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NUCLEAR ENERGY PRODUCTION IN JORDAN: OPPORTUNITIES AND THREATS

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Abstract

Energy and Water are two words that overburden the world policies and people lives. Its availability is essential for the development of nations and enhancement of their life standards. Jordan is a country that imports 98% of its energy from outside. The variation of the fuel prices and the instabilities in the region exhausted the country's economy. Citizens are almost shouting from the high prices and the dramatic drop in the living standards. In this study, the nuclear energy production option is selected to be analyzed from its opportunities and threats to the country. It has been found that nuclear reactors are a must for countries which have a large population with few natural resources. Nuclear reactors are rarely exploding, but if it does; its radiation effects on people are full catastrophe. Nevertheless, Jordan has a large area per capita with a very high insolation; Jordan has a high potential of solar power plants construction in its different regions, which is a green save energy. This energy is capable of solving Jordan electric needs and put Jordan in the level of developed countries with high human development indices.

Keywords: Water, Energy, Developing countries, Nuclear Power, Sustainability

Introduction

Energy and Water are two commodities that overstrain people and policies all over the world. Wars that exterminate people and countries are results of these two disaster words. Shortly world to continue developing and even survive, is in an urgent need for water and energy. The funny is that as overall there is enough water and energy in the world (Petrol, Gas, Coal, Solar and even Nuclear). The problem is that, it is not well distributed according to the needs of each country, plus cupidity of the powerful countries to control all energy and water sources. Wisdom could be a brief answer but where it could be found?

People around the world start suffering from the shortage of water and the high price of energy. Revolutions are initiated in most of the developing countries; destruction prevailed. In this study, and as a try to cover a part of the water and energy needs in Jordan, the nuclear energy production is selected to be highlighted studying its opportunities and threats, whether Jordan has other options to get out of its water and energy problems.

Jordan is suffering from an extreme shortage in water and energy. Jordan imports 98% of its energy needs; the energy cost in Jordan is more than 20% of its national income, being as a large block in the way of developing the country, and affect the country political stability. According to IAEA 2010, Jordan generates 14.3 billion kWh of electricity, mostly from natural gas, and imports 0.4 billion kWh of electricity in 2009 for its six million people. In 2012, due to gas supply constraints from Egypt, its electricity supply was 25% from natural gas imported (unreliably), 32% from heavy fuel oil, 32% from diesel, and 11% was imported. It has 2400 MWe of generating capacity and expects to need 3600 MWe by 2015, 5000 MWe by 2020 and 8000 MWe by 2030 when it expects doubled electricity consumption. About 6800 MWe of new plants is needed by 2030, with one third of this projected to be nuclear. The per capita electricity consumption is about 2000 kWh/yr [10]. World Nuclear Association states that Jordan has regional grid connection of 500 MWe. Also it has a "water deficit" of about 600 million cubic meters per year. It pumps about 60 million m^3/yr of fossil sub artesian water from the Disi/Saq aquifer, and this is set to 160 million m^3/yr in 2013. It contains elevated, but not hazardous, levels of radio-nuclides, principally radium.

Jordan's 2007 national energy strategy envisaged 29% of primary energy from natural gas, 14% from oil shale, 10% from renewable and 6% from nuclear by 2020. People in Jordan are standing opposite to the nuclear energy. Here in this study the nuclear power plants are highlighted with its benefits and threats to have an idea whether nuclear energy should be stopped or continued.

World Energy

In the area of energy there are energy-rich and energy-poor countries. Out of the world's population 6.7 billion, over 5 billion people live in the economically poor countries, about 3 billion live in rural areas. While these people on one hand face natural climate like droughts and floods, making them even much poorer and socially unstable, on the other hand these people face high oil and gas prices. In fact, one-third of those people still do not have access to modern energy services. The energy policies deployed by various countries have been basically planned depending upon the

availability of the energy resources, and hence, each country has its own energy policy.

Nuclear power is just one of the options of providing safe, environmentally, reliable and economically competitive energy services. Nuclear power over the world provides about 21% of electricity through 440 nuclear power plants with a total installed capacity of 361.582 GW [1]. Massive increases in energy demand are projected for countries such as China and India over this century e.g., many 100s of megawatts of electricity (MWe) of additional electrical capacity by 2050, with more additions later, are being considered for each of them [2].

Nuclear electricity generation is virtually free of direct greenhouse gas emissions, but as with any generation technology, there are indirect emissions associated with mining, fuel fabrication, construction, decommissioning of the power plant and disposal of the waste. [3]. To reduce the risk resulted from the nuclear reactors, there is a growing interest in the development and deployment plan of Small and Medium Sized Reactors (SMRs) which can be seen through the numerous concepts that are under design certification and the several units that are under construction [4]. In addition a review and analysis made by [5] for the sustainability of nuclear power showed that several issues must be overcome in order to consider nuclear power sustainable. It must not be forgotten that nuclear energy plays an important role in limiting greenhouse gas emissions. In OECD (Organization for Economic Co-operation and Development) countries nuclear energy is by far the largest source of low-carbon electricity, with a share of over 21% of the electricity production [NEA, 2011]. Even in the aftermath of the Fukushima Daiichi accident, many governments consider that nuclear power can continue to play an important role in low-carbon energy future [6]. So shall Jordan start its nuclear power generation? Does it worth? Or stay depending on the fossil fuels! Is there any other alternative?

World-Wide Nuclear Power Plants

Opportunities

Nuclear power stations are operated in 31 countries allover the world. With a total of 440 operated nuclear reactor. The reactors produce a net electrical power of 372210 MWe. There are 68 reactors under construction now. The USA has the largest number of nuclear reactors it has 104 reactors producing 101465 MWe. It is followed by France, Japan, Russia, Canada, United Kingdom etc. As shown in Table 1.

Table.1. Nuclear power plants world-wide, in operation and under construction, IAEA as of 18 January 2013.

Country	In operation		Under construction	
	Number	Electr. net output MW	Number	Electr. net output MW
USA	104	101,465	1	1,165
France	58	63,130	1	1,600
Japan	50	44,215	3	3,993
Russian Federation	33	23,643	11	9,927
Korea, Republic	23	20,754	3	3,640
China	23	17,834	21	31,353
India	20	4,391	7	4,824
Canada	19	13,665	-	-
United Kingdom	16	9,246	-	-
Ukraine	15	13,107	2	1,900
Sweden	10	9,325	-	-
Germany	9	12,068	-	-
Spain	8	7,560	-	-
Pakistan	3	725	2	630

These countries are producing a huge a mount of energy from nuclear power, this energy is used mostly in generating electricity, and heating water. Let us remember that Jordan needs are less than 3600 MW which is almost 2 reactors. These reactors are equivalent to energy, with simple calculations it can be shown that even non-oil producing countries come to be better than some oil-producing countries (see figure 1.), Notice that USA almost one of the biggest oil exporting countries. It produces what is equivalent to 1432400 barrel/day!!!

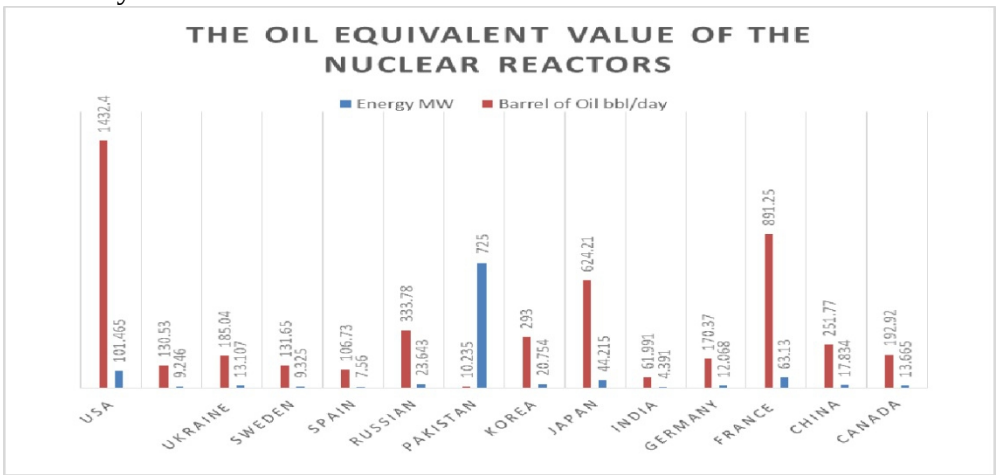

Figure 1. The oil equivalent value of the nuclear reactors.

If we had a look on the oil exporting countries, as it is noticed from table 2 USA is producing energy from its nuclear reactors as one from the first 10 oil exporting countries (a huge sum).

Table 2. the oil exporting countries (world fact book).

Country	Oil Exports (bbl/day)
Saudi Arabia	8063
Russia	7075
United Arab Emirates	2198
Nigeria	2176
Norway	1912
Iraq	1726
Qater	1589
Algeria	1537
Libya	1458
Canada	1158

This result is attracting it may take Jordan to be independent of its energy and help in opening new factories, have more working opportunities and keep its own political decisions. Table 1 indicates also that most of the developed countries stopped constructing new reactors. An indication which may refrain the running blind behind nuclear power and requires an answer why they stopped constructing new reactors?

The availability of energy is not the only factor in nation's development and civilization, to see the effect of nuclear reactors on the country industrialization; the industrialized countries with their nuclear power plants are viewed. Industrialized countries can be defined as countries that have attained a higher standard of living as a result of an increase of economic production, per capita income and consumption, also natural and human resources are being optimally used.

Table 3 indicates the top 10 industrialized countries, and the number of reactors the own.

Table 3. List of industrialized Countries, and the number of nuclear reactors

Country	# Nuclear Plants
China	17
Germany	8
U.S.A.	104
India	20
South Korea	23
Taiwan	6
Canada	19
Brazil	2
Singapore	0
Japan	50

Most of industrialized countries have their nuclear reactors which indicate the strong relation between industry and energy, but some have either no or just few reactors as Singapore, Brazil and Germany. Table 3 emphasizes on the importance of energy to be an industrialized country, but it shows as well that the presence of nuclear reactors is not a must to be industrialized. Then let us switch to check the effect of nuclear reactors on the Human Development Index (HDI). The UN HDI is a statistical measure that gauges a country's level of human development. While there is a strong correlation between having a high HDI score and a prosperous economy, the UN points out that the HDI accounts for more than income or productivity. Unlike GDP per capita or per capita income, the HDI takes into account how income is turned into education and health opportunities and therefore into higher levels of human development.

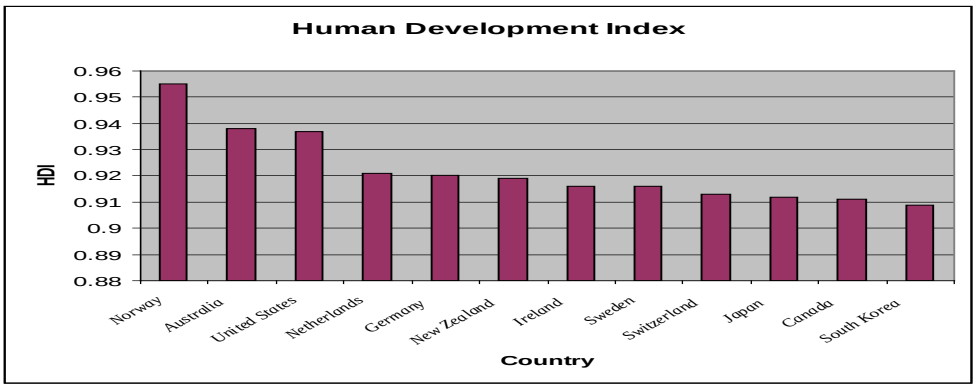

Figure 2. The list of developed countries with its HDI.

Some of these countries are non-nuclear countries; figure 3 shows the HDI with the number of reactors of each country. Even though some of the nuclear countries are between the top HDI countries like USA, Japan, Germany, Canada and southern Korea, it is obvious from figure 3 that the most HDI countries are non nuclear countries. This again emphasizes on the importance of nuclear energy for countries, but it gave other evidence that implementing nuclear reactors for energy is not a must.

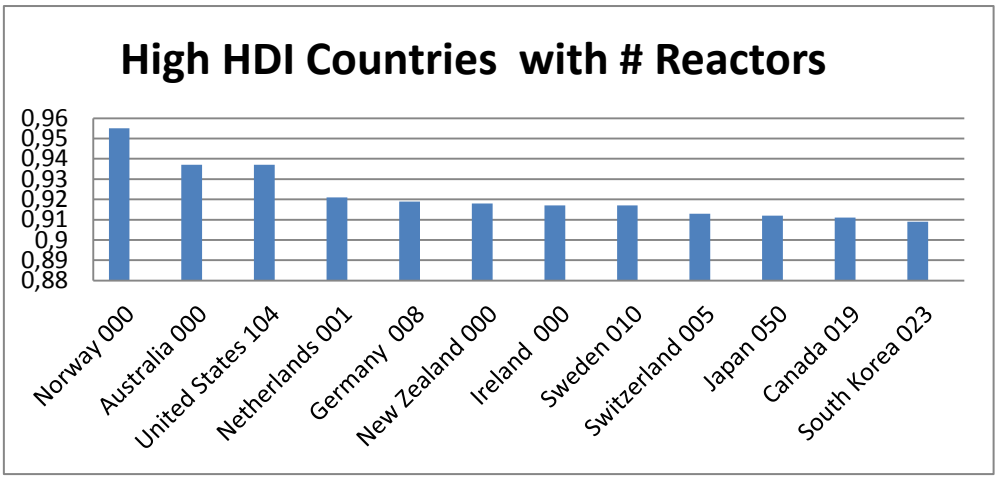

Figure 3. The list of developed countries with its HDI and # of Reactors.

Then the question comes when a country may need the nuclear energy and why other countries may not need this power. To answer such a question the relation of the countries area with its population is investigated. Table 4 shows the list of developed countries with its area, population and number of reactors.

Table 4. The list of developed countries with its area population and number of reactors.

Country	**Area km2**	**Population Million**	**React.#**
Norway	385,199	5	-
Australia	7,692,024	22.68	-
United States	9,826,675	313.9	104
Netherlands	41,526	16.77	1
Germany	357,021	81.89	8
New Zealand	268,680	4.433	-
Ireland	84,421	4.589	-
Sweden	449,964	9.517	10
Switzerland	41,285	7.9	5
Japan	377,94	127.6	50
Canada	9,984,670	34.88	19
South Korea	100,210	50	23

Table 4 shows that the high populated countries mostly require more energy thus it may need nuclear reactors. Figure 4 shows the country with population density and its nuclear reactors.

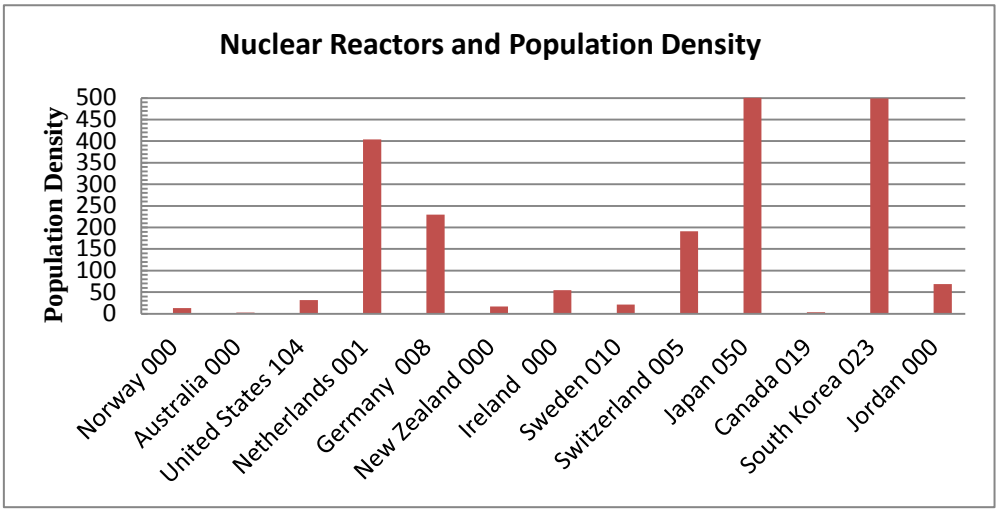

Figure 4. Nuclear Reactors and Population Density for HDI Countries.

Interesting results can be obtained from figure 4, this figure indicate that mostly high population density countries depend on nuclear reactors, but it shows also that low density countries may have nuclear reactors such as Canada and Sweden. These are very cold country, which require huge sum of energy for heating purposes. Jordan has a quit high population density more than Canada, Sweden and USA, but it is not a cold country neither industrialized. Jordan may need the nuclear reactor to move to industrialized ountries, but it may not need it for being from HDI countries. To increase the HDI of Jordanians, the income should be raised and cost must be reduced. To do so the energy cost must be decreased and stabilized.

The implementation of nuclear energy may lead to,

1- Wider industry.
2- More Jobs.
3- Higher salaries.
4- Lower products costs.

Wow…let us go ahead with nuclear?!

These are the positive features of nuclear reactors, but what about threats?

Threats

To give a right decision the threats of the nuclear energy must be discussed. There are only four main accidents happened from 1957-2014

which are

1- FUKUSHIMA 2011
2- Chernobyl, Ukraine, 1986
3- Three Mile Island, 1979
4- Windscale, UK, 1957

The Windscale fire of 10 October 1957 was the worst nuclear accident in Great Britain's history, ranked in severity at level 5 on the 7-point International Nuclear Event Scale. The fire took place in Unit 1 of the two-pile Windscale facility on the northwest coast of England. The fire burned for three days and there was a release of radioactive contamination, which may lead to cancer of the thyroid, and it has been estimated that the incident caused 240 additional cancer cases. No one was evacuated from the surrounding area. The Three Mile Island accident was a partial nuclear meltdown that occurred on March 28, 1979, in one of the two Three Mile Island nuclear reactors in Dauphin County, Pennsylvania, United States. It was the worst accident in U.S. commercial nuclear power plant history. The incident was rated a five on the seven-point International Nuclear Event Scale: Accident with Wider Consequences. Cleanup started in August 1979, and officially ended in December 1993, with a total cleanup cost of about $1billion. Chernobyl, Ukraine, 1986 which was categorized as level 7 major accident resulted in Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures. FUKUSHIMA 1, 2011. was an accident with local consequences, minor release of radioactive material. The level of these accidents and its impact on people and environment should be clear,

1- Fukushima

a) 300,000 people evacuated the area.

b) 70% higher risk of developing thyroid cancer for girls exposed as infants.

2- Chernobyl

a) 116 000 people were evacuated.

b) Fewer than 60 deaths could be linked directly to Chernobyl or about 4,000 from UN estimates.

3- Three mile

a) There was an evacuation of 140,000 pregnant women and pre-school age children from the area.

No immediate health effects would be expected in the general public from a nuclear power plant accident. That is because the amount of radiation present would be too small to cause immediate injury or illness. However, there is a risk of long-term health effects. Cancer may develop many years after the exposure. New Scientists give a brief description to what diseases my effect human. It explains that radiation damages DNA, especially as it

assembles in dividing cells. That means tissues which contain many dividing cells, such as the gut lining, skin and bone marrow, are most at risk of damage. High enough doses also damage brine cells and such doses are invariably fatal. Seventy percent of the radiation is estimated to have fallen on Belarus and 10 years later babies are still being born with no arms, no eyes, or only stumps for limbs. No one can predict the exact number of human victims. It is estimated that over 15 million people have been victimized by the disaster in some way. It has also estimated that ultimately the accident will claim more victims than World War II. It will cost over 60 Billion dollars to make these people healthy (see pic 1) [12].

Picture 1. Sample Nuclear Reactors Accidents Victims [12, 13].

Jordan Green Energy (Solar).

Jordan is blessed with an abundance of solar energy which is evident from the annual daily average solar irradiance that ranges between 4-7 kWh/m2 (see figure 5). The average sunshine duration is more than 300 days per year, with a long average sun shine hours figure 6. All of this makes Jordan one of the best locations to implement solar energy power plants.

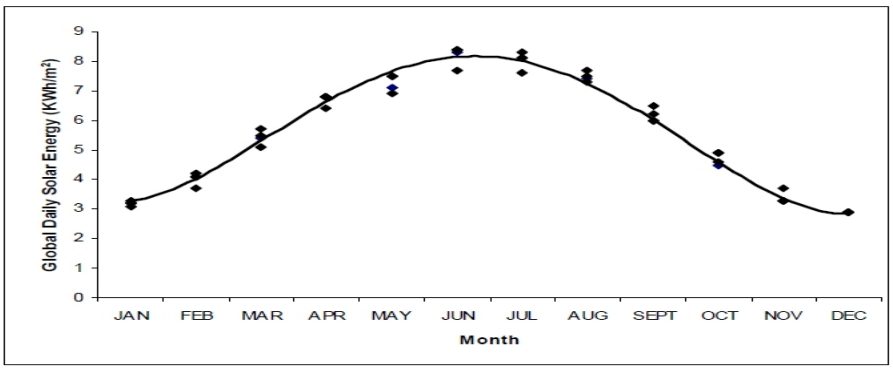

Figure 5 Solar Energy all over the year in Jordan [14].

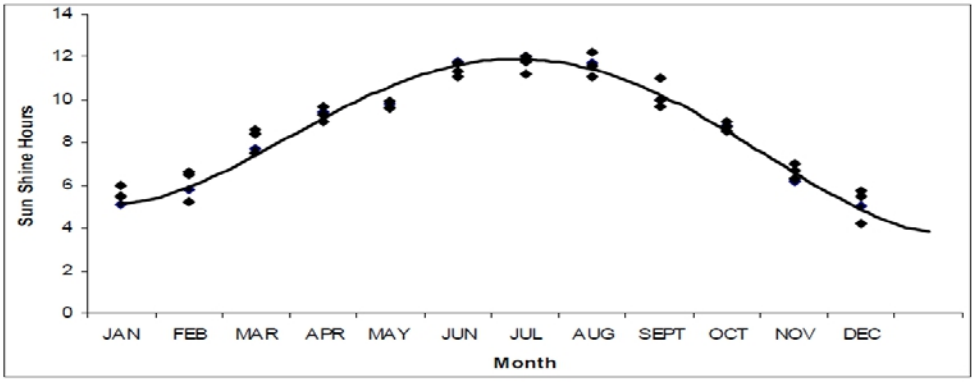

Figure 6 Sunshine periods all over the year in Jordan [14].

World-wide Solar Power Plants.

Table 5 shows the amounts of MW of solar energy created by different solar plants. The photovoltaic power plants prove its workability and easy maintenance. Table 5 shows the amount of solar energy produced from the photovoltaic power plants.

Table 5. World's largest photovoltaic power stations (50 MW or larger)

Country	Capacity MW
USA	1250.7
Germany	1124.4
China	1006.5
India	341
Ukraine	310.06
France	298
Canada	165
Italy	154.7
Spain	112
Thailand	84
South Africa	75
Japan	70
Bulgaria	50.6

Table 6 Worldwide Solar Thermal Power Plants Under Operation

Capacity MW	Country
200+3*150+8*100+13* 50+..=2005	***Spain***
250+280*2+354+392+75+64+=1700	***USA***
100	***UAE***
52.5	***India***
25	***Algeria***
20	***Egypt***
20	***Morocco***
17.25	***Iran***
12.5	***China***
9	***Australia***
5	***Italy***

Even countries are not producing large amounts of energy from solar power plants; it is noted the HDI countries which need more energy started to depend on the solar energy instead of nuclear reactors.

Table 7. World's Solar Thermal Power Stations under Construction.

Under Construction Solar Thermal Power Stations	
Capacity MW	**Country**
350	India
200	Spain
160	Morocco
150	South Africa
110	USA
50	China

Such plants are efficient free and have a short rate of return periods. Also it is noted that all the implemented solar power plants represents only a small part of the total energy consumed or produced. It does not represent more than 6 Nuclear power plants from the 440 nuclear power plant available.

Table 8 shows that Jordan has a yearly global radiation almost double of the European countries; solar energy is much more valuable in Jordan. This free energy may be extended to cover all the needs of electrical energy of the country and some of the industrial needs.

Table 8 represents the solar global radiation of Jordan with respect to other countries.

Yearly Global Radiation	
Country	kWh/m2
Jordan	2080
Germany	1000
Paris	1038
London	944
USA	1427

Electricity generation feasibility.

To compare between the different electricity generating technologies, the costs per unit of output for different generating technologies such as advanced nuclear, natural gas, conventional coal**,** wind onshore and offshore, solar PV and solar thermal are shown in table 9

Table 9 *Comparision between nuclear conventional and renewable electricity generation technologies.* [15]

Electricity Generating Technologies	Cent/kWh
Advanced Nuclear	5.0-8.2
Combined cycle natural gas	6.6
Conventional coal	10-11
Wind onshore	8.7.
Offshore wind	22.2
Solar PV	14.4
Solar thermal	26.2

Conclusion

Energy is an important commodity for countries to survive development and provide a good HDI. Energy that comes from other countries is expensive and instable. Each country should try to depend on its natural resources to cover its needs. Nuclear reactors for Jordan are an attractive option. It has a long stable life and high danger. To reduce the risk resulted from the nuclear reactors, Small and Medium Sized Reactors are used. Nuclear reactors are Low-carbon electricity energy. Most of industrialized countries have their nuclear reactors which indicate the strong relation between industry and energy. But most of the HDI countries are non nuclear countries. These all show that nuclear power plants are not essential in developing the country but it is a must for the industrialized ones. New Scientists explains that radiation damages DNA, damages brine cells and such doses are invariably fatal. Unless the country has a very high population per capita ratio it is advanced to switch to green energy. Jordan is a sunny country and can use its available green energy to cover its needs as most of the developed countries. Combining between the solar energy and nuclear power must be under the rule that maximum number of solar power plants with the minimum number of nuclear reactors.

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