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Estimating the Potential to Achieve Electrical Energy from Biomass Resources in Iran (A Case Study in Isfahan)

Hossein Shahinzadeh[1] , Hajar Ghotb[2] , Masoud Tavanarad[3], Sayed amin feghhi[4] , Mohammad Hajahmadi[5]

[1] Department of Electrical Engineering, Islamic Azad University, Isfahan, Iran .
[2] Department of Electrical Engineering , Najaf Abad Branch , Islamic Azad University , Najaf Abad , Iran .
[3] Department of Chemical Engineering, Isfahan University of Technology , Isfahan , Iran .
[4]Department of Mechanical Engineering, Isfahan University of Technology , Isfahan , Iran .
[5] Department of Mechanical Engineering , Najaf Abad Branch , Islamic Azad University , Najaf Abad , Iran .

ABSTRACT

The IRAN has a significant biomass resource, estimated at an annual 25 million tons, but only a fraction of this is captured effectively for energy, contributing approximately 3.8% of the IRAN's heat and electricity production. Much biomass combustion technology may be considered as mature, although bottlenecks in the quality and quantity of feedstock are apparent, and further fundamental research is required to increase crop yield in a sustainable manner, with low chemical inputs to ensure efficient energy balance. In the short term, it could be useful for the IRAN to focus on developing a limited number of bioenergy chains, linked to combined heat and power micro-generation and the use of bioenergy for community and public sector projects. This should be linked to a joined up policy and regulatory framework. A clear strategy for land management is also required, since many competing uses for land will emerge in the coming decades, including food production, nature conservation, carbon sequestration, urbanization and other forms of renewable energy use. This finite resource must be managed effectively. In the long term future, considerable excitement exists about the possibility of new bioscience technologies harnessed to improve photosynthetic gains for bioenergy, including the use of synthetic biology. It may be possible to produce the designer energy plant whose outputs would include high quality chemical and liquid biofuels. Gasification of biomass also requires further technology development.

Keywords: *Micro-generation, Biogas resource, Renewable energy, Bioenergy, combined heat and power (CHP).*

I. INTRODUCTION

Bioenergy from photosynthetic solar conversion is the ultimate source of renewable energy, being defined as any biological mass derived recently from plant or animal matter, including material from forests (round wood, cutting residues and other wood brashings), dedicated crop derived biomass (woody short rotation coppice energy crops willow and poplar, grass crops miscanthus, timber crops), dry agricultural residues (straw, poultry litter) and wet waste (slurry, silage), food wastes, industrial and municipal waste. Bioenergy derived from these biomass streams, in general, has a lower carbon intensity and better energy balance relative to the use of fossil fuels and biomass to liquid conversions.

The IRAN has a considerable biomass resource, estimated at an annual 25 million tons, that may be utilized as a source of renewable energy, including for small scale heat and power production using a variety of waste streams, dedicated energy crops and forest residues. The Energy White Paper suggested that bioenergy could make an important contribution to the Government's energy and environment objectives, including energy security and the reduction of greenhouse gas emissions, relative to current practices.

It also highlighted the role of bioenergy in rural diversification and development. Despite this, attempts by the Government to stimulate the bioenergy sector in the IRAN have so far had limited success, although recently this market has seen increasing activity in combined heat and power micro-generation developments and the use of biomass to co fire power stations, where banding of the renewables obligation certificates should in future ensure that more IRAN grown dedicated crops are used for co firing. The report on bioenergy and the report attributed the general lack of progress to a focus on promoting specific technologies without full consideration of the wider market; the lack of integration of biomass supply with its utilization; and issues of public perception and planning, i.e. a whole systems approach requiring policy incentives and investment from several government departments [1].

Bioenergy for heat and electricity is complicated since several feed-stocks (sources of biomass), as identified, may contribute to this output for electricity generation, as depicted. In addition to the type of feedstock, different conversion technologies, including combustion, thermal and biological routes, are all possible. For electricity, bioenergy contributes over 80% of the renewable input, although, for both heat and electricity, the total contribution to the IRAN supply is approximately 3.8%. Specialist biomass crops include fast growing grasses such as miscanthus (called elephant grass) and coppiced trees willow and poplar. These crops are perennial and may achieve phenomenal yields in ideal conditions, producing in excess of 30 oven dried tons per hectare per year) close to the theoretical optimum, although these are rarely observed in commercial scale operations. Traditional food crops such as wheat and rape may also be used for bioenergy Varying amounts of land have been suggested for biomass feedstock production from the 17 million hectares of IRAN agricultural land available [2].

II. VEGETATION CHARACTERISTICS OF IRAN

The Islamic Republic of Iran (I.R.IRAN) with area of about 1,648,000 km2 is located in the southwest of Asia and lies approximately between 25N and 40N in latitude and between 44E and 64E in longitude. Iran with an area of more than 1.6 million square km, Iran is the sixteenth largest country in the world (FAO, 2005). Placed in the Middle East and surrounded by the Armenia, Azerbaijan, Caspian Sea, Turkmenistan on the north, Afghanistan and Pakistan on the east, Oman Sea and Persian Gulf on the south and Iraq and Turkey on the west. Population of Iran is about 70 million and the growth rate estimated as 1.7%. (FAO, 2005) and it has 30 Provinces.

Iran's important mountains are Alborz and Zagros ranges. Alborz and Zagros Chains stretch in northwest-northeast and northwest- southeast direction. These mountains play an important role in determining the non-uniform spatial and temporal distribution of precipitation in the whole country. The area within the mentioned mountain ranges is high plateau with its own secondary ranges and gradually slopes down to become desert which continues into southern part of Afghanistan and near the Pakistan border. Elevation ranges from 500 to 2500m. Damavand peak in the Alborz reaches 5600m above mean sea level while the Caspian coastal area is below sea-level (-28 m).

The country's climate is mainly arid or semi-arid, except the northern coastal areas and parts of western Iran. The climate is extremely continental with hot and dry summer and very cold winter particularly in inland areas. Apart from the coastal areas, the temperature in Iran is characterized by relatively large annual range about 22°C to 26°C. The rainy period in most of the country is from November to May followed by dry period between May and October with rare precipitation. The average annual rainfall of the country is about 240 mm with maximum amounts in the Caspian Sea plains, Alborz and Zagros slopes with more than 1,800 and 480 mm, respectively.

Since Iran is in the arid zone, some 65% of its territory is arid or hyper arid, and approximately 85% has an arid, semi-arid or hyper arid environment, the specific features and location of Iran causes it to receive less than a third of the world average precipitation.

Prolonged drought in this area and availability of moisture in other parts of Iran has led to the formation of different ecological zones (Figure 1) [3].

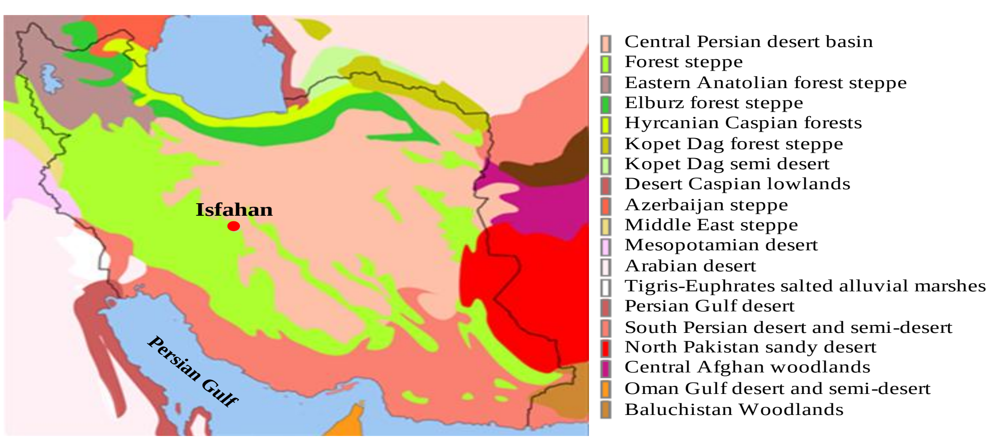

Figure 1: Distribution of four ecological zones of Iran

III. CLIMATIC CHARACTERISTICS OF ISFAHAN

The climate of Isfahan is semi-arid and considered temperate. It is characterized by relatively high summer temperatures, low rainfall and humidity. Winter night-time temperatures are cold.

a) *Hot Summer Temperature* – Maximum temperatures rises to 43°C, and remains relatively high at night-time even with a 21 degree fluctuation.
b) *Winter temperature below freezing* – The months of November through March have the potential to drop below freezing at night.
c) *Strong Sun* – UV index at 11 in the summer months is considered very high or extreme.
d) *Very Dry* - less than 5 inches of rain annually, principally in the winter months.
e) *Low Humidity* – Humidity ranges from a high of 60% in the winter to a low of 25% in the summer.
f) *Wind Direction and Speed* – Wind is typically westerly, ranging from 8 Km/Hr. in the winter to 22 km/hr. in the spring. Wind has been recorded up to 58 km/hr. creating dust/haze.
g) *Daylight* – Isfahan is located at 32°38'N with maximum summer daylight hours of 14 hours, and 10 hours in the winter.
h) *Earthquakes* – Iran is prone to earthquakes, and Tehran (340 KM to the north of Isfahan) sits on 100 fault lines. Isfahan is considered a moderate fault zone.

In summary, the climatic factors of Isfahan mean that they are not within the temperature comfort zone, swinging between being hot and dry in the summer (with strong sunlight) and relatively cold and dry in the winter.

IV. CATEGORIES OF BIOMASS MATERIALS

Within this definition, biomass for energy can include a wide range of materials. The realities of the economics mean that high value material for which there is an alternative market, such as good quality, large timber, are very unlikely to become available for energy applications. However there are huge resources of residues, co-products and waste that exist in the world which could potentially become available, in quantity, at relatively low cost or even negative cost where there is currently a requirement to pay for disposal. There are five basic categories of material (Figure 2):

a) *Virgin wood*: from forestry, arboricultural activities or from wood processing.
b) *Energy crops*: high yield crops grown specifically for energy applications.
c) *Agricultural residues:* residues from agriculture harvesting or processing.
d) *Food waste*: from food and drink manufacture, preparation and processing, and post-consumer waste.
e) *Industrial waste and co-products:* from manufacturing and industrial processes [4].
f)

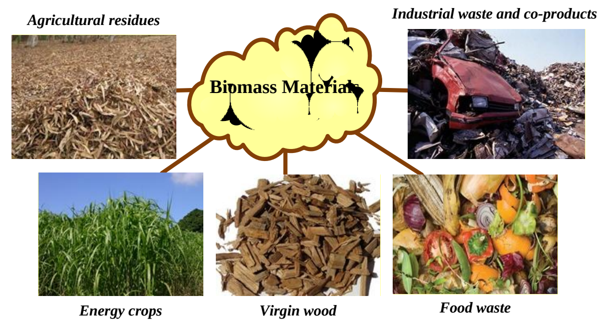

Figure 2: Categories of Biomass Materials

V. BACKGROUND CONDITIONS

The future success of bioenergy developments in IRAN depend on many factors, such as the policy framework conditions, the availability of suitable and high efficient conversion technologies, the long term and cost effective biomass fuels supply security, and the impacts on environmental and social issues.

In IRAN, the national energy policy promotes renewable energy to address the key issues on energy security, the reduction of energy imports and the reduction of greenhouse gas emissions. Among other instruments the Energy Conservation Promotion Fund is the government's tool to implement power purchase and subsidy programs for power producer from Renewable Energy. Promotional Measures are the provision of "Adder" for power generation using Renewable Energies and the provision of soft loans for the implementation of Renewable Energy projects [1]. For power generation from biomass the rate of adder (or feed in premium) varies on the installed capacity of a project and is fixed for a supporting period of 7 years. Projects with an installed capacity of ≤1MW receive a feed in premium of 0.5 $/kWh, projects above 1 MW only 0.3 $/kWh. Special adder of 1 $/kWh is provided if projects are implemented in three of the Southern Provinces.

Since IRAN is a tropical country and the climate is offering an ideal environment for Biomass production, bioenergy is the most important Renewable Energy in future [5].

TABLE I: Electricity Generation from Renewable Sources in IRAN

Renewable Sources	Unit Existing capacity
Wind	380.13 MW
Solar	160.7 MW
Hydro	5800 MW
Biomass	52 MW
Total electricity from Renewable Sources MW	6392.83 MW

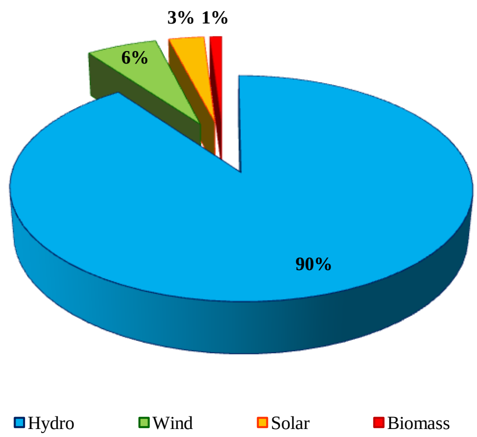

Figure 3: Segmentation of Renewable Electricity Generation in Iran

Within the Alternative Energy Development Plan of the Iranian Government until the year 2025 a tripling of Power Generation and a significant increase of liquid biofuel production for the transportation sector is expected. Thus, the demand for biomass as energy source will inevitably increase over time, putting pressure on fuel supply security and associated topics. If sustainability requirements do not receive the necessary consideration, this pressure might affect pricing for agricultural products and food security supply aspects too. For this reason, the use of agricultural residues as Energy sources offers a promising opportunity to promote the future development of bioenergy utilization. Since using agricultural residues as energy sources will not interfere with food security, such fuels will meet the requirements for a future sustainable based energy supply [6].

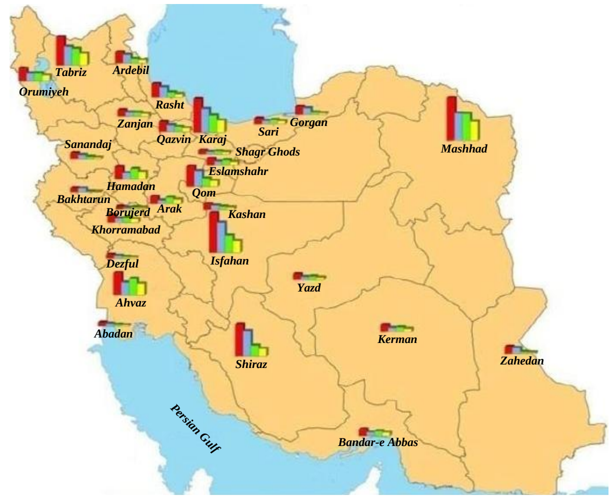

Figure 4: Evaluation of Energy Generation from Biomass Sources in Different Regions Iran

TABLE II: The Amount of Power Generation from Biomass Sources in Different Regions Iran

City name	Pinc (mw)	Ppg (mw)	Pad (mw)	Pslf (mw)
Abadan	2.13	1.53	1.03	0.72
Ahvaz	12.00	6.90	8.99	6.34
Arak	3.91	1.95	3.44	2.34
Ardebil	5.95	4.48	2.42	1.71
Bakhtarun	2.35	2.09	0.30	0.21
Bandar-e Abbas	3.62	2.02	2.68	1.89
Borujerd	1.23	0.68	0.94	0.66
Dezful	2.20	1.59	1.07	0.75
Eslamshahr	3.64	2.08	2.74	1.93
Gorgan	4.22	3.45	1.26	0.89
Hamadan	6.56	3.21	5.47	3.86
Isfahan	21.16	16.02	9.06	6.39
Karaj	17.78	12.58	9.07	6.40
Kashan	2.92	2.05	1.52	1.07
Kerman	3.85	2.14	2.46	1.73
Khorramabad	3.89	2.31	2.73	1.93
Mashhad	22.60	14.43	14.26	10.05
Orumiyeh	6.50	4.03	4.06	2.86
Qazvin	5.11	3.58	2.63	1.85
Qom	10.64	8.22	4.21	2.97
Rasht	7.42	5.70	2.79	1.97
Sanandaj	3.20	2.33	1.49	1.05
Sari	3.05	1.73	2.26	1.59
Shagr Ghods	2.09	1.19	1.57	1.11
Shiraz	17.29	13.72	5.98	4.22
Tabriz	15.11	9.85	8.83	6.22
Yazd	2.98	1.66	1.90	1.34
Zahedan	3.81	3.15	1.00	0.71
Zanjan	3.41	2.19	2.12	1.49

Pinc: Power generation using livestock and agricultural waste
Ppg : Power generation using human and industrial wastewater
Pad : Power generation using anaerobic digestion process
Pslf : Power generation using food and forest waste

VI. EXISTING TECHNOLOGY FOR CONVERSION RESIDUES

The appropriate technology for biomass energy application in a power plant depends on the type of power generation and its capacity. As coal-fired boilers haven't still developed in Iran, installation of a separate biomass-fired boiler or a biomass gasify is considered as an alternative for fossil fuel substitution in steam power plants. Raw biomass or processed solid fuels such as chars, pellets or Refuse Derived Fuel (RDF) can feed these units.

A considerable number of Iranian thermal power plants are based on gas turbines. They use originally natural gas but diesel fuel is supplied for them during natural gas shortage periods. Suitable technologies for these power plants are who can produce liquid or gaseous fuels from biomass or wastes. Gasification process can produce synthetic gas from biomass or RDF, but additional expensive units are necessary to enhance the quality and heating value of sync-gas so it can be used in existing gas turbines without considerable lowering their efficiency. However, modern conversion technologies have recently been commercialized to produce liquid fuels from biomass with more reasonable prices [7].

VII. THERMOCHEMICAL CONVERSION

The thermochemical conversion processes require fuels with high heating values and for this reason lower water contents of the biomass fuels. The most common process is the direct combustion of the fuels to produce thermal energy, which can be used e.g. for steam production and in further steps for electricity generation by using steam turbines, steam engines or other energy converter. Further suitable thermochemical processes are gasification and pyrolysis processes, which will convert the biomass into so called secondary bio fuels, such as combustible gases or oils as a fuel for gas engines and gas turbines to generate electricity (see figure. 5) [8]. A promising advanced Biomass Power Generation concept for the future is the combination of gasification technologies with advanced gas turbines to biomass integrated gasification combined cycle concepts which will result in higher efficiencies compared to conventional Biomass Power Technologies. Net conversion to electricity is projected to be approximately 30% for biomass integrated gasification combined cycle plants, compared to 18 to 22% for conventional biomass combustion plants. integrated gasification combined cycle is a proven concept for coal-based power generation (reaching electrical efficiencies up to 45% in large scale applications), but since up to now only large scale applications seem to be economic feasible, the conventional steam cycle processes will remain the most important technological solutions for the next years [9].

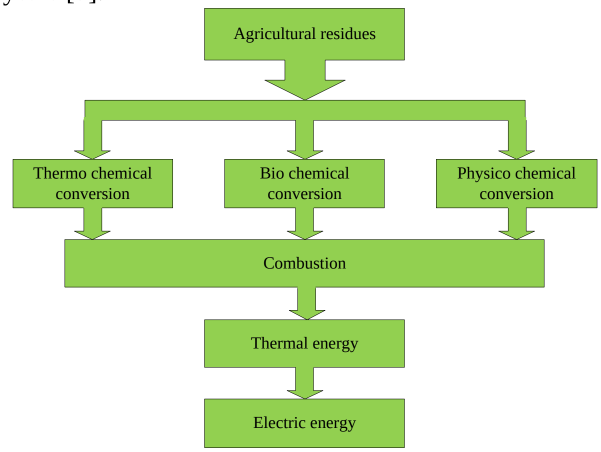

Figure 5: Conversion Routes for Agricultural Residues.

VIII. STEAM CYCLE BASED BIOMASS POWER GENERATION

The conventional conversion technologies for solid biofuels by combustion have a great importance for the electricity generation. Most of the biomass power generation plants use direct fired systems, whereby the biomass is burned directly and the released thermal energy is used to produce steam leading to the generation of electricity via so called conventional steam cycle processes. The combination of direct biomass combustion technologies, steam generators and power generation facilities like steam turbines, steam engines, steam screw engines and systems is already established at market and the power range between 0,2 max. 15 MW meets the requirements of the decentralized utilization of biomass. Most of the systems (especially in the lower power range below 15 MW) are grate boilers, whereby the fuel is fed to the grate with the help of mechanical or pneumatic fuel feeders [10]. The fuel is burned on the grate and the hot combustion gases are passing through heat exchanger to generate high pressure and high temperature steam to run a steam turbine (see figure 6). Most of the biomass power plants are operated with relatively low temperature and pressure steam parameters (steam pressures of between 29-60 bar and temperatures between 450 485°C). Such systems can reach typical net electrical efficiencies between 20-25%, depending on plant capacities and steam parameters [11-12]. Since there is a correlation between plant capacities and technological complexity, only some demonstration plants are operated with increased steam parameters reaching higher electrical efficiencies of approx.

Fluidized bed combustion systems can be economically used for higher plant capacities and such systems are for this reason a promising opportunity for co firing systems with coal in large scale applications. The biomass co firing in coal fired power plants offers significant advantages: it is highly efficient, approximately between 35% and 42%, depending on the efficiency of the coal fired unit (35-41%). Such co firing with coal is the simplest way to use biomass since an existing coal fired power plant is used and this is more cost effective than building a new power plant. Typical share of biomass in such co firing systems is between 10-18 % contributing to the substitution of the coal and related environmental issues such as the mitigation of greenhouse gases [13].

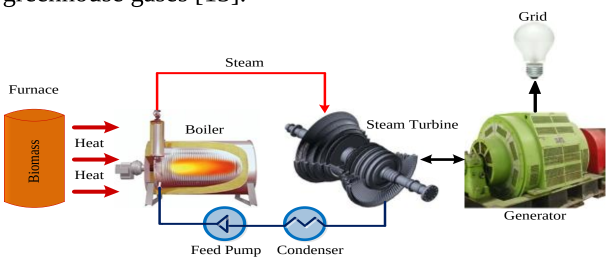

Figure 6: Flow Sheet Diagram of Conventional Steam Cycle for Power Generating

IX. The Theoretical Potential for Energy Recovery from Biomass Resources in Isfahan

Isfahan is the capital of Isfahan Province in Iran, located about 340 km south of Tehran. It has a population of 1,583,609 and is Iran's third largest city after Tehran and Mashhad. The Isfahan metropolitan area had a population of 3,430,353 in the 2006 Census, the second most populous metropolitan area in Iran after Tehran.

Estimate the potential for extracting energy from biomass resources in this area, Start to the data collection and processing of a number of basic industries, the number and capacity of sewage networks within Cities with the facilities, the rate of production in the food industry, number and type the animals, population of people in cities above 5000, and the amount of agricultural land and production products agricultural and garden in this area. Figure 7. Shows recycling and waste conversion plant in Isfahan.

Figure 7. Recycling and Waste Conversion Plant in Isfahan

In Table 3 we examine the statistics and data from this study, and will checked of Potential and energy utilization rate of this method.

TABLE III: Evaluation Biomass Potential in Isfahan

Input materials	Production of input materials (Thousand tons)	Electric energy production (Mwh)	Price ($)
Livestock waste	4996.4	969.9	62478
Agricultural and forest waste	2314.75	930.886	59964
Human sewage	Cities over 100 thousand	41.65	2683
Industrial Wastewater	-	47.498	3059
Total production using anaerobic digestion process	-	279.76	18022
Total	-	2269.694	146206

X. CONCLUSION

IRAN has abundant biomass resources for power generation. Caused by governmental targets to increase the share of renewable energies within the national energy mix and since biomass is the most important renewable energy source used in IRAN, the demand for biomass as energy source will inevitably increase over time, putting pressure on fuel supply security and associated topics. The use of agricultural residues as an energy source is a promising opportunity to reduce this pressure, since the use is, in the most cases, in compliance with sustainability criteria such as the protection of resources, compatibility with environment and climate, social compatibility issues, low risk and error tolerance and is furthermore offering a comprehensive economic efficiency. It is estimated that agricultural residues could provide up to 20% of the total primary energy demand of the country and a considerable share could be used for power generation.

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