Suggestion a Novel Scenario in Iran Renewable Energy Planning Based on Modified ANN Method

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Abstract: In this study end-users energy consumption of Iran are predicted using ANN (artificial neural network) by historical data and socio-economic parameters (1990-2013) up to 2030 horizon. Iran energy balances are forecasted by bottom up analysis using LEAP (long-range energy alternative planning). On other hand solar energy promotion policies around the world, Iran policies and its solar energy potentials are investigated. Novel policy for Iran photovoltaic systems promotion are proposed and impact of this scenario implementation evaluated on Iran energy balance. Result show 750 MBOE (million barrel of oil equivalents) will be saved and 320 million metric tons co_2 equivalent emission reduced up to 2030.

Keywords: Energy Consumption, Energy Planning, ANN, LEAP, Policy, Photovoltaic

1. Introduction

The energy demand and co_2 emission in Iran increase rapidly by progress in population and other socioeconomic development, the sustainability and clean environment should be considered to guarantee the people health and the secure energy supplies by energy management or resources replacement [1]. Iran has various energy resources, besides abundant conventional sources of energy, like oil and natural gas, the country is blessed with large renewable energy resources such as solar, wind, geothermal, hydro, etc. [2]. So development strategies and policies must use alternative resources and governments do energy planning to realize impact of this replacement.

In this study in section 2 and 3 are reviewed studies about energy planning and relation between socio-economic parameters on energy consumption. In section 4 is provided energy consumption and balance forecasting for Iran. Solar energy promotion policies in different countries are investigated in section 5. In section 6 are presented Iran policy for photovoltaic systems promotion with detailed information and potential of solar irradiation. Obstacles of household solar energy promotion are detected in section 7 and proposed novel scenario based on policies that is used around the word. Finally is presented conclusion of implementation this new scenario in section 8. Flowchart of this study has been shown in Figure 1.
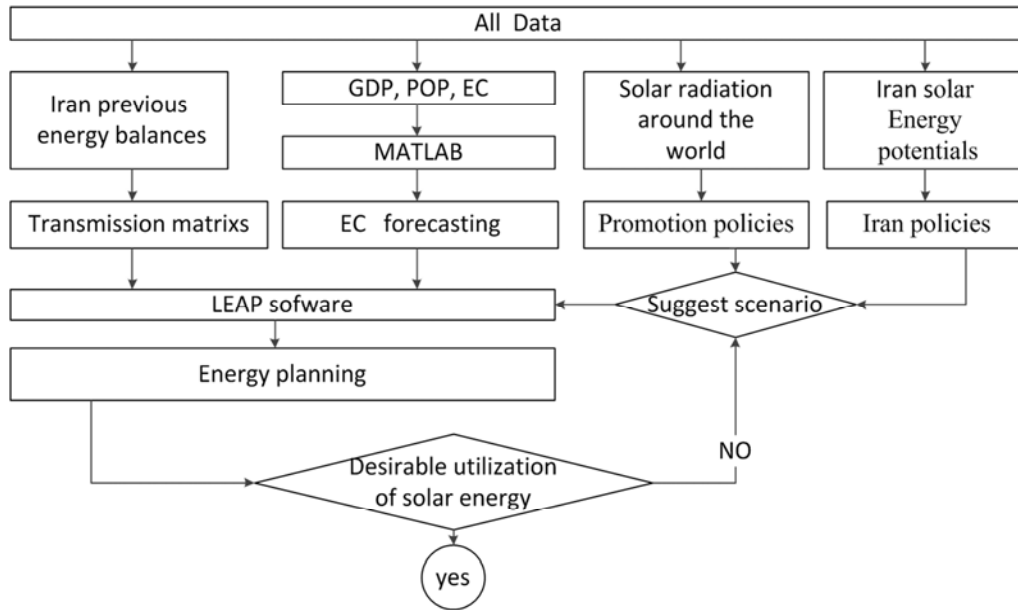
Figure 1. *Flowchart of this study.*

2. Studies Energy Planning with Focus on Renewable Energy

Several studies have been conducted that focus on renewable energy planning and policies around the world. In [3] Tsoutsos et al. inspected available renewable energy in island of Crete in Greece and exploit the multi-criteria methodology for the sustainable energy planning. They proposed four scenarios with several criteria. Their proposed scenarios were; 1. install only wind farms, 2. install wind farms and PV systems, 3. install wind farms, PVs and four olive kernel units and 4. install wind farms, PVs and oilstone biomass and finally they suggested PROMETHEE[1] model to sustainable energy planning. In [4] Mishra et al. provided an overview of generation and transmission planning studies to share solar, wind and geothermal energy in energy planning that whereby Australia will have 20% renewable energy penetration by 2020. In [5] Ćosić et al. designed 100% renewable energy system of Macedonia in the year 2050. High share of biomass, wind power and solar power as well as different storage technology was investigated and energy planning is conducted by making use of EnergyPlan model. In [6] MCDA[2] was developed by Mourmouris and Potolias and proved that RES exploitation at a regional level can satisfy increasing power demands through environmentally-friendly energy systems that combine wind power systems, biomass exploitation, and PV systems by investigation a case study. In [7] Roxas et al. discovered Weakness of the current planning system in Philippine and suggested Alternative framework for renewable energy planning that whereby Philippine can achieve National RE Program in period 2011-2030. In [8] Flores-Quiroz et al. proposed column generation

solution approach for solving generation expansion planning problems and investigated energy planning with penetration of renewable energy for Chilean power system up to 2030 and showed neglecting short term constraints in planning timescales produce extra costs of ≈7% between years 2012–2030. In [9] Zeng et al. suggested integrated planning with renewable energy that minimize the sum of economic and CO_2 emission costs over planning horizons, LCP[3] formulated and tested for several case studies and showed can be used for economic and technical planning. In [10] Zheng et al. conducted energy planning with interconnected smart grids in integrating renewable energy and implementing demand side management (DSM) and named IRSP-sgs[4]. This model traded off between traditional power plant (TTP), efficiency power plants (EPP) and power grid recourse. They suggested scenario that helps to reduce electricity generation by 784.38 TWh and reduce CO_2 emission by 999.57 million tons during 2013-2025.

3. Studies on Relation Between Energy Consumption and Socio-Economic Parameters

In 2005 liner and ANN forecasting of electricity consumption were investigated for Taiwan [11]. National income (NI), population (POP), gross of domestic production (GDP), and consumer price index (CPI) During the 156 months were used as input parameters. Finally was shown the ANN is more appropriate to be applied to build an economic forecasting model and both methods agreed that POP and NI influence electricity consumption the most, whereas GDP the least. In 2006 York investigated demographic and economic

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1 Preference ranking organization method for enrichment evaluation
2 Multi-Criteria Decision Analysis

3 Low carbon planning
4 integrated resource strategic planning- smart grids

factor on energy consumption and found that population size and age structure have fundamental role and showed urbanization, economic development; GDP and GDP per working age contribute substantially to changes in energy consumption [12]. In 2008 Liu showed, it is a stable long run relationship amongst total energy consumption, population, GDP and urbanization level when total energy consumption is the dependent variable in China [13]. In the work carried out by Amjadi et al. in 2009 were forecasted electricity demand based on GDP, population, number of customers electricity and average price electricity [14]. The weighting factors of the proposed models were estimated by genetic algorithm (GA) and particle swarm optimization (PSO). It has been found that the proposed PSO and GA based on linear model perform similarly and the proposed PSO based on non-linear model provides the best-fit solution to the available data. Lotfalipour et al. conducted a study in relation with economy growth, carbon emission, and fossil fuel consumption for 1967-2010 in Iran [15]. They observed single direction Granger causality between carbon emission, GDP and two energy consumption indices: crude oil production and natural gas consumption. In 2011 Al-Mulali and Sab investigated relation between energy consumption and CO2 emission on GDP growth and the financial development in thirty Sub Saharan African Countries [16]. They use Panel Granger causality to find this relation and finally showed that the financial development indicators and GDP growth had a positive causal relationship with the total primary energy consumption and CO2 emission. In 2012 Ardakani and Ardehali examinated impact of two input data type on energy consumption including historical data of EEC (Electricity Energy Consumption) and socio-economic data (gross domestic product, energy imports, energy exports, and population). They showed that socio-economic data are more effective as input for energy consumption forecasting [17]. In 2013 Aydin modeled energy consumption of Turkey based on population and GDP using regression analyze [18]. He validated his model and proved that it can accesses acceptable error. Finally forecasted the future of energy consumption of Turkey and showed it would vary between 174.65 and 203.13 Mtoe (million tons of oil equivalent) in 2025. In 2014 [19] Saidi and Sami studied impact of CO2 emissions and economic growth (GDP per capita) on energy consumption in 58 countries using dynamic panel data model and proved the effect of GDP per capita on energy use is positive and statistically significant in the global panel.

4. Forecasting

4.1. Iran Energy Consumption Forecasting

According to the previous studies there is relative relationship between GDP, POP and energy consumption. Amirnekooei et al. investigated (EC, GDP) and (EC, POP) relationship for Iran energy balance by mathematical correlation function and showed there is meaningful relation for both of them [20]. So this study forecasts Energy

consumption using of GDP and POP as input to artificial neural network for Iran. Artificial neural network is a good method to predict energy consumption because it learn the relationship between the input parameters and the controlled and uncontrolled variables by studying previous data and detect complex nonlinear relationships between dependent and independent variables [21, 22].

A multi-layer perceptron ANN with Levenberg-Marquardt training was used in this study and the architecture of used ANN was showed in Figure 2. The ANN inputs are POP, GDP and EC from 1991-2013. These parameters must be normalized based on:

$$X_n = \frac{2(X_{actual} + X_{min})}{X_{max} - X_{min}} \qquad (1)$$

Where X_n, X_{actual}, X_{min}, and X_{max}, are normalized data, actual data, minimum and maximum data respectively and n is number of data.
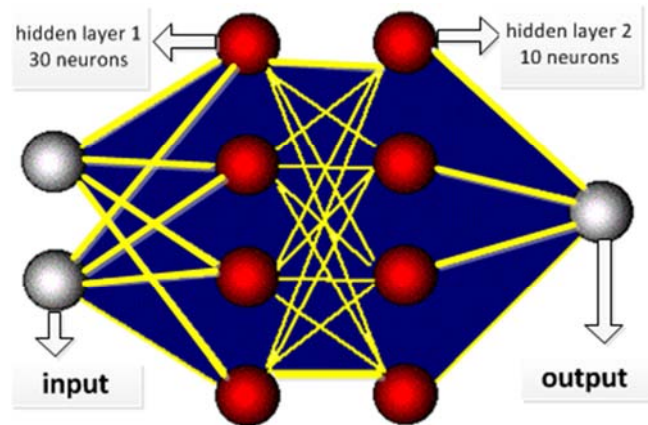

Figure 2. The designed ANN architecture (2:30:10:1).

The designed ANN is trained for 75 percent of input data and tasted for residual data. This network is run for each sub-sector individually if the MSE (mean square error) less than the acceptable MSE well be continue forecasting in otherwise the network will be train again. (Acceptable MSE for train data is 10^{-6} and acceptable MSE for test data is 10^{-4}).

POP and GDP are ANN inputs, so they must be estimated. Considering rural and urban divisions in Iran, and dramatic migration from suburban areas to cities, POP is likely to grow slower as compared with the last decade, mainly because POP growth is influenced by urban residents who are less interested in having numerous offspring. In this study, POP is forecasted linearly based on (1991-2013) historical data [20]. The grey theory is used for GDP estimating. One of the major advantages of grey prediction theory is that only small amounts of data are needed to describe the system behavior and reveal the continuous changing process in the system, GM (1, 1) provides an excellent approach to the development dynamic system such as GDP [21, 23]. So GDP is forecasted by GM (1, 1) based on (1991-2013) historical data.

Thus all of sub-sectors consumption (residential, industry, transportation, agriculture and non-energy sector)

for each of energy carrier (electricity, oil, natural gas, and etc.) will be forecasted by this designed ANN separately. For example result for residential electricity consumption and designed ANN convergence are showed in Figure 3 and Figure 4.
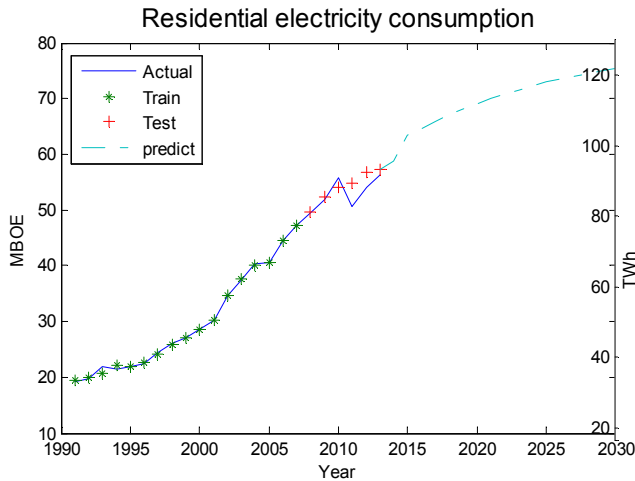

Figure 3. *Actual, train, test, and predict data for residential electricity consumption using ANN.*
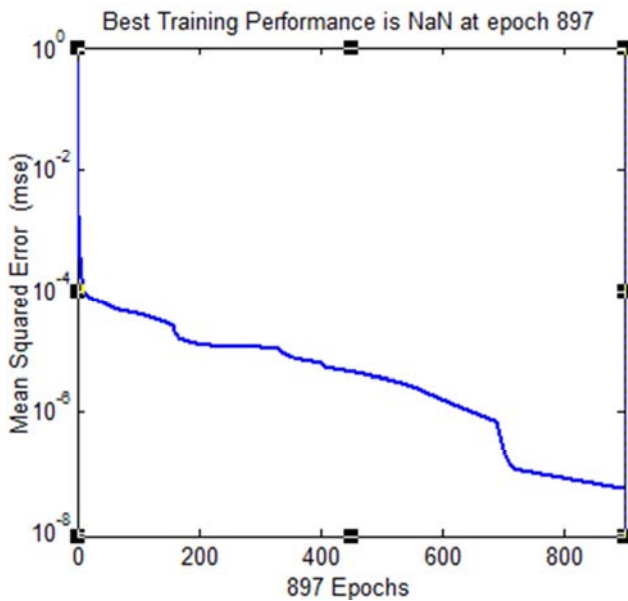

Figure 4. *The ANN training process accuracies and convergences for Residential Electricity consumption.*

4.2. Iran Energy Balance Forecasting

Iran energy balance has three general section:

1- Total primary supply include: Production, Export, Import, International fuel container ships and Stock changes.
2- Total Transformation include: Oil Refineries, Power plant, Coal mining and Transmission and Distribution.
3- Total Demand include: Residential, Industry, Transportation, Agriculture and Non energy use.

Indeed each of above sub-sector has different quantities for various energy carriers. In previous section third layer (total

demand) of energy balance is forecasted up to 2030. Now other layers with detailed information is forecasted by LEAP software. LEAP inputs are: 1- total demand for each energy carrier based on various sub-sector up to 2030 (third layer) and 2-Iran energy balances from 1991-2013. So LEAP forecaste other two layers of energy balance and their detailed information by a bottom up analysis [24].

5. Photovoltaic Systems Promotion Policies Around the World

There are barriers to develop renewable energy around the world. They classified in three category;

1- Cost and pricing, consist of; subsidies for competing fuels, high initial capital costs, difficulty of fuel price risk assessment, unfavorable power pricing rules, transaction costs and Environmental externalities.
2- Legal and regulatory, consist of; lack of legal framework for independent power producers, restrictions on siting and construction, transmission access, utility interconnection requirements and liability insurance requirements.
3- Market performance, consist of; lack of access to credit, perceived technology performance uncertainty and risk, lack of technical or commercial skills and information [25].

Various polices and strategies in the face of these barriers are applied such as; feed-in tariff, quota obligation or tending system, net metering or retail market, tax and subsides, and CDM and R&D project.

Feed-in tariff: a payment made to households or businesses generating their own electricity through the use of methods that do not contribute to the depletion of natural resources, proportional to the amount of power generated. Feed-in tariffs require utilities to provide renewable generators with a long-term fixed price for electricity. These prices are typically structured either as a fixed payment based on the cost of system generation. Most feed-in tariffs also require utilities to interconnect all eligible renewable generation, thereby guaranteeing that renewable electricity can "feed in" to the grid [26].

Quota obligation or tending system: In this system, calls for tenders in relation to energy supply from renewables are made at intermittent intervals. Each renewable technology is given a quota, and the provider of the lowest asking price is given the contract. Finally various provider are committed to provide their quota obligation [27].

Net metering or retail market: A variation on pricing laws, 'net metering' permits consumers to install small renewable systems at their homes or businesses and then to sell their excess electricity into the grid. This excess electricity must be purchased at wholesale market prices by the utility. In some cases, producers are paid for every kWh they feed into the grid; in other cases they receive credit only to the point where their production equals their consumption [25].

Table 1. Photovoltaic systems promotion policies around the world.

	Feed-in tariff	Quota, Tendering	Net metering	Tax, subsides	CDM, R&D	Ref
USA	*	*		*		[28], [29]
Canada			*	*	*	[30]
Brazil	*		*			[31], [32]
Germany	*			*		[33]
UK		*		*	*	[34]
France	*			*	*	[35]
Spain	*					[36]
Italy		*	*	*	*	[37]
The Netherland		*	*			[38]
Belgium		*		*		[39]
Austria	*			*		[40]
Portugal	*					[41]
Poland		*				[42]
Romania		*				[43]
Greece	*					[44]
Turkey				*		[45]
Australia	*	*		*		[46]
Japan	*	*		*		[47]
China			*	*	*	[48], [32]
Iran	*					[49]
Taiwan					*	[50]
UAE					*	[51]
South Africa					*	[52]

Tax and subsides: This solution is measure that keep prices of renewable energy for consumers below market levels or for producers above market levels, or reduce costs for consumers and producers. Renewable energy subsidies may be direct cash transfers to producers, consumers, or related bodies, as well as indirect support mechanisms, such as tax exemptions and rebates, price controls, trade restrictions, and limits on market access.

CDM and R&D project: Programs for promoting less carbon-intensive development by penetration renewable energy based on international protocols (such as Kyoto Protocol) or programs that are in research phase still [53]. In table 1 various policies or strategies has listed and these information and Sun radiation has showed in Figure 5.

6. Solar Energy in Iran

6.1. Solar Energy Potentials in Iran

Solar energy is widely available in most regions of Iran, especially in the central and southern parts. Different geographical positions in Iran have various potentials for solar energy. The average of solar radiation of Iran has been recorded about 19.23 MJ/m2 [54]. Although Iran has great potential for solar power generation, limited investigations have been done for solar energy in Iran. The main reason is the plentiful oil and gases reservoir in the country which led to the low price of fossil fuel for electricity generation [55]. Haghparast Kashani et al. investigated solar energy potential and solar system capacity in Iran and illustrated these potentials on the various maps [56]. The various colors in Figure 6 illustrate various solar irradiation and the household electricity consumption for each province has specified on this map in terms of megawatt-hours.

6.2. Iran's Policies for Photovoltaic Systems Promotion in the Household Sector

Two solutions have been suggested in Iran in order to encourage the household usage of the Photovoltaic systems, one of which could optionally be adopted by the customer:

1- If the customer installs the Photovoltaic system only for their own consumption half of the installation and initialization cost is paid by the Ministry of Power as a financial aid with no return.

2- If the customer produces an additional amount of power other than their own consumption, the Ministry of Power will buy it for 8000 Rials per kWh [57].

The guaranteed purchase of electricity from the customer' power stations has been declared by a high-rank official of the Ministry of Power as shown in Table 2.
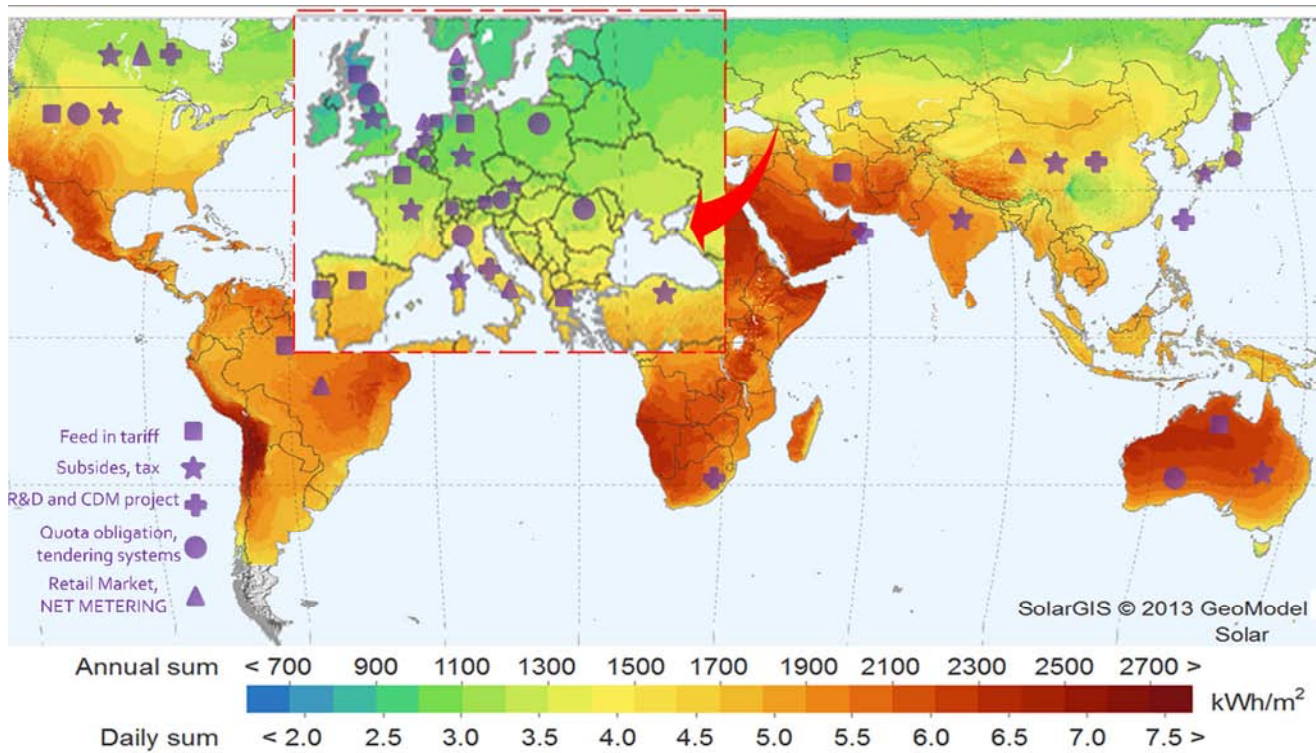
***Figure 5.** Solar irradiation around the word [58] and Photovoltaic systems promotion policies around the world [table 1 of this study].*

***Table 2.** The Guaranteed Tariff of the Ministry of Power [49].*

allocated to the consumers and limited to the connection capacity	Guaranteed electricity purchase tariff (IRRs per kWh)
with the capacity of 100 kilowatt and less	7000
With the capacity of 20 kilowatt and less	8000

Presently, the cost of the installation of a one kW Photovoltaic system is about 100 million Rials, whereas the cost of electricity consumption for the customer is 600 Rials per kWh. Therefore the customers are usually not interested in such an investment about which they do not have enough information.

7. The Proposed Scenario

Three policies 1) Quota obligation or tending system, 2) Subsidies and Tax, and 3) Local Investment in Research and Development have not been utilized in Iran so far. Assuming that the studies conducted by the government organizations in order to locate the regional potentials of the Photovoltaic systems for household use are done according to the type and the number of houses and the amount of solar radiation, and provided that the private section investor who intends a mass investment takes the distinct zones in an auction based on the research results and the purchase commitment of the Ministry of Power instead of installing a power station.

So the encouragement of consumers to utilize the household Photovoltaic systems becomes a competition among the private companies, then the subsidies on the electricity cost can be lowered gradually and the customer would be able to choose between either buying the electricity at a high price from the conventional production systems or allowing the organized private companies to install solar panels resulting in a lower price for electricity.

By following this scenario the three established policies which were discussed in the Foreign Policies section will be applied in addition to the encouraging policy of the cost reduction that has been applied so far in order to utilize of the clean unending and silent source of solar energy.

Provinces with a net radiation rate of more than 4.7 hours (including all provinces of Iran except for East Azarbaijan, Ardebil, Gilan, Mazandaran, Golestan and North Khorasan) comprise ≈ 83 percent of the "residential" part of the electricity consumption [59]. The household consumption comprises ≈ 84 percent of the consumption categorized under the title "residential" which is a level of the energy balance.

Assuming that 15 percent of the usage of the provinces with a 4.7 plus hours of radiation is gradually utilized until 2030, then the reduction in "residential" consumption of electricity in 2030will be:

$$Reduction = 0.83 \times 0.84 \times 0.15 \times Consumption\ residential$$
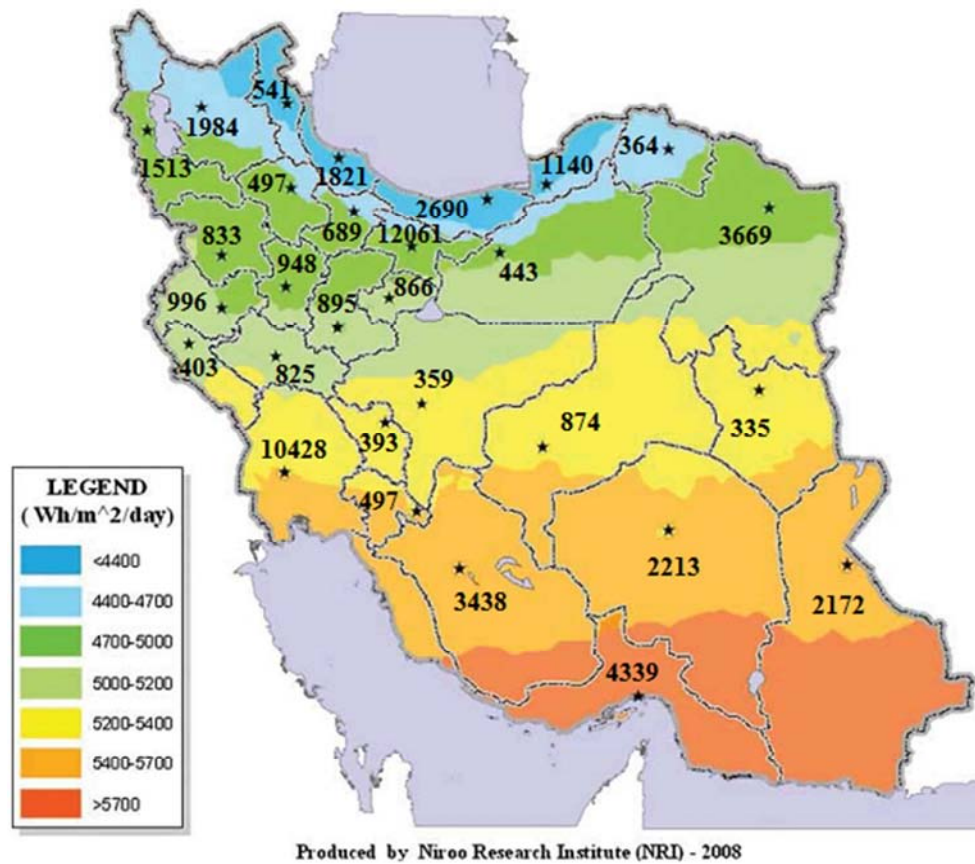
Figure 6. *Map of solar global irradiation on horizontal surface of Iran annually [56]. And household electricity consumption for each province [59].*

All the consumption data including the type of the fossil fuel, the type of the consumption and also all transfer matrices such as the losses of production and transmission, refinery losses, and the amount of available and obtainable fuels used in the power station, are processed by the LEAP software. Now if we assume the consumption reduction in 2030 as mentioned above, the LEAP software applies this reduction gradually until the desired point in time and obtains an energy balance that includes such changes in the production and transmission sections too.
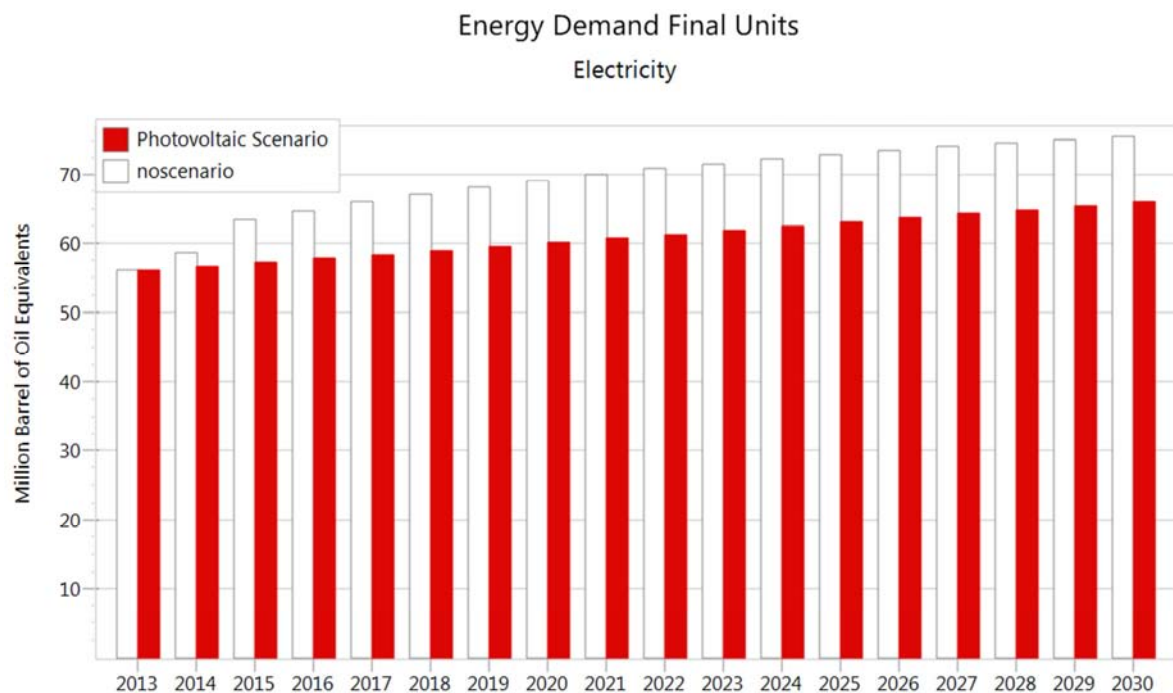
Figure 7. *Comparison photovoltaic scenario and no scenario energy demand final units, electricity.*

As shown in Figure 7. and Figure 8. an amount of energy equivalent to 750 million barrels of crude oil is saved by implementation this scenario. Moreover the LEAP software after a precise analysis shows a reduction of air pollution equal to 320 million metric tons co2 of greenhouse gases.
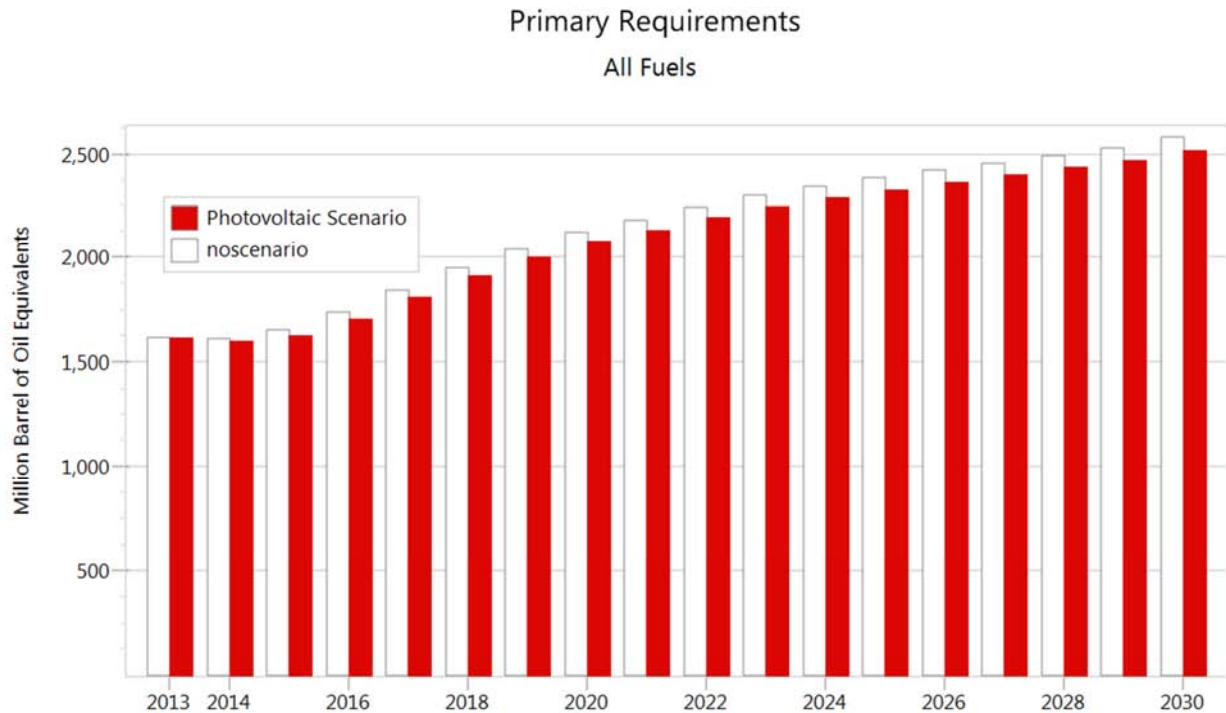
Figure 8. Comparison photovoltaic scenario and no scenario in primary requirement, all fuel.

8. Conclusion

The estimate of consumption using artificial neural networks of MATLAB software by taking into account the effects of population and gross domestic production and usage historical data of consumption in each section demonstrates good results for future energy consumption. In this study, by using a bottom-up approach the plan for future energy consumption was carried out. Then the policies of several countries as well as the Iran's solar potentials discussed and a new scenario was proposed in order to improve the usage of solar energy. The consequences of the scenario in the energy management up until the year 2030 were also addressed. The scenario was also applied to the LEAP software along with other required information in order to find out the amount reduction of primary energy supply and pollution. The result show a reduction of 320 million tons of greenhouse gases co2 in addition to a saving of 750 million barrels of crude oil equivalents.

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