Sustainable Development and Energy Demand of Iran Analysis Genetic Algorithm Approach

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Abstract: This paper investigates sustainable development and the effects of energy and population on it in Iran. One of the goals of this paper is to estimate the energy demand of Iran based on economic indicators using genetic algorithm approach. The used economic indicators are Gross Domestic Product (GDP), population, export and import figures in Iran. Two forms of Genetic Algorithm Energy Demand Model (GAEDM), linear and non-linear form, are used to estimate energy demand. This model also can be used to estimate energy demand in future. This estimation gets by optimization the parameters value. At this study, energy demand of Iran is evaluated until year 2020. The linear form of GAEDM can better estimate the future energy demand of Iran because of the lower SSE than the non-linear form. In order to estimate energy demand of Iran in future, we have employed two scenarios.

Key words: Energy demand estimation • genetic algorithm approach • economic indicators • SSE • sustainable development

INTRODUCTION

Iran is heavily reliant on energy-market for domestic economic production and export. It also has high dependence on oil products to meet primary energy needs and for its petrochemical and metal industries.

The energy demand of Iran in every sector has been increasing, depending on the population, Gross Domestic Product (GDP), export and export figures.

Estimating the future energy demand is an important issue to calculate the cost of energy investment projects and energy production. Total energy demand’ GDP and population in the last 25 years increased by rate of 5.87, 2.65 and 2.39%, respectively, when compared with the 1979 figures [1-3].

The optimal renewable energy mathematical (OREM) model, model for analysis of energy demand (MAED) and energy simulation model (ESM) by Ullanir have been developed in order to estimate the future energy demand based on the variation of GDP and population. However those energy estimation models can not explicitly deal with the general import and export figures during the energy demand estimation.

The estimation of energy demand based on economic indicators may be modeled by using various forms of equations. These equations may be linear or non-linear forms. The linear form of the GAEDM equations can better estimate the future energy demand of Iran [4-5].

For solving the different form of equations, genetic algorithm approach is proposed. The GA can be used to estimate the future energy demand under different scenarios by appropriately estimating the weighting parameters with current data. The available is partly used for finding the optimal, values of the weighting parameters and partly for testing the model. The obtain result are compared with observation data. The result shows that the genetic algorithm approach can be used to estimate the energy demand of Iran.

SUSTAINABLE DEVELOPMENT AND EFFECTS OF ENERGY

The concept of sustainable development refers to development 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. This has social, economic and environmental dimensions. In all three the way energy is used and produced plays an essential role.

Iran is heavily reliant on energy-intensive industries for domestic economic production and export. It also has a high dependence on oil products to meet primary energy needs and for its petrochemical and metal industries. Despite diversification for energy sources for domestic, energy price reform has not been effectively pursued and energy intensity remains high, posing a serious threat to the economy [6].

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Iran economy’s is highly energy intensive. The main reason for this is low energy prices that have led to over-consumption for energy and low efficiency. Meanwhile the presence of energy-intensive industries such as metal and petrochemical plants are also contributing factor. The aspect of energy intensity in Iran is its increasing growth. Although this may be partly justified as a measure of welfare improvement (in household consumption), mismanagement is in undoubtedly the main cause [6-7].

Currently Iran possesses proven of approximately 133 billion barrel of oil and 24 thousand billion cubic meters of natural gas. These constitute 11.6 and 15.6% of the world proven oil and gas reserves, respectively. Iran has the second richest oil and gas reserves in the world.

In 2003, Iran produced 1967 million barrels of crude oil equivalent (MBCE) of primary energy. Net of exports and imports 1001 MBCE is available for domestic consumption. 97.2% of domestic consumption of primary energy originated from petroleum, (44% from oil and 52.4% from gas).

In past four decades’ total final energy consumption has growing at a rapid pace: from 1967-77, during the industrialization transformation period of the country, total final energy consumption grew at an annual rate of 14.2%. Just prior of the revolution and during the Iran/Iraq war (1977-89), the rate of growth slowed to 5.2%. Over the course of three Five Year Development Plans (FYDPs), from 1980 to 2003, growth has continued at an average annual rate of 5.3%.

Historically, with a century of exploitation, extraction and refining, oil has been the predominant source of primary and final energy in Iran. In 1990, at the beginning of after – war economic reforms, immense domestic consumption of oil product, combined with a rapid rate of growth, we recognize as serious threat to the economy particularly. If the trend continued as it would leave sufficient crude oil for export. The main goal was to substitute other sources of energy for oil products in domestic consumption [5-8].

Certain policies and programs, such as energy price reform and expanding production capacities and grids in gas and electricity were selected to support the main goal and strategy.

**SUSTAINABILITY AND POPULATION**

"sustainable development" connotes the processes by which people satisfy their needs and improve their quality of life means a higher standard of living, usually measured in terms of income level and uses of resources and technology. Inherent in the concept of sustainable development is the principle of equity in order to achieve economic and environmental goals, social goals such as universal access to education, health care and economic opportunity must also be achieved.

With globalization and new and emerging technologies and modes of production and consumption, the relationship among population, environment and development have become issues of heightened concern for government, the international community and the people. Therefore, population and development policies, especially those relating to the sizing, growth and distribution of population, are necessary and vital to ensure sustainable development and to safeguard the environment during the twenty-first century and beyond.

The interrelationship between population, sustainability and development should therefore have clear policy priority for the future that stresses the need of harmonizing population and economic growth rate in Iran. Indeed, if sustainable development is to take place, the population growth rate should not exceed the GDP growth rate.

As a matter of fact, overly rapid population growth will entail plowing a sizable portion of investment capital into non-productive sectors, concentrating development effort on reducing the imbalance between the population and available food and combating environmental degradation [8-9].

**GENETIC ALGORITHM AND ITS APPLICATION FOR ENERGY DEMAND**

Many optimization problems are very complex and difficult to solve by conventional methods. Therefore, evolutionary algorithm simulating natural processes were developed to solve them. Among them, GA has been successfully in solving many optimization problems. Originally proposed by Holland, GA is a stochastic searching technique based on the mechanism of genetic and natural selection.

Many studies have showed that GAs can efficiently find near optimal or even the optimal solution for many combinatorial optimization problems. Most GAs, including those in this study, use roulette wheel approach belongs to the fitness-proportional selection and can select a new population with respect to the probability distribution based on fitness values. The GAs in this study employs the fitness function (i.e. minimum sum of squared errors (SSE)).
Begin
  \( t = 0 \)
  Initialize \( P(0) \);
  Evaluate \( P(0) \);
  Find the best and worst chromosomes of \( P(0) \);
  \( \text{While } t < \text{a predetermined iteration number do} \)
    \( \text{Select two parent from } P(t); \)
    \( \text{Generate two offspring by crossover and mutation;} \)
    \( \text{Evaluate the offspring;} \)
    \( \text{If the offspring is fitter than the worst chromosome of } P(t) \text{ then} \)
      \( \text{Randomly select a parent except the best one and replace it;} \)
    \( \text{Find the best and worst chromosomes of } P(t); \)
  \( t = t+1; \)
end

Fig. 1: Proposed genetic algorithm

\[
\text{MaxF}(x) = 1/ \sum_{i=1}^{m} S_i (E_{obs} - E_{est})^2, i = 1, 2, \ldots, m
\]  

(1)

Where \( E_{obs} \) and \( E_{est} \) are the observed and estimated energy demand, \( m \) is the number of observation and \( S_i \) is the weighting factor.

In the original GA, all parents are replaced by their offspring to form a new generation, which is called generational replacement. Offspring may be less fit than parent because GAs are blind, causing some fitter chromosomes to be lost from the evolutionary process. Therefore, several replacement processes have been examined to resolve this problem. Holland proposed a crowding strategy that selects a parent that is most closely resemble the newborn offspring to die when the offspring is born. Gen and Cheng proposed that both parent and their immediate offspring are all candidates for the new generation to preserve the best chromosome. The GAs in this study follows a similar strategy. The population at iteration \( t \) Fig. 1 describes the basic GA [9-10].

GA uses three main operators: reproduction, crossover and mutation.

Each generation of a GA yield a new population from an existing one. The selection operator is responsible for choosing the member that will be allowed to produce during the current generation. These members are selected on the basis of their fitness (F) values and the most fitted individual are passed on to future generation.

Further manipulation is conducted by crossover and mutation operators before the replacement is actually done in a view of the next cycle. Crossover is to provide a mechanism for the exchange of chromosomes between mated parents. Mated parents then create an offspring with a chromosome set that is some mix of the parent’s chromosomes. For example, parent #1 has chromosome ‘abcde’, while parent #2 has chromosome ‘ABCDE’. One possible chromosome set for the offspring is ‘abeDE’, where the position between ‘e’ and ‘D’ chromosome is the crossover point. Mutation is a background operator, which produces spontaneous random changes in various chromosomes. A simple way to achieve mutation would be to alter one or more genes.

**THE GAEDM COEFFICIENT AND DECODING AND ENCODING**

One of the basic parts of GAEDM is to determine the coefficient which is made of GAEDM parameters.

The way to encode a solution into a chromosome is a key issue in using GAs. In fact, genetic algorithm works on the coding space (chromosome). The genes of the chromosome are real number to represent the weight invest in the assets. The encoding of space to the real numbers is performed as follow:

We assume that the weighting parameters would be \( \Psi = (w_1, w_2, \ldots, w_n) \). We can select eight bit binary variable for indicating the weighting parameters. If \( x \) would be the vector of chromosomes:

\[
x = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}
\]

\[
w_1 \quad w_2 \quad w_3 \quad w_4 \quad w_5 \quad w_6 \quad w_7 \quad w_8
\]

For converting the form of binary string to the real numbers, we can use the following equation:

\[
\psi_i = \psi_{i, \text{min}} + \frac{\psi_{i, \text{max}} - \psi_{i, \text{min}}}{2^i - 1}, i = 1, 2, 3, \ldots, z
\]

Where \( \psi_{i, \text{min}}, \psi_{i, \text{max}} \) are the minimum and maximum values of GAEDM parameters and \( \Phi_i \) is the integer value, \( z \) is the number of parameters and \( l \) is the number of binary bits per weighting parameters.

After encoding the chromosomes in a binary string, random generation of a population are selected. Then, for each subject is determine the fitness value by the fitness function as following form:

Where \( E_{obs} \) and \( E_{est} \), respectively, are the observed and estimated energy demand of Iran, \( m \) is the number of observation and \( S_i \) is the weighting factor.

The GA picks the fittest member of the population based on the maximum fitness value, effectively converting the fitness function to the continuously increasing function, such that the GA seek, the model with the largest value of \( P(x) \).

Figure 1 indicates the structure of GA optimization model. The input of this algorithm are population size (m),
Table 1: GAEDM and relative errors

<table>
<thead>
<tr>
<th>Year</th>
<th>Observed energy demand</th>
<th>GAEDM_{ine}</th>
<th>GAEDM_{exp}</th>
<th>GAEDM_{ine}</th>
<th>GAEDM_{exp}</th>
</tr>
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<tr>
<td>1979</td>
<td>37739</td>
<td>43891.06045</td>
<td>47406.73331</td>
<td>3784784.7750</td>
<td>9345006.380</td>
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<td>1980</td>
<td>39027</td>
<td>45245.36134</td>
<td>42041.95919</td>
<td>3868801.7740</td>
<td>9030916.016</td>
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<td>1981</td>
<td>43609</td>
<td>45467.97754</td>
<td>40785.07928</td>
<td>1519248574</td>
<td>7974528232</td>
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<tr>
<td>1982</td>
<td>50909</td>
<td>48996.88887</td>
<td>49576.10054</td>
<td>3656168983</td>
<td>1776620962</td>
</tr>
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<td>1983</td>
<td>43640</td>
<td>37065.54979</td>
<td>36326.00785</td>
<td>4322395600</td>
<td>53494481110</td>
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<td>1984</td>
<td>50661</td>
<td>45680.11294</td>
<td>43620.58355</td>
<td>16653639200</td>
<td>49567463770</td>
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<td>1985</td>
<td>54641</td>
<td>58785.78672</td>
<td>55059.06435</td>
<td>17179256980</td>
<td>17477779810</td>
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<td>1986</td>
<td>51895</td>
<td>68787.73686</td>
<td>68248.39053</td>
<td>19051554700</td>
<td>17591752830</td>
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<td>1987</td>
<td>56064</td>
<td>69267.91226</td>
<td>70530.25123</td>
<td>17434329800</td>
<td>209272424800</td>
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<td>56248</td>
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<td>81384.82551</td>
<td>350693023400</td>
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<td>1989</td>
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<td>78449.31718</td>
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<td>1990</td>
<td>68775</td>
<td>69877.75974</td>
<td>71424.61086</td>
<td>1216079043</td>
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<td>65566.30432</td>
<td>14055244700</td>
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<td>1992</td>
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<td>66327.1384</td>
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<td>1993</td>
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<td>75866.5248</td>
<td>76421.89011</td>
<td>52908097570</td>
<td>448530796500</td>
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<td>1994</td>
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<td>92015.8189</td>
<td>95656.61755</td>
<td>14048999897</td>
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<td>1995</td>
<td>94571</td>
<td>96361.35256</td>
<td>95535.98315</td>
<td>3205362275</td>
<td>9311924799</td>
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<td>1996</td>
<td>95714</td>
<td>102206.4153</td>
<td>103390.0453</td>
<td>42151456340</td>
<td>58921671610</td>
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<tr>
<td>1997</td>
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<td>105128.2797</td>
<td>104458.6882</td>
<td>10005599800</td>
<td>87099966950</td>
</tr>
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<td>1998</td>
<td>106555</td>
<td>109484.0174</td>
<td>107585.6622</td>
<td>8579142813</td>
<td>10622640230</td>
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<tr>
<td>1999</td>
<td>110894</td>
<td>112570.7458</td>
<td>111085.795</td>
<td>2811476443</td>
<td>3678533061</td>
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<tr>
<td>2000</td>
<td>120704</td>
<td>115201.8851</td>
<td>113573.7674</td>
<td>30273818930</td>
<td>50848217350</td>
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<tr>
<td>2001</td>
<td>126331</td>
<td>115327.1433</td>
<td>109758.4373</td>
<td>121084861300</td>
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<tr>
<td>2002</td>
<td>131960</td>
<td>116910.3338</td>
<td>107100.0126</td>
<td>290690749000</td>
<td>721458924500</td>
</tr>
</tbody>
</table>

Source: Research results

The probability of crossover (P_c), probability of mutation (P_m), the number of generation (k), number of decision variable for the problem (Z) and the number of possibilities of each decision variables (I).

By using this algorithm, the weighting factors of GAEDM are obtained.

This algorithm includes three loops:

- The outer loop performs the mutation and proceeds to the next generation.
- The middle loop do select and crossover on the chromosome.
- The inner loop I the basic one that evaluate the chromosomes using fitness function.

Finally, the coefficient of GAEDM is derived from inner loop.

**APPLICATION OF GAEDM**

Using economic indicators which included GDP, population, import, export and observation energy demand, are gathered from different resources between 1979 and 2002 (WDIJ, WTO, OECD and World Bank Indicators).

Figure 3 is showed the economic indicators between 1979 and 2002.

Two form of GAEDM are as follow:

\[ Y = w_1 X_1 + w_2 X_2 + w_3 X_3 + w_4 X_4 + w_5 X_5 \]  \hspace{1cm} (3)

And the exponential form is:

\[ Y = w_1 X_1^m + w_2 X_2^m + w_3 X_3^m + w_4 X_4^m + w_5 X_5^m \]  \hspace{1cm} (4)

Where Y is the energy demand of Iran, X_1 is GDP, X_2 is population, X_3 is export, X_4 is import and w_1, w_2, ..., w_5 are the weighting parameters that are estimated by GAEDM.

Based on experimental data, the appropriate values for GA parameters can be reported by Table 1.

The resulting of GAEDM can be as following forms:

The linear form of equation can better estimate the future energy demand due to the lower value of SSE.

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Fig. 2: Diagram of GAEDM. Source: search results

Fig. 3: Energy demand GNP, export and import figures of Iran. Source: search results
DIFFERENT SCENARIOS FOR ESTIMATION OF FUTURE ENERGY DEMAND: PERSPECTIVE OF TWENTY YEARS SOCIAL-ECONOMIC DEVELOPMENT PROGRAM OF IRAN

For estimation the future energy demand of Iran, we can use different scenarios which are designed based on Twenty Years Social-Economic Development Program of Islamic Republic of Iran. These scenarios are shown in Fig. 4.

**Scenarios 1:** This scenario is employed the average growth rate of GDP, population, export and import between 1979 and 2002 to estimate the energy demand of Iran until year 2020 [11].

**Scenario 2:** Trend line model (i.e. time series model). The polynomial trend is fitted to 24 data between 1979 and 2002 year that can indicate the trend line of observation. The equation of trend line can be as follow:

\[ Y = 113.17X^2 + 1210.7X + 38031 \]  

Where \( Y \) is energy demand, \( X \) is the year such that year 1979=1, 1980=2 and so on until 2020.

According to scenarios 1 and 2, the estimation value of scenario 2 is lower than its scenario 1, but this
approach may be used to estimate the energy demand of Iran lower than what will actually be needed in the long run [11-14].

CONCLUSION

This paper studies sustainable development and the effect of energy and population on it. In the other part of this paper, energy demand of Iran based on, GDP, population and export and import figures has estimated between 1997 and 2020. This study was performed by using GA approach. For estimation of future energy demand, we employed two scenarios.

The resulting data are comparable with observation data. We can describing the results as follows:

The linear form of equation can better evaluate the future energy demand of Iran than the exponential form. The GAEDM is very flexible in nature to estimate the future trend of energy demand and to optimization many near optimal solution.

One of the advantages of GAEDM is to find the optimal solution of a very large population. Therefore, this metal can overestimate the future energy demand by optimizing the parameters values.

The other advantage of this model is that each mathematical problem can be solvable by this model if the fitness function would be determined appropriately. The trend line and non-linear form of GAEDM estimate the energy demand lower than the linear form.

The actual values energy demand of Iran is between these values between of fluctuation of economic indicators and growth rate of Iran.

Future study should survey the energy demand of Iran in different sectors by using GAEDM.

The economist can use GAEDM for estimating and optimizing many economic problems. This model is very useful for future economic planning particularly [10-14].

REFERENCES