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Nuclear Power and Its Role in CO_2 Emissions from the Electricity Generation Sector in Iran

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Abstract *Electricity demand in the Islamic Republic of Iran will continue to increase dramatically in the future due to the rapid pace of economic development leading to construction of new power plants. All forms of electricity generation have some level of environmental impact, such as air pollution, water resource use, water discharge, solid waste generation, and land resource use, and greenhouse gas emission. Concerns about greenhouse gas emissions affect decision-making about construction of new power plants. Comparison of different kinds of power plants indicates that nuclear power is not directly emitting greenhouse gas emissions. So nuclear power plants could be a suitable replacement for thermal power plants. Of course, renewable power plants could be used too, but the capacity of nuclear power plants is almost more than renewable power plants. Power plants in Iran are mainly thermal, burning fossil fuels, which emit a great deal of pollutants and greenhouse gases. The only nuclear power plant of Iran (Bushehr nuclear power plant) will be operating in 2009. This article attempts to interpret the role of Bushehr nuclear power plant in the* CO_2 *emission trend of the power plant sector in Iran.*

Keywords climate change, CO_2 emission, electricity generation, emission, greenhouse gas, nuclear power plant

Introduction

During the last decades, electricity generation contributed to socioeconomic development and changed people's lives radically (Söderholm and Sundqvist, 2003; Sundqvist, 2004). Today, electricity demand is growing rapidly leading to construction of new power plants (Wehner, 2006; Zwaan and Gerlagh, 2006). Lately, health issues raised as harmful consequences of power plants are rising rapidly (López et al., 2005; Wang and Mauzerall, 2006).

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Evaluation of power plants is not simple as several criteria are involved to cover every aspect of modern society. Multicriteria analysis and externalities assessment can be applied to evaluate electricity generation systems on the living standard (Chatzimouratidis and Pilavachi, 2007; Chatzimouratidis et. al., 2008). Fossil fuels supply more than 68% of the commercial electricity. The huge dangers of climate change are caused mainly by fossil fuel combustion (Verbruggen, 2008).

According to the current situation, concern for environmental preservation has increased the demand for more efficient management and environmentally sound and sustainable development of nuclear energy (Lee and Koh, 2002).

The international response to climate change began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The UNFCCC's principal framework for action aims to stabilize atmospheric concentrations of greenhouse gases to avoid "dangerous anthropogenic interference" with the climate system. The international endeavor culminated with the entering into force of the Kyoto Protocol to the UNFCCC in February 2005, which commits developed countries and economies in transition (known as Annex B countries) to reduce their overall emissions of six greenhouse gases (GHGs) by an average of 5.2% below 1990 levels between the years 2008–2012 (i.e., the first commitment period) (Weisser et al., 2008).

One disagreement at the United National level is whether or not nuclear power should play a role in a post-2012 climate change agreement. The fact is that nuclear power virtually emits no GHG at the level of the power plant and ranks among the lowest electricity generating option with regard to life-cycle GHG releases (Weisser, 2007).

Indeed, recent international studies point to a role of nuclear power in combating climate change alongside other energy supply and demand side mitigation options (IEA, 2006a; EPRI, 2007; IPCC, 2007). It is necessary to mention that nuclear energy has been excluded from Kyoto Protocol's mechanisms as an eligible technology (Weisser et al., 2008).

Electricity generation contributes to a large share of CO_2 emissions in Iran (MOE, 2009). Several alternative technologies are available to reduce this industry's emission, such as hydropower. A substantial supply side shift away from fossil fuel resources will likely rely on diverse technologies, due to limitations of each individual alternative. Massive expansion of hydroelectric, wind, and solar power is limited by a combination of liabilities, including resource constraints, declining site characteristics, intermittency, and grid stability (Meier et al., 2005).

Nuclear power on earth can be considered as an unlimited resource only when fusion will be technically, economically, and safely possible (IEA, 2006b).

Environmental benign nuclear fission is a carbon-free process. Other emissions (inert gases) in the air are not as massive and diverse as emissions from fossil fuel combustion. Release of radioactive isotopes is the most significant source of contamination; massive releases happen in the case of accidents (Shrader-Frechette, 1991).

Advocates of nuclear power have recently framed it as an important part of any solution aimed at fighting climate change and reducing greenhouse gas emissions (Benjamin, 2008).

Resources of fossil fuels are plentiful, but finite, which eventually will limit the use of these fuels. The Islamic Republic of Iran, with a considerable amount of oil and gas resources, is one of the exporters of primary energy. However, during the past three decades, due to the ongoing process of social and economical developments, the present strategy of utilizing energy resources in the country is being halted. On the other hand, environmental issues are becoming important worldwide (Gorashi, 2007).

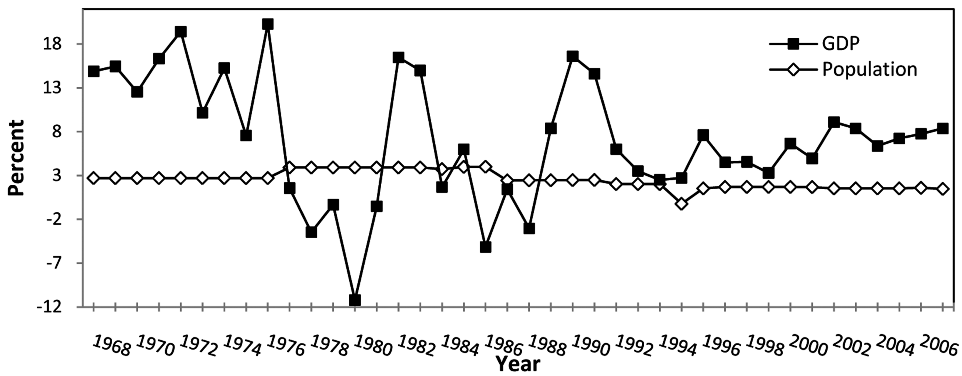

Figure 1. Annual growth of population and GDP during 40 years in Iran (1968–2007) (%). (*Source*: MOE, 2001, 2008, 2009.)

A large amount of GHG emissions belong to the Energy Sector[1] of Iran, especially thermal power plants. In other words, thermal power plants are responsible for most of the anthropogenic GHG emission in Iran. The fraction of GHG emission in thermal power plants was 24% in 2007[2] (MOE, 2009).

Electricity Generation in Iran

According to the population census in 2006, Iran has a population of over 70.5 million (MOE, 2001, 2008, 2009). Figure 1 shows the annual growth of population and GDP during 40 years (1968–2007) in Islamic Republic of Iran.

Primary energy production and final energy consumption has been 2,427.8 and 975.2 million crude oil equivalent barrels, respectively, in 2007. Annual growth of total primary energy and total final energy consumption during 40 years in Iran (1968–2007) are shown in Figure 2 (MOE, 2001, 2009).

Thermal power plants play the main role in electricity generation in Iran. Steam power plants, combined cycle power plants, gas power plants, hydro power plants, and diesel power plants have the most shares in electricity generation, respectively. Renewable power plants (including wind and solar) have a small role in electricity generation. In Figure 3, electricity generation in Iran and worldwide have been compared by different types of power plants (MOE, 2007; IEA, 2009).

Electricity demand fluctuates in the short term in response to business cycles, weather conditions, and prices (EIA, 2009).

According to current policies in Iran for diversification in electricity supply, substitution of renewable and nuclear energy with fossil fuels is considered as future plans. According to its time table of different power plants operating, capacity of MOE power plants should be increased by about 45,007 MW from 2008 to 2015 (MOE, 2009).

[1]Energy sector in Iran means energy consumers sector, which includes the household and commercial sector, transport sector, industry sector, refinery sector, and agriculture sector.

[2]At the time of preparing this article, the last official statistical report of the energy sector and GHG emissions in Iran was in 2007. Thus, the data used in this article is for a 40-year period from 1968 to 2007.

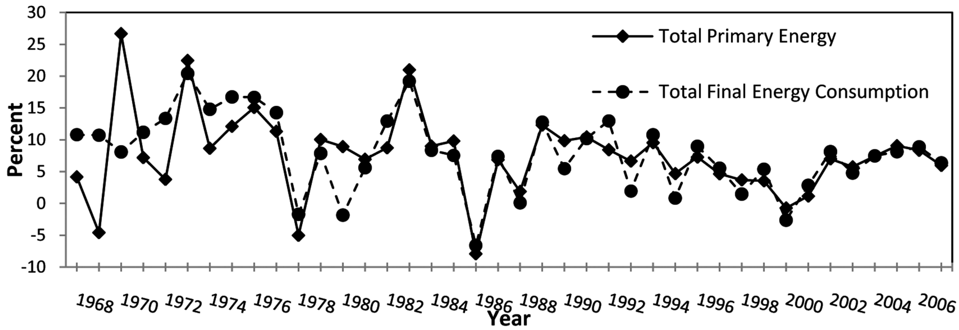

Figure 2. Annual growth of total primary energy and total final energy consumption during 40 years in Iran (1968–2007) (%). (*Source*: MOE, 2001, 2009.)

Figure 4 shows the annual growth of electricity generation and consumption during 40 years in Iran (1968–2007) (MOE, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009).

Electricity generation in Iran has been an increasing trend during the past 40 years (1967–2007). The increasing trend shows that electricity generation in 2007 is 100 times more than electricity generation in 1967. Also, electricity consumption has the same trend in the studied period. Figure 5 indicates the gross electricity generation and electricity consumption during 40 years in Iran (MOE, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009).

CO_2 Emissions and Power Plants

Thermal power plants are the major polluters of man's environment, discharging into the atmosphere the basic product of carbon fuel combustion, CO_2 (Prisyazhniuk, 2008), which results in a build-up of the greenhouse effect and global warm-up of our planet's climate (Prisyazhniuk, 2006). According to increasing electricity generation during the studied period in Iran, CO_2 emission has been increased too. As shown in Figure 6, CO_2 emission from thermal power plants of Iran in 2007 is almost 80 times greater than that related to 1967 (MOE, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009).

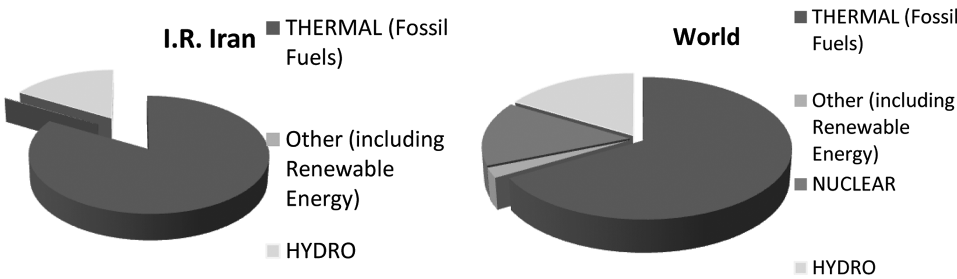

Figure 3. Comparison of electricity generation by different types of power plants (World and Iran), 2006. (*Source*: MOE, 2007; IEA, 2009.)

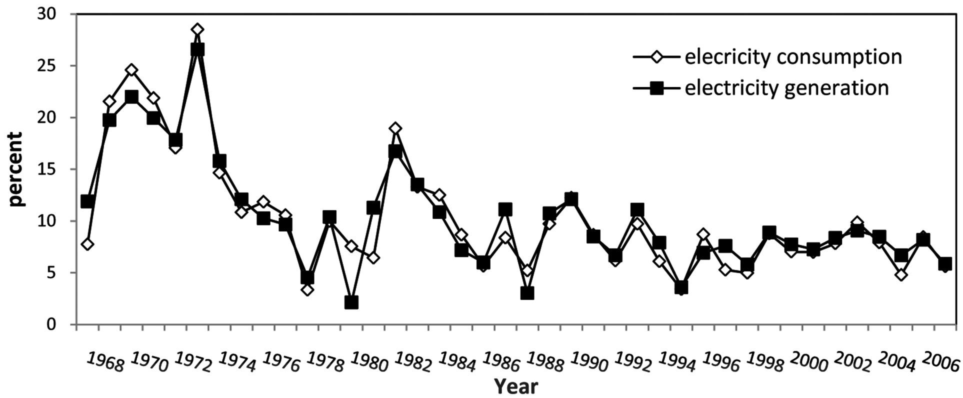

Figure 4. Annual growth of electricity generation and consumption during 40 years in Iran (1968–2007) (%). (*Source*: MOE, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009.)

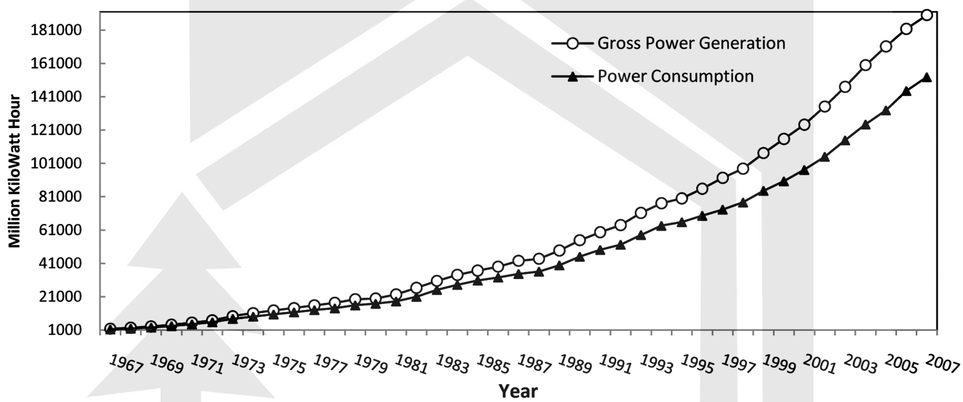

Figure 5. Trend of gross electricity generation and power consumption during 40 years (1967–2007) (MKWh). (*Source*: MOE, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009.)

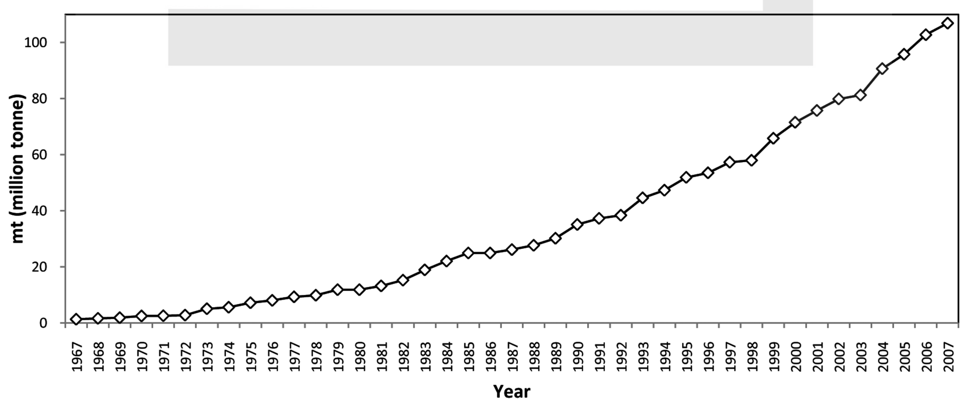

Figure 6. Trend of CO_2 emission in thermal power plant sector of Islamic Republic of Iran during 40 years (1968–2007). (*Source*: MOE, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009.)

Nuclear Energy in Iran

One of the main missions of the Atomic Energy Organization of Iran (AEOI) is to apply nuclear energy to generate electricity under the supervision of International Atomic Energy Agency safeguards. In relation to nuclear power plant construction and development, the most important activities of the AEOI could be categorized to the following main fields: "completion of Bushehr Nuclear Power Plant (BNPP)," "design and construction of IR-36 based on domestic potentials," and "site selection for new nuclear power plants with capacity of 20,000 MW" (MOE, 2008).

In order to supply the required nuclear fuel for future nuclear power plants, Iran has been managed by the following activities:

- Uranium exploration and mining,
- Uranium concentration production (Yellowcake),
- Uranium processing for different uranium products (uranium conversion facility [UCF]),
- Uranium enrichment,
- Production of pipes,
- Zirconium bars and other new alloys (zirconium production plant [ZPP]),
- Production of nuclear fuel assembly (fuel manufacturing plant [FMP]), and
- Production of heavy water (D_2O) in industrial scale.

Figure 7 indicates the location of the above centers in Iran (Secretariate of Scientific Cooperation Council, 2008).

Introduction of Bushehr Nuclear Power Plant (BNPP)

BNPP with a VVER1000/V446 pressurized water reactor has four coolant loops, a reactor coolant pump, and a horizontal steam generator on each loop. The reactor coolant system (RCS) transports heat from the reactor core to the steam generators that provide steam to the turbine generators through the main steam lines. Four primary coolant loops have a common flow path through the reactor vessel. Each RCS loop includes a horizontal steam generator and a main circulation pump. The pressurizer, which maintains overall system pressure (16 MPa), compensates the changes in the primary coolant volume. The pressurizer is connected to the cold leg and hot leg of the primary loop piping by a spray pipeline and an injection pipeline in one of the loops. The steam generators are horizontal units with submerged tube bundles. The primary coolant flows through the tube side and the feedwater is delivered to the shell side (Nematollahi and Zare, 2008). Some characteristics of BNPP (especially reactor) have been described in Table 1 (Nematollahi and Zare, 2008; Public Relation of BNPP, 2009).

Results and Discussion

Effect of Bushehr Nuclear Power Plant on CO_2 Emission

In order to study the effect of BNPP on CO_2 emissions from the electricity generation sector in Iran, two scenarios could be assumed as follows:

1. Operating of nuclear power plant in coming years (1,000 MW nuclear power plant),
2. Substitution of a fossil fuel power plant instead of BNPP (1,000 MW thermal power plant).

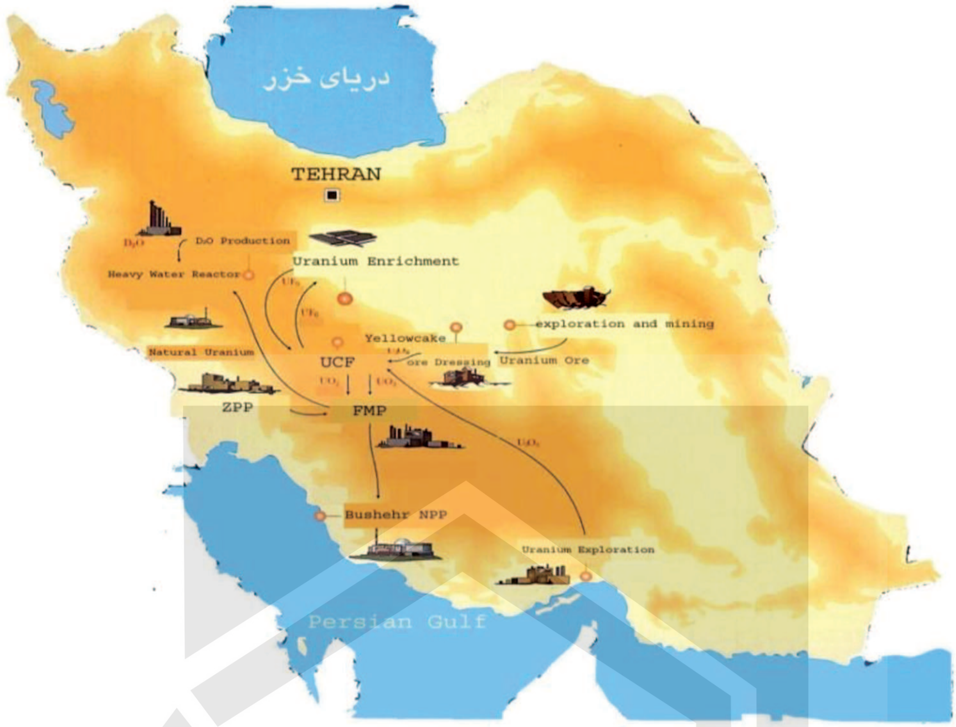

Figure 7. Location of nuclear cycle activities in Iran. (*Source*: Secretariate of Scientific Cooperation Council, 2008; color figure available online)

Table 1
Some characteristics of Bushehr Nuclear Power Plant

Parameter	Dimension	BNPP[a] value
Thermal reactor power	MW	3,120
Electric power	MW	1,000
Fuel type	—	Uranium dioxide
Weight of fuel	Ton	80
Number of fuel complex	—	163
Height of fuel complex	m	4.57
Pressure at the reactor outlet	MPa	15.7 ± 0.3
Pressurizer level	M	7.80
Coolant temperature at the reactor inlet	°C	291
Coolant temperature at the reactor outlet	°C	321
Secondary pressure	MPa	6.27 ± 0.1
Main feed–water temperature	°C	220
Emergency feed–water temperature	°C	40

[a]Bushehr Nuclear Power Plant.
Source: Nematollahi and Zare, 2008; Public Relation of Bushehr Nuclear Power Plant, 2009.

Scenario 1: Trend of CO_2 Emission in the Power Plant Sector of Iran with Operating of BNPP

By operating BNPP in 2009, nominal capacity of electricity generation in the Islamic Republic of Iran will be increased by about 1,000 MW, which could increase the electricity generation almost 7,000,000 MWh per year.

On the other hand, according to statistics, a 2,562 MW thermal power plant will be operated in 2009, which consists of 12.4% gas power plants, 83.7% combined cycle power plants, and 3.9% hydro power plants (MOE, 2009).

Also, according to the same statistics, all nominal capacity of thermal plants in 2015 will be 45,007 MW, in which the share of steam power plants, gas power plants, combined cycle power plants, hydro power plants, and nuclear power plant (BNPP) are, respectively, 1.4, 6.5, 79.7, 10.2, and 2.2% (MOE, 2009). Therefore, the electricity generation plan in Iran is to develop combined cycle power plants in the future.

Scenario 2: Substitution of a Fossil Fuel Power Plant Instead of BNPP (1,000 MW Thermal Power Plant)

In this scenario, CO_2 emission will be determined, if a fossil fuel power plant is assumed to be instead of BNPP. Considering the plan of Iran for developing combined cycle power plants and reducing other kinds of thermal power plants, it is assumed that a combined cycle power plant with the same electricity generation as BNPP is operated. The CO_2 emission trend for two scenarios is shown in Figure 8.

As shown in Figure 8, BNPP will decrease the CO_2 emission in the power sector of Iran. The trend of CO_2 emission in Scenario 1 is almost 18 times less than Scenario 2 in 2015, whereas the CO_2 emission in Scenario 2 is almost 32 times greater than the one related to Scenario 1 in 2009. Obviously, the role of BNPP is very important and considerable in decreasing CO_2 emissions from the power plant sector in the Islamic Republic of Iran. It is predictable that according to developing nuclear power plants in Iran at about 20,000 MW, this value will be more considerable in future years.

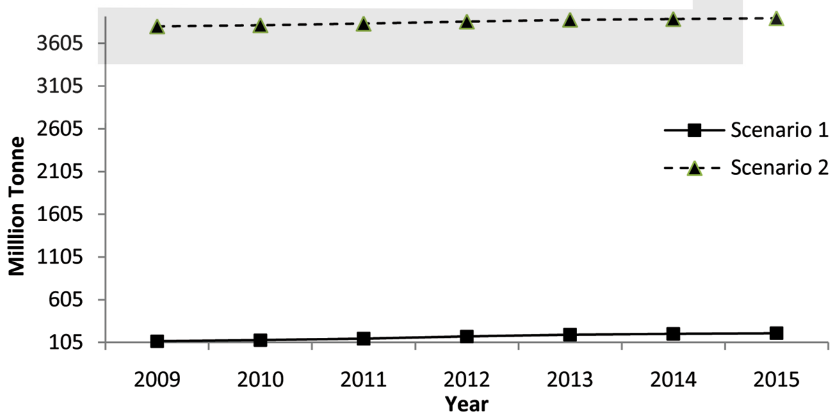

Figure 8. CO_2 emission trend for Scenario 1 and Scenario 2.

Conclusion

- Electricity generation in Iran in the year 2007 is 100 times more than the electricity generation in 1967.
- Fossil fuels combustion in power plants is responsible for most of the anthropogenic GHG emission in Iran. The fraction of GHG emission in thermal power plants has been 24% in 2007.
- CO_2 emission from thermal power plants of Iran in 2007 is almost 80 times greater than the one related to 1967.
- The nuclear power plant is a carbon-free technology for electricity generation.
- BNPP has a considerable effect on the trend of CO_2 emission of the power plant sector in Iran.
- It is predictable that the operation of a 20,000 MW nuclear power plant in Iran will cause a considerable decrease in the trend of CO_2 emission from the power plant sector.

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