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Global Electricity Demand and Clean Energy Source Growth Scenario

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Abstract: It is impossible to overstate the importance of energy. Just thinking about where humanity would be without it may be enough to demonstrate this point. Like in the past, energy will play a vital role in shaping future industries, cities, nations, and the world. That is why we believe that energy is a critical factor in shaping future paradigms in any target entity or world. To have a better understanding of the role that energy plays in the world today and in the future, in this article, we briefly look at the definition of energy and its different forms, and review some data related to energy consumption in the world and the United States. Furthermore, as a source of clean energy, we believe the future of nuclear power technology, despite the challenges it faces, is an important option for this country and the rest of the world to meet future energy needs without emitting CO (carbon monoxide) and CO_2 (carbon dioxide), or other GHGs (greenhouse gases), and other atmospheric pollutants and it is more efficient among its other comparable sources of renewable energies, such as solar, wind, etc. Globally, renewables made up 29 percent of electricity generation in 2020, much of it from hydro-power (16.8 percent). A record amount of over 256 GW of renewable power capacity was added globally during 2020 and continues to be the focal point for climate and energy solutions. Demand for electricity is direct function of population growth globally and is also driven by the present century's extraordinary technological developments.

Key words: Electricity demand, energy flow, energy storage, energy grid, resilience system, population growth, and modern technology.

1. Introduction

It is impossible to overstate the importance of energy. Just thinking about where humanity would be without it may be enough to demonstrate this point. Like in the past, energy will play a vital role in shaping future industries, cities, nations, and the world.

That is why we believe that energy in a clean and free of any environmental pollution and GHGs (greenhouse gases), is a critical factor in shaping future paradigms in any targeted entity or world. To better understand the role that energy plays in the world today and in the future, in particular, the rule has in producing demanded electricity, we have looked at the definition of energy and its different forms. And second, we reviewed the data related to energy consumption both globally and in the United States at more granular level in a book written by these authors (i.e., Zohuri et al. [1]) here.

In summary, by the science of physics definition, energy is the quantitative property that must be transferred to an object to work on or heat the thing. Energy is a conserved quantity; the law of conservation of energy states that energy can be converted in form but not created or destroyed. The SI (international system) unit of energy is the joule, which is the energy transferred to an object by moving it a distance of 1 m against a force of 1 N.

Typical forms of energy include the kinetic energy of a moving object, the potential energy stored by an

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object's position in a force field (gravitational, electric, or magnetic), the elastic energy stored by stretching tangible things, the chemical energy released when a fuel burns, the radiant energy carried by light, and the thermal energy due to an object's temperature.

Mass and energy are closely related. Due to mass-energy equivalence, any object with mass when stationary (called rest mass) also has an equivalent amount of energy whose form is called rest energy. And any additional energy (of any form) acquired by the object above that resting energy will increase the object's total mass just as it increases its total energy. For example, after heating an object, its increase in energy could be measured as a slight increase in mass with a sensitive enough scale.

Living organisms require energy to stay alive, such as humans' energy from food. Human civilization requires energy to function, which it gets from energy resources such as fossil fuels, nuclear fuel, or renewable energy. The processes of Earth's climate and ecosystem are driven by the radiant energy Earth receives from the sun and the geothermal energy contained within the Earth [1].

"When it comes to energy, there is one matter everyone agrees on. For the near future, at least, the world will need more of it—and how it is produced and used will be a critical factor in the future of the global economy, geopolitics, and the environment". Scott Nyquist-McKinsey & Company.

Its resiliency, without any interruption, assures us existence of it by producing electricity to meet our demand of us human as a guarantee that we rely on it [2-5].

Energy resilience is about ensuring business and end-use consumers have a reliable, regular supply of energy and contingency measures in place in the event of a power failure, generating a source of power such as electricity for daily needs from an uninterrupted source of energy no matter either renewable or nonrenewable. Causes of resilience issues include power surges, weather, natural disasters, or man-made accidents, and even equipment failure. The human operational error can also be an issue for grid-power supply to go down and should be factored into resilience planning. As the energy landscape undergoes a radical transformation, from a world of large, centralized coal plants to a decentralized energy world made up of small-scale gas-fired production and renewables, the stability of the electricity supply will begin to affect energy pricing. Businesses must plan for this change.

The challenges that the growth of renewables brings to the grid in terms of intermittency mean that transmission and distribution costs consume an increasing proportion of bills. With progress in the technology of AI (artificial intelligence) integration of such progressive technology in recent decades, we are improving our resiliency of energy flow, so we prevent any unexpected interruption of this flow. Ensuring your business is energy resilient helps insulate against price increases or fluctuations in supply, becoming critical to maintaining operations and reducing commercial risk [5].

Energy has always been a central factor in the formation, transformation, and development of human societies. Availability, the form, and technology to utilize energy is the driving force in the creation and advancements of civilizations from the very beginning of human settlements. It is impossible to overstate the importance of energy. Just thinking about where humanity would be without it is enough to demonstrate this point [1].

2. Nuclear Energy as a Source of Renewable Energy

Knowing whether a source of energy is renewable or non-renewable is essential when considering energy and sustainability. Renewable energy is defined by the U.S. Environmental Protection Agency thus: "Renewable energy includes resources that rely on fuel sources that restore themselves over short periods and do not diminish" (Source: U.S. EPA [6]). Non-renewable energy is energy that cannot restore itself over a short period and does diminish. It is usually easy to distinguish between renewable and non-renewable.

To further enhance our knowledge of energy and its different type and source of it, once again, we will go to the US EIA (Energy Information Administration) for a description of renewable energy sources.

The key points are summarized below.

2.1 Non-renewables

- Coal, oil, and natural gas are fossil fuels. Even though they all get their energy from the sun, none are renewable. They all emit CO_2 and other emissions when burned.
- Nuclear is also non-renewable but not a fossil fuel. It is carbon-free but causes radioactive waste.
- Most importantly, for all intents and purposes, whatever coal, oil, natural gas, and nuclear exists today is all that we will ever have.

2.2 Renewables

- Solar, wind, and hydro are renewable, carbon-free, and effectively inexhaustible.
- Bioenergy is renewable and carbon-neutral. It emits CO_2, but no more CO_2 than was initially pulled from the atmosphere. Even though it is considered renewable, it is possible to use bioenergy unsustainably by harvesting it more quickly than it can be replenished.

Note that we hear a lot about renewables and natural gas in the U.S., as their use has been growing rapidly for some time now. But as you can see in Fig. 1 from the EIA, coal and nuclear still constitute over 40% of all electricity generation in the U.S. Solar, despite its massive growth and growth potential, is only 1.8%. We have a long way to go yet.

Bear in mind that, living organisms require energy to stay alive, such as the energy humans get from food. Human civilization requires energy to function, which it gets from energy resources such as fossil fuels, nuclear fuel, or renewable energy. The processes of Earth's climate and ecosystem are driven by the radiant energy Earth receives from the sun and the geothermal energy contained within the Earth.

All forms of energy are associated with motion. For example, any given body has kinetic energy if it is in motion. A tensioned device such as a bow or spring, though at rest, has the potential for creating motion; it contains potential energy because of its configuration. Similarly, nuclear energy is potential energy because it results from the configuration of subatomic particles in the nucleus of an atom [1].

Furthermore, although, Energy has been the engine of growth and development in the world. Even though during the past few decades, access to different types of energy becomes more feasible, nevertheless oil, gas, and coal have been the most important source of energy. Fig. 2 demonstrates the consumption of different types of energy between 1965 and 2015 in the world [1]. Studying the trend shows that while the demand for all sources of energy except nuclear has been increasing, the degrees of change in consumptions have not been the same.

However, Fig. 3 demonstrates the year-to-year percentage change in primary energy consumptions in the world between 1966 and 2019.

Moreover, as it is presented in Fig. 4, it demonstrates year-to-year changes in primary energy consumption by source, in the world between 1966-2019 [1].

Now the question is can we consider, "Nuclear Energy as a Renewable Source of Energy"?

Assuming, for the time being, we are taking fission reaction as the foundation for present (GEN-III) and future (GEN-IV) nuclear power reactors, as source nuclear energy source to somewhat degree, we can argue it is a clean source of energy.

Although nuclear energy is considered clean energy, its inclusion in the renewable energy list is a subject of significant debate. To understand the debate, we need to understand the definition of renewable energy and nuclear energy first. However, until we manage through future technology of these fission reactors to manage to bring down the price electricity per kilowatt

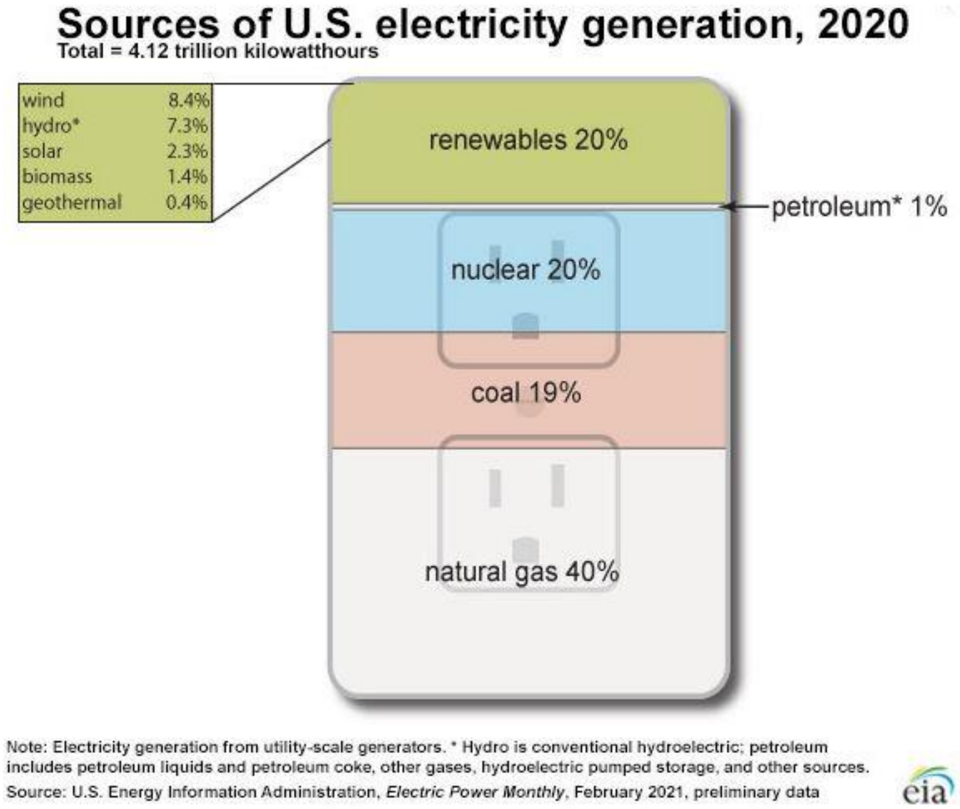

Fig. 1 United States of America electricity generation 2020, by source.
Source: United States Energy Information Administration.

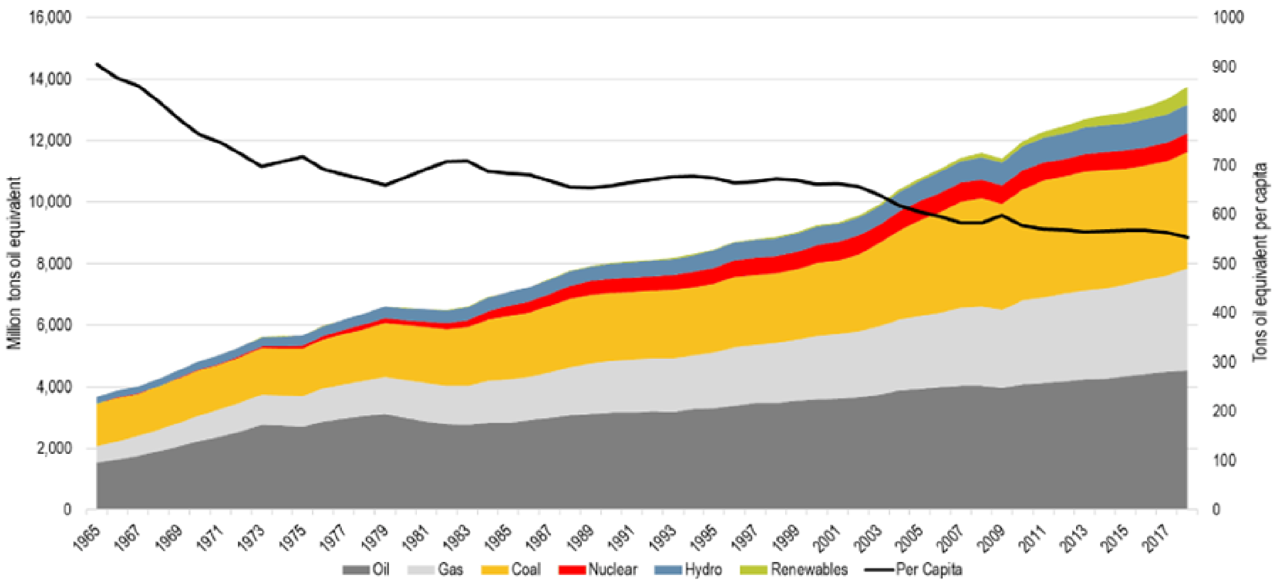

Fig. 2 Energy consumption between 1965 and 2015.
Source: World Bank.

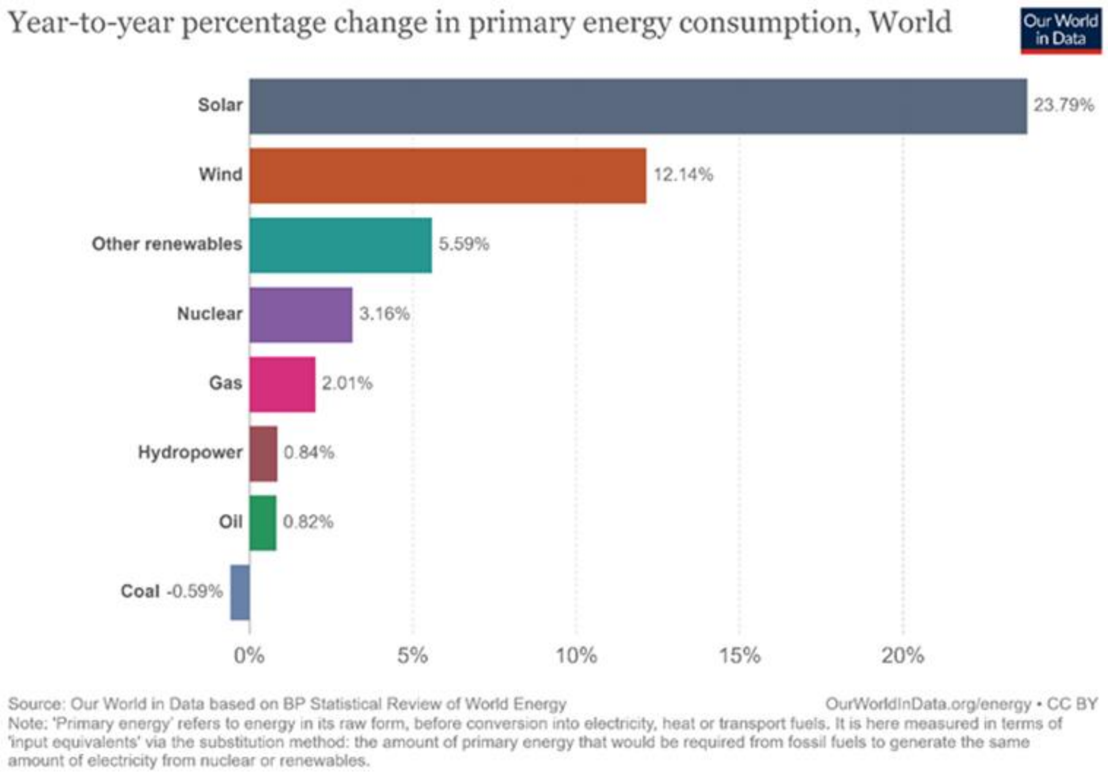

Fig. 3 Year-to-year change in primary energy consumption by source.
Source: US Department of Energy.

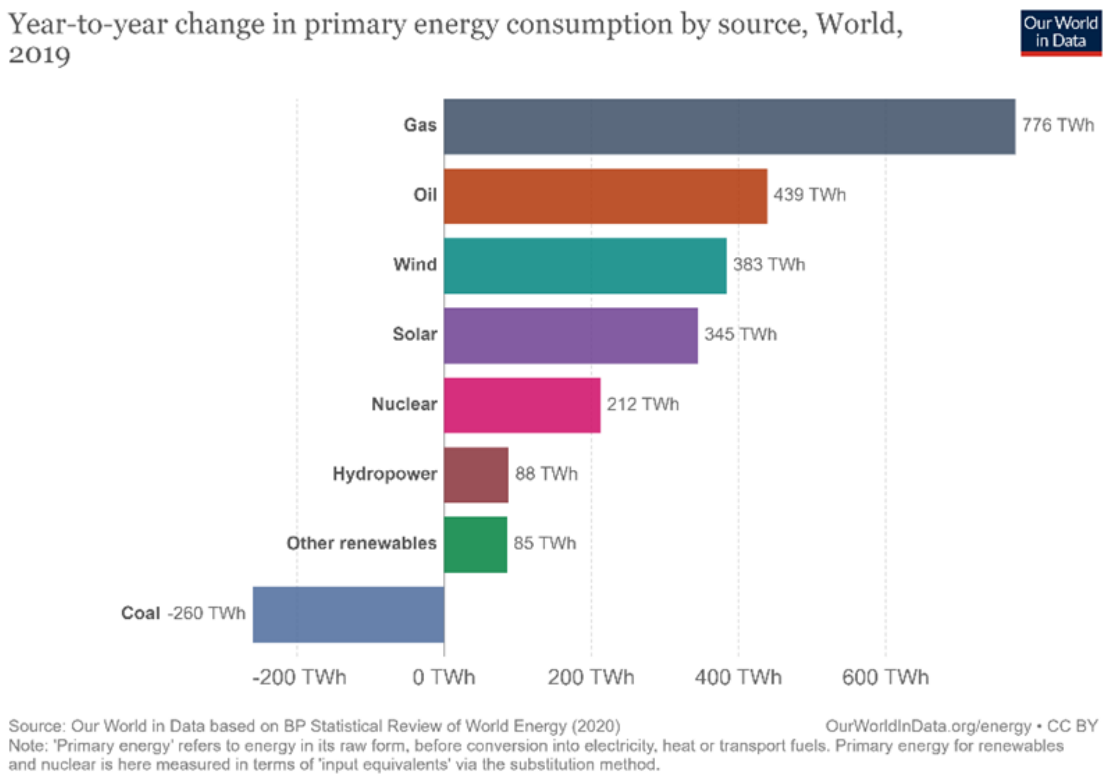

Fig. 4 Year-to-year change in primary energy consumption by source, in the world between 1966-2019.
Source: US Department of Energy.

hours driven by fusion energy down to the point of those by gas or fossil fuels, there is no chance to push these reactors beyond GEN-III.

However, efforts toward reducing the price of electricity driven by nuclear fission power plants, especially using some innovative design of GEN-IV plants with high-temperature baseline in conjunction with some thermodynamics cycles such as Brayton and Rankine, is on the way by so many universities and national laboratory such as Idaho National Laboratory and Universities such as MIT (Massachusetts Institute of Technology), UC Berkeley, and the University of New Mexico as well as this author.

Renewable energy is defined as an energy source/fuel type that can regenerate and can replenish itself indefinitely. The five renewable sources used most often are biomass, wind, solar, hydro, and geothermal.

Nuclear energy, on the other hand, is a result of heat generated through the fission process of atoms. All power plants convert heat into electricity using steam. Nuclear power plants create heat to make the steam when atoms split apart—called fission. This process releases energy in the form of heat and neutrons. The released neutrons then go on to hit other neutrons and repeat the process, hence generating more heat. In most cases, the fuel used for nuclear fission is Uranium.

One question we can raise here in order, to further understand whether, or not, we need to present nuclear technology as a source of energy is:

What is the difference between clean energy and renewable energy? Put another way, why is nuclear power in the doghouse when it comes to revamping the nation's energy mix?

The issue has come to the forefront of the time during the debate over the Waxman-Markey energy and climate bill. This, of course, is provisions for a national renewable-energy mandate.

To put it, Republicans have tried and failed several times to pass amendments that would christen nuclear power as a "low-emissions" power source eligible for all the same government incentives and mandates as wind power and solar power.

Many environmental groups are fundamentally opposed to the notion that nuclear power is a renewable form of energy—on the grounds that it produces harmful waste byproducts and relies on extractive industries to procure fuel like Uranium.

Even so, the nuclear industry and pro-nuclear officials from countries, including France, have been trying to brand the technology as renewable because it produces little or no greenhouse gases. Branding nuclear as renewable could also enable nuclear operators to benefit from some of the same subsidies and friendly policies offered to clean energies like wind, solar, and biomass [1].

So far, however, efforts to categorize nuclear as a renewable source of power are making little headway.

The latest setback came in around August of 2009 when the head of the IRENA (International Renewable Energy Agency)—an intergovernmental group known as IRENA that advises about 140 member countries on making the transition to clean energy—dismissed the notion of including nuclear power among its favored technologies.

"IRENA will not support nuclear energy programs because it's a long, complicated process, it produces waste and is relatively risky," Hélène Pelosse, its interim director general, told in general.

Energy sources like solar power, Ms. Pelosse said, are better alternatives—and less expensive ones, "especially with countries blessed with so much sun for solar plants," she said in 2009.

However, no matter what? One thing is obvious "Nuclear Energy" is a clean source of energy and free of CO or CO_2 or any other greenhouse effect and gases, and other atmospheric pollutants.

3. Argument for Nuclear as Renewable Energy

Most supporters of nuclear energy point out the low carbon emission aspect of nuclear energy as its primary characteristic to be defined as renewable energy. According to nuclear power opponents, if the goal of building a renewable energy infrastructure is to lower carbon emission, then there is no reason not to include nuclear energy in that list [7].

But one of the most compelling arguments for including nuclear energy in the renewable energy portfolio came from Bernard L. Cohen, a former professor at the University of Pittsburg. Professor Cohen defined the term “indefinite” (time span required for an energy source to be sustainable enough to be called renewable energy) in numbers by using the expected relationship between the sun (source of solar energy) and the earth. According to Professor Cohen, if the Uranium deposit could be proven to last as long as the relationship between the Earth and Sun is supposed to last 5 billion years, then nuclear energy should be included in the renewable energy portfolio [8].

In his paper, Professor Cohen claims that using breeder reactors (nuclear reactors able to generate more fissile material than it consumes), it is possible to fuel the earth with nuclear energy indefinitely. Although the amount of uranium deposit available could only supply nuclear energy for about 1,000 years, Professor Cohen believes the actual amount of uranium deposit available is way more than what is considered extractable right now. In his arguments, he includes uranium that could be extracted at a higher cost, uranium from seawater and, also uranium from eroding earth crust by river water. All of those possible uranium resources, if used in a breeder reactor, would be enough to fuel the earth for another 5 billion years and hence renders nuclear energy renewable energy.

4. Argument against Nuclear as Renewable Energy

One of the biggest arguments against including nuclear energy in the list of renewables is the fact that uranium deposit on earth is finite, unlike solar and wind. To be counted as renewable, the energy source (fuel) should be sustainable for an indefinite time, according to the definition of renewable energy.

Another major argument proposed by the opponents of including nuclear energy as renewable energy is the harmful nuclear waste from nuclear power reactors. The nuclear waste is considered as a radioactive pollutant that goes against the notion of a renewable energy source. Yucca Mountain is one of the examples used quite often to prove this point. Most of the opponents in the US also point to the fact that while most renewable energy sources could render the US energy independent, uranium would still keep the country energy-dependent as the US would still have to import uranium [1].

5. Why We Need Nuclear Power Plants

The significant growth in the electricity production industry in the last 30 years has centered on the expansion of natural gas power plants based on gas turbine cycles. The most popular extension of the simple Brayton gas turbine has been the combined cycle power plant with the Air-Brayton cycle serving as the topping cycle and the Steam-Rankine cycle serving as the bottoming cycle for a new generation of nuclear power plants that are known as GEN-IV. The Air-Brayton cycle is an open-air cycle, and the Steam-Rankine cycle is a closed cycle.

The air-Brayton cycle for a natural gas-driven power plant must be an open cycle, where the air is drawn in from the environment and exhausted with the products of combustion to the environment. This technique is suggested as an innovative approach to GEN-IV nuclear power plants in the form and type of SMRs (small modular reactors). The hot exhaust from the Air-Brayton cycle passes through a HSRG (heat recovery steam generator) prior to exhausting to the environment in a combined cycle. The HRSG serves the same purpose as a boiler for the conventional Steam-Rankine cycle [9].

“Nuclear power’s track record of providing clean and reliable electricity compares favorably with other energy sources. Low natural gas prices, mostly the result of newly accessible shale gas, have brightened the prospects that efficient gas-burning power plants could cut emissions of carbon dioxide and other pollutants relatively quickly by displacing old, inefficient coal plants. However, the historical volatility of natural gas prices has made utility companies wary of putting all their eggs in that basket. Besides, in the long run, burning natural gas would still release too much carbon dioxide. Wind and solar power are becoming increasingly widespread, but their intermittent and variable supply makes them poorly suited for large-scale use in the absence of an affordable way to store electricity. Hydropower, meanwhile, has minimal prospects for expansion in the United States because of environmental concerns and the small number of potential sites."

"The United States must take a number of decisions to maintain and advance the option of nuclear energy. The NRC's initial reaction to the safety lessons of Fukushima must be translated into action; the public needs to be convinced that nuclear power is safe. Washington should stick to its plan of offering limited assistance for building several new nuclear reactors in this decade, sharing the lessons learned across the industry. It should step up its support for new technology, such as SMRs and advanced computer-modeling tools.

And when it comes to waste management, the government needs to overhaul the current system and get serious about long-term storage. Local concerns about nuclear waste facilities are not going to disappear magically; they need to be addressed with a more adaptive, collaborative, and transparent waste program."

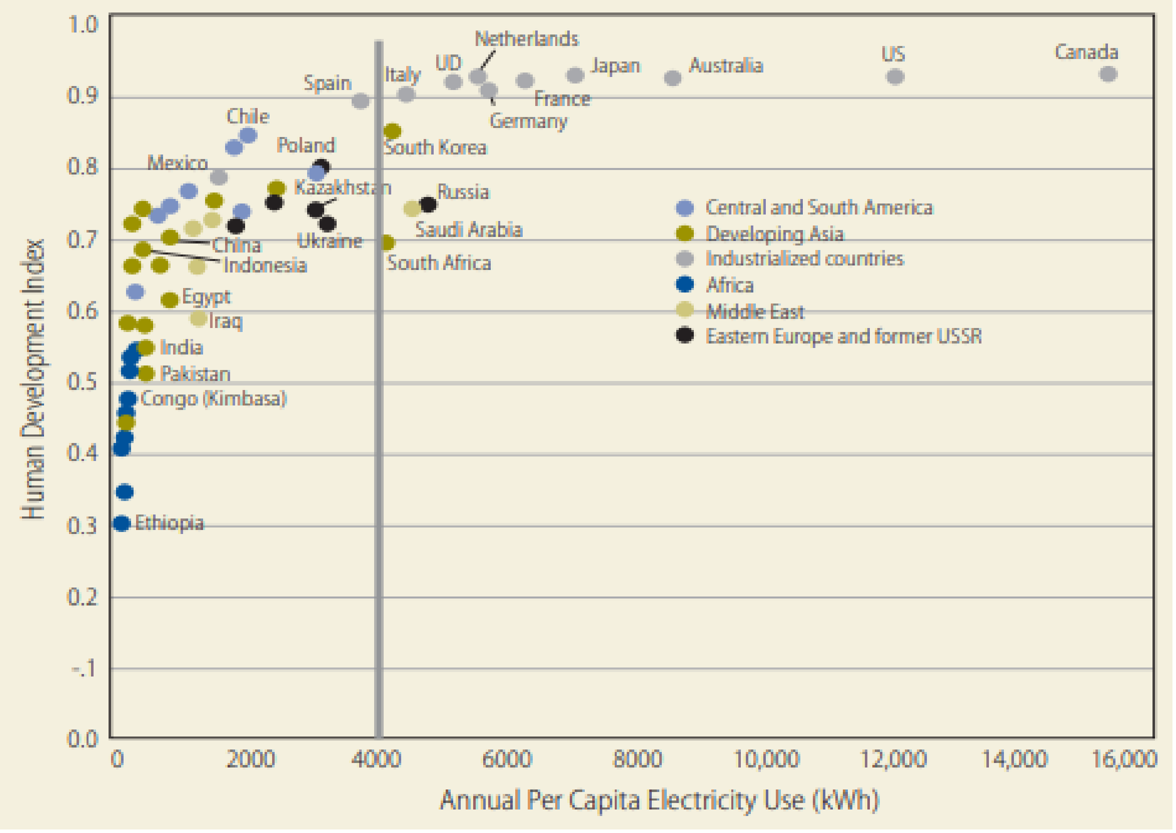

Fig. 5 Correlation between HDI (human development index) and per capita electricity consumption.
Source: S. Benka, Physics Today (April 2002), p. 38.

These are not easy steps, and none of them will happen overnight. But each is needed to reduce uncertainty for the public, the energy companies, and investors. A more productive approach to developing nuclear power—and confronting the mounting risks of climate change—is long overdue. Further delay will only raise the stakes [1].

6. Conclusion

According to an MIT study of "The Future of Nuclear Power, 2003" [10], the United States National Academy of Engineering has declared electrification as the leading engineering accomplishment of the twentieth century. This recognition, for a century of extraordinary technological developments, acknowledges the profound impact of electricity on quality of life and suggests that governments around the world will continue to attach very high priority to providing adequate electricity infrastructure and supply to their citizens, within their means to make such investments.

Today the per capita consumption of electricity spans three orders of magnitude, as shown in Fig. 5 (S. Benka, Physics Today (April 2002) p. 38). The empirical dividing line between advanced and developing economies, as represented by the United Nations HDI, is 4,000 kWh per person per year of electricity use. The HDI is based on health, education, and economic criteria.

"The underlying assumption in our mid-century electricity demand scenario is that the developed countries continue with a modest annual increase in per capita electricity use and the developing countries move to the 4,000 kWh per person per year benchmark if at all feasible. Specifically, we have taken developed country annual per capita electricity growth rates between 0.5% and 1%, values that bracket (Energy Information Administration (EIA) expectations for the United States over the next twenty years (EIA Annual Energy Outlook, 2001); over the last quarter century, the growth rate averaged about 2%, falling to 1.5% in 2000 and expected to decline further in the years ahead. We present the 1% case in our table below. We take the same per capita growth rate for the Former Soviet Union countries".

"Although these are not necessarily robust economies today, they do enjoy substantial per capita electricity use already. Total electricity production is then computed using the United Nations population projections to mid-century" [10].

At the conclusion, bear in mind that the prospects for nuclear energy as an option are limited, the report finds, by four unresolved problems: high relative costs; perceived adverse safety, environmental, and health effects; potential security risks stemming from proliferation; and unresolved challenges in the long-term management of nuclear wastes.

"There is no question that the up-front costs associated with making nuclear power competitive, are higher than those associated with fossil fuels," said Dr. Moniz. "But as our study shows, there are many ways to mitigate these costs and, over time, the societal and environmental price of carbon emissions could dramatically improve the competitiveness of nuclear power."

However, the central premise of the 2003 MIT Study on the Future of Nuclear Power was that the importance of reducing greenhouse gas emissions, in order to mitigate global warming, justified reevaluating the role of nuclear power in the country's energy future. The 2003 study identified the challenges to greater deployment and argued that the key need was to design, build, and operate a few first-of-a-kind nuclear plants with government assistance, to demonstrate to the public, political leaders, and investors the technical performance, cost, and environmental acceptability of the technology. After five years, no new plants are under construction in the United States and insufficient progress has been made in waste management. The current assistance program put into place by the 2005 EPACT has not yet been effective and needs to be improved. The sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation".

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