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Implications of air pollution on future electricity generation

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ABSTRACT: Scientists are unable to agree on the real causes of global warming. Whatever the cause, one plausible ingredient—carbon emissions—stands to damage the air environment and health. This paper argues that any source of energy that produces carbon must be heavily curtailed. Considering that most of the world's energy comes from coal, other substitutes must be legislated, and the energy sources selected must deliver in gigawatt quantities day and night and be "clean". Only nuclear energy fits that bill. This paper discovers that modern day nuclear energy is "renewable". Nuclear energy cost is competitive against energy from fossil fuels, and safety concerns are easily managed while people's perceptions are becoming more favorable towards nuclear energy. Various concerns of nuclear energy are dispelled.

1 INTRODUCTION

Hansen et al. (2006) from the National Aeronautics and Space Administration (NASA) put the rate at 0.2°C per decade over the past thirty years. Maybe that However, Robinson et al. (2007) establish that sea-surface temperatures in the Sargasso Sea were higher in 1,000 AD by 1°C and in 1,000 BC by 2°C.

Antarctica is reported to have warmed only 0.2°C from 1850 to 2000, and actually cooled markedly during the 1990s while the Southern Hemisphere rose by 1.4°C over the past century (New Evidence 2006). According to data provided by Robinson et al. (2007) the average ice core temperatures were this high 110,000 years ago.

Of one thing there is no doubt: global warming is a fact and has been an old story for the past 15,000 years, helping us emerge from the ice age into a beautiful garden. But, not all parts of the Earth are heating uniformly. The current alarm about global warming is important, but must be placed in perspective and not exaggerated (Hieb 2003; Michaels 1998).

Therefore, it is meaningful to note that the cause of global warming is disputed vehemently by scientists. The differences of opinion and interpretation between science writers and climatologists, astronomers and solar-terrestrial physicists, atmospheric scientists and astrophysicists, chemists and paleoclimatologists, and so many other scientists, are substantial, such that it is hard to believe in any one of them with any certainty (Kaplincki 2006).

1.1 *Greenhouse gases*

Important greenhouse gases are water vapor, methane, nitrous oxide, carbon dioxide, and miscellaneous gases such as chlorofluorocarbons (CFCs). Greenhouse gases—produced by natural and industrial processes, result in CO_2 levels of 380 parts per million per volume (ppmv) in the atmosphere. The levels in 1900 were about 300 ppm. (Wikipedia: Greenhouse Gas 2008; Patterson 2005). But, water vapor has been shown to be the largest contributor to greenhouse gases by far (Lindzen 1992; Hieb (2008) reports that 95 percent of all greenhouse gases are water vapor:

"Of the 186 billion tons of CO_2 that enter Earth's atmosphere each year from all sources, only six billion tons are from human activity. Approximately ninety billion tons come from biologic activity in Earth's oceans and another ninety billion tons from such sources as volcanoes and decaying land plants"

Apparently, only 3.2 percent of atmospheric CO_2 is generated from human activities such as coal plants and fossil fuel burning, whereas the plant kingdom and natural volcanic activity contribute to natural CO_2. In contrast, 99.99 percent of water vapor is natural and comes from oceans and clouds. And, eighteen percent of methane and 65 percent of CFCs are from human activity (Hieb 2008). Even if all human induced methane and CFCs increased ten times, which is realistically impossible, they would likely have a miniscule effect on global warming. In addition, Essenhigh (2008), a professor of energy conversion, believes that CO_2 is simply unable to drive global warming, but that global warming may drive CO_2 increases. And, if humankind wishes to reduce the greenhouse effect of water vapor, it is absolutely beyond our control.

An increase of 2°C can occur if the CO_2 concentration increases to 450 ppm, which may take a century or two (How much 2006). But, this estimate is based on models that make too many assumptions and can therefore not stand up to scientific rigor. At most, the human contribution to the greenhouse effect is 0.28 percent, which is too small to matter (Hieb 2003).

It can thus quite safely be deduced that CO_2 is probably not the big culprit of global warming that the media has made it out to be (Chandler 2007; Beck 2006), though it is not entirely causeless.

2 HEALTH EFFECTS OF AIR POLLUTION

2.1 *Fog and smog*

The fact is that while the relatively small amounts of CO_2 and nitrous oxides put into the atmosphere probably do not have a significant impact on global warming, they have a very significant impact on air pollution and air quality.

Nitrogen oxide gases are produced from fossil-burning power plants and the transportation sector. They irritate the lungs of humans, birds, and animal species, causing bronchitis. Owing to reduced resistance to respiratory infections, they increase the incidence of pneumonia among humans.

Several pollutants are produced by burning fossil fuels and contribute to the noxious fumes that cause smog; these include carbon monoxide, nitrogen oxides, sulfur oxides, and hydrocarbons. Hydrocarbons combine in the atmosphere to form tropospheric ozone that descends to surface levels and becomes a major component of smog.

"Human exposure to ozone can produce shortness of breath and, over time, permanent lung damage. Research shows that ozone may be harmful at levels even lower than the current federal air standard. In addition, it can reduce crop yields" (The Hidden 2008).

Our entire industrial activity, which is supposed to alleviate the human condition, is creating conditions that harm us.

2.2 *Acid rain*

The phenomenon of acid rain occurs in industrialized areas that emit nitrogen oxides and sulfur oxides into the atmosphere. These gases—and smog—combine with water vapor in clouds to form sulfuric and nitric acids, which become part of rain. Carbon dioxide combines with water in the clouds to form carbonic acid. As the acids accumulate on the surface after acid rain, lakes and rivers become too acidic for plant and animal life (The Hidden 2008). Humanity is simply hurting itself.

Acid rain falls on a third of China's territory and 70 percent of Chinese rivers and lakes are toxic, unfit for drinking. Moreover, the sulfur dioxide (SO_2) produced in coal combustion, in addition to causing acid rain, causes about 400,000 premature deaths a year. Most of these deaths are from lung and heart-related diseases as SO_2 causes constriction of the finer air tubes of the lungs, thus making it difficult to breathe naturally." (Air Pollution 2008)

2.3 *Ozone*

Although CO_2 is not a lung irritant, Jacobsen (2008) found that CO_2 serves to increase ground-level ozone. This ozone is a lung irritant. Cases of asthma have gone up, such that by 2020, there could be twenty-nine million Americans suffering from asthma (Pew 1998).

2.4 *Health risks*

Children are more quickly affected by air pollution and more easily develop bronchitis and earaches (Outdoor 2008). It is well known that the incidence of respiratory diseases is on the rise all around the world. In one of the longest, largest studies on the effects of air pollution on lung cancer and heart diseases, 500,000 adults were surveyed in more than one hundred cities from 1982 to 1998, Pope et al. (2002) found air pollution as a convincing cause of increased lung cancer and cardiopulmonary diseases.

"More than 220 million Americans breathe air that is one hundred times more toxic than the goal set by Congress ten years ago, according to figures calculated by the Environmental Defense Fund (EDF). And for eleven million people, the cancer risk from their neighborhood air is more than one thousand times higher than Congress's goal, the group says" (Most Americans 1999).

2.5 *Global spread of air pollution*

A report last year identified China as the worst air polluter in the world; 656,000 Chinese per year die from diseases caused by air pollution alone. The corresponding numbers for India are 527,000 (Platt 2007). We also know that air pollution from China is traveling across the Pacific. NASA satellite data have confirmed that nearly 10 billion pounds of aerosol pollution reached North America from East Asia (NASA 2008), the largest contributor of which was China. Cliff (2006) reports that we are already breathing Chinese pollution in North America.

3 THE KYOTO AGREEMENT

The Kyoto Agreement accepts that global warming is a result of burning fossil fuels, which we have shown is possibly unconvincing. The Kyoto Agreement goes a step further in their false premise to require that gaseous emissions be cut by 2012 by 5.2 percent below the emission levels of 1990 (Bloch 2008). At best, the effect of the Kyoto Agreement would be a reduction in global temperature by one-twentieth of a degree Fahrenheit by 2050 (Global Warming 2003). Thus, even in its own argument, the Kyoto Agreement doesn't go far enough.

A deeper and bolder global agreement is needed, one that has real teeth, like eliminating coal generation by 2050.

4 FEASIBLE SOLUTION

If we accept the likely premise that humans will not forego their electricity use and modes of transportation, and will thus resist reverting to the Middle and Dark Ages, what is the solution if we don't want to damage our health? It is evident that we must target energy production, for which two areas stand out most prominently: energy production and transportation fuel.

This paper is focusing only on energy production. Technologists propose renewable energies such as solar, wind, and geothermal. However, like any energy engineer will tell you, the electricity that can be potentially harnessed from these sources is not more than 25 percent of our needs. Night production of solar and wind is a problem, and storage mechanisms are in an immature stage of development. What's more, hydroelectricity causes severe ecological damages of its own, not to mention that the potential is limited. Many novel sources of energy, such as tidal and wave power, are still being researched for safe and reliable implementation, since hostile ocean conditions pose challenges for wave structures (Wave and tidal 2000; Wave power 2008). Ocean thermal energy conversion is a new possibility for renewable energy, but one that lacks a track record.

So what's next, if we want to steer away from fossil fuel energy, but still want a decent standard of life? Practical engineers and politicians cannot live on hope that new technology will arrive one day. Nations could be steeped deep in crises by that time. It's not reasonable to wait till new inventions arrive to secure our future.

5 ENERGY PRODUCTION

The aim now is to produce "clean" energy, in "large quantities," with no "environmental effects." Well, the total electric installed capacity in the United States was 1,000 gigawatts (GW) in 2005 (Industry 2008; Wind power 2008). The distribution was approximately as follows:

Coal, 49%; Nuclear, 19.3%; Natural gas 18.7%; Hydropower 6.5%; Fuel oil 3.0%; Biomass 1.6%; Wind 1.2%; Geothermal and Solar 0.6%.

Thus, 73% of the electricity comes from fossil sources. The USA consumes 12,000 kWh of electricity per person per year. This is twice the amount that Germany produces, and nine times the world average (Solar/Wind, 2008 (1997 data)).

The World Energy Outlook of the International Energy Agency (2006) says "the current pattern of energy supply carries the threat of severe and irreversible environmental damage—including changes in global climate." Therefore, it is imperative to reverse the trend of energy production in the world.

Importantly, the world is fast running out of oil, which will bring fossil fuel electricity generation and transportation closer to a standstill. Some other form of energy generation will have to be substituted at a fast pace. World demand is quickly depleting oil reserves. The oil company, Royal Dutch Shell, estimates that " . . . after 2015 supplies of easy-to-access oil and gas will no longer keep up with demand" (Shell 2008). The same article consequently concludes that there will be a need for nuclear power and alternate sources.

It is possible to produce a maximum of 20 percent of the United States' energy needs through wind power (Solar Energy International 2008), another 5 percent by solar power, and about 7 percent by hydroelectric power. However, these will not replace or close down existing fossil fuel power plants, unless repealed by legislation, which is definitely recommended. The total world installed capacity for solar power is a mere 0.8 GW (Solar/Wind 2008). Solar power for consumption on a mass scale is currently impeded by technical difficulties in storing energy during cloudy periods and night. The technology is simply undeveloped for a reliable, continuous supply of electric power. The feasibility of wind and sun sources of energy producing in gigawatt quantities day and night is not established. Geothermal energy is not available everywhere. Thus, we have to think of "clean" alternates other than solar and wind energy to meet world energy demands. Surely, there must be a better way to generate electricity that does not damage health. Luckily, there is.

6 NUCLEAR ENERGY

The only logical and available answer for the world is nuclear energy, at least for the foreseeable future or until some other technology proves to be effective. Let's look at nuclear energy in greater detail:

6.1 *Production capability and trends*

Of the relatively large countries, 70 percent of France's electricity comes from nuclear energy, while for the United States the number is 20 percent. China and Russia are extremely busy cornering the world's uranium market and India is also on the path of nuclear renaissance. The United States is also apparently heading towards a nuclear revival.

There are 442 nuclear power plants in the world, of which 104 are in the United States. Worldwide, thirty-four reactors are under construction, and 280 are proposed. In China alone, 116 new reactors are planned or proposed (Uranium 2006; Freeman 2005). As many as twenty-nine new reactors may receive licenses for construction in the United States (Biello 2007). General Electric, the world's largest utility company, plans to enter into partnerships for nuclear construction around the world (General 2007; New Nuclear 2005). These statistics illustrate that the world is moving head on towards nuclear power.

One ton of nuclear fuel delivers as much energy as 20,000 tons of coal. Consequently, the advantages in the logistic management of uranium compared to coal are evident.

Apparently, there is no shortage of uranium on Earth. Uranium can even be extracted from sea water. There are about 4.5 billion metric tons of uranium available in the world's oceans (Uranium from Sea water 2006). This is enough to last humankind approximately 36,000 years, compared to 130 to 300 years from coal reserves, for electricity production (World Coal Institute 2008; Elert 2005).

6.2 *Carbon saving*

In an MIT study that aimed to expand current worldwide nuclear generating capacity almost threefold by the year 2050, it was found that 1.8 billion metric tons of carbon emissions would be saved annually (MIT 2003). This much is equal to about one-third of the total current carbon emissions. Nuclear energy production is not "carbon-free," but it does minimize carbon emissions in its process cycle (Nuclear Comeback, 2007). The world has no choice but to resort to the only electricity generating technique that can deliver the goods, once fossil fuels are depleted, which is expected to start around 2012 (Shell 2008).

Needless to say, the period between 2015 and 2020 might be tumultuous for the world owing to energy shortages and skyrocketing prices of oil. These will further affect food distribution, plausibly causing widespread famines (Edwards 2000). The disruption to society from mining to manufacturing to transportation might be tremendous.

6.3 *Nuclear waste and fuel recycling*

That nuclear waste has a disposal problem is a myth from the days of old technology when conventional thermal reactors operated in a "once-through" mode. Today, it is possible to recycle spent nuclear waste from thermal reactors by reprocessing in a "closed" fuel cycle, or from fast reactors by reprocessing in a balanced "closed" fuel cycle (MIT 2003). Robinson and colleagues (2007) affirm that spent nuclear fuel can be recycled into new nuclear fuel and does not need to be stored in repositories, such as the Yucca Mountain repository in Nevada. Hence, neither radioactive decay nor storage are engineering problems for the future, at all.

6.4 *Safety of nuclear power plants*

The safety of nuclear power plants centers on two main issues: (1) maintaining public safety in the event of radioactivity leaks, and (2) eliminating damage through malfunctions or accidents.

Radioactivity leakage has been a concern for many decades. In 2000, four of the eight reactors in Pickering, Canada were finally shut down as a result of tritium leaks, which is a cancer causing substance (Sierra Club 2001). The Oyster Creek Plant in New Jersey was reported to have elevated levels of cesium-137 near the plant. Cesium-137 is another carcinogenic substance (Cacchioli and Larsen 2006). There are many more such cases around the world. Thus, when people are concerned about radioactivity leaks from nuclear power plants, it is not altogether without reason (Leak forces 2000).

Nevertheless, it is not well known that the Three Mile Island (Pennsylvania) accident was contained without immediate harm to anyone. The world can also be confident that a Chernobyl type of poor design will never be repeated again in IAEA supervised countries, though human errors cannot be ruled out (for anything). In over 12,700 cumulative reactor years of commercial operation in thirty-two countries, there has never once been a death outside of Chernobyl. Moreover, current reactor design emphasis has shifted in the last eight years from reliance on containment structures to safety through improved design of the reactor plant itself (History of Nuclear 2008). Safety (2007) reports:

"The U.S. Nuclear Regulatory Commission (NRC) specifies that reactor designs must meet a 1 in 10,000-year core damage frequency, but modern designs exceed this. U.S. utility requirements are 1 in 100,000 years, the best currently operating plants are about 1 in 1 million and those likely to be built in the next decade are almost 1 in 10 million."

Advanced nuclear reactors, known as next-generation reactors, such as the ones going up in Japan (the first of which was constructed in 1996), contain safety improvements based on operational experience. Beyond the safety engineering already standard in Western reactors, they have passive safety systems, which require no operator intervention in the event of a major malfunction. All modern reactors are designed to automatically shut down in the event of earthquakes. Owing to an emphasis on safety, safety systems account for about one-fourth of the capital costs of modern reactors (Safety 2007). Safe (2004) reports that Generation-IV reactors, which will be in service by 2030, will provide dramatic improvements in reactor design. Generation-III+ reactors are already markedly improved over the Generation-I. These assure that radioactivity leakage is minimized below harmful levels.

6.5 *Pilferage of nuclear material*

There has been general concern that a multitude of nuclear power plants in the world will make them more susceptible to pilferage of nuclear material for terrorist operations. There are many cost-effective practicable steps that can be taken to prevent this, as well as circumstances that already prevent it:

1. Place all new nuclear power plants under International Atomic Energy Agency (IAEA) safeguards
2. Increase security, much of which is already enhanced at nuclear plants around the world,
3. Weapons-grade plutonium and uranium require purification up to 80 percent levels, which nuclear plants don't do.
4. Generation-IV reactors are more resistant to attempts to divert material for illegal weapons manufacturing (Safe 2004).

Moreover, existing pilferage around the world is unknown in IAEA supervised reactors. What happens in Russia, China, and Pakistan by way of missing uranium fuel can continue to happen with or without increased nuclear energy.

6.6 *Safety from terrorism*

Shopping malls, football games, and conventional industrial facilities have traditionally lesser security than nuclear power plants. Thus, nuclear plants are inherently safe. With regard to aerial or missile attacks, the following studies were done:

1. A Boeing 767 hitting at 560 kph would cause no penetration of the containment.
2. Sandia labs demonstrated that an F4 Phantom jet hitting a 3.7-m concrete slab at 765 kph would destroy the plane. The concrete penetration would only be 6 cm (Safety 2007).

Because containment structures are huge, an attack inside a plant that causes loss of cooling, core melting, and breach of containment, would not result in significant radioactive releases (Safety 2007). The death and destruction from terrorist attacks at other installations can have worse outcomes.

6.7 *Safety comparison with coal*

How safe is nuclear energy compared to its rivals coal and others? For the period 1970–1992, immediate fatalities were as follows: coal, 6400; natural gas, 1200; hydroelectricity, 4000; nuclear, 31 (all in Chernobyl). This data is self-explanatory, in that fatalities from other energy sources are much more inspite of the hype of nuclear catastrophe.

Moreover, because all deep-earth minerals contain radioisotopes, they generate radioactivity when burning (McBride et al. 1978). Aubrecht (2003) reported that coal has uranium and thorium radioisotopes ranging representatively from 1 ppm to 2 ppm. Their conclusion was "that Americans living near coal-fired power plants are exposed to higher radiation doses, particularly bone doses, than those living near nuclear power plants that meet government regulations." Francis (2001) discovered that "a coal plant releases about 74 pounds of uranium-235 each year, enough for two or more nuclear bombs."

6.8 *Costs of nuclear power*

Studies have shown that nuclear energy is cheaper than energy from coal or gas, while other studies find nuclear energy comparable or slightly more expensive than coal ("The Economics of Nuclear Power" 2007). Overall, nuclear power is competitive with coal from a cost perspective. A report from the Organization for Economic Cooperation and Development (OECD 2005) found that nuclear power was cheaper than fossil fuels among 80 percent of the countries in a represesntative sample (Nuclear Energy Agency 2005). Data was projected to the year 2010.

However, the World Nuclear Association (Ritch 2006) claims that the OECD (2005) report underestimates the nuclear advantage and so claims that the generating costs for the year 2010, projected at a 5 percent discount rate, are 2.1 to 3.1 cents/kWh for nuclear energy; 2.5 to 5.0 cents/kWh for coal; and 3.7 to 6.0 cents/kWh for natural gas. Additionally, nuclear energy production costs in the United States have dropped from a total of 2.47 cents/kWh in 1981 to 1.72 cents/kWh in 2003. Uranium prices have risen dramatically, but coal prices rose by 42 percent between 2000 and 2006 (U.S. Price 2008). Further, operating costs of nuclear plants in the United States dropped by 44 percent between 1990 and 2003 (Ritch 2006).

6.9 *Construction costs of nuclear plants*

In OECD (2005), nuclear power construction costs are believed to be in the order of $2.3 billion for a 1.2-GW nuclear plant. Add to this the economies of scale that can bring about savings of 15 to 20 percent. Holt and Behrens (2003) report that costs range anywhere on average from $3 to 6 billion. It is not clear what size the plants are in these two latter reports. Many nuclear plants are constructed with two and three reactors together; the CANDU reactor in Pickering, Canada, had eight reactors. In this regard, the final cost data of OECD as verified in Robinson et al. (2007) is taken as representative: the current estimated cost of a 1.2-GW plant is $2.6 billion.

Thus, estimates of electricity use to 2050 in the USA indicate that if new clean energy plants must be constructed and the old, dirty coal plants be replaced, the total cost for nearly 1,000 additional gigawatts will be $2.95 trillion. Spread over 41 years—a rough economic estimate—brings the total annual investment to $72 billion, which is easily financed in the current economic environment of the United States.

How much do coal-fired plants cost to construct? More than 130 new coal-fired plants have been proposed over the next ten to twenty years. However, Odell (2008) reports, "The costs of constructing and operating these plants are highly uncertain due to multiple factors in the industry, and the owners will face significant financial, economic, and environmental risks." Given that coal plants might simply be shut down due to air pollution concerns, implies that investors will be unable to recover their invested sums. This is making bankers and lenders balk. Nevertheless, coal plants are typically cheaper than nuclear plants. A 1-GW coal plant can be expected to cost between $1.3 to 2.77 billion depending on whether it is a traditional plant, an integrated gasification combined cycle plant, or a fluidized bed plant (What is a coal fired plant 2008; Energy Information Administration 2008; Wald 2007). So, coal plants could be half as expensive to construct, or else nearly as expensive as nuclear plants, but definitely more expensive to operate.

7 PUBLIC OPINION ON NUCLEAR POWER

In the eyes of the public and numerous bureaucrats and legislators, nuclear power is still a dirty word. The damage to the good effects of nuclear power was considerable after the Three Mile Island episode. In many parts of the United States, however, public opinion is now becoming favorable toward nuclear power. In a survey, Bisconti (2007) discovered that

"Using a mix of low-carbon sources, including nuclear energy and renewables, makes sense to the public for producing the electricity we need while limiting greenhouse gases. There is near consensus (85 percent) on this concept, and this consensus encompasses the range of demographic groups."

Moreover, it was seen that fifty-six percent of the public would "definitely build more nuclear power plants in the future," while "72 percent agree that we should keep the option to build more nuclear power plants in the future." Overall, about 63 percent favor nuclear energy, while 31 percent oppose it. It can thus be interpreted that there is a more than good chance that increased nuclear energy will come to be a reality in the United States in the next few years.

8 SUMMARY AND CONCLUSIONS

Coal and oil still contribute up to 50 percent of the world's electricity, but we don't have time on our side to continue using them. Oil will be depleted in about three decades, while the accompanying gasses and particulate matter that are emitted by burning coal and fossils fuels are major air pollutants that have serious health risks for world citizens and animal life. In addition, CO_2 causes surface ozone to form, which is a lung irritant. It is appropriate to ask what type of air we are bequeathing to future generations. From an engineering and medical perspective, we have to reverse direction now.

Nuclear energy is a clean available alternative to the hazards of burning coal, biomass, and fossil fuels for electricity. I argue that neither radioactive waste, nor the safety of nuclear plants, nor the threats of terrorism are significant concerns in relation to nuclear energy. In addition, all spent fuel can be recycled with modern nuclear technology. Moreover, nuclear plants emit less radioactivity than coal plants, since all deep-earth materials, such as coal, have some uranium and thorium. More ominously, uranium-235 can be extracted from coal emissions. Sooner or later, every country in the world, rogue or not, will be able to do so.

While the capital costs for coal plants to install 1 to 1.2 GW of electricity range from half the cost of nuclear plants to equal the cost, the increasing health hazards of coal plants are beginning to make coal plants a risky venture that is turning away financiers. Operation costs of coal plants are significantly higher than nuclear plants, not to mention the enormous logistics of transporting huge quantities of coal from mines and coal extraction factories to coal power plants, given that one ton of uranium produces as much energy as 20,000 tons of coal.

Public opinion of nuclear energy is now favorable by a 2:1 ratio, making it likely that the future of electricity in the USA and the world is likely to be nuclear energy in the years to come.

It takes four years to construct a 1-GW nuclear plant, and ten years to develop uranium mines. Thus, if we are serious about maintaining our quality of life, and breathing clean air, we must make a conscious policy agreement now to switch to nuclear energy. The world has no other sensible alternative at the current moment. The future of electricity generation is staring us in the face and the technology is sitting there for us to adopt, unless we wish to revert to the middle ages.

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