Overview of the "Commercial-Scale" Version of Expansion Energy's Patented "VPS Cycle" for Power Storage: 2 MW to 20 MW

Background

In addition to the "Utility-Scale" (20 MW to 100's of MW) version of Expansion Energy's "VPS Cycle" liquid air energy storage (LAES) technology, Expansion Energy has recently developed a smaller, simplified and lower-cost **"Commercial-Scale" version of the VPS Cycle—2 MW to 20 MW**—which are pre-designed and 100% factory-manufactured, then delivered to the deployment site on skids, eliminating the need for on-site construction. **(Under certain operating models, even smaller VPS plants—less than 2 MW—are economically feasible.)** This approach greatly increases the deployment potential (and market size) for VPS plants. Commercial-Scale VPS is deployable at virtually any location that consumes at least 2 MW of power and is connected to an electrical grid and a natural gas grid. As such, Commercial-Scale VPS represents a potential "paradigm shift" in how energy is produced, delivered, stored and used worldwide.

Like Utility-Scale VPS, Commercial-Scale VPS is designed to operate on a daily cycle, storing energy during the overnight off-peak period and **delivering 8-12 hours of power per day (at a constant release rate)** during the grid's peak demand period—making VPS a "baseload" power storage solution. However, there are certain key differences between the larger Utility-Scale VPS and the smaller, modular Commercial-Scale VPS plants, which are summarized in the table below.

Utility-Scale VPS vs. Commercial-Scale VPS – Key Differences

	Utility-Scale VPS	Commercial-Scale VPS
Scales	20 MW to 100's of MW	2 MW to 20 MW
Construction	Field-erected (site-constructed, like a power plant)	Factory-built (a modular, manufactured "appliance")
Design / Engineering	Custom design/engineering (new design for each VPS plant)	Standardized design/engineering (each design pays "dividends" across dozens/hundreds of units)
Application	Centralized/substation energy storage	Distributed energy storage + End-user reduction of peak demand and power consumption; back-up/reliability
Customers	• Utilities & Power Cooperatives • Power Generators	• Utilities & Power Cooperatives • Power Generators • Industrial Power Users • Commercial Power Users • Microgrids & Military
Competing Technologies	Pumped Hydro + CAES (each require scales > 100 MW)	Virtually no competition (2-20 MW is too large for Batteries and too small for Pumped Hydro + CAES)
Market Potential (# of plants)	Dozens or hundreds	Thousands
CAPEX per Plant	~ $75 million for 45 MW VPS plant	~ $4 million for 2 MW VPS plant ~ $20 million for 10 MW VPS plant
CAPEX/kWh of Daily Capacity	$125-$250/kWh	$165-$275/kWh

Utility-Scale VPS vs. Commercial-Scale VPS – Key Similarities

Despite the key differences between Utility-Scale VPS and Commercial-Scale VPS outlined above, Commercial-Scale VPS preserves the many important advantages that Utility-Scale VPS delivers, such as:

- A highly efficient "distributed generation" power plant with storage built in
- Turns intermittent power sources (e.g., wind, solar) into "firm" power sources
- Also beneficial for storing base-load power (e.g., coal, nuclear, gas) off-peak
- VPS components are 100% commercially available ("off-the-shelf")
- "Round-trip efficiency" (RTE) > 90%
- 8 to 12+ hours of power release capacity—daily cycling, at a constant release rate
- Low capital cost per kWh (of daily storage & release capacity): $165-$275/kWh
- Can be constructed virtually anywhere above-ground
- Substantially reduces grid congestion if sited near high-demand end-users/load centers
- Ultra-high BTU conversion efficiency—Heat Rate = ~ 4,000 BTU/kWH (vs. 6,660-7,700 for combined cycle plants)
- Fast start – less than 20 minutes to reach full outflow capacity (+ partial outflow faster)
- 10 X greater storage density than compressed air energy storage (CAES) + much higher RTE than CAES
- VPS is 100% man-made (no reliance on special geologic conditions/caverns)—reliable, predictable, replicable
- Expected useful life of 40+ years

Customers/End-Users

Whereas the target customers for Utility-Scale VPS plants are necessarily limited primarily to utilities, power cooperatives and power generators, the market for Commercial-Scale (4-20 MW) VPS plants includes the following, among others:

- Industrial facilities / factories / refineries
- Utility – T&D "tight spots" / capacity upgrades
- Military bases
- Hospitals
- Office parks / corporate campuses
- Shopping centers
- Airports & shipping ports
- Microgrids
- Wind farms & solar farms
- University campuses
- Data centers / server farms
- Food processing / refrigerated warehouses
- Mines & quarries
- Other critical buildings / infrastructure

VPS Integration with Gas-Fired Turbines—An Optimal Application

In addition to "stand-alone" Commercial-Scale VPS plants, another recent advancement of the VPS technology is the potential for integration of VPS with existing simple-cycle gas-fired power plants (e.g., peakers). In other words, existing simple-cycle power plants can be retrofitted with VPS technology to convert them into "daily duty" power storage assets—making them far more valuable assets than the occasionally used "peakers" that they are today. Hundreds of such peakers exist around the world, representing a large market opportunity.

Additional Benefit: Back-up Power & Resiliency

If access to grid power is interrupted for any reason, the prime mover (e.g., gas turbine or natural gas engine) of Commercial-Scale VPS plants can continue to generate power (1 MW to 4 MW, depending on the scale of that particular VPS plant) for an extended period (hours/days/weeks/months) even if no new liquid air is produced by the "front end"

of the VPS plant. As long as the VPS plant's connection to the natural gas pipeline system is intact, each VPS plant will continue to have 10% to 20% of its rated power outflow capacity available as back-up generation.

If truck-delivered L-Air, L-N_2 or L-O_2 can be delivered to the VPS plant (as opposed to making L-Air, L-N_2 or L-O_2 on-site), then the VPS plant can operate at 100% of its rated power output 24/7 for an indefinite period of time, providing even more back-up power and resiliency benefits. (See "Additional VPS Operating Model: Truck-Delivered L-Air / L-N_2 / L-O_2" section below.)

VPS Integration with Air Separation Plants—"Low-Hanging Fruit"

One particularly "synergistic" category of VPS end-users are the hundreds of air separation plants that exist worldwide today to make industrial gases such as oxygen, nitrogen and argon. These plants tend to operate 24/7 and therefore face high "demand charges" and high peak-period energy consumption charges from electric utilities. The "front end" (power Inflow-to-Storage) portion of VPS plants resembles portions of air separation plants that already exist. Therefore, utilizing VPS at air separation plants would require only building/deploying the Outflow-from-Storage portion of a VPS plant—substantially reducing the capital cost, complexity and footprints of such deployments. Specifically, the capital cost of VPS plants deployed at air separation plants can be reduced by about 33% versus stand-alone VPS plants. Thus, air separation plants are "low-hanging fruit" for VPS deployments—delivering substantial and immediate value to the customer/host, whether the VPS plant is owned by the air separation plant or by a third party (e.g., an IPP or ESCO).

Because air separation plants already inherently have the ability to produce L-Air (or L-N_2 or L-O_2), the air liquefaction portion of stand-alone VPS plants does not need to be built, making even smaller-scale—less than 2 MW—VPS plants economically feasible due to substantially lower capital costs.

In addition to VPS's value to air separation plants as end-users (i.e., as power consumers), VPS also represents a major opportunity for additional revenues and profits for existing air separation plants, by providing a new market for the cryogenic liquids they produce/sell, as described in the following section.

Additional VPS Operating Model: Truck-Delivered L-Air / L-N_2 / L-O_2

The smaller scale of Commercial-Scale VPS plants make it economically feasible to deploy simpler, lower-cost versions of the VPS Cycle—specifically by eliminating the need for producing L-Air on-site in the Inflow-to-Storage phase of the Cycle. Rather than producing L-Air on-site, L-Air, liquefied nitrogen (L-N_2) or liquefied oxygen (L-O_2) can be trucked to the VPS site, where such delivered L-Air, L-N_2 or L-O_2 is utilized by VPS's Outflow-from-Storage phase in exactly the same way as if it had been produced on-site.

L-N_2 or L-O_2 or L-Air is produced by the hundreds of air separation plants that exist around the world, owned and operated by companies that produce/sell industrial gases. These companies routinely and safely deliver L-N_2, L-O_2 and other cryogenic liquids by tanker trucks/trailers. As such, VPS plants utilizing any of these truck-delivered cryogenic fluids represent a major new market opportunity for existing air separation facilities. In fact, many air separation plants have a surplus of either L-N_2 or L-O_2 (because their key customers need only one of those products). VPS can utilize such surplus products (either L-N_2 or L-O_2), providing an additional revenue stream for existing air separation plants, resulting in greater profitability and resource efficiency. If desired, air separation plants can also be designed to simply produce L-Air for VPS plants (rather than the "separated" elemental gases—L-N_2 or L-O_2, etc.).

Eliminating the on-site Inflow-to-Storage phase of a VPS plant **reduces the capital cost for such VPS plant by about 33%.** This allows more VPS plants to be deployed with less capital. It also makes deployment of even smaller-scale VPS plants cost-effective. **Under this operating model, VPS Cycle plants at scales of 2 MW or less are economically feasible.**

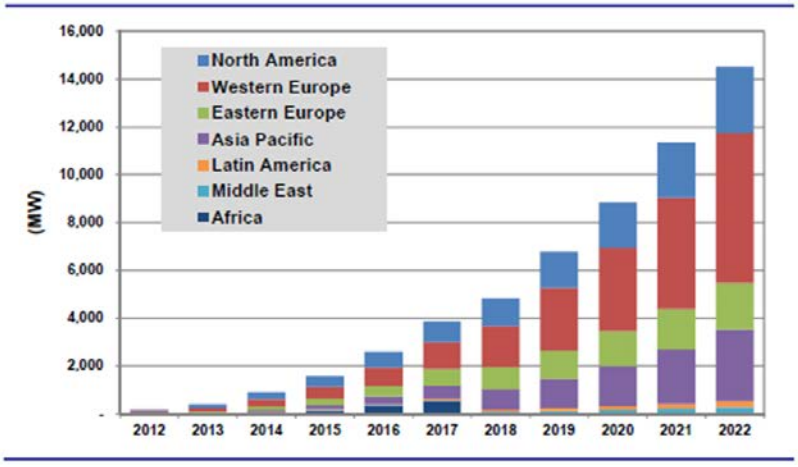
Utilizing truck-delivered cryogenic fluids also provides an additional degree of reliability for VPS plant owners, as the L-Air, L-N_2 or L-O_2 can be sourced from any number of nearby air separation plants.

Economics / ROI

Information from independent energy policy organizations such as the New York State Energy Research & Development Authority (NYSERDA) suggests that the 25-year **Present Value (PV)** of energy storage assets that reduce an industrial customer's peak demand charges and peak power consumption charges **may exceed $5,000/kW**—far higher than the capital cost of VPS plants deployed at air separation plants (~$1,300/kW) or at other types of industrial facilities (~$1,600-$2,000/kW). Thus, the return-on-investment (net present value) potential for Commercial-Scale VPS plants at many industrial facilities is extraordinarily high. There is also a high ROI pattern for utility owners of Commercial-Scale VPS plants in regions where power storage is in demand—either because of market need or government/regulatory policy.

Large, Fast-Growing Market

Because Commercial-Scale VPS plants can be deployed for so many applications, **VPS represents a multi-billion-dollar revenue opportunity for VPS technology licensees**. In addition, the market for bulk power storage is projected to grow fast, as shown in the chart below from Navigant Research division.



Source: Navigant Research

Using Navigant's MW projections, Expansion Energy estimates a total **annual market size of nearly $20 Billion by 2020**.

Hundreds of pre-engineered, factory-built, skid-mounted Commercial-Scale VPS units could be deployed annually worldwide, with each VPS unit providing all or a portion of its power output to the host site, and with the "surplus" portion (if any) sold to the grid.

Targeted Licensees of Commercial-Scale VPS Technology

Potential licensees of Commercial-Scale VPS technology include any of those listed in the "Customers/End-Users" section above plus **manufacturers/vendors of energy equipment** serving the markets for power generation, power storage or power distribution, which may be interested in selling factory-built VPS plants to the market.

Conclusions

Commercial-Scale VPS plants are smaller, simpler and lower-cost than Utility-Scale versions of VPS. Commercial-Scale VPS addresses an even broader and larger market than Utility-Scale deployments. **These modular, standardized, factory-built "appliances" serve the large market for power storage at 2 MW to 20 MW—scales where today there is virtually no cost-effective technological solution**, as these scales are generally too small for CAES and pumped hydro and too large for battery storage.

Moreover, Utility-Scale VPS plants have value for situations where larger (> 20 MW) storage assets are required. For example, Expansion Energy recently completed a feasibility study with the New York City utility, Con Edison, which was sponsored by the New York State Energy Research & Development Authority (NYSERDA). The study found that a **~ $98 million VPS plant** (turnkey cost) **would yield a total Net Present Value of $218 million** to the electrical system—and such value could be split between Con Edison (as a return on its VPS investment) and the ratepayers. This high ROI was due in large part to the fact that VPS can be sited close to the load—which brings many more benefits to the electrical system than storage projects sited far from the load (where nearly all CAES and Pumped Hydro projects would necessarily reside).

Expansion Energy has also analyzed the economics for Commercial-Scale VPS deployments using the same methodology and assumptions utilized for the NYSERDA feasibility study referenced in the previous paragraph. Results show that **Commercial-Scale VPS plants generally deliver Net Present Values (NPV) of 2-3 X their turnkey capital cost**—an extraordinarily high return-on-investment.

The market opportunity for Commercial-Scale VPS Cycle plants is massive, and Commercial-Scale VPS represents a potential "paradigm shift" in how energy is produced, delivered, stored and used. Worldwide, virtually every facility that uses more than 2 MW of power from the electric grid and is served by a natural gas grid connection is a candidate site for a Commercial-Scale VPS plant. Each VPS deployment could eventually become part of a widespread network of cost-effective, low-emissions distributed storage and distributed generation assets—**combining the well-recognized economic and operational benefits of power storage *and* distributed generation**—two of the most important trends in the power industry today.

Contact Information

Energy equipment vendors/manufacturers who wish to license the VPS technology and large power consumers/end-users who wish to own/deploy VPS plants are invited to contact Expansion Energy for further information by visiting the "Contact Us" page of our website (www.expansion-energy.com) or by emailing us at **info@expansion-energy.com**.