Summary

The project that is being proposed is a small-modular reactor (SMR) that will be constructed to supply energy to poverty-stricken countries that need power. Not only will it provide energy, it will help reduce the emission of carbon and greenhouse gases. The engineer who is proposing this project is Gregory Kim who is a student at CUNY City College in New York City. He does not have any years of engineering experience. He hopes to graduate in 2020 with a bachelor's degree in mechanical engineering. The proposed budget for this project is $20 billion dollars.

Title page

(CUNY)

Introduction

These are the articles that will be referenced in this final proposal. One article is "Power outages, extreme events and health" written by Klinger, C., Landeg, O., & Murray, V. It was published by the *National Center for Biotechnology Information* in 2014. The second article is "Economic viability of light water small modular nuclear reactors" written by Black, G. A., Aydogan, F., & Koerner, C. L. It was published by *Renewable & Sustainable Energy Reviews* in 2019. The third article is "Energy consumption levels and technical approaches for supporting development of alternative energy technologies for rural sectors of developing countries." written by Muhumuza, R., Zacharopoulos, A., Mondol, J. D., Smyth, M., & Pugsley, A. It was published by *Renewable & Sustainable Energy Reviews* in 2018. The fourth article is "Productive use of energy – Pathway to development? Reviewing the outcomes and impacts of small-scale energy projects in the global south." written by Terrapon-Pfaff, J., Gröne, M.-C., Dienst, C., & Ortiz, W. It was published by *Renewable & Sustainable Energy Reviews* in 2018.

In *Productive use of energy*, it states that it is widely accepted that access to sustainable and affordable energy is important in reducing poverty (Terrapon-Pfaff et al., 2018, p. 198). According to

Energy consumption levels, there are about 1.1 billion people in the world who do not have access to electricity (Muhumuza et al., 2018, p. 90). About 2.6 billion people use biomass, which brings about air pollution (Muhumuza et al., 2018, p. 90). The *Productive use of energy* article looks on how various renewable energy technologies were used in 20 different developing countries. These technologies include solar, wind, hydro, and biomass power to meet needs such as food preparation, lighting, electricity, and irrigation. In terms of energy usage, solar power represented the largest at 45%. The second largest is technology that uses biomass, such as biogas, biomass combustion, or gasification at 32%. Hydropower accounted for 13%. The article claims "that access to clean, affordable, and reliable energy services provided by renewable energy technologies will contribute to social and economic development. This development may take the form of employment, income and/or the strengthening of the local economy, as well as improving welfare – for example, by reducing hardship and increasing time availability" (Terrapon-Pfaff et al., 2018, p. 202). Thus, energy production is vital to a nation's economy such that it will reduce poverty. It is important that investments in energy continue.

One energy source that is not mentioned in *Productive use of energy* article is nuclear energy. Due to the demand for energy consumption along with the need to reduce carbon and greenhouse gas emissions, investments in new carbon-free energy technology has become very important in today's age (Black et al., 2018, p. 248). The small modular reactor (SMR) is an attractive technology, because of its small size, modular design, and better safety compared to existing nuclear technology. As the demand for energy increases and climate change becomes worse, the need for developing non-fossil energy has become imperative. The use of SMR can be used anywhere, especially for developing nations, "many of which are experiencing what the United Nations has termed 'energy poverty' – the inability to obtain cost-effective energy production. SMR has the potential to help both emerging and industrialized economies to continue economic development while reducing the impact on global climate change" (Black et al., 2018, p. 248). Thus, SMRs are a viable solution based on its safety, relative low cost, and

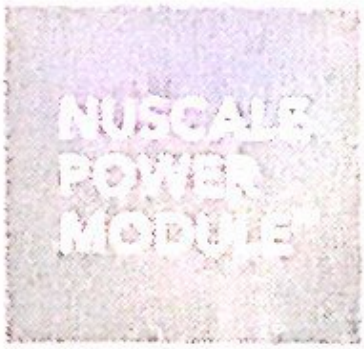
pollution-free technology (Black et al., 2018, p. 249). It will also solve the problem of energy poverty that these developing countries are ~~having~~ experiencing.

Black et al. notes that nuclear power has a history with problems of negative public perceptions of safety, financial losses, and project cancellations (Black et al., 2018, p. 249). Black et al. reference S Tsoulfanidis who explains that "small modular nuclear reactors provide an alternative to large reactors and provide many of the benefits of clean energy production without many of the construction, planning, and safety concerns of their large nuclear counterparts" (Black et al., 2018, p. 249). In *Economic viability of light water*, it is clearly stated that the small modular reactor is a better choice than regular nuclear power, because of its safety as well as less construction overhead cost to build the plant. That is why it should be considered to help developing countries that have energy poverty.

Make sure to clarify that it was for clean energy, not nuclear

The background of the problem is that Professor of the English Department at CUNY City College provided an article to the class that showed the new technologies that were currently available. After doing some research, I thought the technology of the small modular reactor developed by NuScale had the most practicality in terms of reducing greenhouse gases as well as providing energy to many who need it. The Professor also mentioned that hospitals in general have a need for energy, in which patients' lives depended on it. But after doing some research, I found that the idea was not practical. In my research, I found that many developing countries needed an infrastructure for energy production that could meet their demands. Thus, I have decided that my final proposal should focus on explaining why these countries should invest in nuclear energy particularly the small modular reactor technology.

What I hope to accomplish in this final proposal is to inform my audience that a small modular reactor is a viable option in providing energy to countries that need it based on its safety, relative low cost, and pollution-free technology. However, since the technology is relatively new, it is expected that it will take some time for the idea to be implemented. Not only that, it is still expensive to build and run



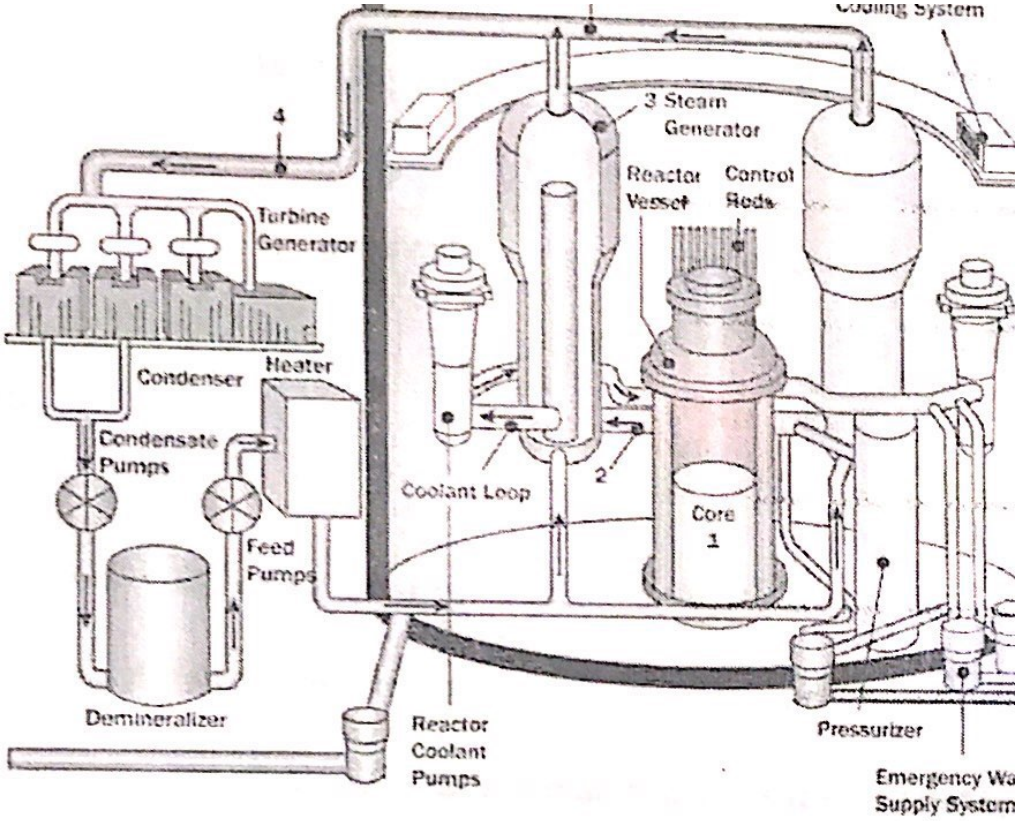


Figure 2: Typical Water Pressurized Reactor

http://encyclopedia.che.engin.umich.edu/Pages/Reactors/NuclearReactors/N

Thermal Capacity	200MWt
Electrical Capacity	60MWe
Capacity factor	>95%
Weight	700 tons

Table 1: Specification of a NuScale Power Module

Innovation Process

Even though I was able to find literature sources on the cost of building and running a small modular reactor, I could not find adequate material on the labor, time, and material that are required to build the reactor. Therefore, the final proposal will mainly discuss the costs of building a SMR. The economic viability of the SMR will be assessed by comparing its cost to existing energy production plants such as nuclear power. The detailed cost estimates for a PWR-12 NPP, provided by the Oak Ridge National Laboratory, will be used to estimate both direct and indirect capital costs (Black et al., 2018, p. 252). Later, the cost-estimation methodology used will be adapted to the design of the NuScale SMR, which is the only SMR currently being designed in the United States. NuScale was chosen because its SMR design is most likely to be deployed within the next several years (Black et al., 2018, p. 257). It is the only commercial SMR design whose certification application is being reviewed by the Nuclear Regulatory Commission (Black et al., 2018, p. 257).

General Cost Estimation

To use a baseline as a comparison, the PWR-12 design of 3400 MWt nuclear plant is used. Black et al. uses a detailed PWR-12 cost estimate provided by the Oak Ridge National Laboratory's report on

Advanced High Temperature Reactor Systems and Economic Analysis (Black et al., 2018, p. 252). The PWR-12 by Westinghouse, made around the 1970s, is a "four-loop pressurized-water reactor (PWR) with a core thermal power of 3417 MW, nuclear steam supply power of 3417 MW and net electrical power of 1147 MW. Light water is used for both cooling and as a moderator. Pressurizer, steam generator, coolant circulation pump, pressurized reactor vessel and control rods installed at the top of the reactor vessel are some of the components in the containment" (Black et al., 2018, p. 252). Figure 2 shows the containment vessel of the PWR-12. In addition, the reactor is powered by 193 fuel assemblies including UO_2 nuclear fuel. The reactor is designed for a 30-year life (Black et al., 2018, p. 252). Table 2 shows the cost analysis of the PWR-12 and the NuScale Power Module. The data for the PWR-12 was then adjusted for the manufacture and construction of a typical SMR design (Black et al., 2018, p. 257). From the results, it is clear that NuScale SMR is less expensive than PWR-12 NPP in terms of cost and investment.

Base Construction Cost	$2,469,326,752	$6,408,426,240	$3,939,099,488

Table 2: Cost Comparison for NuScale SMR and PWR-12

Economic viability of light water small modular nuclear reactors

As shown in Table 2, the NuScale model is much less expensive than the PWR-12 design in total base construction costs as well as both capitalized direct and indirect costs (Black et al., 2018, p. 256). Total base construction is $3.94 billion less than PWR-12. Capitalized direct cost is $1.23 billion less. Capitalized indirect cost is $2.7 billion less (Black et al., 2018, p. 256). The net power output for NuScale is 685 MWe while the PWR net output is 1147 MWe (Black et al., 2018, p. 257). So, the power output is about half less, but the savings is much more.

The plant will use boron reactor to cool the sheet and provide adequate cooling.

Conclusion

In conclusion, the small modular reactor (SMR) is a viable technology that will provide energy to developing nations that need it. Because of its small size and modularity, it can be easily maintained and built. Not only supplying a lot of energy, the small modular reactor also reduces carbon and greenhouse gas emissions such that it will help reduce climate change. It is friendly to the environment as well as providing the necessary energy to the people that need it. Even though it is expensive to build, its cost is significantly less than the current nuclear plants that are out there. In addition, SMR is much safer, because it has less of a chance in having an accident by reducing unnecessary pipes and pumps. It relies on gravity, convention, and conduction in its mechanism to sufficiently cool the device.