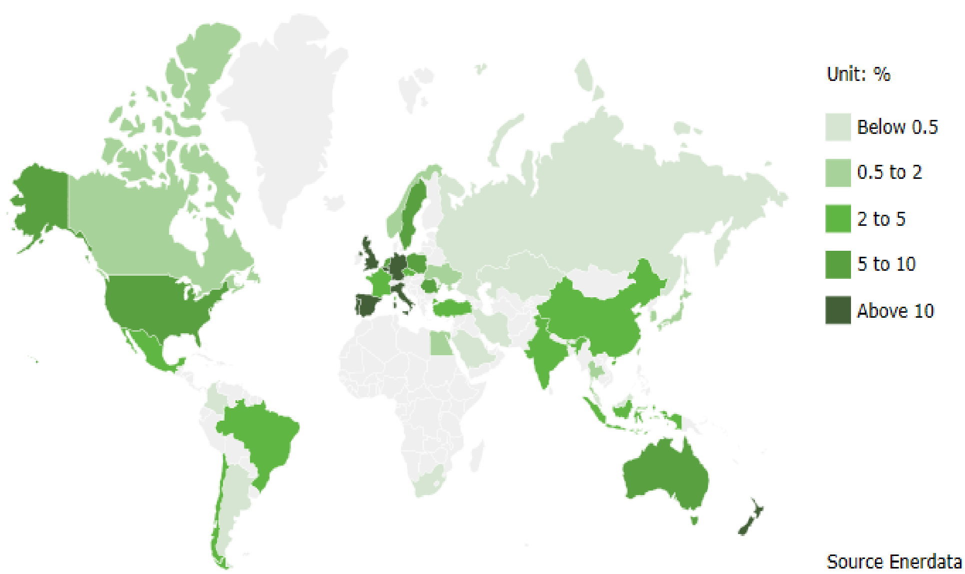


Fig. 4. Share of wind and solar energy in electricity production over the world.

B. Distribution renewable energy for energy access providing essential and productive services

As stated earlier, considering a total installed capacity of roughly 147 GW, still more than one billion of our planet inhabitants which is equal with15% of the global population, lack access to electricity.. Moreover, approximately 2.9 billion people lack access to clean forms of cooking. Distribution of renewable energy technologies has elevated these numbers by provision of essential and productive energy services in remote rural areas across the developing world. Therefore, renewable energy technologies playa significant role in that respect via individual household systems and increasing the number of mini and micro-grids. This is mainly because they are cheaper and more convenient than the conventional sorts of energies. In addition to further spread of existing and well established technologies (solar home systems, hydro stations, solar thermal collectors, etc.), 2014 witnessed the evolution of new types of energy generating equipments, configurations, and applications. This includes following issues: simple and inexpensive pico-wind turbines used for remote telecommunications, solar-powered irrigation kits, and digitization of ancillary services and monitoring. All above-mentioned facilities could improve sales' services and reduce the costs; so that, companies can reach more people. Several factors have resulted in enhanced funding (public and private) allocated to distributed renewable energy. These factors reinforce the insight that isolated cooking and electricity, particularly renewable systems, are presumed as most cost-effective available options in energy services' provision and also in taking new economic opportunities applicable to households and businesses in remote areas. As such, renewable energies have more and more become vital elements of rural electrification processes and clean cooking targets and policies in many countries (Renewables global status report, 2015).

There is rising awareness worldwide that renewable energy and energy efficiency are critical not only for addressing climate change, but also for creating new economic opportunities, and for providing energy access to the billions of people still living without modern energy services. Renewable energies are vital elements of rural electrification programs in many countries, and dozens of international actors are involved in advancing energy access through these modern sorts of energies during 2014(National Energy Administration of China, 2015).

By the year 2013, the most recent year of which the data are available, renewable energy provided an estimated of 19.1% of global final energy consumption. Of this total share, traditional biomass, which are primarily used for cooking and heating in the remote and rural areas of developing countries, accounted for about 9%, and modern renewables increased their share to approximately 10.1% slightly over 2012 (Renewable Energy Market Report, 2014, SE4ALL Site, 2015).

Modern renewable energy is being increasingly used in four distinct markets: power generation, heating and cooling, transportation, and rural/off-grid energy services. In 2013, hydropower accounted for an estimated of 3.9% of final energy consumption; where, other renewable power sources accounted for only 1.3%. Also, renewable heat energy was responsible for approximately 4.1% and transport biofuels provided about 0.8% of final energy consumption (SE4ALL Site, 2015).

Given the importance of rural energy as an integral component of Iranian energy system, it is indispensable to present an overall picture and a well-grounded prospect of rural energy consumption in Iran. To do so, the main objective of this study is to design an applied model explaining the optimum energy use with the emphasis on renewable energies.

C. Energy situation in Iran

Iran is one of the main non-renewable energy producers in the world due to its plentiful fossil fuel resources. Natural gas and petroleum utilization for transportation purposes and industrial sectors has been vastly developed in Iran because of their low prices (Hosseini *et al.*, 2013). After Venezuela, Saudi Arabia and Canada, Iran holds the fourth largest crude oil reserves in the world. Supporting this idea, statistics show that Iran posses second largest reserved natural gas in the world (Najafi *et al*, 2009). Regarding plentiful fossil fuel resources in Iran, alternative fuel and renewable resources have not been seriously considered.

The same as the coal, oil and natural gas are non-renewable fossil fuels. The contribution of these non-renewable fuels in the energy pattern of the world and Iran is about 81% and 99%, respectively. Despite the existence of plenteous renewable energy resources, unluckily, the contribution of renewable and sustainable energy in energy mixture of Iran is less than 1%. Fig. 5 shows energy mix scenario in Iran compared to the world scenario in the recent years (Ghobadian, 2012). International Energy Agency (IEA) has anticipated that natural gas and crude oil will be run out within the next 60.3 and 41.8 years, respectively; therefore, it is expected that renewable source energies will the most important energy sources in the future (IEA, 2010).

Additionally, regarding environmental problems created by fossil fuel consumption, renewable and sustainable energy resources are obviously recommended to be used by different countries in the world. The contribution of RSE resources in transportation system and power generation has been projected to increase 7% and 29%, respectively, by the year 2030(WEO, 2012). The primary energy demand in the year 2011 in Iran was reported as 228.6 MT which had 2.5% increment compared to the year 2010 (Fig. 6).

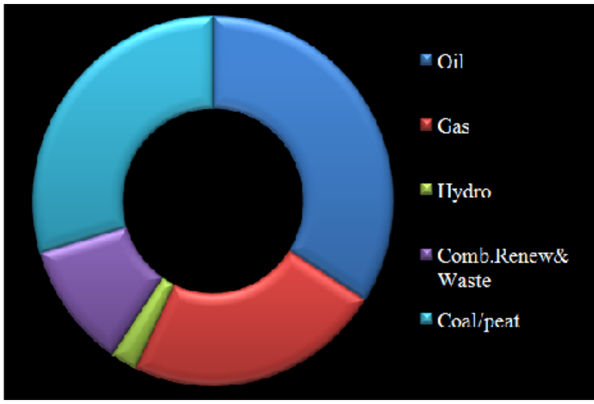


Fig. 5. Iran energy mix scenario.

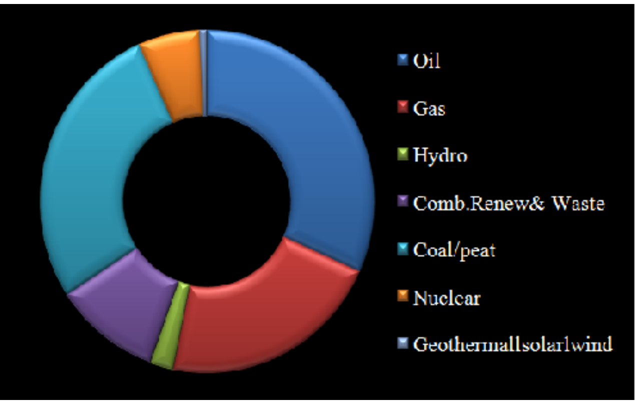


Fig. 6. World energy mix scenario.

Electricity demand has been reported to be 50,000MW in Iran and is around 80% of the amount which has been generated by fossil fuel consumption. It has been predicted that Iran’s electricity demand will be about 200,000MWinthe year 2030 and obviously, fossil fuel resources could not supply this electricity demand percentage at that year (Ghorashi and Rahimi, 2011). To address this increasing energy demand trend, importing energy and some new strategies such as energy mix application (use of renewable energy) should be taken by Iranian government. Hence, transition from traditional to renewable and sustainable energy resources has been recently accepted as a fundamental issue in energy mix strategy by Iranian government and as a result different programs have been established for green energy development by Renewable Energy Organization (REO). Wind and solar energies' share in Iranian electricity production and also their share in world electricity production (highest and lowest ten) are illustrated in figures 7 and 8 respectively. According to figure 8, it is observed that Iran is the seventh lowest country of the word in terms of wind and solar energy usage. Due to growing energy crisis and environmental degradation threats, renewable energy sources are expected to play a leading role in rural energy supply. The reasons that necessitate renewable energy technologies' development and utilization in Iran are enhancement of required capital investments for conventional energy supply systems and also aggravation of environmental problems produced by large projects with using non-renewable sources (Ardehali, 2006).

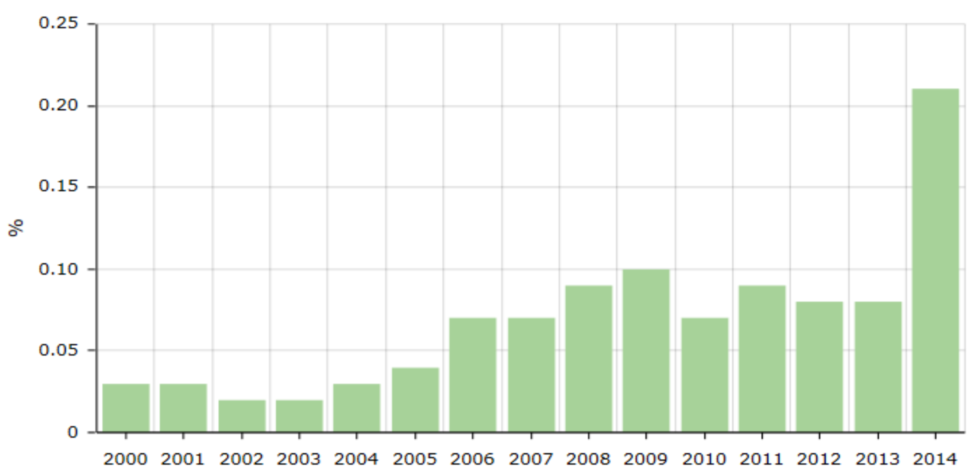


Fig. 7. Share of wind and solar energy in electricity production in Iran.

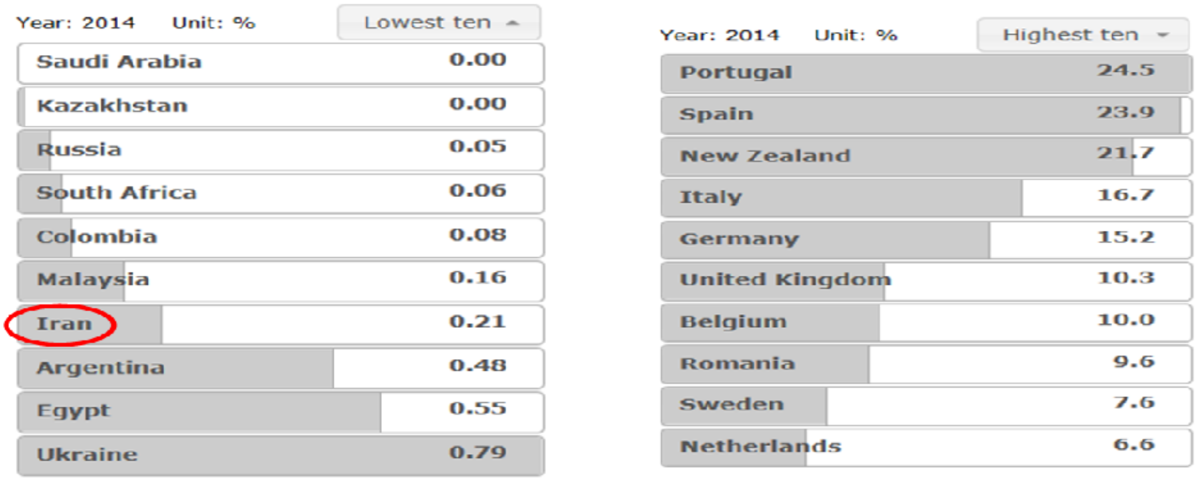


Fig. 8. Share of wind and solar energy in electricity production of the world.

In some countries like China and USA, coal plays an important role in the energy policies; however, in Iran it affords just 0.21% of the total energy demand. Reports has revealed that coal is only applied in iron and cement industries and there is no coal power plant in Iran yet (Mohammadnejad *et al,* 2011). As was mentioned, nearly half of the world's population lives in developing countries' rural areas (Biswas and Goswami, 1996). There is no doubt that rural energy policy plays a vital role in rural energy development and consumption in a developing country like Iran. However, the question rises and needs to be addressed now is: "Do we have any policy for rural energy policy?"

The fact is that nominstry is specified for rural energy services and obviously rural energy generation and consumption are still unresolved issues in Iran; while, other countries such as China have these considerations and are consequently associated with the State Statistics Bureau (SSB, representing governmental statistics) and Ministry of Agriculture (MOA, belonging to sectorial statistics). These two departments extracts different information aspects through different channels (Zhang *et al*, 2009). Now, given the fact that Iran' rank is nineteenth in the world in terms of energy consumption volume, and living a large part of the population of Iran in the villages and their increasing required energies, provision of a practical energy consumption model based on renewable energy use, looks absolutely essential.

LITERATURE REVIEW

Wijayatunga and Attalage (2003) found that the usage of biomass for cooking purposes was rather independent from electrification level; while, electricity usage was directly correlated to household income level.

Ramachandra *et al.* performed a broad survey of 90 villages to study the regional and seasonal effects on energy use; nevertheless, they did not include space heating (Ramachandra *et al*, 2000). Reddy carried out a comprehensive study measuring entire energy use in six villages. The results showed that the energy use per capita for each village ranged from 10,800 to 13,900 MJ cap_1 yr_1 (Reddy, 1982).Village energy utilization sectors consisted of: domestic (88.3%), industry (4.7%), agriculture (4.3%), lighting (2.2%), and transport (0.5%). A similar study accomplished in the Indian state Assam by Sarmah *et al.*, revealedthat energy use per capita calculated for six rural villages was 7500e12,700 MJcap_1 yr_1(Sarmah *et al*, 2002).

Njitiand Kemcha in their article reviewed the energy studies of Cameroon and found out that wood consumption rates were between 260 and580 kg cap_1 yr_1 (Nitiand Kemcha, 2003). Their review also noted that most wood collection occurs during the dry season; when, there is no farming activity. In Mali, a recent study reported the rates of wood consumption indifferent districts. According to this study its rate in the Sahel was equal with 510e910 kg cap_1 yr_1 and in the Niger delta and Sahara was 110e290 kg cap_1 yr_1 (Johnson and Bryden, 2012).

Madubansiand Shackleton implemented a ten-year study of five villages in South Africa before and after grid electrification (Madubansi and Shackleton, 2006). Before grid electrification, domestic energy use was 8100 to 14,000 MJcap_1 yr_1 in five selected villages. Households in the study area used an average of four different energy sources before and after grid electrification.

For heating and cooking purposes, the study uncovered that 45% of households used only wood and 50% of households used wood and kerosene before grid electrification. Following grid electrification, the number of households using only wood remained unchanged; 22% of households used wood and kerosene, and 31% of households supplemented these fuels with electricity. Household fuel choice for lighting showed little evidence of electricity usage instead of other options (8%); but it was very common to find households that coupled electricity with candles and kerosene (76%). Before grid electrification, disposable batteries were used to power personal electronics in 81% of house holds. After grid electrification, only 28% of households used batteries.

Zha e*t al.* compared energy related CO_2 emissions resulted from urban and rural residential energy consumptions during the years 1991 to 2004 (Zha *et al,* 2010).Similarly, Yao *et al.* analyzed rural residential energy consumption and its corresponding impacts on climate change in China from 2001 to 2008 (Yao *et al,* 2012).

Zhuang *et. al* estimated that the area of marginal-land resources suitable for the cultivation of major energy generating crops is estimated19.90 million hectares in which these lands could annually afford about 58.65 Mt of biodiesel (Zhuang *et al,* 2011).

A number of studies have been conducted for agricultural energy consumption assessment in different geographical situations and agro-climatic conditions, different crop cultivation types and different farm sizes (Department of Farm Machinery and Power Engineering, 1988, Gajendra and Chancellor, 1975, Giriyappa, 1989, Kulsherestha, 1979, Pathak, 1985, Pathak and Singh, 1978, Rao, 1985, Senapathi, 1976, Singh and Miglani, 1976). A positive relationship has been found between energy consumption (particularly commercial energy consumption) and agricultural production. (Gajendra and Chancellor, 1975, Pathak and Singh, 1978, Senapathi, 1976). Findings has illustrated that energy consumption in agriculture increases along with the increase in farm size, in which the irrigation activity accounts for the largest share of energy usage (Giriyappa, 1989, Kulsherestha, 1979, Pathak, 1985, Pathak and Singh, 1978, Rao, 1985, Senapathi, 1976).

From a sustainability point of view, the potential of hydrogen generation from clean renewable energy sources is preferable (Santarelli *et al*, 2004, Afgan *et al*, 2007, Contreras *et al*, 2007, Paul and Andrews, 2008).

Water electrolysis powered by photovoltaic (PV) energy is regarded as one of the promising options and generally the most desirable choice for remote power supply applications (Meurer *et al.* 1999; Bilgen, 2004, Turner *et al.* 2008).

MATERIAL AND METHODS

As the data on village energy uses in Iran was not appropriately available, survey method using interviews, filling questionnaires etc were applied. Data collection methods used in this study included structured household and community interviews, in addition to engineered data obtained from involved organizations in the design and development of the village power system. As already said, detailed rural energy data is not clearly available in most developing countries as well as Iran. So, the most appropriate means of data sources in this study was conducting survey on the site.

A. Identifying the optimized local use

For Optimized local use of renewable energy with emphasis on the villages of Chaharmahal va Bakhtiari Province, Geographic Information System (GIS) software and wind intensity formula, radiation formula, the data collected from biomass in the study area (Chaharmahal va Bakhtiari Province) and also weather layer and Calculation menu from GIS were used for wind, solar and biomass energies separately. Finally, best places for wind, solar and biomass energies were identified. In the next step, layers were combined and most optimal area for all kinds of energies were recognized in order to find out the best combination of renewable energies in the study area and then selecting a village in optimized local area of the case study.

B. Potential survey of Biomass, solar and wind energies in a typical village as an application version

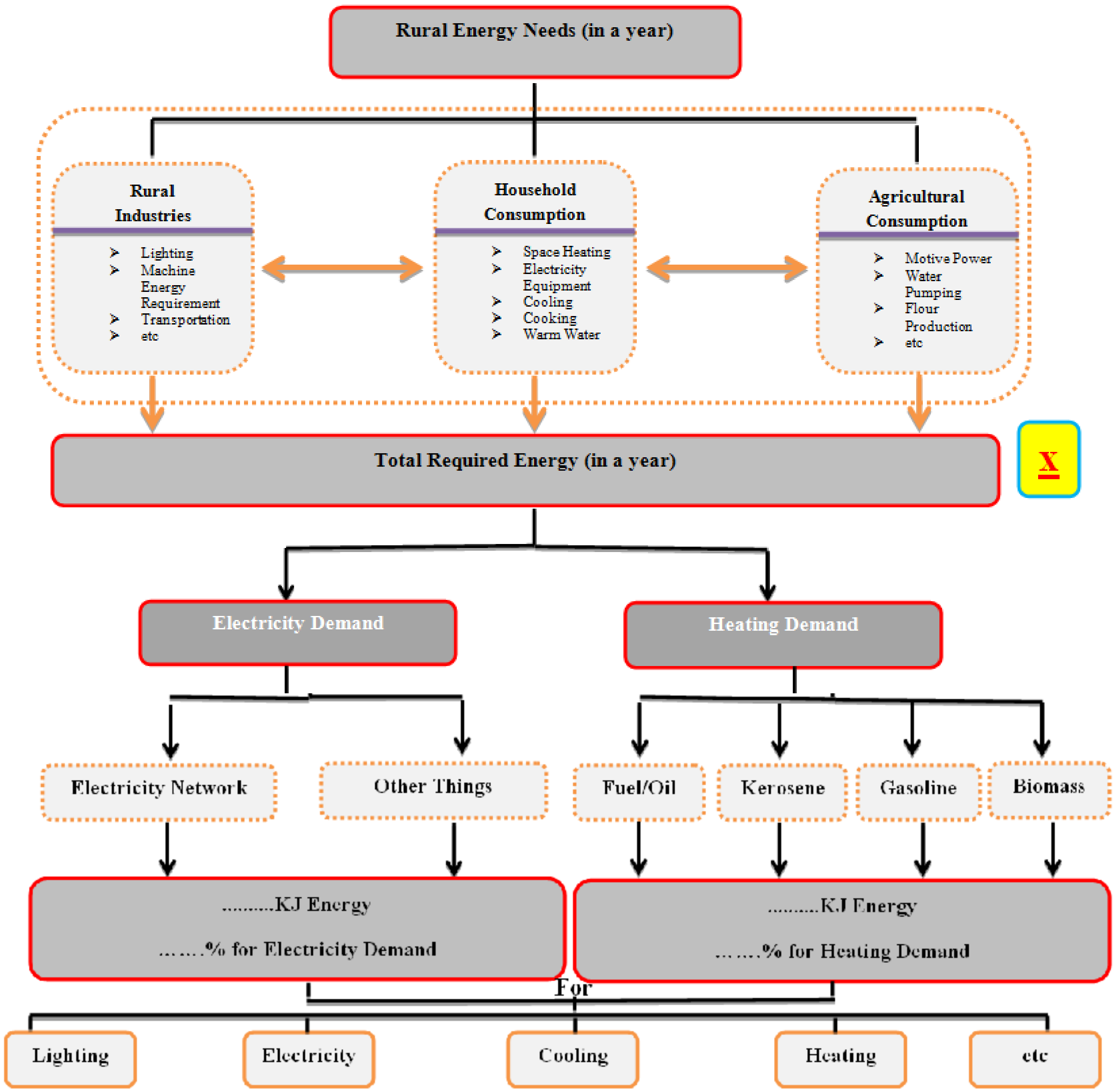
After identifying the optimum location by GIS, a village in an area with available Energy was selected and following information was gathered through the survey:

-Animal (Cattle, sheep, goats and poultry) waste, garden and agriculture waste, rural waste etc.

-Light intensity according to nearest synoptic station average

-Server wind according to nearest synoptic station average

Later on, amount of derived energy was calculated and then gas and electricity requirements for water heating and cooking purposes in rural areas were studied using survey method. Then, according to the potential of the area, digester size, wind farm and solar farm size were all determined.



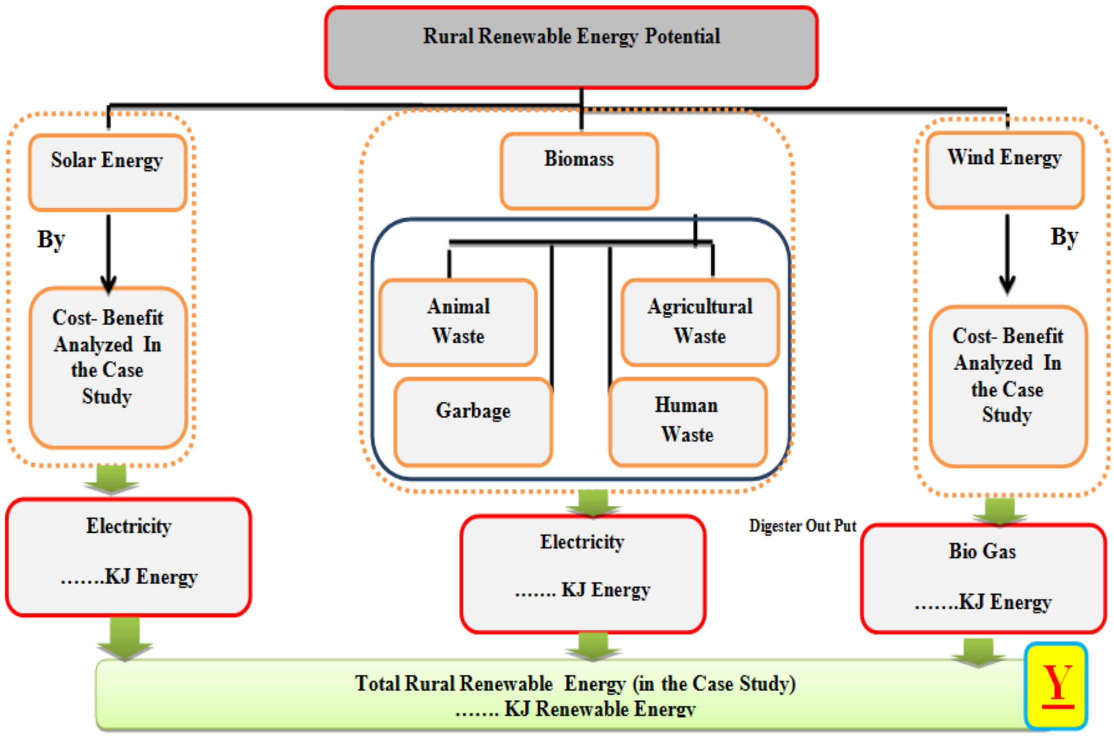
Framework 1: Rural Energy Needs in the Case Study (REN).

C. Optimum combination and operation version from synthetic renewable energy

A hybrid version and optimized model was presented for studied village via examining its cost-effectiveness and supporting population, using HOMER software.

RESULT AND DISCUSSION

This study investigated the household and rural community energy demand patterns of energy sources in rural areas in Iran. As a result, in this research, it was attempted to design and implement an applied rural development model with the emphasis on renewable energies. The energy model presented in this study (with the emphasis on rural renewable energy), consisted of two frameworks in which were illustrated in frames one and two. At the first step, to design an applied model, and for Optimized local use of renewable energy with the emphasis on case study villages, Geographic Information System (GIS) software and wind intensity formula, radiation formula, the data collected from biomass in the study area, weather layer and also Calculation menu from GIS were used for wind, solar and biomass energies (in a separated format).



Energy Saving in the Case Study(%)=(Y/X)*100

Framework 2: Rural Renewable Energy Potential in the case Study (REP).

Finally, based on the model, best places for wind, solar and biomass energies were separately determined In the next step, in order to find out the best combination of renewable energies in the study area, layers were combined and most optimal area of all kinds of energies was identified. Thereafter, a village in optimized local area was selected for the study. Afterwards, the total required energy in the case study (referring to the framework one), and then according to the study area, rural renewable energy potentials in biomass, wind, solar and geothermal energies were distinguished (referring to the framework two). Eventually, according to collected data, all saved energies in the case study were calculated (Energy Saving in the Case Study (%)=(b/a)*100).

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