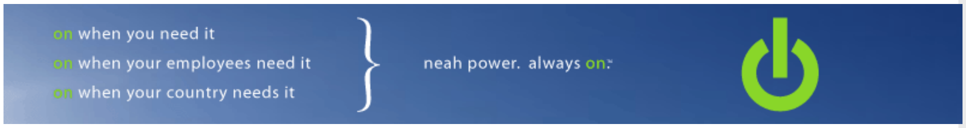
ENERGY STORAGE SOLUTIONS USING SILICON - BASED FUEL CELLS

A Neah Power Systems White Paper



Neah Power Systems
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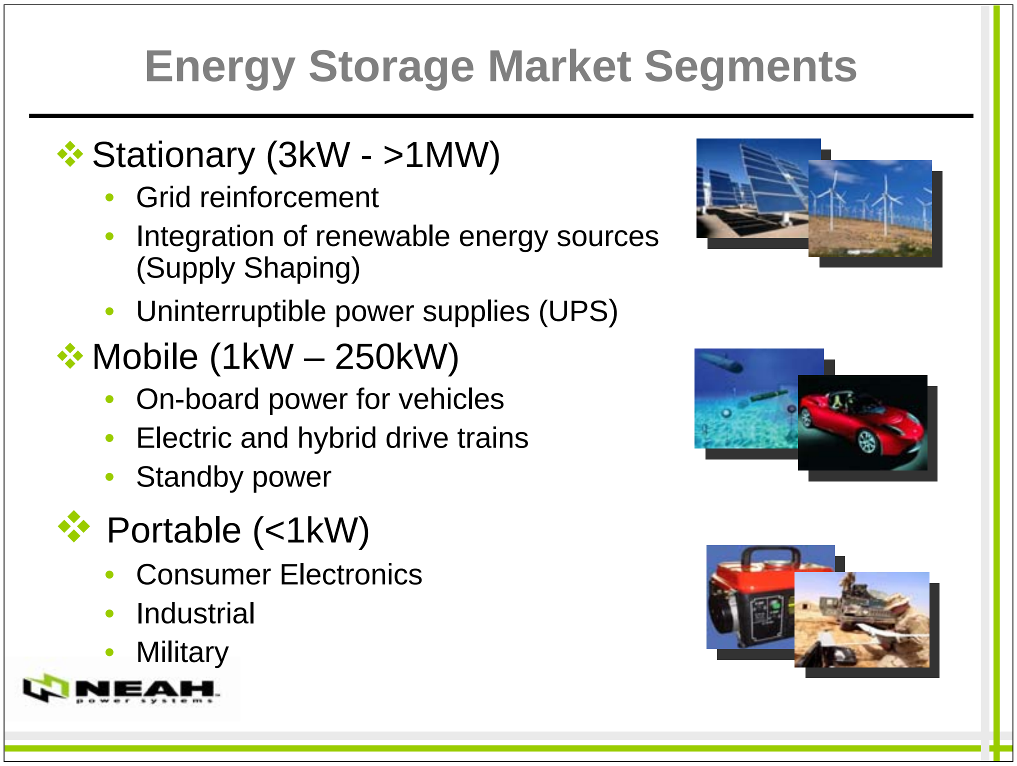
The quest for efficient energy affects every country on the planet. Worldwide there is an increasing interest in developing clean, reliable alternatives to petroleum fuels. Fuel cells are proof that there are smart, safe, and clean alternative power sources.

There is an opportunity to better utilize renewable energy sources such as solar or wind by integrating them with energy storage systems that would provide a reliable pathway towards a clean, alternative energy economy.

This article presents a position on the future of energy storage solutions and introduces Neah Power Systems, a developer of the leading technology and integration solutions critical for the future of this market.

FORWARD LOOKING STATEMENTS

Certain of the statements contained herein may be, within the meaning of the federal securities laws, "forward-looking statements," which are subject to risks and uncertainties that could cause actual results to differ materially from those described in the forward-looking statements. Such forward-looking statements involve known and unknown risks, uncertainties and other factors that may cause the actual results, performance or achievements of the company to be materially different from any future results, performance or achievements expressed or implied by such forward-looking statements. See Neah Power System's Form 10-KSB for the fiscal year ended September 30, 2008 for a discussion of such risks, uncertainties and other factors. These forward-looking statements are based on management's expectations as of the date hereof, and the company does not undertake any responsibility to update any of these statements in the future

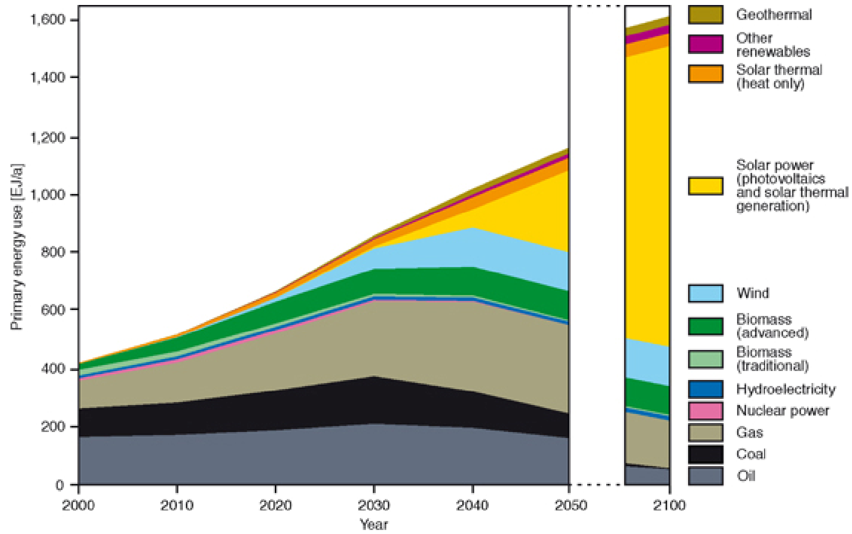


The energy storage market can be most easily divided into stationary, mobile and portable segments. The most important sector of the whole market is the stationary component, sometimes described by utility and industrial applications, including grid reinforcement, integration of renewable energy sources, and uninterruptible power supplies (UPS). Mobile component is dominated by on-board power for vehicles; and new drive trains, such as electric and hybrid. The portable sector of the market includes computing, cell phone, and camera applications.

This study looks primarily at energy storage solutions for stationary applications because the creation of the new energy economy based on reliable renewable energy sources could inevitably lead to revolutionary improvements in the transportation and portable markets as well. For example, a technology for electricity production from a renewable energy source, coupled with a method for efficient energy storage could ultimately lead to a rapid acceptance of electrical or hybrid vehicles if a cheap and reliable network of recharging stations could be established. Solar photovoltaic electricity or wind turbine electricity could be used to produce hydrogen, store it and use it at the time of demand to either refill the hydrogen storage tanks on board of vehicles or to convert it back to electricity in fuel cells and recharge the batteries in electrical or hybrid vehicles.

Similarly, the advances in the wireless energy transmission field seem to indicate that portable devices in the future could be powered predominantly through wireless recharging, eliminating thereby the need for direct or wired energy exchange. It is not hard to imagine the day when abundant, renewable and clean electricity generation stations could be distributed in both populated and remote areas; and when these stations could be transmitting electricity to charge portable devices in their vicinity. This vision of the future doesn't mean automatic elimination of the need for portable power, but indicates that a shift is likely to occur and that the enabling technologies must adapt in time.

Energy Production Mix could Change



Energy demand projections by source (World Energy Council)

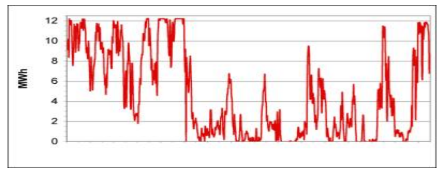
The only possible solution to meet the energy demand decades from now and to protect the environment is to use alternative energy sources derived principally from the enormous power of sun's radiation. While energy production mix forecasts vary, there is no doubt energy sources such as solar, wind, ocean, geothermal, and biomass, in addition to already established hydroelectric energy, could be the primary drivers in the new energy economy and could generate the majority of energy needs by the middle of the twenty-first century.

While hydroelectricity provides about 7% of world's total energy demand and traditional biomass still accounts for significant use in developing countries, all other renewable energy sources are underrepresented and provide less than 1% of total energy demand. One of the main reasons for this slow pace of progress is in the apparent inability of renewable energy technologies to provide steady and reliable power.

Renewable Energy – The Problem

- Renewable Energy
  - Abundant
  - Clean

- Problem: Intermittent
  - Climate
  - Time

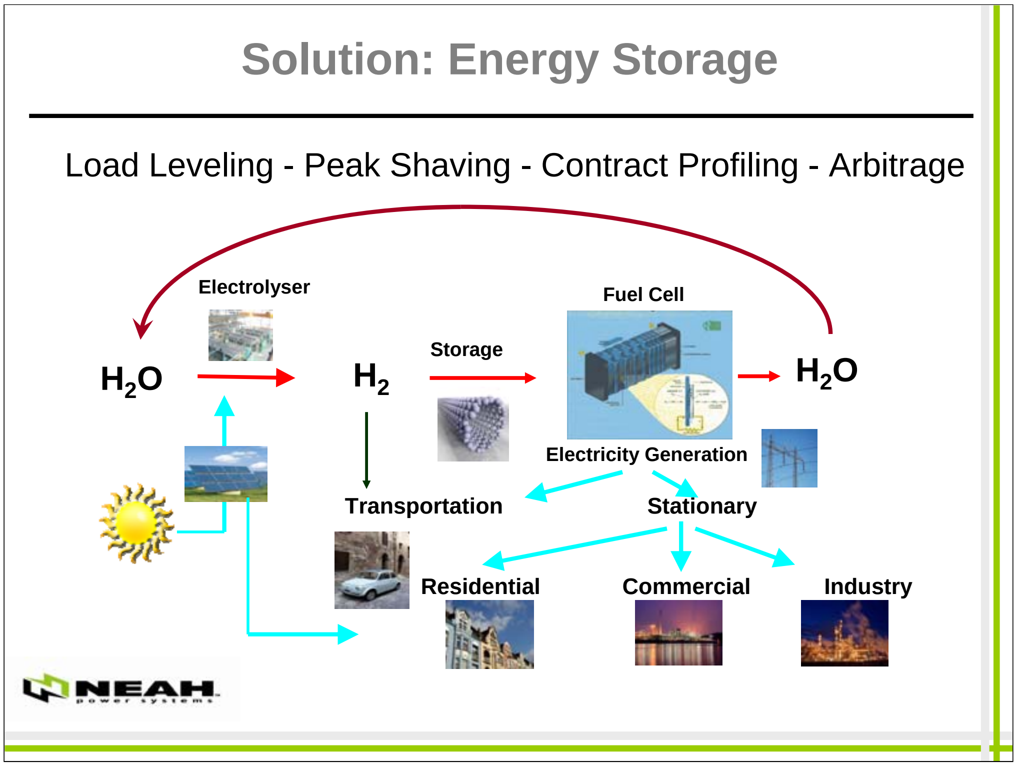


NEAH power systems

The demand for energy is not constant and it varies over the day, the week, and the year. This demand is met by the electricity supply systems structured to provide power whenever needed. Renewable energy sources must also fit into the matching supply and demand scenarios. *The problem with all renewable energy technologies is that they are time and climatic condition dependent, which makes the implementation of reliable electrical output difficult without methods to store energy during the periods of excess and then use it when needed.*

This inability to provide continuous electricity is one of the major stumbling blocks for widespread introduction of renewable energy sources. There is a fundamental question of what should be done on a day without solar or wind power; and even more important question what to do with surplus sunshine or wind.

For the wide acceptance of technologies such as solar photovoltaic, wind, biomass or small hydro, they must be integrated into hybrid systems with energy storage devices. One of the most interesting and attractive energy storage methods relies on the hydrogen economy.

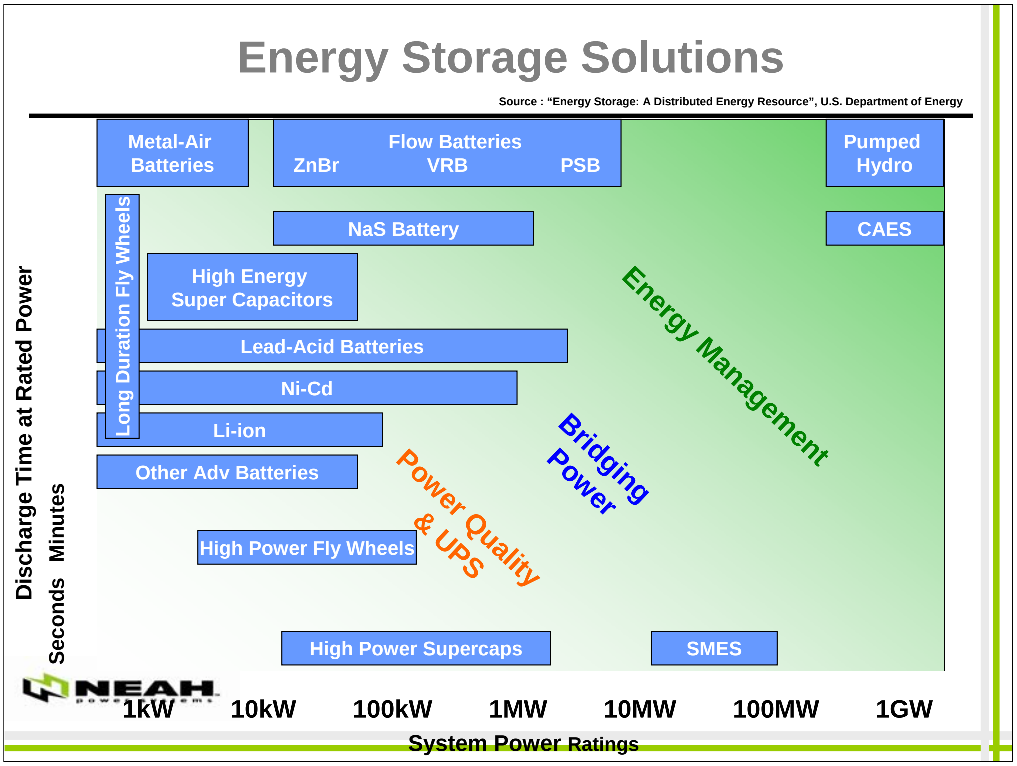


Consider a hybrid system consisting of electricity production from a renewable energy source such as solar or wind to electrolyse water to produce hydrogen integrated with a fuel cell energy storage system to store hydrogen then use it at the time of demand in fuel cells to produce electricity.

Storage offers energy services in the form of price arbitrage in energy markets, as well as capacity/power services such as peak and peak reserve capacity; frequency regulation; spinning and standby reserve; black start; load following / ramping; and T&D deferral.

Wind increases opportunities for storage in several ways. One, wind adds to price volatility which increases arbitrage opportunities; wind curtailment results in potentially lost revenue for the operator or low cost energy for storage owners. Second, wind increases ancillary service requirements.

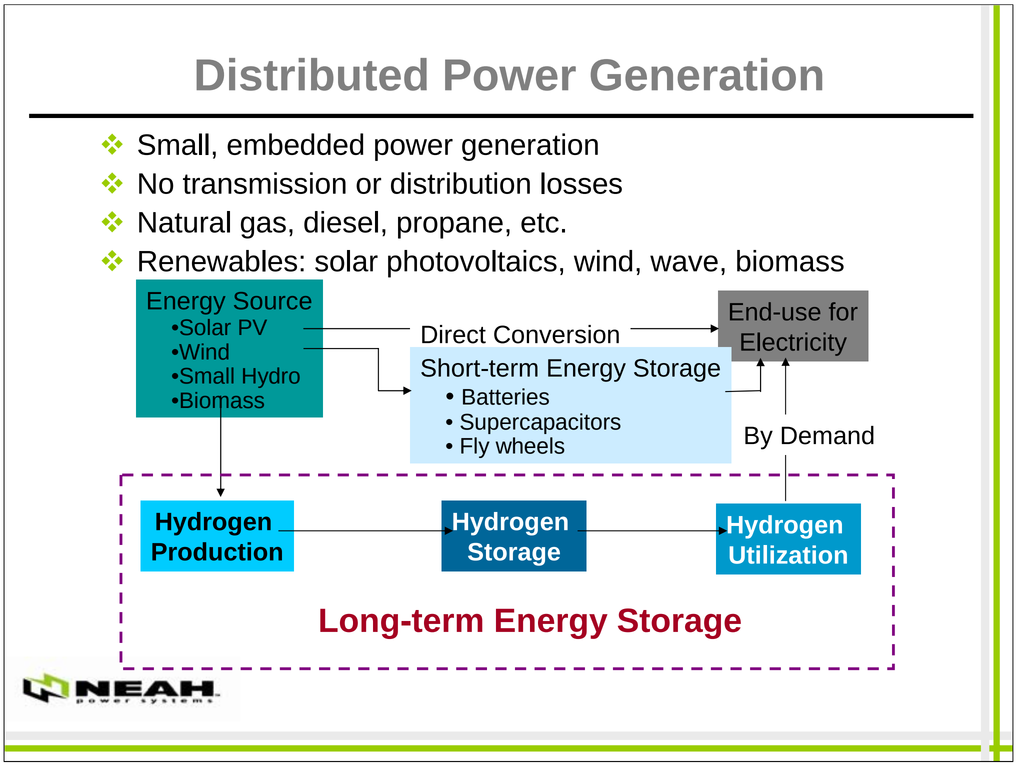
Co-located, dedicated renewable energy storage reduced transmission demands and can help overcome transmission constraints – reducing pressure on the transmission grid not only by providing an alternative to new transmission but also by allowing less transmission for a given amount of delivered energy. For example, sizing a transmission line at 90% of the line rating in conjunction with storage provides for filling up the transmission line completely during high demand and stored wind power is time-shifted for use when the generation is less.



A range of technologies is available to meet rapid and possibly unexpected demand fluctuations. Pump storage plants are used typically in conjunction with hydroelectric power plants. At the time of low demand, surplus electricity is used to pump water into high level reservoirs, which can be later used to generate electricity within seconds. Small gas turbines and diesel generators can be brought to full power in 30 minutes or less, but their main disadvantage is of course that they consume fossil fuels and are less thermally efficient than larger "base-load" power stations. Compressed air energy storage uses off –peak electricity to compress air (> 100 atm) and store it in underground caverns. At the time of demand this air is fed to a gas turbine and enables reduction in gas consumption of up to 60%.

Lead acid batteries are sometimes used by electricity utilities for peaking power and emergency backup. The largest capacity reported is 40 MWh system in California. The limitations of lead acid batteries are of course in the number of cycles that a battery can endure before degrading. A sodium-sulfur battery, which operates at high temperature (> 300°C) uses a positive electrode of molten sulfur and negative electrode of molten sodium. At the time of low electricity demand, the battery is recharged by regenerating the elemental sulfur and sodium. Several of such energy storage systems in the MW range are in use in Japan.

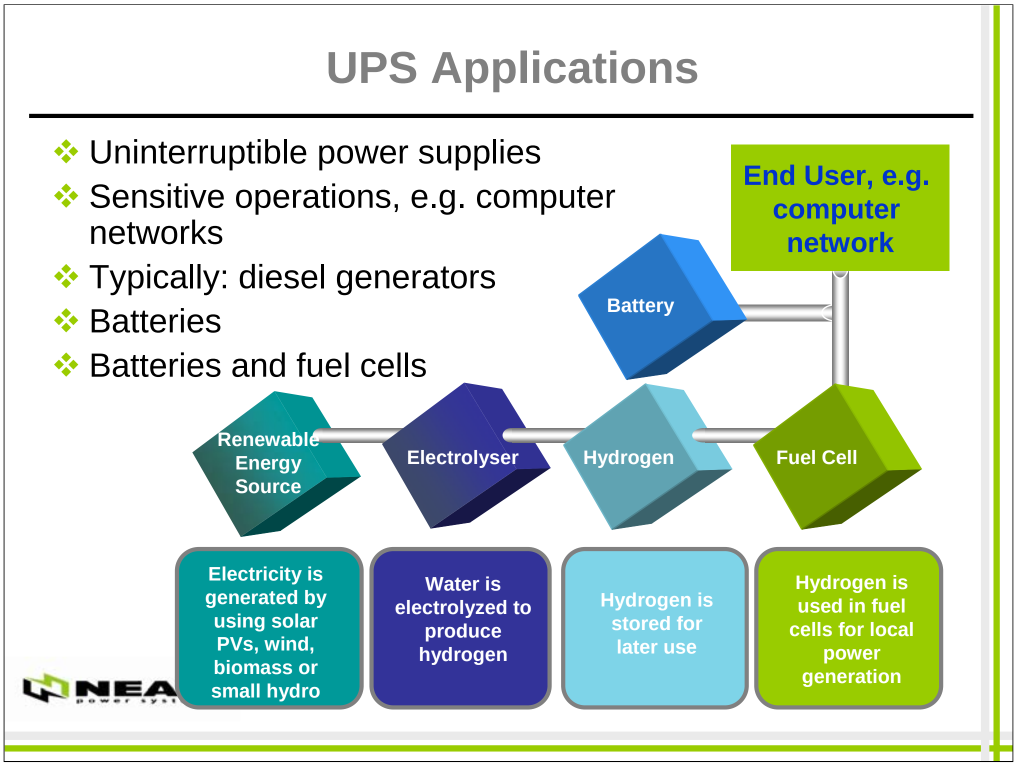
Flow batteries have also been used in UK and Japan. These batteries use active chemicals that are liquids and can be stored in tanks separately from the battery itself. Systems have been demonstrated in 15 MW range using sodium bromide and sodium polysulfide; and based on vanadium or zinc bromide.



One way to accomplish effective demand management and eliminate the need for large scale utility grids is to introduce a concept of distributed power generation based large numbers of small embedded power stations. These small, modular electricity generators are located close to customer loads and offer advantages that large-scale, capital-intensive, central-station power plants cannot provide. Distributed generation avoids transmission and distribution power losses and provides a choice of energy systems to the utility customer. Many distributed power systems produce so little noise or emissions that they can be located inside, or immediately adjacent to, the buildings where the power is needed. This greatly simplifies the problems of bringing power to expanding commercial, residential, and industrial areas.

Distributed energy systems offer the promise of reliability for consumers who need dependable, high-quality power to run sensitive digital equipment and can provide alternative, less-expensive power sources during peak price periods. The potential market for providing power during peak price periods is as high as 460 GW, according to a DOE study. Distributed power generation technologies use a variety of fuels, including natural gas, diesel, biomass-derived fuels, fuel oil, propane, hydrogen, sunlight, and wind.

Distributed power generation based on renewables is especially attractive for remote applications. “Stand alone” systems can eliminate the need to build expensive new power lines to remote locations while providing completely autonomous power generation.

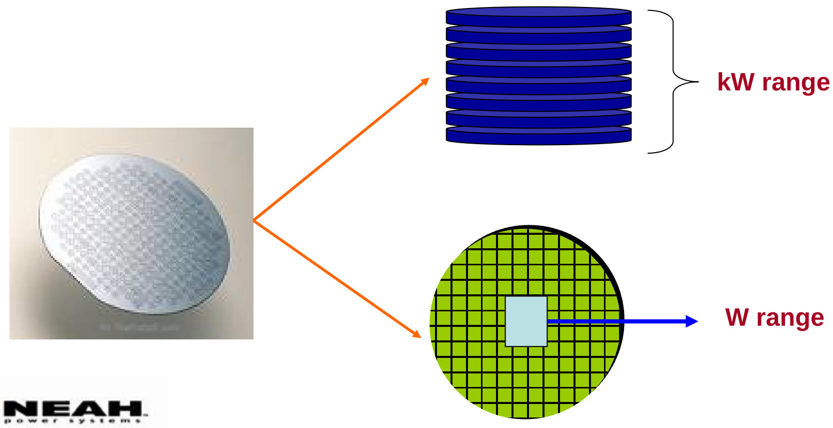


Uninterruptable Power Supplies (UPSs) are becoming essential components of the modern electricity delivery systems. Most of those systems use liquid fuel generators or batteries. Fuel cells have also been used as direct replacement for batteries for long-term backup (i.e., extended autonomy time), but batteries remain a part of the system because of their ability to deliver instantaneous full power. If the power loss occurs, the batteries carry the load until a fuel cell reaches its full operating power (typically 3-10 minutes). This means that UPS systems with fuel cells can be regarded as long-term back-up power solutions and they are usually employed only for applications where this is the requirement.

The type of fuel used in fuel cells is a critical issue for these applications. Many solutions, particularly in urban areas with availability of natural gas, use natural gas as a fuel. The alternative is to store hydrogen that is either shipped or produced on site in electrolysers.

Energy Storage on Silicon Platform

- Unique platform suitable for multi-functional devices
- Highly scalable: mW to kW range
- High-volume manufacturing processes



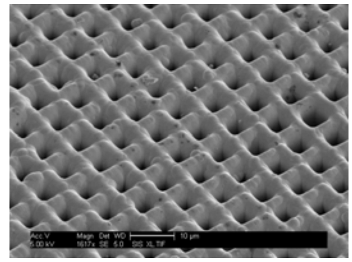
NEAH power systems

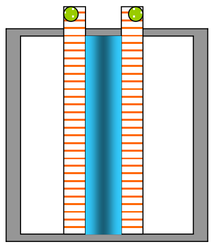
Neah Power Systems has developed a unique proprietary technology to produce highly scalable fuel cells. Besides many advantages of this technology (described bellow) the flexible configuration used by Neah Power offers unprecedented opportunities for utilization of the proprietary silicon platform in multi-functional devices and for seamless integration into larger energy storage systems.

Neah Power Systems concept is adaptable for use in a number of different schemes involving energy production and storage. Furthermore, the range of applications is enormous: from portable applications for laptop computers to larger stationary applications in the hundreds of watts and into kW range. Remarkably, Neah Power could be able to use the same manufacturing process regardless of the size of the system. This is based on the outstanding capability of producing silicon platform in high volume processes, but also because of the obvious quality of silicon to be made into very small chips.

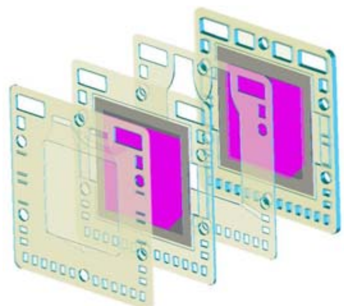
Silicon-Based Fuel Cells

- Porous silicon substrate
- Highly structured substrate
- Predictable performance
- Liquid electrolyte
- Faster electrode reaction





Basic concept of Neah Power cell



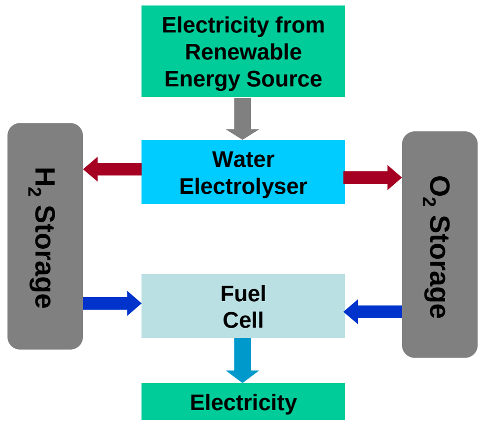
This is the only technology that relies on porous Si as electrode substrate and reactant distribution structure. The configuration enables the use of liquid electrolyte in place of solid polymer electrolyte membranes that have all but reached their usefulness.

This type of fuel cell is unique because of the characteristics of the extremely well controlled geometry of the porous Si structures. Contrary to “random” porosity distribution and size of the catalyst layer typically used in PEM membrane-electrode assemblies, the porous Si offers enormous advantages because of the extremely small deviations in the pore size and distribution. This presents a much larger opportunity to develop a perfectly engineered fuel cell system.

Porous Si offers critical opportunities that go beyond structural advantages. The fabrication process relies on extremely well defined silicon processing methods and very high-volume manufacturing. This presents a huge opportunity to not only develop a functional and efficient fuel cell, but to be able to produce them very inexpensively in high-volumes. No other fuel cell technology is even close to demonstrating the high-volume manufacturing and that is one of the main reasons fuel cells are still far from widespread commercial applications. The Neah Power Systems concept offers the promise of delivering a highly scalable and versatile fuel cell.

Neah Power Hydrogen-Oxygen Fuel Cell

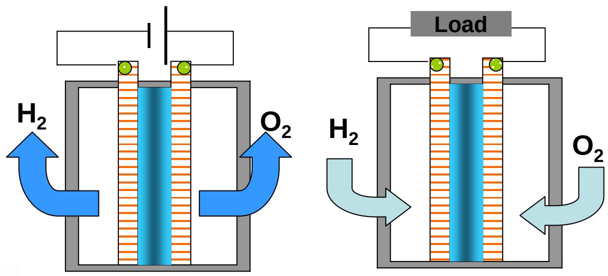
- Present system: flow-through methanol anode and nitric acid cathode.
- Development of air cathode and hydrogen-oxygen fuel cell based on porous silicon structure and liquid, acidic electrolyte.
- Gas-liquid interface inside the pores of silicon.
- Hybrid energy solutions market: a H_2-O_2 fuel cell coupled with a renewable energy sources and an electrolyser.



Present system used by Neah Power includes flow-through methanol anode and nitric acid cathode. However, the company is developing air cathode and is planning the development of hydrogen-oxygen fuel cell based on its proprietary porous silicon structure design and liquid, acidic electrolyte. The main feature of silicon electrodes modified for gaseous reactants is the creation of the gas-liquid interface inside the pores of silicon that extends throughout the pore. The company is developing this approach partially because of the intention to enter the hybrid energy solutions market where a H_2-O_2 fuel cell could be coupled with a renewable energy sources and an electrolyser.

Reversible Neah Power Cell

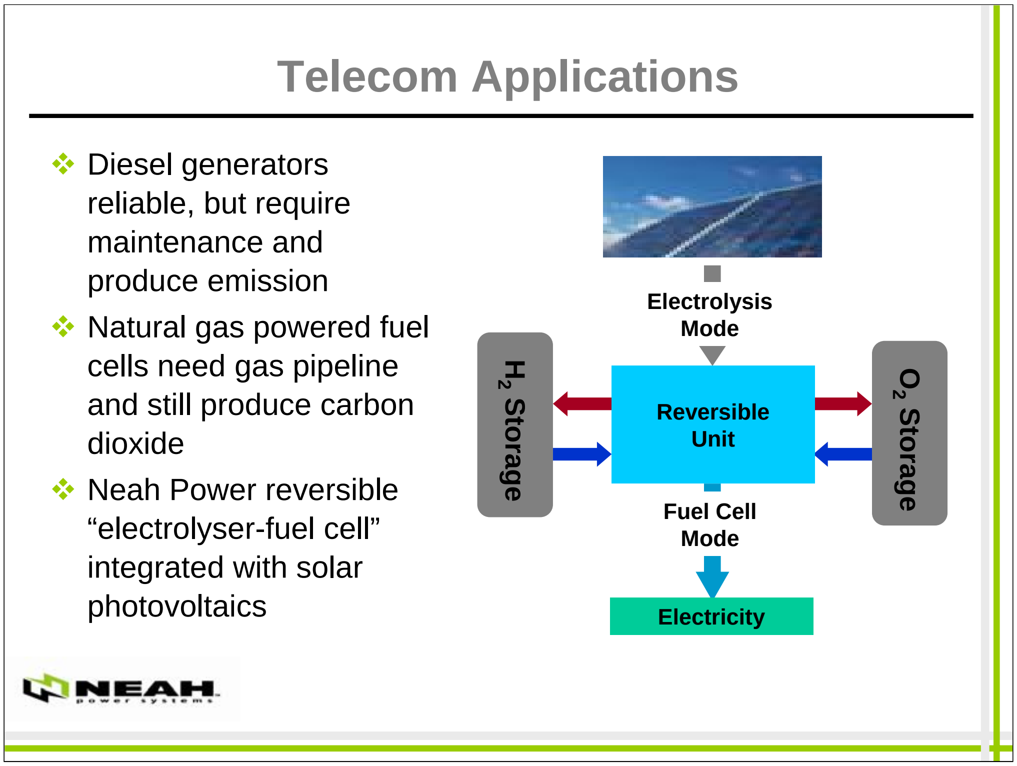
- Significant potential for optimizing its technology into a reversible cell capable of functioning both as an electrolyser and a fuel cell.
- Gas separation accomplished in the pores of silicon; the catalyst reaction zone removed from the bulk of the electrolyte.



Electrolysis mode   Fuel Cell mode

Because of the nature of it's liquid electrolyte system and porous electrode structure, Neah Power cell has significant potential for optimizing its technology into a reversible cell capable of functioning both as an electrolyser and a fuel cell.

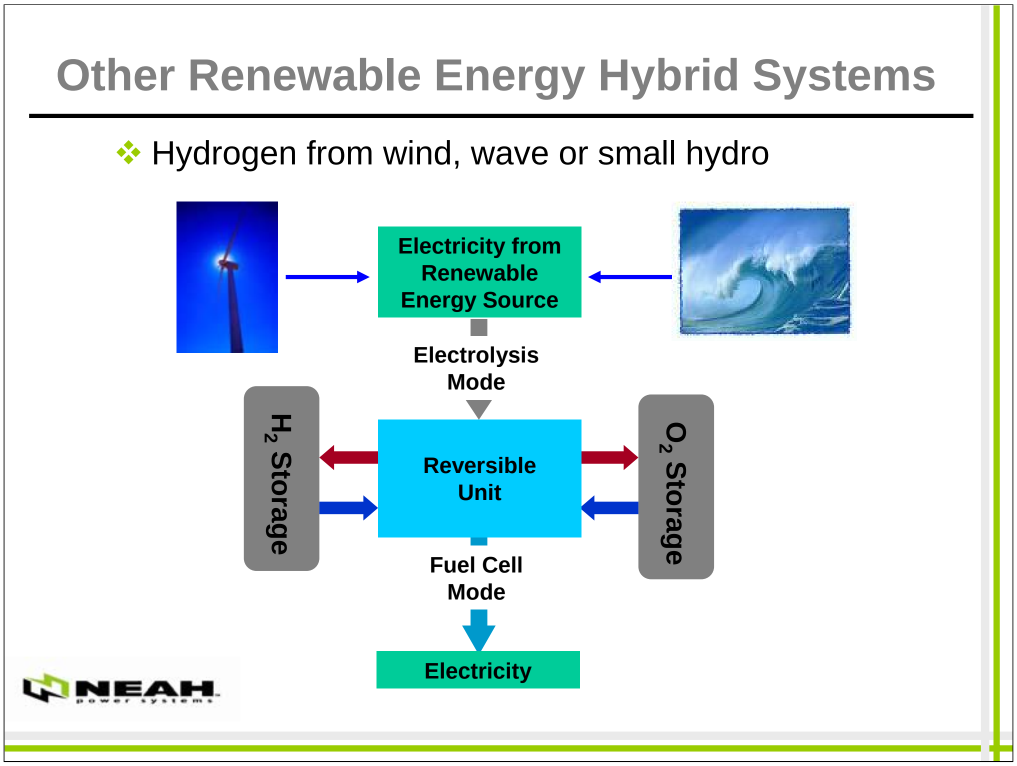
Gas separation, which is a critical issue for designing electrolysis process can be relatively easily accomplished in this system by taking advantage of the length of pores in silicon and the ability to establish catalyst reaction zone away from the bulk of the electrolyte.



Remote power supply for *telecom* applications is becoming an area of great importance. At present, the power for these applications is provided by batteries or conventional diesel generators. Both technologies have enormous fundamental problems: batteries are expensive and they degrade with the number of cycles, while diesel generators bring a multitude of problems related to crude oil price and supply as well as environmental concerns. Recently, some fuel cell manufacturers have been advocating the use of natural gas fuel cells for these applications. However, this approach is also connected with the need for the natural gas pipeline leading to remote locations and still doesn’t eliminate the CO2 emission. It can be concluded that fuel cell technology alone doesn’t meet the present and future requirements for this type of application.

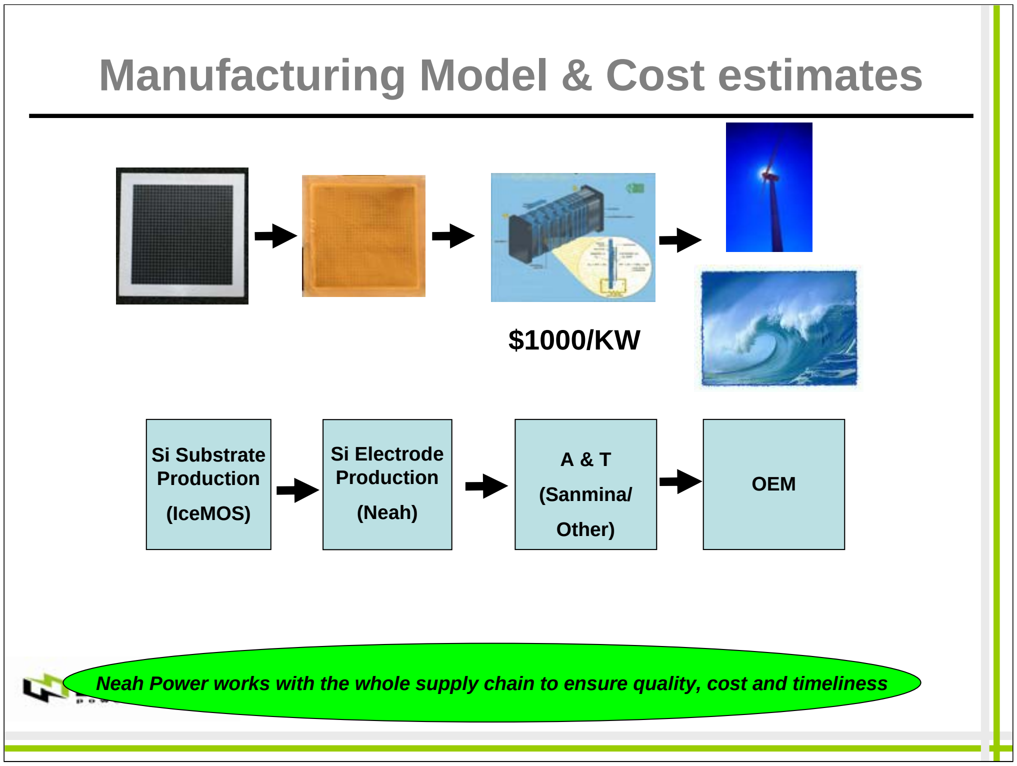
Neah Power Systems is developing a novel concept that relies on a PV-fuel cell hybrid system. This is a completely autonomous system comprising a solar photovoltaic module and a reversible fuel cell based on silicon. During the times of solar irradiation, PV module is powering the *telecom* station and excess power is used to electrolyze water and produce hydrogen. Hydrogen is then stored within the same unit for either short or long periods of time, and later used in the fuel cell when needed. The key technology for this model is the reversible fuel cell – electrolyser unit. Instead of having two separate devices, Neah Power is developing a system that can serve as both the water electrolyser to produce hydrogen and as a hydrogen fuel cell. This approach greatly reduces the cost as it takes the advantages of much lower capital investment and simplicity of operation. Neah Power fuel cell configuration is one of the very few fuel cell technologies that can be practically utilized as reversible systems. The use of liquid acidic electrolyte is equally favorable for both the electrolysis and fuel cell reaction, while highly structured silicon substrate guarantees precise process control in both modes of operation.

The development of this unique concept named “Solar – Reversible Fuel Cells for Telecom Applications”, could be pursued through a consortium of interested partners, including *telecom*, energy, and silicon processing segments.



Besides utilizing solar photovoltaic convertors as the primary source of electricity, other hybrid systems comprising Neah Power Reversible fuel cell could be considered as a part of the overall portfolio. If, for example, wind power is available and more attractive than solar for a certain region; Neah Power reversible fuel cell can easily be integrated with the electricity produced by a wind turbine. The only difference in the overall system design would be a conversion from AC electricity generated by a turbine to DC electricity needed for the electrolyzer, a process that can be accomplished easily and cheaply.

Similarly, the availability of renewable energy sources in remote locations, would lead to hybrid systems comprising wave electricity generating devices, tidal barrages, ocean currents, or even a small hydro. Common for all these renewable energy conversion technologies is that they are clean and un-exhaustible (on a human time scale), but also intermittent, dependent on climatic conditions, and inherently unreliable. They are all usually located in extremely remote areas, with no connection to electricity grid and difficult access for fuels (e.g. gas pipelines, shipped liquid or solid fuels). If permanent, reliable power is needed in those areas, as in the case of *telecom* applications, the only practical, long-term solution is to build hybrid systems that would ensure continuous power supply and require no or minimum maintenance.



Manufacturing Model:

Neah's technology is well suited to an outsourced manufacturing model that leverages world class capabilities that the semiconductor industry currently uses. The semiconductor industry has driven the innovation of foundries and outsourced manufacturing. The foundries build world class manufacturing facilities and keep them updated, aggregate demand from a variety of customers, thereby driving down cost for the individual customer, while creating capital efficient large scale manufacturing systems. This demand aggregation has enabled innovation in the semiconductor industry while simultaneously driving down costs across the entire industry. Neah is leveraging this same capability in the fuel cell arena, and this is a distinctive competitive edge vs. all other fuel cell technologies. Neah has currently defined manufacturing relationships as follows –

1. Porous Silicon foundries – IceMOS is the preferred supplier, with Company T, Inc being qualified as an alternative supplier.
2. Thin film deposition – Currently done in house at Neah, plan is to outsource that to IceMOS and Company T.
3. Final assembly and test – Sanmina – SCI is the current final assembly and test supplier for Neah. Sanmina is a multi-billion dollar outsourced manufacturer with 30+ locations worldwide. They have the logistics, tax, and supply chain expertise to support a variety of customers in different locations throughout the world.

Cost target: Neah believes it could achieve ~ $1000/kW in high volume manufacturing, when the company can fully leverage the supply chain and the various enhancements that are currently under development.

Summary

- Neah Power is developing a dual strategy for entering the field of hybrid energy solutions.
- The company's H_2-O_2 fuel cell can be used to produce electricity from hydrogen and air when there is a source of hydrogen available.
- Alternatively, the Neah Power system design is extremely adaptable for the reversible cell capable of functioning as both electrolyser and a fuel cell. This would be the preferred approach because of the potential capital cost savings.
- The company is interested in partnering with developers of renewable energy sources and working on the system solutions.
- Neah expects to achieve a cost of $1000/KW in HVM

NEAH power systems

Neah Power Systems is developing an extremely efficient, scalable, and cost effective technology for energy storage that combines hydrogen production and fuel cell in a single unit. The company's H2-O2 fuel cell can be used to produce electricity from hydrogen and air when there is a source of hydrogen available. This technology can become a backbone of the future renewable energy systems and ensure, on-demand and reliable energy delivery.

The company is interested in partnering with developers of renewable energy sources and working on the system solutions. To learn more about Neah Power Systems and powering the future with clean, affordable energy, visit www.neahpower.com.