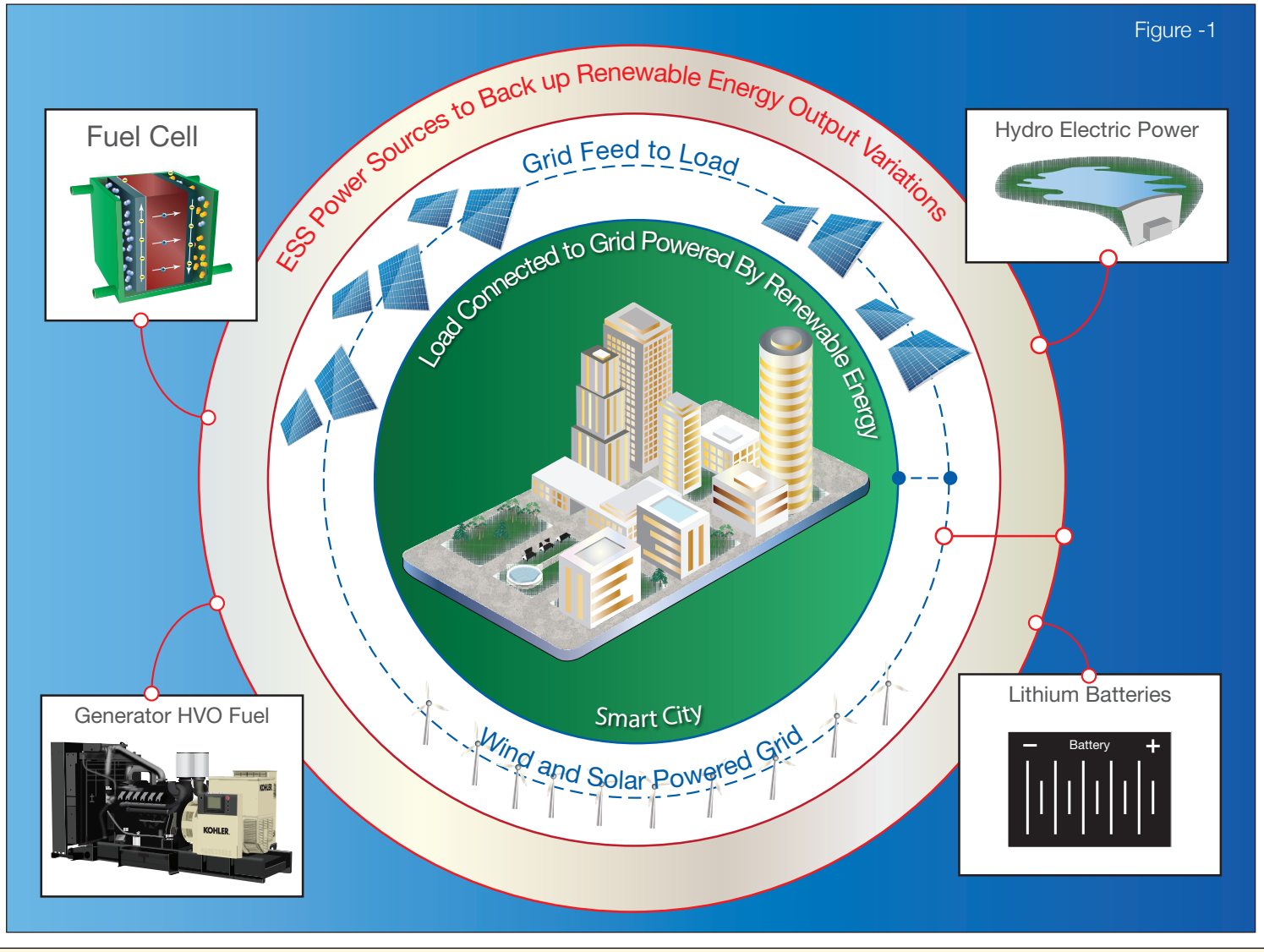
The utility grid supplies electricity from numerous energy sources. Before "Renewable Energy" became synonymous with wind and solar power, most energy sources used to fuel power stations connected to the electrical grid were not considered renewable. These included fossil fuels, both coal and gas, nuclear (steam power plants), and diesel/gas (engine-driven generator systems). Only hydroelectrical plants and their stored water height could be considered a renewable energy source. Fossil fuels and nuclear were formed in the earth eons ago. (However, ethanol from plant growth is considered renewable energy). But the predominant renewable energy sources we think of today are wind and solar. The problem is the wind doesn't always blow, and the sun doesn't always shine. This truism drives demand for grid-connected energy storage beyond a larger pile of coal and larger fuel tanks. This information sheet discusses types of Energy Storage Systems (ESS) being considered to power the grid as wind turbines and solar array power generation systems become a higher percentage of the grid's electrical input. Our concept of stored energy will change as we adopt "Renewable Energy."

1.0 CURRENT ENERGY STORAGE SYSTEMS (ESS) USED TO BACKUP THE GRID:

Utility Grid customers, whether it is the Macrogrid or individual Microgrids, will have varying time tolerances when the grid fails. A data center, operating room, or air traffic control system will have zero tolerance. As society becomes more dependent on connected devices powered by electricity, general tolerance for the duration of power outages will decline.

Sample Energy Storage System (ESS) For Grid Powered by Renewable Energy Sources



1.0 CURRENT ENERGY STORAGE SYSTEMS (ESS) USED TO BACKUP THE GRID: *(Continued from page 1.)*

The solution to outages is ESS providing electrical power when the grid goes offline. Current ESS technology used includes:

- Standby Generator Sets - In this example, the stored energy is chemical energy stored in the form of diesel/gasoline in a fuel tank, or gas under pressure in a propane or CNG tank. The tank size is calculated by considering on-site storage capability, time to source additional fuel, critical loads, and the average time the grid goes off line. Generator systems are used when power interruptions can be measured from several minutes to several days.
- UPS Systems - Uninterrupted Power Systems (UPS) ensure zero interruption in power when the grid goes offline. A typical UPS system uses ESS to supply power when it takes a secondary ESS, such as a diesel generator set, to come online *(See information sheet on UPS).* UPS systems may only supply power for a few seconds.

  UPS can supply electricity using a variety of energy storage systems, including:

  1. Mechanical - The kinetic energy stored in a flywheel will continue to turn a generator to generate electricity.
  2. Chemical - A charged battery through an inverter will provide AC power.
  3. Electrical - A charged capacitor will provide electrical power.
- Batteries - A battery is a chemical ESS—electrons in a chemical-based electrolyte flow between an anode and cathode. As battery technology has developed and economics of scale have reduced prices, battery ESS has evolved from the UPS role to the primary source of standby power for the utility.
- Fuel Cells - Hydrogen-powered fuel cells are an alternative to batteries. The energy is hydrogen stored in tanks that can generate electricity via a chemical reaction in the fuel cell. *(See information sheet on Fuel Cells)*

2.0 LONG DURATION ENERGY VERSUS SHORT DURATION ENERGY:

When considering an ESS solution to back up the primary power feed, the technology to be applied depends on the time/duration the ESS has to supply power. The following are samples of Long or Short Duration:

2.1 SHORT DURATION ESS:

Short Duration ESS (SDES) are used to supply power from a few seconds to, at the most, a couple of hours. A UPS system that is used to provide power while another source comes online is classified as an SDES.

2.2 LONG DURATION ESS:

Long Duration ESS (LDES) has to be able to supply power for ten or more hours to several days. Wind and solar power could not supply the utility grid as reliably as conventional fossil power systems without an effective LDES. To achieve a Net Zero World (no increase in carbon emissions), it is estimated that LDES will have to be 400 times that of current levels.

In a Net Zero World, to effectively manage the average times wind and solar could not meet demand, up to 24 GWh of LDES would have to be installed. The US Department of Energy recognizes this as a key objective to attain Net Zero.

3.0 USING STORED ENERGY TO BACK UP RENEWABLE WIND AND SOLAR POWER:

With the general acceptance that carbon dioxide (CO_2) is trapping heat energy in the earth's atmosphere to produce climate change, and a primary source of CO_2 being the burning of fossil fuels, there has been a big push to generate a higher percentage of electricity from renewable energy sources, particularly wind, and solar. As stated in the introduction, a significant drawback of renewable energy is the wind doesn't always blow, and the sun doesn't always shine.

As countries move towards electricity generated by wind and solar, fossil fuel power stations will be taken offline. It is not economical to keep these power plants in operational readiness, and even if it was, it is hard to predict exactly when the wind doesn't blow, and the sun doesn't shine, albeit never at night.

The viability of renewable energy replacing fossil-fueled power stations is highly dependent on Long Duration ESS (LDES).

The following LDES technologies are currently being used to store energy when the primary renewable wind and solar energy source is unable to meet the load demand:

3.1 BATTERIES:

Electrification of cars has meant significant development of Lithium batteries and has pushed them to the forefront of LDES. Other battery technologies are under development, both old and new; however, Lithium is currently the best option for size, storage, rate of charge, and discharge rate. (See information sheet on Lithium Batteries)

Figure 1 depicts how a lithium battery can be a stored energy source to supply uninterrupted power to both solar and wind power systems.

3.2 FUEL CELLS:

Fuel cells are a Net Zero option when the fuel used for the Fuel Cell is clean/green hydrogen. In the production of electricity, the bi-product is water. However, the requirement is green hydrogen. Most hydrogen produced today is made from fossil fuels.

To produce Green Hydrogen, the electrolysis of water must be adopted. This requires electrical energy, and the only way to retain Net Zero is to ensure electrolysis only uses renewable energy. Countries like Australia that already export large quantities of compressed gas are looking to produce large amounts of Hydrogen using solar power.

4.2 ENGINE DRIVEN GENERATOR SYSTEMS USING EFUELS:

Synthetic diesel fuel made from plant/vegetable based product (plants consume carbon while growing) is been considered as a Net Zero fuel based on carbon created on combustion is nearly equal to carbon taken out of the atmosphere on growth.

Hydro-generated Vegetable Oil (HVO) is a synthetic diesel made from wasted food products. It is more suitable for LDES because it does not degrade over time like distilled diesel. *(See information sheet on HVO)*

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