STATISTICAL STUDIES OF ENERGY IN IRAN VS WORLD

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ABSTRACT:

Iran is increasing domestic demand for electricity has created supply shortfalls during times of peak energy demand. Iran recently increased electricity prices, which is a component of its energy subsidy reform, in hopes to limit demand growth.Iran holds the world's fourth-largest proved crude oil reserves and the world's first-largest natural gas reserves. Despite the country's abundant reserves, Iran's oil production has substantially declined over the past few years, and natural gas production growth has slowed. International sanctions have profoundly affected Iran's energy sector. Sanctions have prompted a number of cancellations or delays of upstream projects, resulting in declining oil production capacity.The aim of the present study is to identify capacity of various source of energy in Iran compared with world and potential of Iran to become top 10 energy producing countries in the world.

Keywords: Energy scenario; Primary energy consumption; Non-conventional energy; Million Tonnes oil equivalent (MTOE);

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Introduction:

Any physical activity in the world whether by human beings or by nature is caused due to flow of energy in one form to other. Energy is required to do any kind of work the work output depends on the energy input. The capability to do work depends on the amount of energy one can control and utilize. We cannot see energy, only its effects, we cannot make it, only use it; and we cannot destroy it, only waste it through inefficient use. The energy is most basic infrastructure input required for economic growth and development of a country. A systematic study of various forms of energy and energy transformation, including human experience and observations is called ***'Energy Science'***. The applied part of energy science useful to human society, nation and individual is called ***'Energy Technology'***.

1.1:Energy:Its definition

To discuss energy in a useful way, it is necessary to arrive at a definition of energy and ascribe to it physical units, so that the concept of energy can be discussed quantitatively and quantitative calculations can be performed. In physics, energy is defined as '***capacity for doing work'***. The word work is used with many different associations, but in physics, it has a very definite meaning: Work = Force x Displacement along the direction of force. To perform this work, energy must be available. In case of a person pushing a thing, the energy may be in the form of food calories. In another case, in which the force is exerted by an electrical device, the electrical energy used may be from electrical energy generating sources.

1.2:Various form of energy

In a sense, energy is simply the capacity for doing work. Energy may be transformed from one type to another and hence, much of the discussion of energy is related to the transformation of energy from one form to another so that it can do useful work. There is an important principle stating that the total amount of energy in a closed system remains constant. Energy may change from one form to another, but the total amount in any closed system remains constant. This principle, known as '***Conservation of Energy'*** is extremely important for understanding a variety of phenomena. Energy can still be changed from some useful form to some other form that for all practical purposes is useless, even though, formally energy is conserved in the process. The

various forms of energy and transformations of energy from one form to another are listed below.

a) Kinetic energy: Energy of motion is called kinetic energy. If an object has a mass, m and velocity v. then its kinetic energy is, KE = 1/2 mv^2.

b) Potential energy: The energy that an object possesses as a result of its elevation in a gravitational field is called potential energy and is expressed as, PE= mgh, where m is mass, g is the gravitational acceleration, h is the height.

c) Chemical energy: Chemical energy arises out from the atoms in the form of heat as they combine or separate. When certain chemicals combine, energy is released usually in the form of heat. It is the chemical energy in coal, natural gas, oil, wood etc. use to generate electricity. Also it is the chemical energy in the food we eat that provides the energy we need for daily life.

d) Electrical energy: Electrical energy arises out due to moving electrons in the form of heat, electro-magnetic radiation and magnetic field. If wires are connected to the battery and are connected to a light bulb or resistor, the energy contained in the battery is transferred through the wires and dissipated as heat in the resistor. There are number of sources of electrical energy besides batteries.

e) Heat energy: Heat energy is the kinetic energy of molecules. In daily life, we frequently refer to the heat content of bodies. It is also called the thermal energy.

f) Radiant energy: Radiant energy is the energy in transit through space. It is emitted by electrons as they change orbit and by atomic nuclei during fission and fusion. Such energy appears ultimately as heat. Only radiant heat can exist alone; all other forms require the presence of matter.

g) Nuclear (Mass) energy: Nuclear energy arises out of the elimination of all or part of the mass of atomic particles. As a consequence of special theory of relativity, it can be shown that when the mass of some system is reduced by an amount Δm, as in nuclear reaction, then the amount of energy released is, $E_n = \Delta mc^2$.

1.3: Classification of various sources:

Energy sources can be classified in the following ways.

1) Based on usability of energy:

a) Primary sources: Energy sources available in nature in raw form are called primary energy resources (fossil fuels, uranium, and hydrogen). This form of energy cannot be used as such. These are converted to a form as required by the consumer.

b) Intermediate sources: Energy sources which are obtained from primary energy sources by one or more steps of transformation are intermediate resources.

c) Secondary sources: The form of energy, which is finally supplied to the consumer for utilization, is known as secondary or usable energy (electric energy, thermal energy, chemical energy).

2) Based on long-term availability:

a) Non-renewable sources: Energy sources which are finite and do not get refill after their consumption, are called non-renewable (fossil fuels, uranium).

b) Renewable sources: Energy sources which are renewed by nature again and again and their supply is not affected by the rate of their consumption are called renewable (solar, wind, biomass, ocean, geothermal, hydro).

Outlet is called non-commercial resource, e.g. wood, animal dung cake, crop residue, etc.

3) Based on origin: The different types of energy based on their origin are as follows:

a) Fossil fuels energy **b)** Nuclear energy

c)Hydro energy **d)**Solar energy

e) Wind energy **f)**Biomass energy

g) Geothermal energy **h)** Tidal energy

i) Ocean thermal energy **j)** Ocean wave energy and many more……

1.4: Energy scenario ofworld (at end of 2013)

1.4.1 (A): Primary energy sources

1) Coal: The proven global coal reserve was estimated to be 891,531 million tonnes (MT) by end of 2013. The USA had the largest share of the global reserve (237,295 MT, 26.6 %) followed by Russian Federation (157,010 MT, 17.6 %) and China (114,500 MT, 12.8 %). Middle East is negligible with 0.1 %, 1122 MT of coal reservoir. (Iran less than 0.05 %)

With the current reserve-to-production ratio coal reserves will last for 113 years.

2) Oil: Total global proven oil reserve was estimated to be 1687.9 thousand billion barrels (TMB) (One Barrel = 158.98 Lit.). Venezuela has largest share (17.7 %, 298.3 TMB) of oil

reserve followed by Saudi. Arabia (15.8 %, 265.9 TMB), Canada (10.3 %, 174.3 TMB) and Iran (9.3 %, 157.0 TMB).Top 10 countries in the world with proven oil reserve listed in Table 1.1. With current reserve-to-production ratio world's oil reserves will last for another 53.3 years.

Table 1.1: World's top countries with proven oil reserve at end of 2013

Position	Country	% share Of world	Proven oil reserve	% of production share Thousandbarrelsdaily	% of Consumption share Thousandbarrelsdaily
1	Venezuela	17.7 %	298.3 TMB	3.3 %	0.9 %
2	S. Arabia	15.8 %	265.9 TMB	13.1 %	3.2 %
3	Canada	10.3 %	174.3 TMB	4.7 %	2.5 %
4	Iran	9.3 %	157.0 TMB	4.0 %	2.2 %
5	Iraq	8.9 %	150.0 TMB	3.7 %	Less than 0.2 %
6	Kuwait	6.0 %	101.5 TMB	3.7 %	0.5 %
7	United Arab	5.8 %	97.8 TMB	4.0 %	0.9 %
8	Russian Federation	5.5 %	93.0 TMB	12.9 %	3.7 %
9	Libya	2.9 %	48.5 TMB	1.1 %	Less than 0.1 %
10	US	2.6 %	44.2 TMB	10.8 %	19.9 %

3) Natural gas: Global proven gas reserve was estimated to be 185.7 trillion cubic metres (TCM)(One Trillion = 10^{18}). The Iran has the largest share of the reserve with almost 18.2 % (33.8 TCM) followed by Russian Federation and Qatar having total share of 16.8 % (31.3 TCM) and 13.3 % (24.7 TCM) respectively. The world's natural gas reserves will last for another 55.1 years.

4) Nuclear Energy: There are around 437 nuclear power plants in the world in 31 countries based on U^{235} generating total power generation ~ 372 GW (563.2 MTOE) which is about

1/6th of world's electricity. The world's top 10 countries nuclear energy consumption is shown in Table 1.2.

Table 1.2: World's top countries with nuclear energy consumption at end of 2013

Position	Country	% of share	Proven oil reserve
1	USA	33.4 %	187.9 MTOE
2	France	17.0 %	95.9 TMTOE
3	Russian Federation	6.9 %	39.1 MTOE
4	South Korea	5.6 %	31.4 MTOE
5	China	4.4 %	25.0 MTOE
6	Canada	4.1 %	23.1 MTOE
7	Germany	3.9 %	22.0 MTOE
8	Ukraine	3.3 %	18.8 MTOE
8	United Kingdom	2.8 %	16.0 MTOE
9	Sweden	2.7 %	15.1 MTOE
10	Spain	2.3 %	12.8 MTOE

The USA has the largest share of the consumption with almost 33.4 % (187.9 MTOE) followed by France 17.0 % (95.9 MTOE) and Russian Federation 6.9 % (39.1 MTOE). Uranium reserves in the world are small and expected to last hardly for 50 years. Concentrated deposits of uranium are not available. Major sources of uranium are available in USA, Canada and Australia. Thorium reserves are expected to be more than those of uranium.

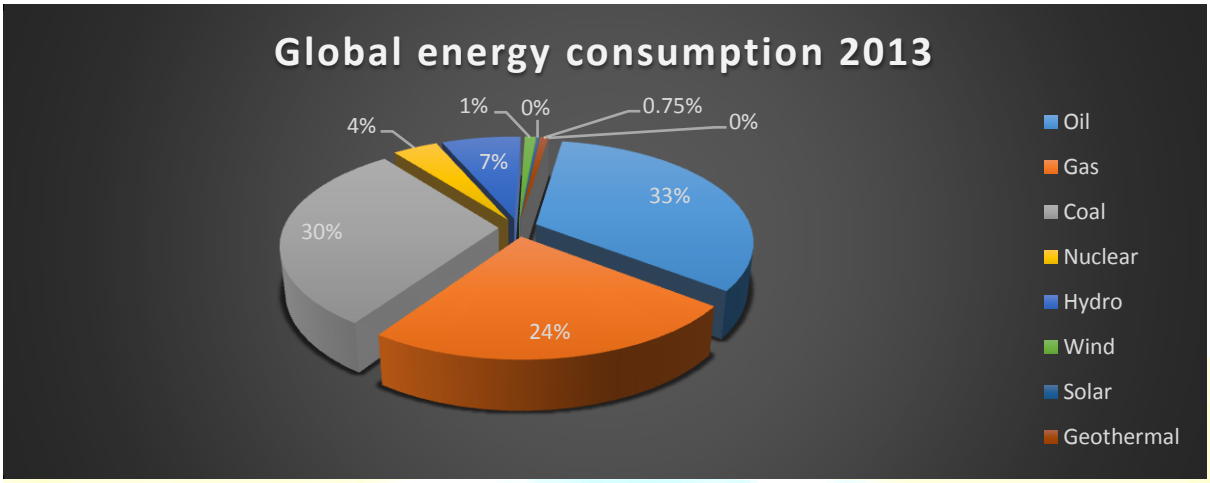
5) Hydroelectricity: Among all renewables, hydropower is the most established source of electric power. Due to requirement of huge capital investment and strong environmental concerns about large plants, only 20 % potential has been taped so far. The global installed generating capacity of hydropower is about 855.8 MTOE, which account 23 % of the world's total installed electric power generation capacity and 7 % of the world's primary energy supply.

Table 1.3: World's top countries with hydro-electric energy consumption

Position	Country	% of share	Proven oil reserve
1	China	24.1 %	206.3 MTOE
2	Canada	10.4 %	88.6 MTOE
3	Brazil	10.2 %	87.2 MTOE
4	USA	7.2 %	61.5 MTOE
5	Russian Federation	4.8 %	41.0 MTOE
6	India	3.5 %	29.8 MTOE
7	Norway	3.4 %	29.2 MTOE
8	Venezuela	2.2 %	19.0 MTOE
9	Japan	2.2 %	18.6 MTOE
10	France	1.8 %	15.5 MTOE

Biggest hydroelectric power station is located in China, at in Hubei. Its capacity is 22,500 MW. The dam is 1045 km^2.The world's top 10 countries hydro-electric energy consumption is shown in Table 1.3.As seen in the figure, the China is the biggest hydro-electric consumer in the world with 206.3 MTOE which is 24.1 % of globe's hydro-electric consumption. This is followed by Canada with 88.6 MTOE (10.4 %) and Brazil with 87.2MTOE (10.2 %) respectively.

It is interesting to note that the about 87 % of world's energy supply comes mainly from fossil fuels i. e. from oil, natural gas and coal whereas the remaining 13 % of the world's energy supply comes mainly from nuclear and hydro-electric energy.



1.4.1(B): Global Primary Energy Consumption

The global primary energy consumption at the end of 2013 was equivalent to 12730.4MTOE. The primary energy consumption for few countries is shown in Table 1.4.

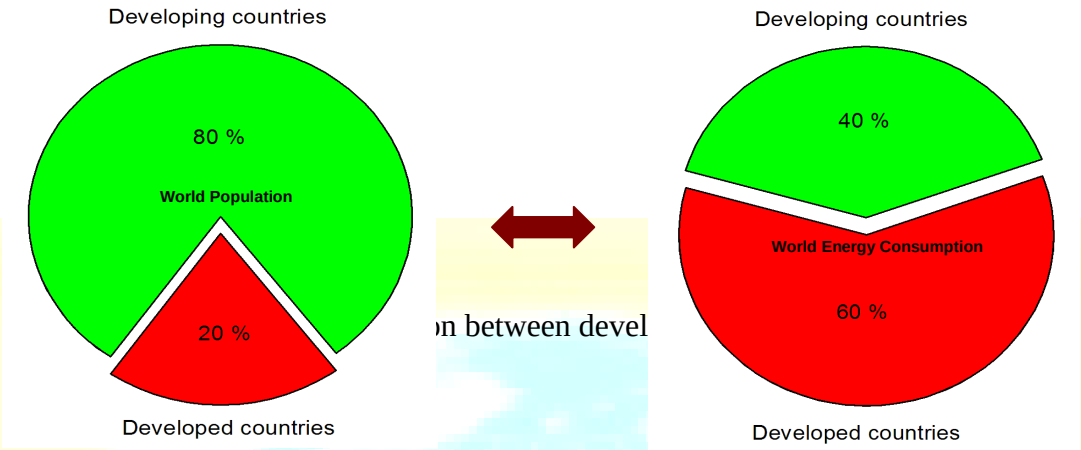
Table 1.4: Primary Energy Consumption by Fuel, 2013

Country	Oil	Gas	Coal	Nuclear	Hydro	Renewables	Total (MTOE)
China	507.4	145.5	1925.3	25.0	206.3	42.5	**2265.8**
USA	831.0	671.0	455.7	187.9	61.5	58.6	**2265.8**
Russian Federation	153.1	372.1	93.5	39.1	41.0	0.1	**699.0**
India	175.2	46.3	324.3	7.5	29.8	11.7	**595.0**
Japan	208.9	105.2	128.6	3.3	18.6	9.4	**474.0**
Canada	103.5	93.1	20.3	23.1	88.6	4.3	**332.9**
Germany	112.1	75.3	81.3	22.0	4.6	29.7	**325.0**
Brazil	132.7	33.9	13.7	3.3	87.2	13.2	**284.0**
South Korea	108.4	47.3	81.9	31.4	1.3	1.0	**271.3**
France	80.3	38.6	12.2	95.9	15.5	5.9	**248.4**
Iran	92.9	146.0	0.7	0.9	3.4	0.1	**243.9**
TOTAL WORLD	**4185.1**	**3020.4**	**3826.7**	**563.2**	**855.8**	**279.3**	**12730.4**

The China is largest primary energy consumer in the world followed by USA and Russian federation. Iran is 11th largest primary energy consumer in the world.

1.4.1(C): Energy distribution between developed and developing countries

Although 80 % of the world's population resides in the developing countries, their energy consumption amounts to only 40 % of the world total energy consumption (See figure 1.2).



The high standards of living in the developed countries are attributable to high-energy consumption levels. Also, the rapid population growth in the developing countries has kept the per capita energy consumption low compared with highly industrialized developed countries.

The world average energy consumption per person is equivalent to 2.2 Tonnes of coal. In industrialized countries, a person uses 4-5 times more than the world average and 9 times more than the average for the developing countries. An American uses 2.2 times more energy than an Iranian.

1.4.2: Non-conventional energy sources

Non-conventional technologies are under growth stage and their share is very small.

1) Solar energy: Solar photovoltaic (PV) is a method of generating electrical power by converting solar radiation into electricity On an average earth receives solar power of 22,25,04,000 TW, which is about 13,000 times the current world's energy consumption. World's total installed PV power is ~136GW(as of the 2013).The International Energy Agency (IEA) estimates the total global solar power capacity will grow from 98 GW in 2012 to 308 GW in 2018.Large-scale photovoltaic power plants in the world are listed in Table 1.5.

Table 1.5: Large-scale photovoltaic power plants in the world

Position	PV Power Station	Country	Capacity
1.	Longyangxia Hydro-solar PV Station	China	320 MWp
2.	Agua Caliente Solar Project	USA	250 MWp

3.	California Valley Solar Ranch	USA	250 MWp
4.	Charanka Park PV power plant	India	214 MWp
5.	Golmud PV power plant, Golmud	China	200 MWp
6.	Gonghe Industrial Park Phase I	China	200 MWp
7.	Centinela Solar	USA	170 MWp
8.	Solarpark Meuro	Germany	166 MWp
9.	Mesquite Solar I	USA	150 MWp
10.	Solarpark Neuhardenberg	Germany	145 MWp
11.	Catelina Solar Project	USA	143.2 MWp
12.	Campo Verde Solar Project	USA	139 MWp
13.	Solarpark Templin	Germany	128 MWp
14.	Arlington Valley Solar Energy	USA	139 MWp
15.	Centrale solaire de Toul-Rosières	France	115 MWp
16.	Perovo I-V PV power plant	Ukraine	105.56 MWp
17.	Chengde PV Project Phase I and II	China	100 MWp
18.	Jiayuguan PV power plant	China	100 MWp
19.	Xitieshan I,II,III PV power plant	China	100 MWp
20.	Sarnia PV power plant	Canada	97 MWp

2) Wind energy: The wind power potential is estimated ~ 1.6 x 10^7 MW, but harnessed so far is 318.137 GW. It is most economical among all renewable energy sources and is expanding at a rate of 30 % per year. Top 10 countries by wind power installed capacity are listed in Table 1.6.

Table 1.6: Installed wind power as on June 2013

Position	Country	Capacity
1	China	91,424 MW
2	United States of America	61,091 MW

3	Germany	34,250 MW
4	Spain	22,959 MW
5	India	20,150 MW
6	United Kingdom	10,531 MW
7	Italy	8,552 MW
8	France	8,254 MW
9	Canada	7,803 MW
10	Denmark	4,772 MW
…….	Iran	Around 100 MW

There has been remarkable growth of wind power installation in the world. Wind power installations worldwide have crossed 318,137 MW (installed capacity). China is the world leader in wind power with installed capacity of 91,424 MW.

3) Biomass energy: Energy resources available from animal and vegetation are called biomass energy resources. This is an important resource for developing countries, especially in rural areas. Principal biomass resources are,

i) Trees (wood, leaves and forest industry waste)
ii) Algae and other vegetation from ocean and lake
iii) Urban waste (municipal and industrial waste)
iv) Rural waste (agricultural and animal waste, crop residue, etc.)

Solar energy absorbed by plants (through photosynthesis process) is estimated to be $2x10^{21}$ J /year. Biomass material may be transformed by chemical or biological processes to produce intermediate bio-fuels such as biogas (methane), ethanol and charcoal, etc. At present there is millions of biogas plants in the world, most of them are in China.

4) Geothermal energy: Geothermal energy is derived from a huge amount of stored thermal energy in the interior of the earth. However, its economic recovery is not feasible everywhere on

the surface of the earth. Its overall contribution in total energy requirement is negligible. However, it is a very important resource locally. World's total present (end of year 2013) installed electrical power generating capacity from geothermal resource is about 11,765 MW (in 24 countries). Globally, geothermal power is growing steadily at a rate of about 8.5 % per year. The island of Hawaii derives 25 % of its electricity from geothermal resources.

Table 1.7:10 topperInstalled geothermal capacity up to 2013

Position	Country	Capacity
1	United States of America	3,389 MW
2	Philippines	1,894 MW
3	Indonesia	1,333 MW
4	Mexico	980 MW
5	Italy	901 MW
6	New Zealand	895 MW
7	Iceland	664 MW
8	Japan	537 MW
9	Kenya	215 MW
9	Costa Rica	208 MW
10	El Salvador	204 MW

5) Ocean tidal energy: The potential in ocean tides resource estimated is nearly 45,000 MW. It is in the developing stage. There are at present only few operational tidal power plants. The first and the biggest 254 MW tidal plant was built in Sihwa Lake Tidal Power Station, South Korea. Second one with capacity of 240 MW tidal plant was built in 1966 in France at the mouth of La Rance river, near St. Malo on the Brittany coast. The 240MW Swansea Bay Tidal Lagoon project, to be built at Swansea Bay in the UK, is the world's biggest tidal power project and will become the world's third biggest tidal power project upon completion.

Table 1.8: World's operational tidal power plants

Position	Country	Station	Capacity (MW)
Under construction	South Korea	Incheon Tidal Power Station	818 or 1,320
1	South Korea	Sihwa Lake Tidal Power Station	254
2	France	Rance Tidal Power Station	240
3	UK	Swansea Bay Tidal Lagoon	240
4	Scotland	MeyGen Tidal Energy	86
5	Canada	Annapolis Royal Generating Station	20
6	China	Jiangxia Tidal Power Station	3.2
7	Russia	Kislaya Guba Tidal Power Station	1.7
8	South Korea	Uldolmok Tidal Power Station	1.5
9	UK	Strangford Lough SeaGen Station	1.2

1.5:Energy scenario ofIran

1.5. (A): Primary energy sources in Iran

1) Oil Supply: Iran's proven oil reserve is 157TMB (9.3 %) of total oil reserves. The country's annual crude oil production is peaked at about 3558 Thousand Barrels/day (4%) against the peak demand of about 92.9 million tones. In the current scenario, the oil production of Iran is 3558 thousand barrels per day against the consumption of 2002 Thousand Barrels/day. Thus the net export of the oil is 1556 Thousand Barrels/day. It has been estimated that with the current reserve to production ratio the oil reserve will last for more than 100 years.(at the end of 2013)

2) Coal Supply: Iranhas less than 0.05 % of proven recoverable reserves of coal in the world. It may last for about 15 -20 years at the current reserve-to-production ratio. In contrast, the world's proven coal reserves are expected to last only for 113 years at the current reserve-to-production ratio.

3) Natural Gas Supply: Iran's proven natural gas reserve is 18.2 % (33.8 TCM) of world's total natural gas reserves. The current natural gas production rate is 166.6 Billion cubic meters/year

against the consumption rate 162.2 BCM/year at the end of 2013. Thus the net export of thegas is about 4.4 BCM of natural gas per year and this demand is expected to increase in future.

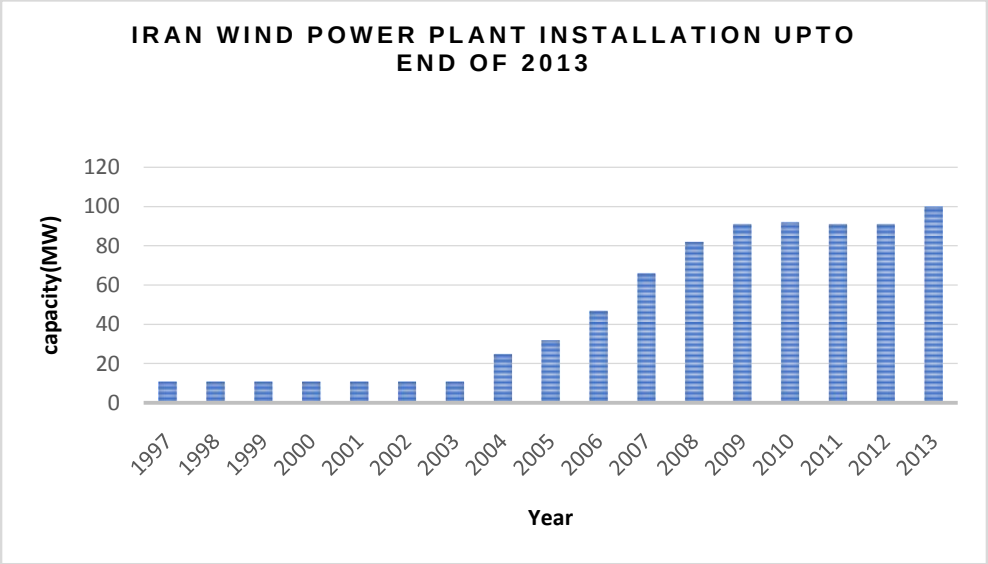
4) Nuclear Power Supply: Nuclear power is 3th largest source of electricity in Iran after thermal, hydroelectric. The Iranian government took control over the management of the plant in late 2013, around the same time the nuclear power plant began commercially producing power at its full capacity of 1,000 megawatts (MW), according to BMI. Two additional units are planned at Bushehr, each with a planned capacity of 1,000 MW, according to the World Nuclear Association.Iran plans to generate 23,000 MWh of electricity through nuclear technology by 2025 to meet its increasing demand for energy.

5) Hydro Power Supply: Iran is endowed with a vast and viable hydro potential for power generation. Iran stands 32th in the list of nations with hydro resources. Total share is 3.4 MTOE at the end of 2013(11 GW).

1.5. (B): Non-Conventional Energy Sources in Iran

Iran located in the region, is endowed with large renewable energy resources i. e. solar, wind and biomass including agricultural residue. Harnessing these resources is best suited to meet the energy requirement in rural areas in a decentralized manner. Iran has potential of generating more than 100,000 MW from non-conventional resources.Up to March 2013, the electrical power generation by non-conventional resource has reached only 0.1 MTOE (323 MW), which is about less than 1 % of total electrical power generation.

1) Wind energy: Iran has the potential to generate 20 to 30 GW of wind energy. That is half of the total energy consumption needs of the country.



2) Solar photovoltaic energy: Iran's unique geographical position means 90% of the country has enough sun to generate solar power 300 days a year. According to PressTV Iran has 520 watts per hour per square meter of solar radiation every day.

3) Biomass energy:A large quantity of biomass is available in Iran(20 Million Tonnes per year) in the form of dry waste like agro residues, fuel wood, etc. and wet wastes like cattle dung, sugarcane bagasse, banana stem etc. Biomass power generation in Iran has a potential ranges from 5000 MW to 10000 MW.

4) Geothermal energy: Iran has the potential to become the 9th largest geothermal energy producer. The first geothermal electricity generation station in Meshkinshahr, Ardebil with capacity of 250 MW installed in 2010.

5) Ocean wave and tidal energy: The global tidal range energy potential is estimated to be about 200 TWh/y, about 1 TW being available at comparable shallow waters. Within the European Union, France and the UK have sufficiently high tidal ranges of over 10 meters. Beyond the EU, Canada, the CIS, Argentina, Western Australia and Korea have potentially interesting sites. Additionally for Iran, there is a wide range of potentially interesting sites for tidal ranges.

Conclusions:

Currently, Iran is the 11th largest energy consumer in the world and the country's energy consumption is expected to increase in the near future. In the past, Iran has derived most of its energy from gas and oil but recently the country has been making efforts to extract energy from other sources. However, fossil fuels still remain the largest energy source.Iran has become self-

sufficient in designing, building and operating dams and power plants and it has won a good number of international bids in competition with foreign firms, so our target should be promotion of renewable energy with support of investorsby legislation of correct energy policy against world.

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