ARC Nuclear Canada Inc.: ARC-100 Clean Integrated Energy System

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1.1 Introduction

With worldwide demand for electrical power expected to double over the next 25 years, the world faces a daunting challenge of providing reliable electricity to an expanding population without exacerbating climate change [7][8]. Many countries aim to have a primary energy supply with net-zero emissions by 2050, and in order to meet these clean energy goals, a holistic approach will be required that leverages all the clean energy sources available [9].

To secure a clean energy future, new methods of energy generation and distribution will need to be not only affordable, but also flexible and resilient to accommodate the increasing contribution from variable renewables. ARC Nuclear Canada Inc. (ARC Canada) is developing a revolutionary technology to provide resilient, clean, and sustainable energy supply. The flexibility of the *ARC-100* design reaches beyond delivering continuous and affordable baseload power; it also offers the ability to load follow and produce high grade heat for various applications, all while dealing with current and future nuclear waste.

This report will describe the flexibility of the *ARC-100* design and the various non-electrical energy applications available.

1.2 Nuclear Flexibility

With the growing threat of global warming leading to sea level rise, the melting of the polar ice caps and increases in extreme weather events, the value of resilient power plants and electric grids is becoming increasingly important in mitigating disruptions to critical systems.

The *ARC-100* offers affordability, cost competitiveness, versatility, and has the ability to produce electricity or industrial heat at competitive prices. Additionally, because of its size, dispatch flexibility, inherent safety features, and ability to address waste concerns, the *ARC-100* can be used for non-traditional applications, such as water desalination, shale oil extraction and hydrogen production. The nuclear flexibility of the *ARC-100* design is illustrated in *Figure 1* and will be discussed in further detail in the sections below.

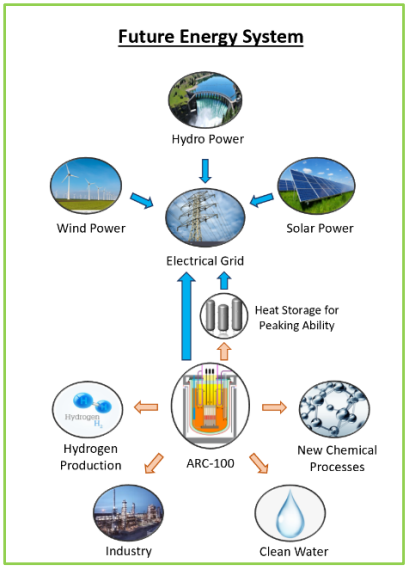

Figure 1: The ARC-100 technology contributing to a clean, holistic energy system while also supporting non-traditional applications.

1.2.1 Reliable Electric Generation

In Canada, we enjoy the benefits of a highly reliable electrical power system. This is in part the result of nuclear energy which plays an important part of Canada's current clean energy mix and will continue to play a key role in achieving Canada's low-carbon future.

The *ARC-100* will generate 286 MW_t to yield 100 MW_e for the electrical grid over a period of 60 years. This is comparable to powering a small city. The ability of the *ARC-100* to operate at maximum output allows the reactor to be utilized for baseload applications, providing a continuous source of clean and reliable electricity to the grid. A unique and attractive characteristic of the *ARC-100* design is its ability to operate for a 20-year interval before refueling is required, resulting in less maintenance and shutdowns.

The ability of the *ARC-100* to operate at maximum output for a 20-year interval is an important aspect of the *ARC-100* design because power grids must have sufficient capacity available to meet the electricity requirements during peak demand. The variability in these peak demand times can be challenging to predict and therefore there are often uncertainties in forecasting these demands. As such, a general rule is that the total amount of capacity of the power grid is required to exceed the expected level of demand [1]. The *ARC-100* can be used to provide the capacity needed to meet these peak demand times and excess reservoir.

In addition to being cost competitive, reliable, and able to be integrated into remote communities, the *ARC-100* is also able to pair with emerging renewable technologies, offer more flexibility, and deal with current and future nuclear waste. The ability of the *ARC-100* to effectively address waste management by generating significantly less volume than the current technologies (8 to 10 times less volume for the same energy produced) and by reconstituting used fuel (over 100 times less volume for the same energy produced and significant reduction in radiotoxicity) differentiates the *ARC-100* design.

1.2.2 Renewable Integration

One of the many benefits of the *ARC-100* technology is that is can support increased integration of variable renewables to assist with meeting peak demand and ensuring a reliable grid. Peak demand changes throughout the day and from season to season. As such, there is a premium placed on resources that have the ability to remain flexible and change their power output to accommodate for changes in demand as well as account for the changes from variable renewables. The *ARC-100* is poised to address this need.

For instance, *Figure 2* illustrates the monthly variability of wind in the province of New Brunswick over a three-year period. As illustrated, not only does the average capacity of wind vary from month to month, and the fluctuation in monthly wind capacity varies, but also on average wind is only available approximately 30 percent of the time and thus additional support is needed 70 percent of the time. The *ARC-100* can adequately compensate for wind output variations using a combination of power maneuvering and turbine bypass, or turbine bypass alone for electrical grids with an increasingly high penetration of wind. In these scenarios, the addition of an efficient load-following *ARC-100* will help minimize the need for fossil-based peaking power while allowing greater penetration of renewable sources and ensuring grid reliability.

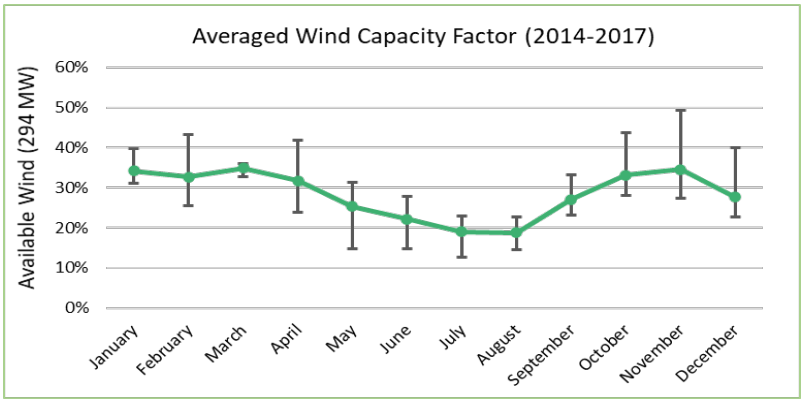

Figure 2: New Brunswick's average wind capacity between 2014-2017; data obtained from Statistics Canada.

Variable renewable energy (VRE) sources are limited in their ability to provide power on demand, as they provide power in accordance with nature. The overall Effective Load Carrying Capability (ELCC) of the technologies drops with greater installed capacity as the grid loses the ability to adapt to the needs of customers [6]. To reflect the demands that are placed on the power grid, *Figure 3* illustrates ELCC curves that were modeled to show the net impact that increased VRE sources have on the grid's ability to reliably meet the needs of customers for each technology [6]. As illustrated in *Figure 3*, the grids reliability decreased as contributions from VRE sources are increased, therefore, it is imperative that VRE sources are compensated by clean load-following technologies such as the *ARC-100,* which has the additional benefit of dealing with waste.

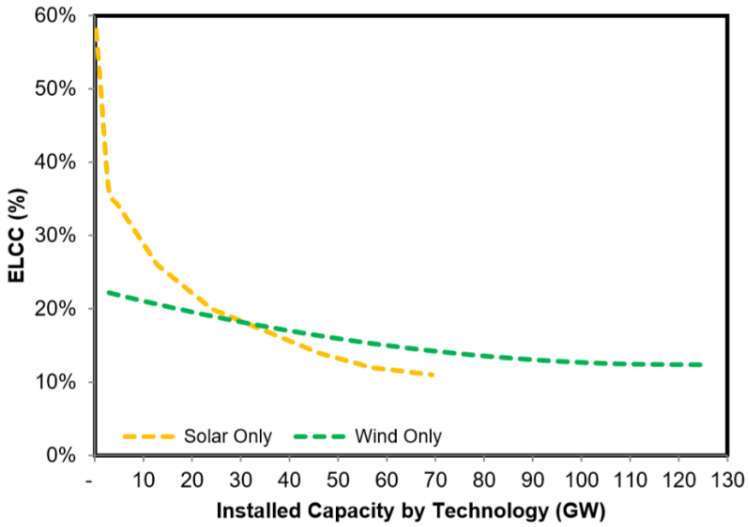

Figure 3: Effective Load Carrying Capacity (ELCC) curves illustrating decreased ELCC as installed capacity is increased over time [6].

1.2.3 Process Heat Applications

Nuclear energy is an excellent source of process heat for various industrial applications, and for the majority of these applications, nuclear energy may be the only credible emission-free option.

The *ARC-100* technology utilizes liquid sodium instead of water as the heat transfer agent, providing a number of advantages. One of these advantages is that liquid sodium is an excellent heat-transfer fluid and as a result the *ARC-100* supplied heat can be efficiently utilized in various industrial applications. The *ARC-100* generates clean high-quality heat at roughly 510°C that can be used for a widespread of energy intensive industrial applications such as hydrogen production, water desalination, oil recovery and oil refining.

1.2.3.1 Hydrogen Production

Hydrogen production has been a hot topic in recent years as it has the potential to be the fuel of the future. There are various methods to produce and extract hydrogen, however, very high temperatures are required for many leading methods being proposed for clean hydrogen production [2]. The *ARC-100* is ideally suited for providing this high temperature heat required.

There are various hydrogen production technologies for which the *ARC-100* can assist. For instance, electrolysis, which is the process of splitting water using electricity to produce hydrogen, is an option of hydrogen production that is well understood, commercially available, produces high purity hydrogen, and has the potential to be a carbon-free energy solution [3]. The *ARC-100* can assist with electrolysis as the *ARC-100* technology is a fast neutron reactor that provides high efficiency and high temperature heat. Further, the *ARC-100* is an emission-free energy source, as such, when utilized during electrolysis, it enables a carbon-free process.

Steam reforming, which is the process of splitting hydrocarbons with heat and steam, is a well understood process that is currently available and highly economic [3]. However, there are various barriers associated with the process, one of which is the CO_2 emissions produced. Traditional

methods used to produce the heat required during steam reforming can be carbon intensive. As an alternative, the *ARC-100* can produce the heat required via an emission-free energy source, thus mitigating the carbon output from the overall steam reforming process.

1.2.3.2 Water Desalination

Safe and readily available water is essential for public health, however, is in short supply in many parts of the world [10][11]. Whether it is used for drinking purposes, domestic uses, food production, or recreational, water is an essential resource for sustainable development and a prosperous lifestyle.

Many regions around the world rely on desalination processes to obtain clean, potable water. These processes are energy intensive and typically have been paired with carbon intensive energy sources, thus contributing to increased levels of greenhouse gases [5]. One of the many benefits of the *ARC-100* is that it can provide the power generation required for electrically driven desalination or heat required for thermally driven desalination, replacing carbon intensive energy sources, and thus reducing emissions at cost competitive rates. In addition, large scale desalination projects require an abundance of energy. Nuclear is well positioned to deliver this plentiful energy [5].

1.2.3.3 Oil recovery

The recovery of oil from the Canadian oil sands is an energy intensive endeavor that currently utilizes carbon intensive energy sources to generate the steam required to extract the desired oil from underground [4]. The *ARC-100* can assist in decreasing carbon emissions associated with the extraction of oil as the reactor can be used to produce clean steam to extract the oil from the oil sands deposits, as well as electricity for the major infrastructure involved.

1.2.3.4 Oil refining

Once the crude oil is recovered, a refining process occurs to produce synthetic crude oil by breaking down the long-chain hydrocarbons by adding hydrogen [4]. This process uses steam reforming of natural gas, however as mentioned in the sections above, nuclear technologies such as the *ARC-100* can be an emission-free alternative to refine and extract this crude oil.

1.3 Conclusion

The energy sector is undergoing a time of transition. As various countries try to move towards net-zero emissions, the demand for energy is continuously increasing. As such, there is a need for innovative technologies that can not only provide for todays energy requirements but also remain flexible to address future demands without compromising safety or the environment.

Traditionally, nuclear has been used as a reliable, 24/7, low-carbon source of baseload electricity ensuring a reliable grid. The flexibility of the *ARC-100* design goes beyond delivering baseload power as it offers exceptional load-following capabilities, high grade heat production for a number of applications, energy flexibility and versatility to complement variable renewables and support grid reliability, inherent safety, and ability to deal with current and future waste. In addition, due to the small size and modular formation of the *ARC-100* design, it can support remote locations and meet the energy needs of any area, whether rural or urban.

As we look to the future, the *ARC-100* can provide clean, affordable, flexible, reliable, and inherently safe energy. The ability of the *ARC-100* to maintain grid reliability as contributions from variable renewables resources are increased, ensures an integrated energy system for future generations.

For additional information regarding the *ARC-100* design, visit www.arcnuclear.com.

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