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RESEARCH ARTICLE

A PROPOSAL FOR NATIONAL EFFICIENT LAND USE PLANNING FOR POWER PLANTS IN EGYPT: AN INTEGRATED NUCLEAR RENEWABLE HYBRID ENERGY SYSTEM

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ABSTRACT

Modern society uses massive amounts of energy. Energy usage rises as population and development increase, and energy production and use often have an impact on biodiversity, land uses and natural resources. For the reduction of direct harm to the world biodiversity, the best energy options are those that use the least amount of land and fresh water, minimize pollution, restrict habitat fragmentation, and have a low risk of accidents that have large and lasting regional impacts on natural areas. Most of the present energy demand in the world is met by fossil fuels and nuclear power plants. A small amount is only met by renewable energy technologies such as the wind, solar, biomass, geothermal etc. There will soon be a time when our plant will face a severe fuel shortage. So, different countries are working now in hybrid energy systems which can integrate different sources of energies such as nuclear and renewable energy systems to meet their needs. On the other hand, electrical power plants are covering and consuming massive land of the urban and rural areas specially the renewable energy. In Egypt, land resources are limited and finite. In the last years, the government has allocated thousands of square meters for energy power plants especially renewable energy. On the other hand, there are a lot of pressure on governmental lands which needs to serve other development activities such as industry, housing, agriculture. According to different studies, nuclear power and renewable energy are forecasted to be the world's fastest-growing energy sources from 2012 to 2040. Newer trends to use hybrid nuclear renewable energy systems are introduced in different countries. This trend aims at using the land of the power plants more efficiently and also using the different sources of energy for continuous loads by economic way. So, a new call for efficient land use planning in Egypt is needed which can be based on hybrid nuclear and renewable energy systems. This paper discusses the different challenges which are facing the hybrid nuclear and renewable energy systems and their different types. It describes the current strategy for power generation in Egypt with emphasis on introducing a new proposal for efficient land use planning for power plants in Egypt which can depend on nuclear renewable hybrid energy power plants. It concludes that land use urban planning in Egypt should look differently for its future strategy for the existing and future allocation of lands for electrical power plants. Also, it conclude that a proposal for El Dabaa site may be considered to introduce another renewable energy such as solar PV in the site beside the nuclear power plant.

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INTRODUCTION

Electricity is vital to modern life. Globally, electricity use is rising rapidly as new major economies develop in different countries. This need for electricity drives a growing demand for electricity generation, with thousands of new power plants needed across the world over the coming decades. Every form of electricity generation has its strengths and weaknesses. Future electricity generation will need a range of options, although they must be low carbon if greenhouse gas emissions are to be reduced. Nuclear energy generation provides reliable supplies of electricity, with very low carbon emissions and relatively small amounts of waste that can be safely stored and eventually disposed of. For many decades almost all the electricity consumed in the world has been generated from three different forms of power plant - fossil, hydro and nuclear. Renewables currently generate a relatively small share of the world's electricity, although that share is growing fast. According to the World Nuclear Association, the world will need greatly increased energy supply in the future, especially cleanly-generated electricity. Electricity demand is increasing twice as fast as overall energy use and is likely to rise by more than two-thirds 2011 to 2035. In 2012, 42% of primary energy used was converted into electricity (World Nuclear association, 2017).

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Now, nuclear power provides about 11.5 % of the world's electricity, and 21% of electricity in OECD countries. All major international reports on energy future suggest an increasing role for nuclear power as an environmentally benign way of producing electricity on a large scale. Also, renewable energy sources such as solar and wind are costly per unit of output and are intermittent but can be helpful at the margin in providing clean power (World Nuclear association, 2017). In the EIA International Energy Outlook 2016, nuclear power and renewable energy are forecasted to be the world's fastest-growing energy sources from 2012 to 2040. Renewables increase 2.6% per year, from 22% to 29% of total. Nuclear increases by 2.3% per year, from 4% of total to 6%, 2.3 PWh to 4.5 PWh. Generation from non-hydro renewables increases by 5.7% each year. Net nuclear capacity increase is mainly recorded in non-OECD countries (growth in South Korea is offset by decrease in Canada and Europe), and China accounts for 61% of the capacity growth (World Nuclear association, 2017). According to the Asia/World Energy Outlook 2016 report by the Institute of Energy Economics, Japan (IEEJ), global installed nuclear generating capacity will increase from 399 GWe in 2014 to 612 GWe in 2040. Over this period, nuclear electricity generation will increase from 2535 TWh to 4357 TWh but its share of total global electricity generation will remain unchanged at around 11.5%. In the high nuclear contribution scenario, the IEEJ states that nuclear in effect "becomes the base power source" for many emerging countries, such as Asian and Middle Eastern countries (World Nuclear association, 2017). Nuclear power plants can run for many months without interruption, providing reliable and predictable supplies of electricity. Also, it can generate electricity "24/7" for many months at a time, without interruption.

On the other hand, renewable energy such as wind, solar and small scale hydro produce electricity with no greenhouse gas emissions at the point of generation and very low amounts of greenhouse gas emissions across their entire lifecycle. The cost of electricity generation from many renewables tends to be higher than other forms of generation, often requiring subsidies to compete with other forms of generation, although these costs are coming down. Many renewables do not produce electricity predictably or consistently. Electricity generation from wind turbines varies with the wind speed, and if that wind is too weak or too strong no electricity is produced at all. The output of solar panels is reliant on the strength of the sunshine, which depends on the time of day and the amount of cloud cover. This means that renewables have to be backed up by other forms of electricity generation, often fossil fuel generation with their resultant greenhouse gas emissions (World Nuclear association, 2017). On the other hand, developing economies jumped ahead of developed countries for the first time in 2015 in terms of total new renewable energy investment. Also, the share of global investment in the total new renewable energy accounted for by developing countries rose from 49% in 2014 to 55% in 2015, with the dollar commitment at $155.9 billion, up from $131.5 billion the previous year while developed economies invested $130.1 billion, compared to $141.6 billion in 2014 (Frankfurt School-UNEP Centre/BNEF, 2016).

In Germany, as example, the renewable energy systems are now generating about 27 percent of the country's electricity, which was about only 9 percent a decade ago. Germany has used different hybrid energy systems. Figure (1) shows renewables as a share of electricity generation in Germany, USA and China. Germany and Figure (2) shows wind turbines surround a coal-fired power plant near Garzweiler in western Germany (Robert Kunzig, 2015).

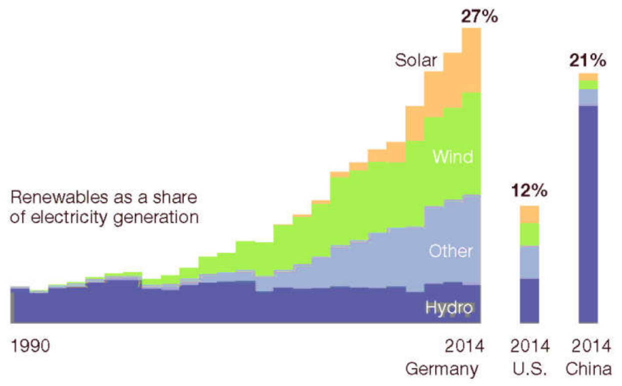

Figure 1. Renewables as a share of electricity generation in Germany, USA and China (Robert Kunzig, 2015)

Figure 2. Wind turbines surround a coal-fired power plant near Garzweiler in western Germany, (Robert Kunzig, 2015)

In March 2017, three European transmission system operators (TenneT TSO B.V. in the Netherlands, Energinet in Denmark, and TenneT TSO GmbH in Germany) have signed a trilateral agreement that intends to develop a large renewable European electricity system in the North Sea, the North Sea Wind Power Hub, which was developed at an optimal location in shallow waters and amidst optimal wind conditions. Such a project could end up accommodating up to 70 gigawatts (GW) to 100 GW of offshore wind power, and all electricity generated could be distributed and transmitted via direct-current connections to all countries bordering the North Sea — the Netherlands, Denmark, Germany, the United Kingdom, Norway, and Belgium — which would also allow the countries to trade electricity as necessary (Joshua S Hill, 2017). This new Hub could supply as many as 70 to 100 million Europeans with renewable energy by 2050. This kind of ideas could actually be a very efficient and affordable way for the different countries to meet the future demand for more renewable electricity as shown in Figures (3) and (4), (Joshua S Hill, 2017).

On the other hand, land use for energy power plants is another concern which had lead different countries to look forward for a solution to the problems of energy security and land use by using a large-scale conversion hybrid nuclear renewable energy system to clean, perpetual, and reliable energy at low cost together with an increase in energy efficiency.

Hybrid Nuclear Renewable Energy Systems

Hybrid energy system is the combination of two energy sources for giving power to the electrical load. In other words it can be defined as "Energy system which is fabricated or designed to extract power by using two energy sources is called as the hybrid energy system." Hybrid energy system has good reliability, efficiency, less emission, and lower cost (Ashish S. Ingole and Bhushan S. Rakhond, 2015). Integrated nuclear – renewable energy production technologies would provide additional options for thermal, electrical, and/or chemical energy to meet industrial and transportation sector demands. These systems would be tailored to regional resources and markets to dynamically optimize the use of thermal and electrical energy. Optimized operation of such hybrid systems would meet growing grid flexibility needs while allowing operation of both renewable and nuclear power sources at maximum capacity factors – hence maximizing economic benefit. Renewable electricity supplied to the grid could thus be significantly increased while avoiding the need for fossil or nuclear plants to operate solely as stand-by dispatchable power sources. The resulting excess generation could, for example, support the production of significant quantities of clean transportation fuels from domestic resources (Bragg-Sitton and Boardman, 2015).

Figure 3. Proposed new wind turbines hub in the north sea, (Joshua S Hill, 2017)

Figure 4. Location of the proposed wind turbines hub in the north sea, (Joshua S Hill, 2017)

Challenges to Hybrid Energy Systems Development

The energy generation sources considered in tightly coupled, integrated energy systems are not novel, but integration in this manner is a novel approach to achieving the goal of low-carbon, reliable energy supply. Design, development, and deployment of tightly coupled integrated energy systems face numerous challenges. These challenges can generally be grouped as follows:

a) Integration Value: Possibility for integration to increase the value of system components; added risk of integration relative to improvement in efficiency and energy availability; market structures that do not necessary monetize the value of grid services that might be provided by an integrated system.

b) Technical: Novel subsystem interfaces; performance; advanced instrumentation and control for reliable system operation; safety risk assessments; commercial readiness of the technology and operational risks.

c) Financial: Business model; cost and arrangement of financing and risk/profit taking agreements; shifts in cultural values and associated market evolution trends for various products; assurance of high capital utilization efficiency.

d) Regulatory: Projected environmental regulations; deregulation or re-regulation of electrical and other energy markets; licensing of a co-located, integrated system; involvement of various regulatory bodies for each subsystem and possible "interface" issues.

e) Timeframe: Resolution of issues/challenges within the timeframe established based on external motivators for these systems (e.g. EPA carbon pollution standards); possibility of hybrid implementations at the rate market forces influence build-out of renewable resources; possibility for grid stability issues to drive alternative solutions that create alternative long-lasting capital investments/inertia, (Bragg-Sitton and Boardman, 2015).

Types of Nuclear Renewable Hybrid Energy System (N-R-HES)

The main purpose of an N-R HES is to use nuclear energy, variable renewable energy sources such as wind and solar, biomass energy, or others as clean energy sources to support electrical and thermal duties of electricity generation, fuels production, chemical synthesis, and other industrial processes at competitive prices and to thus decrease greenhouse gas emissions (GHG) by the electricity, transportation, and industry sectors. Such hybrids would differ substantially from traditional systems that typically use just one or perhaps two energy sources. Increased penetration of variable renewable energy systems such as wind and solar PV increases the need for flexible generation—as can be provided by dispatchable intermediate and peaking units, as well as through more flexible loads—as can be provided by demand-side management, in order to maintain system voltage and frequency within limits. Such flexible generation generally has also greater value in electricity markets than baseload or variable supplies. N-R HES may serve an important role in providing this flexibility, (US DOE, 2015). Flexible N-R HES architectures of interest include the following:

a- Tightly Coupled N-R HES

In this architecture, nuclear and renewable generation sources and industrial processes would all be linked and co-controlled behind the electricity bus, such that there would only be a single connection to the grid, as shown in Figure (5). The closely coupled system would likely be managed by a single financial entity to optimize profitability for the integrated system.

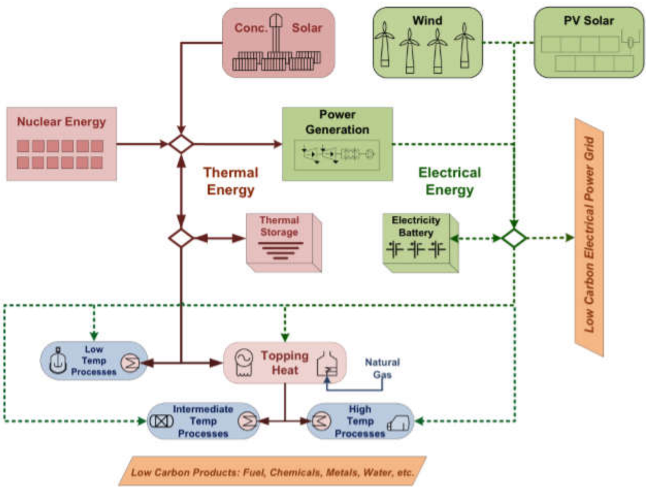

Figure 5. General architecture for a tightly coupled nuclear renewable hybrid energy system, developed by Idaho National Laboratory (US DOE, 2015)

b- Thermally Coupled N-R HES

This architecture would thermally integrate subsystems and tightly couple them to the industrial processes, but the nuclear and renewable electrical subsystems could have more than one connection to the same grid balancing area and would not need to be co-located, but would be co-controlled to provide energy and ancillary services to the grid. The thermally integrated subsystems would need to meet industrial process requirements considering the required heat quality, the heat losses to the environment along the heat delivery system, and the required exclusion zone around the nuclear plant. These systems would likely be managed by a single financial entity as shown in Figure (6).

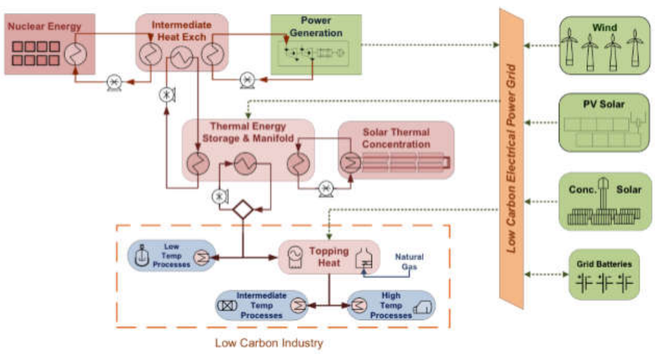

Figure 6. General architecture for a thermally coupled nuclear renewable hybrid energy system, developed by: Idaho National Laboratory (US DOE, 2015)

c- Loosely Coupled, Electricity Only N-R HES

This configuration would be electrically coupled to industrial energy users but there would be no direct thermal coupling of subsystems. This design would allow management of the electricity produced within the system (e.g., from the nuclear plant or from renewable electricity generation) prior to the grid connection. Although there would not be a direct coupling of thermal energy to the industrial processes, the system could include electrical to thermal energy conversion equipment to provide thermal energy input to the industrial process. Such an option may allow for potential retrofit of existing generation facilities with fewer regulatory challenges. These systems could have more than one connection point to the grid but would likely be managed by one financial entity as shown in Figure (7).

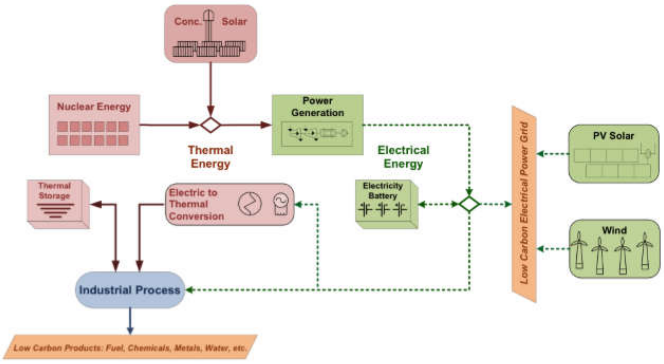

Figure 7. General architecture for a loosely coupled (electricity only) nuclear renewable hybrid energy system, developed by: Idaho National Laboratory (US DOE, 2015)

N-R HES differ from combined heat and power systems to the extent that the goal is not solely cogeneration of heat and power for local industrial plant uses; rather, the goals also include the transfer of as much low-carbon energy to the industrial process as possible. N-R HES are essentially an optimization approach to support grid reliability and stability and to support industrial production, providing power generation and thermal energy to industry while maximizing profitability and minimizing GHG emissions. Figure (8) shows a summary of potential N-R HES applications indicating energy conversion varieties possible and their appurtenant processes. Heat transfer distances are only an approximation based on preliminary calculation under the Next Generation Nuclear Plant (NGNP) Program.

Finally, successfully developed N-R HES could potentially provide significant benefits, which include the followings:

- Reducing the cost and volatility of energy production, particularly by helping balance electricity supplies from variable renewable sources;
- Providing dispatchable, carbon-free electricity generation for the grid, with little to no impact on the nuclear reactor operations profile which can have technical impacts on the core, fuels, and heat transfer loops;
- Providing more efficient utilization of capital equipment by providing a second customer for the heat that can be generated by the nuclear reactor, which at some point may be lower cost than producing heat from combustion sources;
- Providing greater grid support than variable renewable sources alone;
- Reducing the carbon footprint of the industrial sector; and
- Reducing energy system impact on fresh water resources when using excess thermal or electrical energy to produce potable water, and by coupling low temperature heat rejection to an industrial heat user rather than relying on a cooling tower to condense the power cycle water (US DOE, 2015).

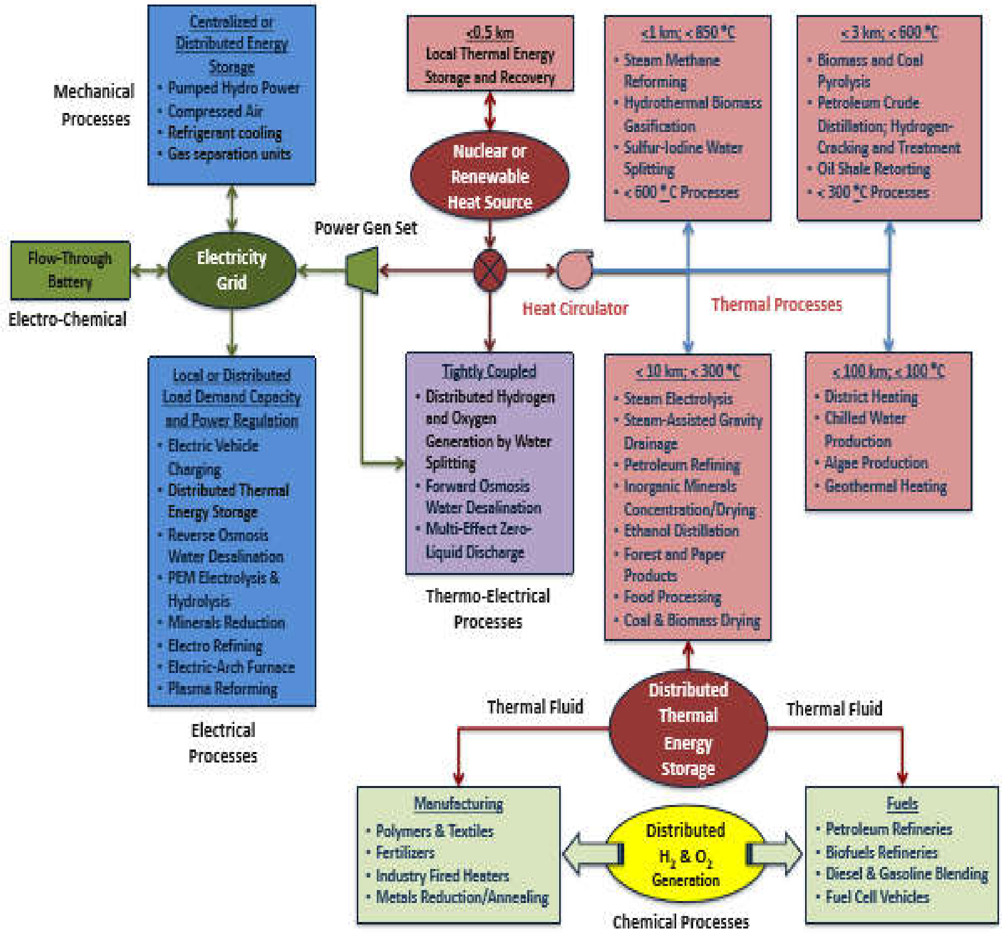

Figure 8. Summary of potential N-R HES applications indicating energy conversion varieties possible and their appurtenant processes. Developed by: Idaho National Laboratory (US DOE, 2015)

Land Use for Power Plants

Land use planning refers to the process by which a society, through its institutions, decides where, within its territory, different socioeconomic activities such as agriculture, housing, industry, recreation, and commerce should take place (FAO Development Series, 1993). Land resources are limited and finite. If human populations continue to increase at the present rate there will be twice as many people in the world in about 60 years. There is therefore an increasingly urgent need to match land types and land uses in the most rational way possible, so as to maximize sustainable production and satisfy the diverse needs of society while at the same time conserving fragile ecosystems and our genetic heritage. Planning to make the best use of land is not a new idea. Planning involves anticipation of the need for change as well as reactions to it. Its objectives are set by social or political imperatives and must take account of the existing situation. In many places, the existing situation cannot continue because the land itself is being degraded. Land use must be economically viable, so one goal of development planning is to make efficient and productive use of the land. For any particular land use, certain areas are better suited than others. Efficiency in land use is achieved by matching different land uses with the areas that will yield the greatest benefits at the least cost. Different countries in early attempts at land-use planning focused too narrowly on land resources without enough thought given to how they might be used. Different land uses are usually also suitable for other competing uses or can be used in an efficient manner. Land-use decisions are not made just on the basis of land suitability but also according to the demand for products and the extent to which the use of a particular area is critical for a particular purpose. Planning has to integrate information about the suitability of the land, the demands for alternative products or uses and the opportunities for satisfying those demands on the available land, now and in the future (Clinton J. Andrews *et al.*, 2011). Figure (9) shows percentage of earth's land area taken for energy production, and it is recognized that nuclear have almost the same percentage in the current and to meet the 100% of global energy demand in 2010 while solar and wind energy need more land of earth to meet the global energy demand.

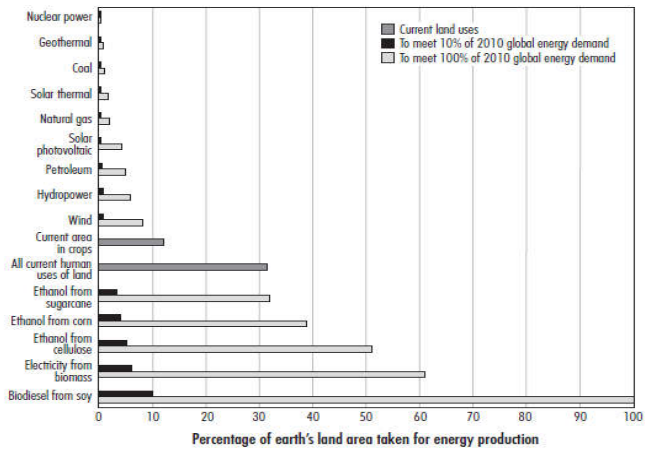

Figure 9. Percentage of earth's land area taken for energy production (Clinton J. Andrews *et al.*, 2011)

Land Requirements for Nuclear and Renewable Energy Power Plants

When the impacts on land use are measured simply by the surface area of the power plants they occupy during their life cycle, some renewable energy technologies appear to have heavy land-use requirements. However, this approach does not take into account the intensity of land use or whether the technology allows for simultaneous use of land for other purposes (The National Academic Press, 2010). A 1,000 MW wind farm would require approximately 85,240 acres of land (approximately 133 square miles). Accounting for a range of capacity factors (32-47 percent), between 1,900 MW and 2,800 MW of wind capacity would be required to produce the same amount of electricity as a 1,000 MW nuclear power plant in a year. The land needed for wind energy to produce the same amount of electricity in a year as a 1,000 MW nuclear power plant is between 260 square miles and 360 square miles. A 1,000-MW solar photovoltaic (PV) facility would require about 8,900 acres (approximately 14 square miles). Accounting for a range of capacity factors (17-28 percent), between 3,300 MW and 5,400 MW of solar PV capacity is required to produce the same amount of electricity as a 1,000-MW nuclear plant in a year. The amount of land needed by solar to produce the same generation as 1,000 MW of nuclear capacity in a year is between 45 and 75 square miles. Table (1) shows the approximate land required for wind and solar to match the electricity produced annually by a 1,000 MW nuclear power plant (Nuclear Energy Institute, 2015).

Table 1. The approximate land required for wind, solar to match the electricity produced annually by a 1,000 MW nuclear power plant, (Nuclear Energy Institute, 2015)

Technology	Capacity Factor, %	Square Miles Needed for 1,000 MW
Wind	32-47	260-360
Solar	17-28	45-75
Nuclear	90	1.3

For comparison, the land area required for 1,000 MW of nuclear capacity is approximately 1.3 square miles. This is based on the median of the 59 nuclear power plant sites in the United States. The largest wind farms in the U.S. are Alta Wind Energy Center in California at 1,548 MW, Shepherds Flat Wind Farm in Oregon at 845 MW, Roscoe Wind Project in Texas at 781 MW and Horse Hollow Wind Energy Center in Texas at 736 MW. As stated above, between 1,900 MW and 2,800 of wind are needed to equal the same generation as a 1,000-MW nuclear power plant in a year. Therefore it would take two to three Shepherds Flat Wind Farms to equal the annual output from 1,000 MW of nuclear generating capacity.
The two largest solar PV plants in the U.S. are the Topaz Solar Farm in California at 550 MW and Desert Sunlight Solar Farm in California at 550 MW. As stated above, between 3,300 MW and 5,400 MW of solar are needed to equal the same generation as a 1,000 MW-nuclear plant in a year. Therefore, it would take between six and ten of these solar farms to equal the annual output from 1,000 MW of nuclear generating capacity. Figure (10) shows graphical comparison of the land use required for a 1000 MW nuclear with those required for wind and solar power plants which can produce the same power annually (Nuclear Energy Institute, 2015).

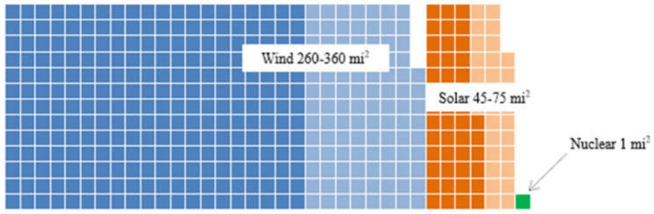

Figure 10. Comparison of 1000 MW nuclear with wind and solar power plants which can produce the same power annually (nuclear energy institute, 2015)

National Strategy for Energy in Egypt

With a rapidly growing population and a host of major energy-intensive industrial facilities, Egypt requires a large supply of power to maintain growth. The government has decisively sought to increase the supply of power. This is happening through two key channels: through a more liberalized tariff framework and a more efficient market structure, as well as through a push to improve the diversity of generating sources, bulking up renewable energy sources as well as supplementing supply with nuclear and coal facilities (Oxford Business Group, 2017). In June 2015, Egypt signed a $9bn deal with Siemens, the largest single transaction in the German company's history. In the transaction, three 4.8-GW gas-steam power plants will be delivered, with plans to have them producing power by 2017. Additionally the company will supply 600 wind turbines for 12 wind parks (Oxford Business Group, 2017). Figure (11) shows the new Siemens power Plant in BeniSuef. Also, GE signed a $1.7bn deal with the country to supply gas turbines that in total will generate 2.6 GW of power.

Figure 11. New Beni suef power plant, www.siemens.com, 31, January, 2017

Electricity in Egypt is generated mainly from thermal and hydro power stations. However, the percentage of hydropower energy generated is gradually reducing due to the fact that all major hydropower sites have already been developed and new generation plants being built are mainly gas fired. Thermal generation is based on combined cycle and steam plant technologies. In its generation investment plan, the Egyptian Electricity Holding Company (EEHC) allocates 38% of its new base load generation capacity to steam power plants and 36% to combined cycle power plants. The electricity transmission and distribution network has developed into a complex interconnected system commonly referred to as the UPS, serving all major load centers countrywide. In 2008, the transmission system had a network of 39,552 km of overhead lines and 77,000 MVA of transformer capacities. The distribution system consisted of 134,005 km of medium voltage lines, 218,408 km of low voltage lines (The Arab Republic of Egypt Power Sector in Brief – 2010). All these power plants and its distribution and transmission routes are using a lot of governmental lands, which are millions of square meters. Currently more than 94% of Egypt's total energy production is covered by fossil fuels and natural gas while hydro power contributes to only 5% and the share of other renewable energies like wind and solar represents less than 1%. With the degradation in the crude oil production over the last few years combined with high concerns about the depletion rate of the Egypt's natural gas reserves, the important role of renewable energy in meeting the growth of electricity demand became clear. The Egyptian government recognized this fact and approved an ambitious plan to produce 20% of the total generated electricity by renewable energy in 2020. This 20% is comprised of 12% (7200 MW) wind energy, 6% (2851 MW) hydropower, and 2% (1320 MW) solar energy. Due to the late political circumstances and development, the target was extended to 2022 (New & Renewable Energy Authority (NREA, 2015). Over the last decade, several projects were developed particularly in the wind and solar energy fields in order to meet the objectives of the Egyptian government on the renewable power level. Figure (12) shows the cumulative installed capacity of wind farms in Egypt till the end of 2016.

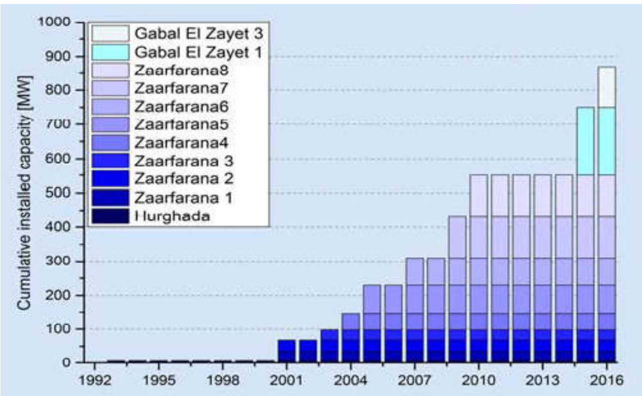

Figure 12. The cumulative installed capacity of wind farms in Egypt from 2001 till the end of 2016 (Noha Saad Hussein *et al.*, 2016)

Land Use for Nuclear and Renewable Energy Power Plants in Egypt

a- Site for Nuclear Power Plant

Egypt had an interest in developing nuclear power for electrical generation since the 1960s. In the 1970's, the process for siting of El Dabaa nuclear power plants started. In 1981, the state declared large parts of ElDabaa governmental property in order to build the first nuclear plant by a Presidential Decree number 309 in 1981. The area of the site is about 50 sq. km. Shown in Figure 13 In September 2015, it was reported that Russia would help Egypt to build its first nuclear reactor. An intergovernmental agreement has been signed between Egypt and Russia for building reactors in the site and the first will be 1200-MW facility.

On the other hand, according to Nuclear Energy Institute in 2015 (Nuclear Energy Institute, 2015), from different international experiences the land area required for a 1,000 MW of nuclear capacity is approximately 1.3 square miles which is about 3 square kilometers of land, so this means that the site for four power plants needs about 12 square kilometers.

Figure 13. Image showing El Dabaa site, Google, 2016

b- Sites for Renewable Energy Systems

The method of levelized cost of electricity (LCOE) makes it possible to compare power plants of different generation and cost structures with each other. The basic thought is that one forms the sum of from all accumulated costs for building and operating a plant and comparing this figure to the sum of the annual power generation. This then yields the so-called LCOE in USD per kWh. It is important to note that this method is an abstraction from reality with the goal of making different sorts of generation plants comparable (NohaSaadHussein *et al.*, 2016). The amount of electricity yield at the power plant location is an important parameter with a considerable influence on the LCOE of renewable energy technologies. In the case of solar technologies, the amount of diffuse or direct solar radiation plays a role depending on the technology (PV or CSP). For wind farms, the full load hours can be calculated from the wind conditions at the power plant location as a function of the wind speed. For that reason, exemplary locations with specific full load hours for wind farms should be studied as well as locations with specific energy sources from solar irradiation as shown in Table 2. At typical locations in Egypt, the global horizontal irradiance (GHI - consisting of diffuse and direct irradiation) is in the range between 1900 and 2500 kWh/(m²a) onto the horizontal surface. This corresponds to a solar output between 1600 and1800 kWh/kWp/a onto an optimally configured PV plant, (Noha Saad Hussein *et al.*, 2016). CSP plants concentrate only direct irradiation onto a focal point where it is converted into electricity or heat. For this reason locations with an annual direct normal irradiance (DNI) from 2000 and 2500 kWh/ (m²a), such as found in Egypt, are favorable for CSP plants and should be taken into consideration. The wind conditions are also location-dependent. Onshore wind power can evince full load hours of only 2000 hours at poor locations.

According to the wind atlas of Egypt developed by New & Renewable Energy Authority (NREA) for selected sites suitable for carrying out wind projects shown in Figure (14), the government had issued different decrees for allocating some lands for wind farms. In May 2006 Red Sea Governor decree No. 136 for the year 2006 was issued for allocating about 656 km^2 to NREA to establish wind farm projects at

Table 2. Annual yields at typical locations in Egypt of PV, CSP and wind power, (Noha Saad Hussein *et al*., 2016)

PV System	Irradiation (GHI)	Electricity output per 1 kWp
Northern Egypt (Alexandria)	2021 kWh/(m²a)	1600 kWh/a
Cairo	2070 kWh/(m²a)	1630 kWh/a
Sinai	2370 kWh/(m²a)	1820 kWh/a
East of Egypt (Marsa Alam)	2330 kWh/(m²a)	1800 kWh/a
Western Desert (Siwa)	2100 kWh/(m²a)	1650 kWh/a
Upper Egypt (Aswan)	2300 kWh/(m²a)	1790 kWh/a
CSP - Parabolic with storage (100 MW)	**Direct normal irradiation**	**Electricity output per 1 kW**
Northern Egypt (Alexandria)	2150 kWh/(m²a)	3900 kWh/a
Sinai	2600 kWh/(m²a)	4560 kWh/a
East of Egypt (Marsa Alam)	2650 kWh/(m²a)	4700 kWh/a
Western Desert (Siwa)	2300 kWh/(m²a)	4270 kWh/a
Upper Egypt (Aswan)	2500 kWh/(m²a)	4570 kWh/a
Wind power	**Full load hours of wind**	**Electricity output per 1 kW**
Low (Hurghada, wind speed 6.7 m/s))	2000 h	2000 kWh/a
Medium (ZRas Sudr, wind speed 7.3 m/s)	3000 h	3000 kWh/a
High (Gulf of El Zeit, wind speed 11m/s)	4000 h	4000 kWh/a
Max	5000 h	5000 kWh/a

Gabal EL Zeit area. In May 30th 2009 a presidential decree No. 138 for the year 2009 was issued to allocate about 1229 km^2 at west of Suez Gulf. In September 2009, a presidential decree No. 319 for the year 2009 was issued allocating some lands to implement wind projects. This land is located in Upper Egypt, West & East of the Nile to governorates of BeniSuef, Minya and Assuit with a total amount of 6418 km^2. The lands will be used according to a usufruct contracts and to some rules approved by the cabinet. In December 2010 a presidential decree No. 738 for the year 2010 was issued to allocate 198 km^2 which is located at the north part from 656,4 km^2 that was previously allocated for NREA by the Red Sea Governorate decree No. 136 for the year 2006. An area with about 3630 acres (equivalent 7525 km^2) is currently under allocation to implement solar power plant with the capacity of 100 MW in Kom-Ombo / Aswan (New & Renewable Energy Authority (NREA), 2011).

Also, NREA had implemented a solar PV project in El-Koraymaat with the capacity of 20 MW. The project was completed in 1/ 6 /2011. The total area of the solar field is 644 thousand Sq.m. The total solar collectors are 1920 including 5370 mirror. In 2016, the government had ambitious plan to implement different renewable energy projects and it had allocated about 7600 square kilometers of desert lands to generate about 7200 MW. These land are located in the Gulf of Suez, BeniSuef, Minia, New Vally and Kom Ombo. Figure (15) shows a map for lands allocated for wind energy in the Gulf of Suez.

Analysis of Egyptian Land Use Planning for Electrical Power Plants

After investigation of the land use approaches which are currently used by different governmental organizations in Egypt for allocation of lands for power plants, it is noticed that the classical approach for land use planning is still used. This classic plan is distributing the land for each type of power plant as a separate stand-alone system such as the lands allocated for the wind farms in Red Sea Coast, land allocated for traditional gas power plant and El Dabaa site for nuclear power plants. This classical approach is using the land not efficiently and not economically because these land can be used for different hybrid power systems in the same time. The study are proposing two different new proposals for the national land use planning of power plants the first is for the existing land which are allocated for power plants and the second for the new land which will be selected for the new power plants.

a- New Proposal for Efficient Land Use of Existing Sites of Power Plants

The study had investigated the site of the nuclear power plant which had been allocated for the first nuclear power plant in El Dabaa, The site had been investigated by the Nuclear Power plant Authority. The site evaluation process is done according the ENRRA requirements (Egyptian Requirements for Site Evaluation of Nuclear Power Plants, (2016)) and the IAEA guidelines, as well as environmental aspects. According to the international experience the 4 nuclear power reactors which will be built in the site may need only about 10 to 12 square kilometers from the total area of the site which is about 50 square kilometers. So, with the new approach for hybrid nuclear renewable energy system, the site can be re-investigated to consider using one of the renewable energy systems such as solar PV system which can be implemented efficiently in the site according to Solar Atlas of Egypt. This proposal can make use of land more economically and efficiently and also can help to fulfill the energy needs in the

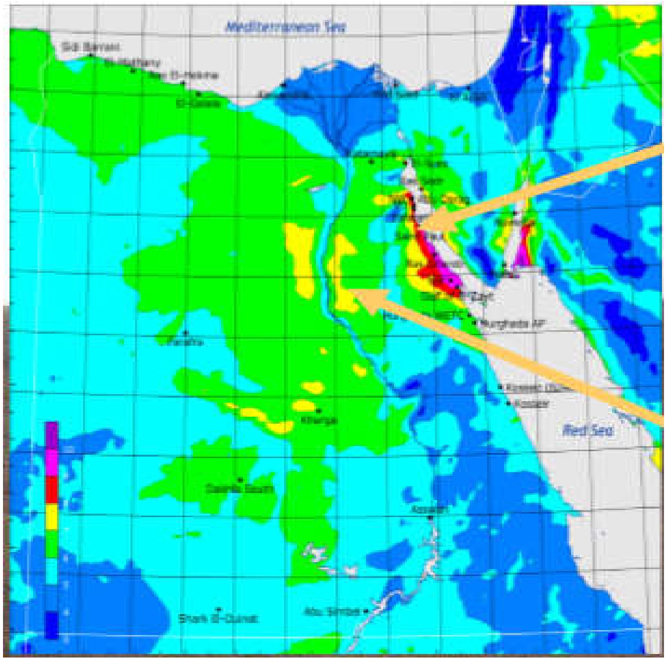

Figure 14a. Wind atlas of egypt showing potentialsites for wind energy, 2005 (New & Renewable Energy Authority (NREA), 2011)

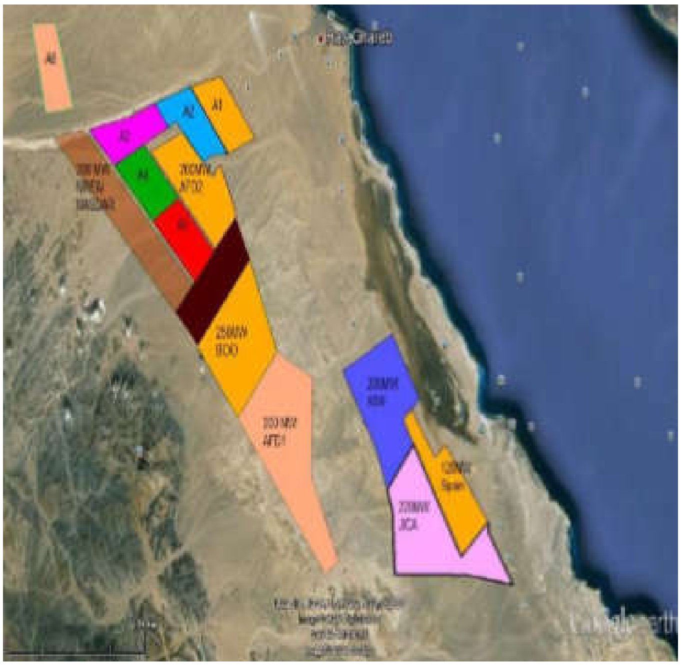

Figure 15. Map showing lands allocated for wind farms in the Red Sea Coast, NREA, 2015

North Coast development projects such as El-Alameen City. However, this proposal needs further investigation to study the interaction between the requirements of siting for nuclear and renewable and nuclear energy generating systems as well as safety and security and regulatory aspects. In any case the safety and security of nuclear power plant should not be jeopardized due to the application of this proposal. The same approach can be used for the land allocated for the new wind farms in the Red Sea Coast, these lands can be re-studied to install solar energy generating systems. An introduction of a nuclear power plant in this region may be less favorable due to the higher seismicity compared with the north west coast of the Mediterranean sea. However economic benefits of the whole system should be then evaluated.

b- New Proposal for Efficient Land Use of New Sites for Power Plants

The new site selection and land use for new power plants should be investigated with the new approach of using nuclear renewable hybrid energy system or any hybrid energy system which can make land use more efficiently and more economically for the future national development projects. This new proposal for using land efficiently with new trend of nuclear renewable hybrid energy system need to be addressed in the national level, it is proposed to introduce a national inter-ministerial committee of all responsible ministries and stakeholders which can include the utilities of the power plants such as: Nuclear Power Plant authority, New and Renewable Energy Authority, Electrical Holding Company, etc. and the regulatory bodies such as: Nuclear and Radiological Authority, Egyptian Electric Utility & Consumer Protection Regulatory Agency, Ministry of Environment, also the related governmental organizations such as Ministry of Housing, Ministry of Local development, and General Organization of Physical Planning. The purpose of this committee is to consider on the national level the question of the efficient land use of energy generating systems in a most economic, efficient way, while securing the safety and security aspects and reducing the environmental impacts of these energy hybrid systems.

Conclusion

The paper assessed and evaluated the new trend of hybrid nuclear renewable energy system. The need for new proposals in Egypt is highlighted to think more efficiently for the land use approach for the power plants. Conclusions can be summarized as follows:

- Nuclear hybrid energy systems are currently in the early stages of development. Several of the identified development needs correspond to technology needs for flexible and resilient energy structures.
- There are different advantages of the nuclear hybrid energy system which include :reduced greenhouse gas emissions in the coming decades, increased energy conversion efficiency through deployment of advanced integration, high reliability of electricity supply and consistent power quality by economically providing flexibility and other ancillary services to the grid; high penetration of renewable energy by transforming the grid infrastructure to provide grid-scale energy storage and dispatch; reduced fossil fuel dependence for the transportation sector via expansion of clean energy sources that can be used by plug-in vehicles, reduced fresh water withdrawals and consumption through higher efficiency thermodynamic power cycles.
- Nuclear and renewable energy offer the potential for plentiful long-term supplies of heat and power at prices not subject to the variations of fossil-fuel prices, and for producing lower GHG emissions than alternative fossil-fuel sources. Renewable energy sources also have the benefits of strong societal acceptance.
- A future hybrid nuclear-renewable energy approach can presents opportunities to use land more efficiently and economically in Egypt.
- To bring hybrid energy systems to practice in Egypt, technical development, systems analysis, and optimization of the concepts should be investigated.

- A proposal for El Dabaa site may be considered to introduce another renewable energy such as solar PV in the site beside the nuclear power plant.
- The new proposal for using land efficiently with new trend of nuclear renewable hybrid energy system need to be addressed in the national level and a national map for land uses of hybrid energy power plants should be developed.

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