IRAN ENERGY BALANCE INVESTIGATION IN TWO SCENARIOS: WIND AND HYDRO POWER PLANT FOUNDATION

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ABSTRACT: *In this paper, IRAN energy balance is investigated to understand the energy flow in IRAN and improve the condition of consumption, production, and transformation of energy with regard to the importance of energy planning. First, the 2011 energy balance for Iran is simulated and the share of different sections such as crude oil, natural gas, coal, biomass, hydroelectric, renewable energy, and nuclear energy is determined. Second, the energy consumption of IRAN is predicted for the next 20 years to determine the energy balance of IRAN. To show the perspective of IRAN on renewable energy resources, two scenarios: a wind power plant and a hydro power plant foundation are investigated. The results show a decrease in the share of natural gas and an increase in the share of wind power in the wind power plant foundation scenario as well as a reduction in the share of natural gas along with an increase in the hydro power plant share in hydro-power plant foundation.*

Keywords: *Energy balance, Renewable energies, Hydro-power plant, Wind power plant*

1. INTRODUCTION

A complete and long-term planning in the energy production and consumption is necessary. Comprehensive management would be obtainable if energy specialists have clear perspective of future energy consumption growth[1]. These problems have been solved by using adequate energy measurement units and a scheme representing the energy flows that enter a country and how energy is used in different sectors along the year. Energy planning in developing countries is based on a reference energy system (RES). A RES is a format for graphical display of energy balance and it is originally designed as a tool for technology assessment. IRAN RES is shown in figure 1. There are a number of approaches one can use to generate RES. The simplest way is the calculation by hand. However, since the use of RES is to study the supply side impact of changes in demand structure in large networks, recalculations can be tedious. So RES matrix formulation is used in this study.

The objectives of energy balance are described as follow [2]:

- To provide essential information about different sectors in the country that specifies the production, transmission.
- To establish the basis for supporting the classification of energy, reliability, accuracy, stability and comparison of the information within the energy sector.
- To identify the energy sectors in detail.
- To analyze the energy supply and demand in the country.
- To assess in terms of energy demand structure, the process and potential of using alternative energy sources.
- To provide the basis to see the effect of public policies implemented in the efficiency and the operation of different energy sectors.
- To replace fossil fuels with sustainable energy sources.

In [3,4 ,5, 6] studies, the energy system are evaluated. Simulation of the fluctuation of decentralized energy production [7] and the interaction between them and available storage systems are also the important subjects [8,9 ,10, 11]. The general power plant model is simulated and optimized [12,13]. The Berlin energy balance is analyzed in [14]. Replacing coal with sustainable energy is performed in the reference [15].

The ultimate objectives of this study are evaluation of IRAN energy balance and understanding the production increase in different parts like crude oil, natural gas, coal, Biomass, hydro, wind, solar. Although IRAN is one of the most important gas rich countries in the world, the end of fossil fuel is not ignorable. The growth in replacing fossil fuels by renewable energy resources is mandatory. Among different renewable energy resources such as solar energy, wind energy, geothermal, hydro energy, biomass, two of the most widely used are wind energy and hydro energy. These two resources are used now in IRAN and to show perspective of IRAN to renewable energy resources, two scenarios including a wind power plant and a hydro power plant are evaluated and the effect of these scenarios on reduction of used natural gas and decrease in pollution are shown.

The paper is organized as follows; Section 2 will introduce the energy balance. Section 3 will present demand projection. Section 4 will provide energy balance estimation in the next twenty years. Section 5 is described two scenarios including wind and hydro power plant foundation and finally the conclusion is presented in section 6.

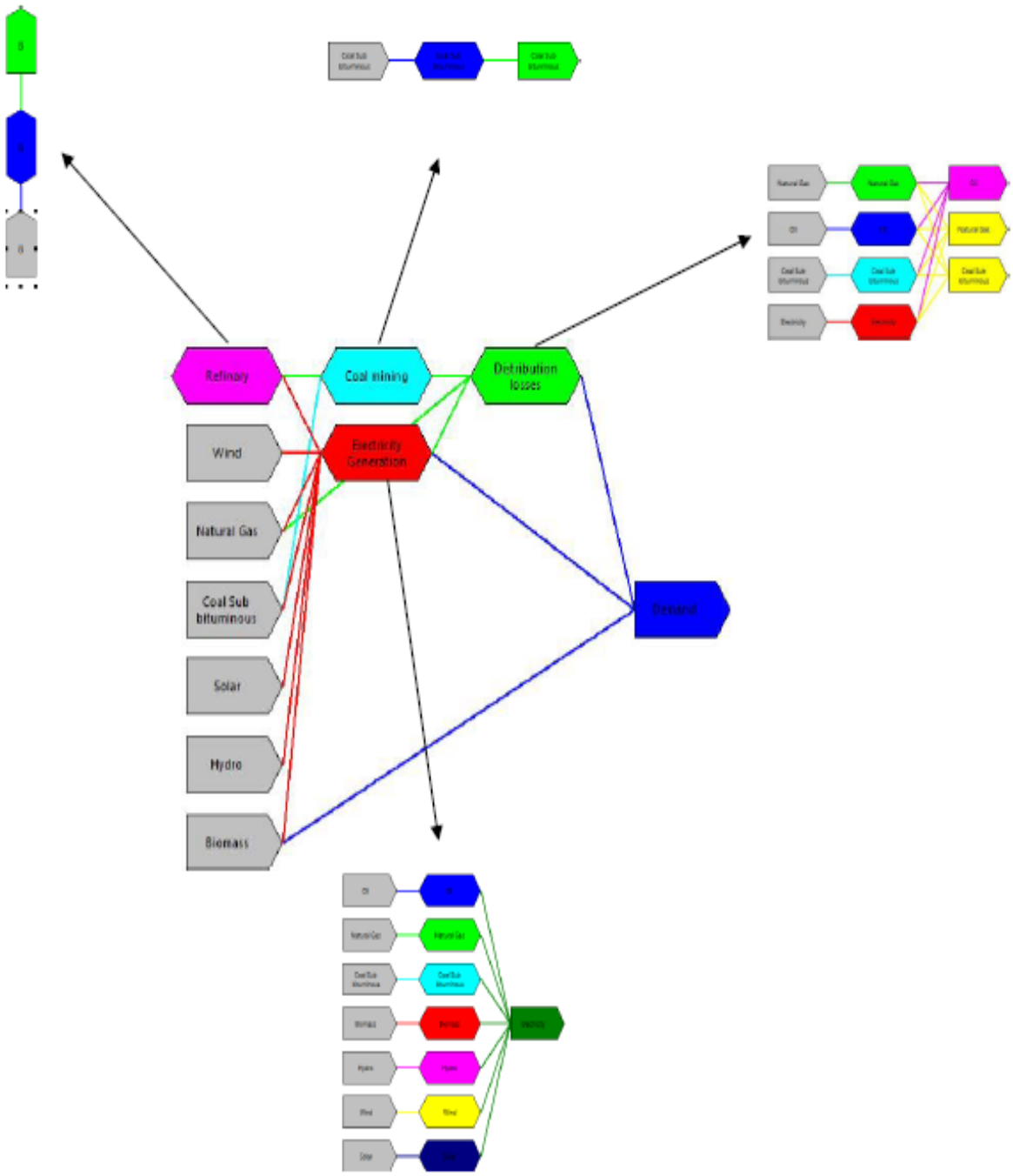

Figure. 1. Iran RES

2. ENERGY BLANCE

The dependence of the country economy development on growing energy prices, strict international environmental rules and energy planning shows the necessity of energy balance.

The energy balance has information about production and use of energy in the country. This data is related to the specific time. It is the equilibrium between what is produced, transmitted, dissipated and used in different sectors of the country [16]. An energy balance generally takes the form of an accounting table that presents the flow of energy from source, through conversion, to final use. IRAN energy balance is depicted on table 1.

2.1. Energy Resources

Some of the most important classification of energy sources is primary, secondary, renewable and non-renewable. The energy sources that are extracted from natural resources such as crude oil, natural gas, wind power, solar energy, geothermal, nuclear energy are called primary energy sources. The renewable resources refer to the sources that are derived from natural processes including biomass, hydro energy, solar and wind energy [16].

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TABLE 1.
2011 IRAN ENERGY BALANCE

Million barrel of oil	Crude oil	Natural gas	Coal	Biomass	Hydro energy	Solar and wind energy	Nuclear energy	Total electricity	Total energy
Production	1595.7	947.8	5.1	5.9	7.1	0.1	0.6	-	2562.3
Import	31.8	74.4	5.9	-	-	-	-	2.1	114.3
Export	-1029.5	-59.7	-1.5	-	-	-	-	-5.1	-1095.8
Fuel ship	-16.4	-	-	-	-	-	-	-	-16.4
Stock changes	37.8	-	-0.9	-	-	-	-	-	36.9
Total primary energy	619.4	962.5	8.5	5.9	7.1	0.1	0.6	-2.9	1601.2
Transmission	-2.8	-	-	-	-	-	-	-	-2.8
Oil refinery	-24	-	-	-	-	-	-	-	-24
Power plants	-140.4	-245.1	-1.4	-0.02	-7.1	-0.1	-0.6	141.2	-253.6
Coke units	-	-	-1.2	-	-	-	-	-	-1.2
Blast furnace units	-	-	-2.2	-	-	-	-	-	-2.2
Transmission and distribution losses	-30.9	-65.4	-1.4	-	-	-	-	-26.8	-124.5
Total use	421.3	652.1	2.2	5.9	-	-	-	111.4	1192.8
Household	55.5	318.1	0.1	5.9	-	-	-	50.7	430.2
Industry	38.5	214.3	0.1	-	-	-	-	40.7	293.6
Transport	257.1	39.3	-	-	-	-	-	0.2	296.6
Agriculture	24.3	3.9	-	-	-	-	-	17.7	45.8
Other uses	-	-	-	-	-	-	-	2.2	2.2
Non energy uses	45.9	76.4	2	-	-	-	-	-	124.3

2.2. Energy Flows

Production shows the energy that is extracted from different energy sources including renewable and non-renewable sources. Import is the amount of energy sources that are entered the country and export is the amount of energy sources that are sent out of the country. The difference between energy stock levels between January and December is stock change.

The consumption rate in different sectors like household, industry, transport, agriculture, other uses and non-energy uses are shown. Then, the primary energy is calculated by using consumption data, different power plant shares and power plant efficiencies and losses. In the next step, the imports, exports and production in different sections including crude oil, natural gas, coal, biomass, hydro, solar, wind and nuclear energy are obtained

3. DEMAND PROJECTION

The main reason to demand projection in different time period is having knowledge about the estimation of future demand. Overestimation causes additional investment and underestimation is the reason of production shortages. In this study, regression method is used for long term demand projection.

The short term and long term objectives of demand forecasting are [16]:

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- Control and reduction in the raw material.
- Having plan for future demand.
- Having appropriate pricing policy
- To avoid overproduction and underproduction.
- To have suitable information about production.
- Having plan for long-term financial goal.
- Planning for optimal use of renewable and non-renewable energy sources.
- Establishing new processes for meeting the requirements.

Using demand data in the last forty years [1], demand rate in household, industry, transport, agriculture and other ~~use~~ sectors by MATLAB tools is forecasted. Different sectors demand projection is shown on figure 2-6. Although using exponential functions with higher degrees increases the accuracy of regression, considering the rational process of data change in past, using lower degrees functions is preferred.

4. ENERGY BALANCE ESTIMATION IN THE NEXT TWENTY YEARS (FORECASTING)

According to demand growth in various sectors in the last forty years, the increase in production and import is expected. Production is estimated in the next twenty years, using LEAP and MATLAB tools. The result is shown in table 2.

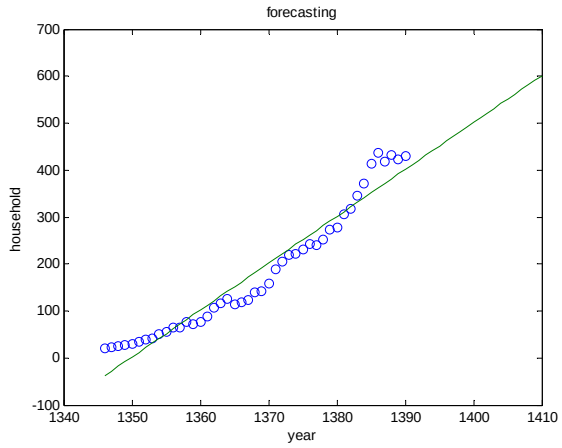

Figure. 1. Household demand projection

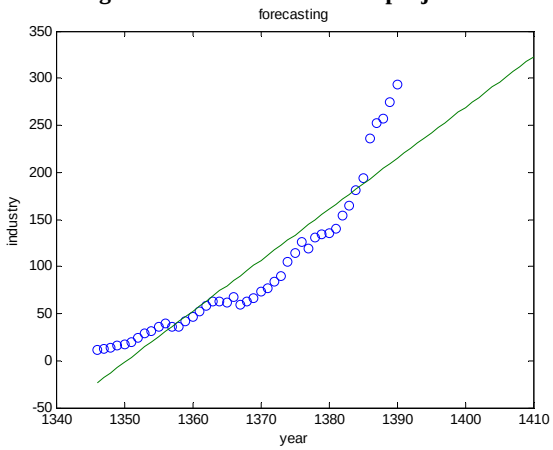

Figure. 2. Industry demand projection

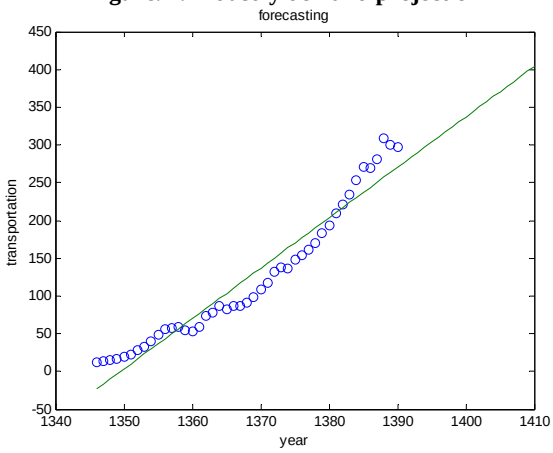

Figure. 3. Transportation demand projection

TABLE 2.
COMPARISON BETWEEN 2011 AND 2031 PRODUCTION

Production(Mboe)	2011	2031
Crude oil	1595.7	1858.76
Natural gas	947.8	1348.64
Coal	5.1	7.98
Biomass	5.9	8.59
Hydro energy	7.1	10.04
Solar and wind energy	0.1	0.28
Nuclear energy	0.6	0.85
Total energy	2562.3	3235.14

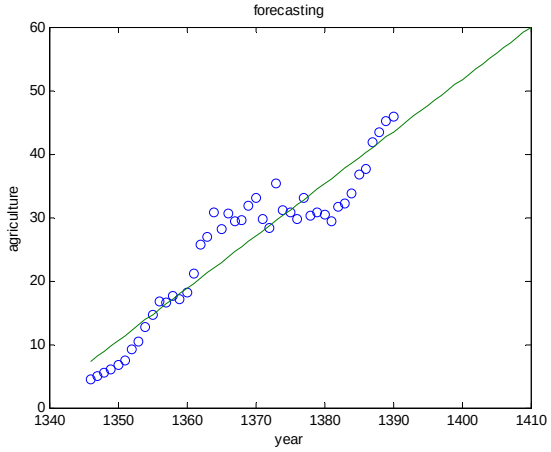

Figure. 4. Agriculture demand projection

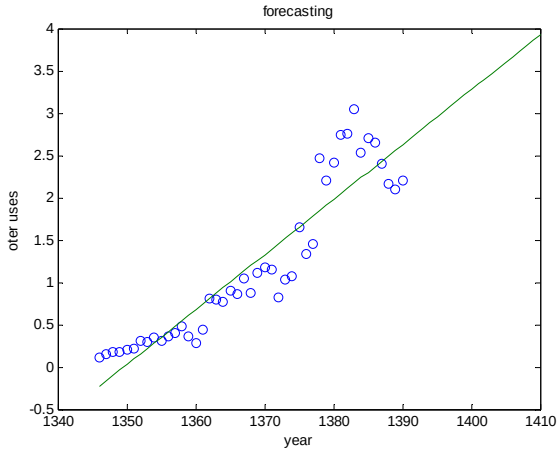

Figure. 5. Other uses demand projection

5. WIND AND HYDRO SCENARIOS

According to importance of renewable energy resources, some changes should be made towards the reduction of natural gas share and crude oil share and augmentation in using the renewable energy resources. Although the electricity generated by renewable resources is more expensive than others, the proper investment can compensate the problem Considering IRAN high potential in renewable energies, investment on them is essential.

The two scenarios for the twenty years forecasting are evaluated. The effect of these scenarios on the production rate and the contamination will be shown. These scenarios are simulated in MATLAB and LEAP tools.

5.1. Wind Power Plant Foundation

IRAN is located on southwest of Asia and more than half of its area is covered by mountain areas. According to wind atlas of IRAN, the nominal capacity of this country is about 60000 MW [17]. It shows the significant potential of IRAN in wind energy and specifies the necessity of investment on it.

In this paper a scenario of 4500 MW wind power plant foundation is surveyed. If the efficiency of wind power plant is assumed to be 35 percent, the energy from wind power plant, wind energy share and natural gas share will be equal to 8.1733 Mboe, 5.29 % and 55.09%, respectively.

The effect on the pollution in 2031 is available in table 3. In this paper, the contamination of power plants and transport sectors as the most important factors of environmental pollution is studied.

As it is illustrated in table 4, applying this scenario has decreased the pollution of power plant significantly. But it does not affect the pollution in transport sector because wind power plant foundation does not change the energy used in this section.

5.2. Hydro Power Plant Foundation

Hydro energy is the third electricity generation source and among the most important renewable resources in the world. It produces electricity through the use of the gravitational of falling or flowing water. Pump storage power plants are included in this category. This energy is reliable and has clear advantages and disadvantages. It can be used for electricity demand fluctuations. Considering IRAN potential, a large number of hydro power plants are in use. Table 5 illustrates the capacity and the year of operation of these power plants.

In this paper, the effect of each power plant in the electricity generation is studied. The energy of hydro power plant between 2011 and 2016 years is calculated and it is available on table 6.

The increase in hydro power plant share between 2011 and 2016 are equal to 6.56%, 6.58%, 9.05%, 9.55%, 10.2% and 11.31% , respectively. So the natural gas share during these years are 58.68%, 58.66%, 56.19%, 55.69%, 55.04% and 53.93% respectively. The natural gas share reduction during these years is obvious based on the data. The natural gas and hydro power plant generation is depicted on table 7.

TABLE 3.
COMPARISON BETWEEN NATURAL GAS AND WIND POWER PLANT RATE

Wind power plant (Mboe)	Natural gas (Mboe)	2016
0.22	275.02	Without scenario
8.39	251.51	Wind power plant foundation

TABLE 4.
COMPARISON BETWEEN POLLUTIONS IN 2031

85773376.2	Without scenario	Power plant pollution (ton)
39220654.15	Wind power plant scenario	
176779385.8	Without scenario	Transport pollution (ton)
176779385.8	Wind power plant scenario	

To evaluate the effect of hydro power plant foundation on pollution, the contamination in transport and power plant sections are calculated As it can be seen in table 8, this scenario decreases the pollution and it causes intense desire in renewable energy resources. It has no effect on the transport pollution because there is no relation between hydro power plant foundation that is located in the energy resources and transport sector that is in the final use sector.

TABLE 5.
HYDRO POWER PLANT FOUNDATION DURING 2011 - 2016 [17]

Foundation year	Annual average energy (GWh)	Power plant name
2011	843	Simare
2015	1121	Khorasan3
2013	4500	Gatoond Olia
2014	1019	Free pump storage
2013	500	Darian
2013	256	Sardasht
2015	577	Cheshmir
2013	986	Roodbar Lorestan
2016	2984	Bakhtiari
2011	1376	Siah bishe
2014	275	Khoda afarin
2011	1385	Tosee Maroon
2011	172	Dez
2012	40	Azad
2012	11	Gavoshan
2011	16.5	Sefidrood

TABLE 6.
AVERAGE ANNUAL ENERGY OF HYDRO POWER PLANTS DURING 2011 - 2016

Annual energy (Mboe)	Annual energy (GWh)	
2.2467	3792.5	2011
0.0302	51	2012
3.6978	6242	2013
0.7666	1294	2014
1.0059	1698	2015
1.7677	2984	2016

TABLE 7.
THE COMPARISON BETWEEN NATURAL GAS AND HYDRO POWER PLANT GENERATION

Hydro power plant (Mboe)	Natural gas (Mboe)	2016
8.01	275.02	Without scenario
18.11	246.21	Hydro power plant scenario

TABLE 8.
COMPARISON BETWEEN 2031 POLLUTIONS

85773376.2	Without scenario	Power plant pollution (ton)
38394579.82	Hydro power plant scenario	
176779385.8	Without scenario	Transport pollution (ton)
176779385.8	Hydro power plant scenario	

6. CONCLUSIONS

In this study, 2011 energy balance of IRAN is investigated and according to demand data in the past forty years, the demand for the next twenty years is forecasted. The forecasting is done by MATLAB and LEAP tools. The energy balance of IRAN for the next twenty years is also obtained. To see the result of various developments during

these twenty years, two selected scenarios are surveyed, the wind and hydro power plants. The wind power plant foundation scenario affects domestic production and decreases the environmental contamination in power plant pollution section. In this scenario the share reduction of natural gas and the share increase of wind power plant are equal to 23.51 and 8.17 million Boe in 2031. The hydro power plant foundation scenario has the same effects on domestic production and environmental pollution. The amount of increase in hydro power plant section is 10.1 million Boe and the decrease in the natural gas section is 28.81 million Boe in 2031. The pollution in power plant sector is extremely decreased. This reduction in the natural gas share for providing final use can affect fossil fuel imports in some countries and it can increase the amount of natural gas export.

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