SCUDERI™ Split-Cycle Engine Technology Overview

SCUDERI ENGINE

Looks Can Be Deceiving

If you were to look quickly and compare a 4-cylinder SCUDERI™ Engine to a traditional 4-cylinder engine, the physical differences are subtle. Both engines have a total of four cylinders, both can be in-line, V, or boxer configured, and both use the same proven technologies: pistons, valves, crankshafts, connecting rods, fuel injectors, etc. However, that's where the similarities end.

The after top-dead center combustion cycle of the SCUDERI Split-Cycle Engine is split between interconnected pairs of compressor and expander cylinders. It completes one combustion cycle for every revolution of the crankshaft. Each of the paired cylinders provides two strokes of the engine's four-stroke cycle: One cylinder of the pair provides the intake and compression strokes; the other cylinder provides the expansion and exhaust strokes.

Interconnecting each of the paired cylinders is a crossover passage. The crossover passage facilitates modulated, high-pressure transfer of air between the cylinders. At each end of the crossover passage there is a fully variable, outwardly opening valve. The crossover-compressor valve (XovrC) controls the transfer of air into the crossover passage from the compressor cylinder. The crossover-expander valve (XovrE) controls the transfer of air into the expander from the crossover passage.

Fuel can be direct-injected into the expander or it can be port-injected into the charge air during transfer into the expander cylinder. As the charge air is transferred to the expander from the crossover passage, sonic flow and high turbulence enhance fuel-air mixing and promote stable, robust combustion. The resulting flame speed is unusually fast, with a 10-90% burn duration of only 12° crank angle. The extremely fast combustion and late fuel addition provide a high knock avoidance characteristic, and rapid expansion during combustion reduces NOx emissions—significantly below conventional engine levels—without using exhaust gas recirculation (EGR).

The combination of discrete, asymmetrically sized cylinders and fully variable valvetrain provides a large degree of flexibility to optimize the engine. Displacement ratios, bore-stroke ratios, compression-expansion ratios, compression-expansion phasing, and gas transfer phasing can all be varied for optimization.

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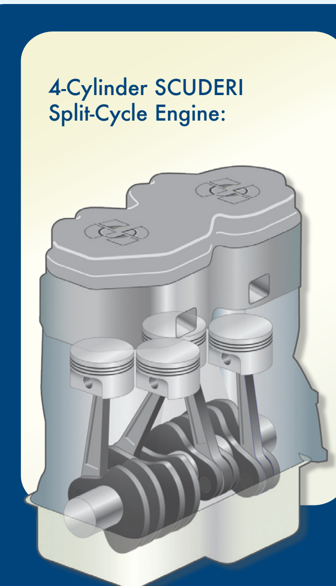
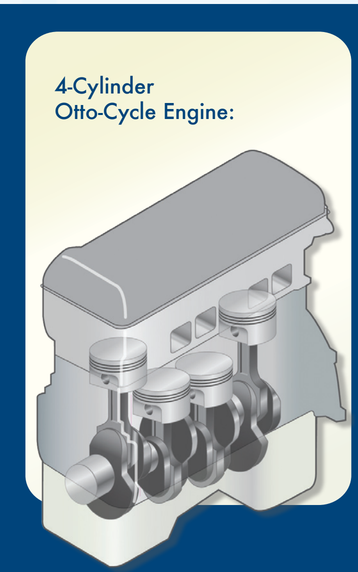
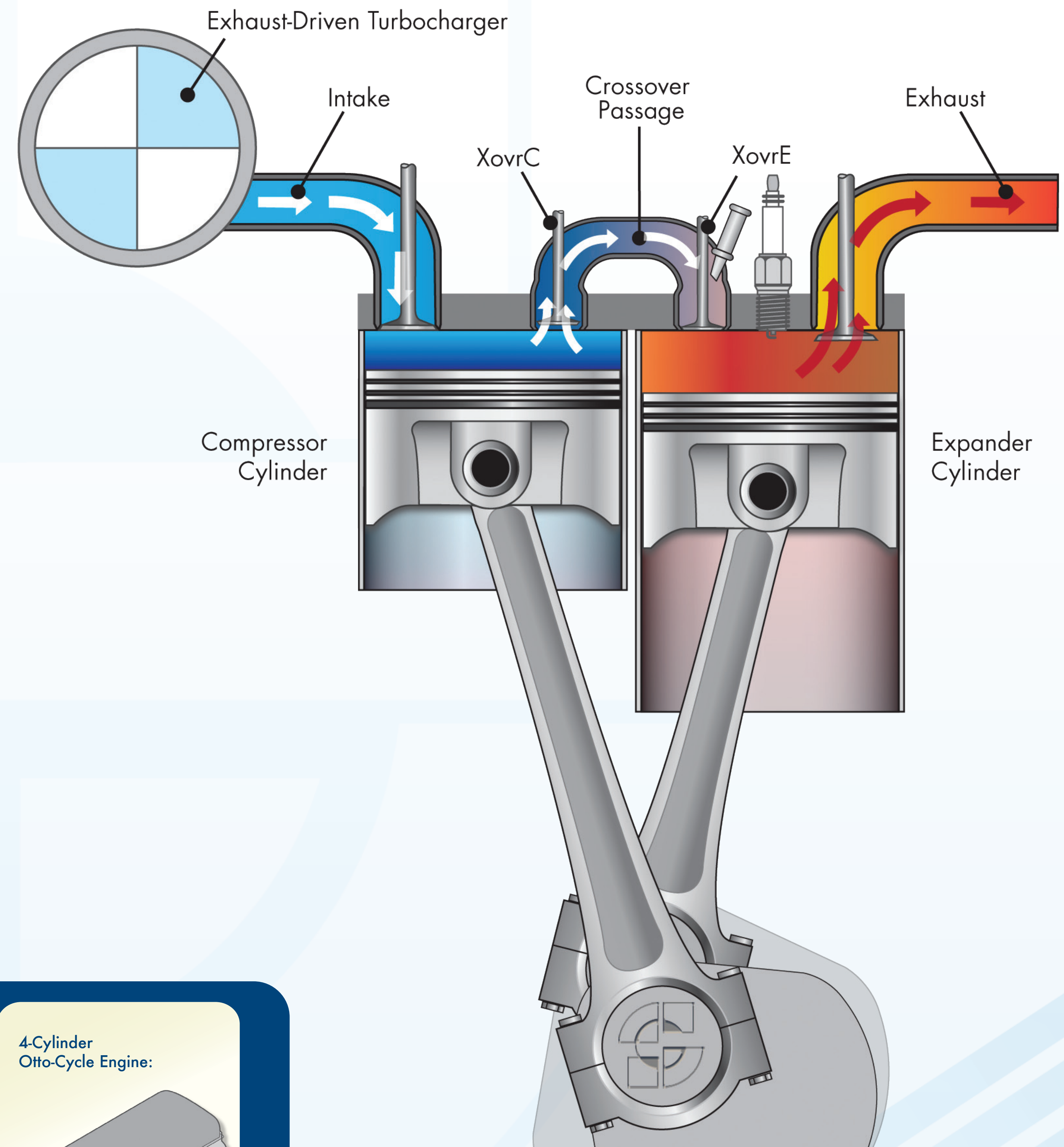






The Miller Cycle

When Frank Miller developed the Miller Cycle, his goal was to increase the thermal efficiency of a supercharged, four-stroke engine by making the compression stroke shorter than the expansion stroke.

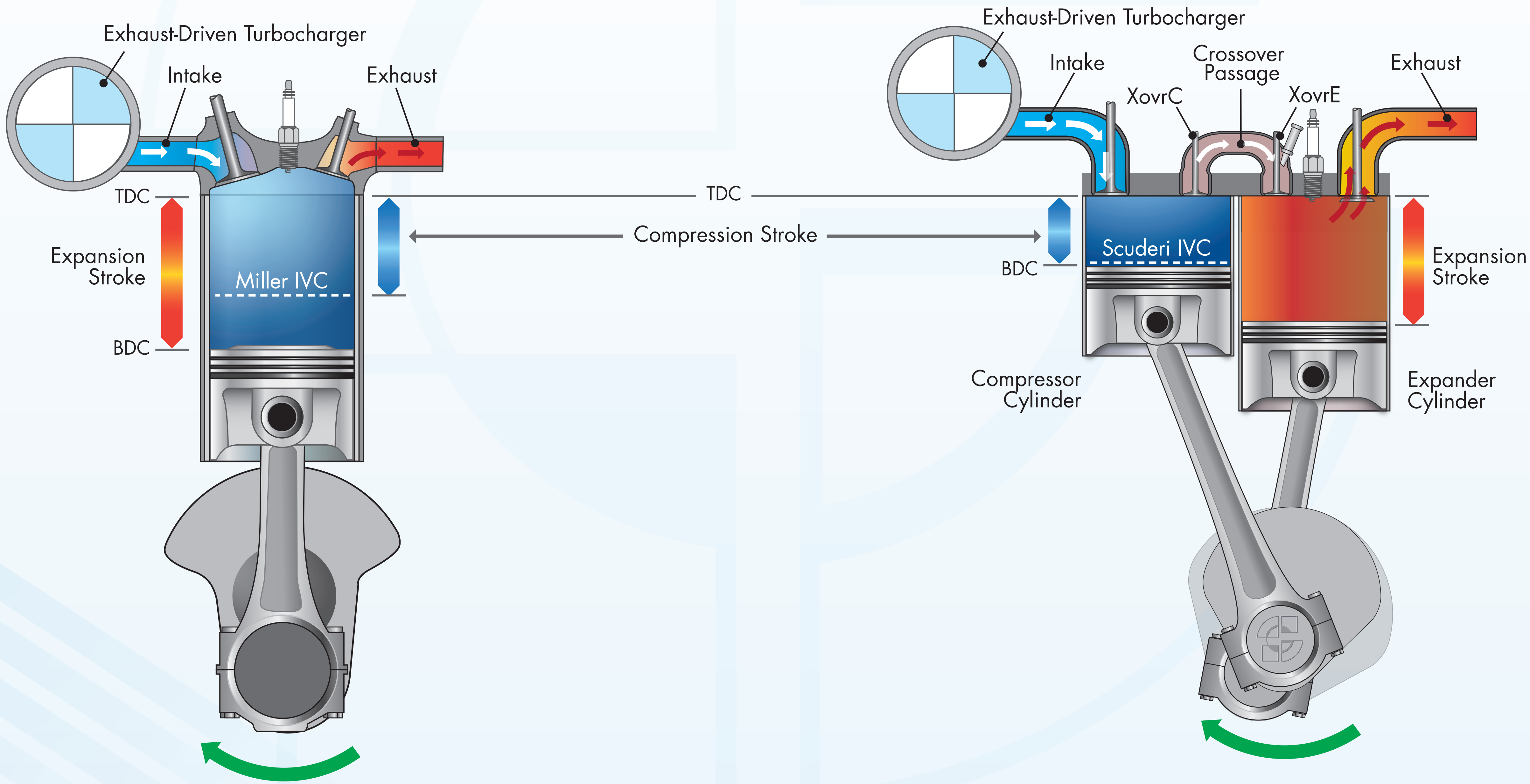
Miller's solution was to employ a valve timing strategy that closed the intake valve early, before the piston reached its bottom dead-center position. The early timing strategy effectively shortened the compression stoke—without shortening the expansion stroke.

By closing the intake valve early, however, the valve event cannot be optimally timed to deliver maximum volumetric efficiency, and a portion of the available displacement cannot be used. Also, when closing the valve early, the valve event occurs when piston velocity and air velocity are high—as is the associated pumping loss.

The SCUDERI™ Split Cycle

The SCUDERI Split-Cycle Engine gains a massive advantage from turbocharging and extended expansion that is simply not possible with traditional Miller-Cycle Engine designs.

Rather than shifting intake valve close (IVC) timing, extended expansion in a SCUDERI Split-Cycle Engine is achieved by reducing the fixed displacement of the compressor cylinder relative to the fixed displacement of the expander cylinder. By differentially sizing the cylinders, IVC is timed at a period of low piston velocity where an optimum trapped mass condition can be attained and pumping losses can be avoided.

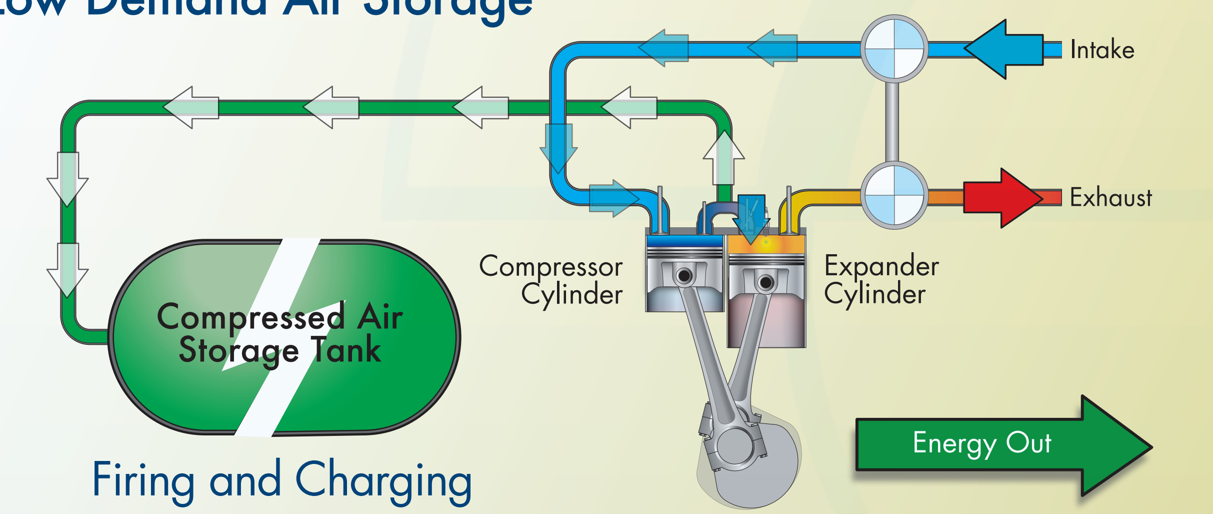


Power—When You Need It

Whether powering a compressor, generator, or the wheels of an automobile, the SCUDERI™ Engine's one-of-kind ability to store compressed air energy during periods of low demand, and use it to produce power during periods of high demand, can be used to reduce engine size and weight, increase specific power and torque, and to reduce fuel consumption and emissions.

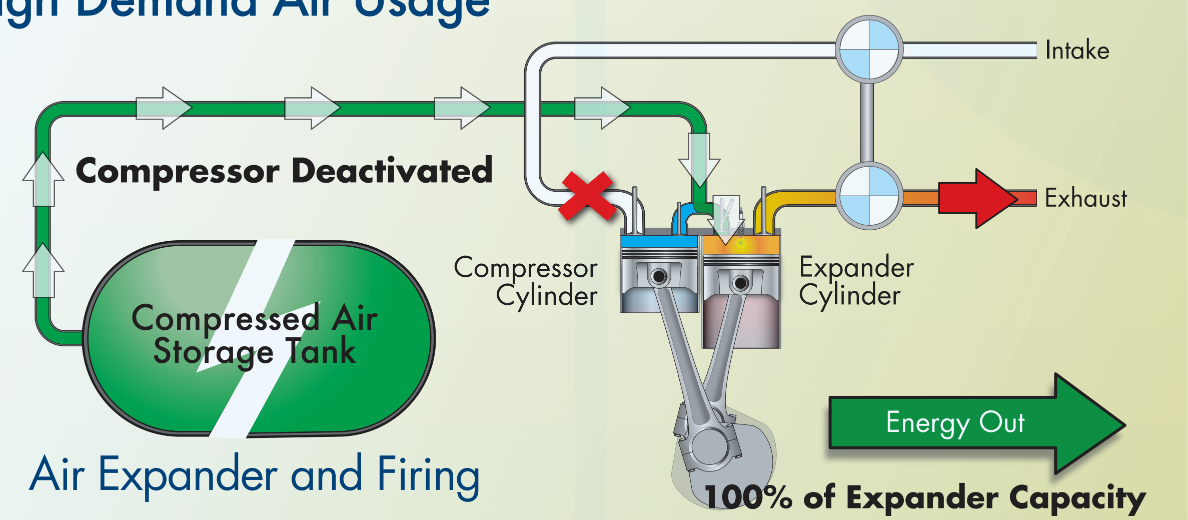
Unlike any other reciprocating internal combustion engine technology, the SCUDERI Engine's split-cycle technology decouples the compression processes from the expansion (combustion) processes. Decoupling the processes enables compression independent of expansion and expansion independent of compression. With the processes decoupled, energy produced by one process can be stored until needed by the other.

Low Demand Air Storage



Firing and Charging

High Demand Air Usage

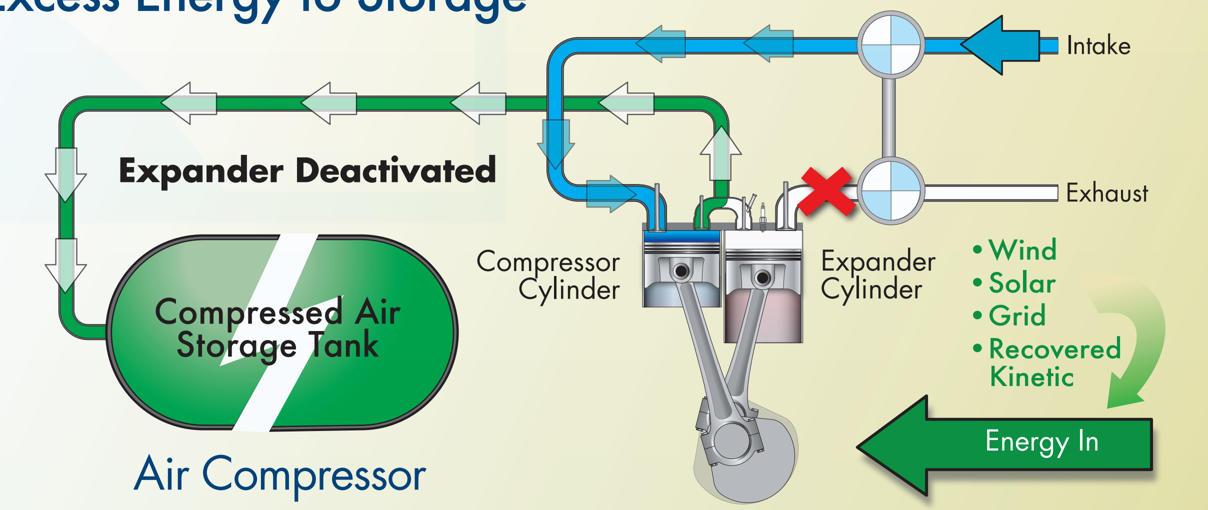


Air Expander and Firing

Storage—When You Don't

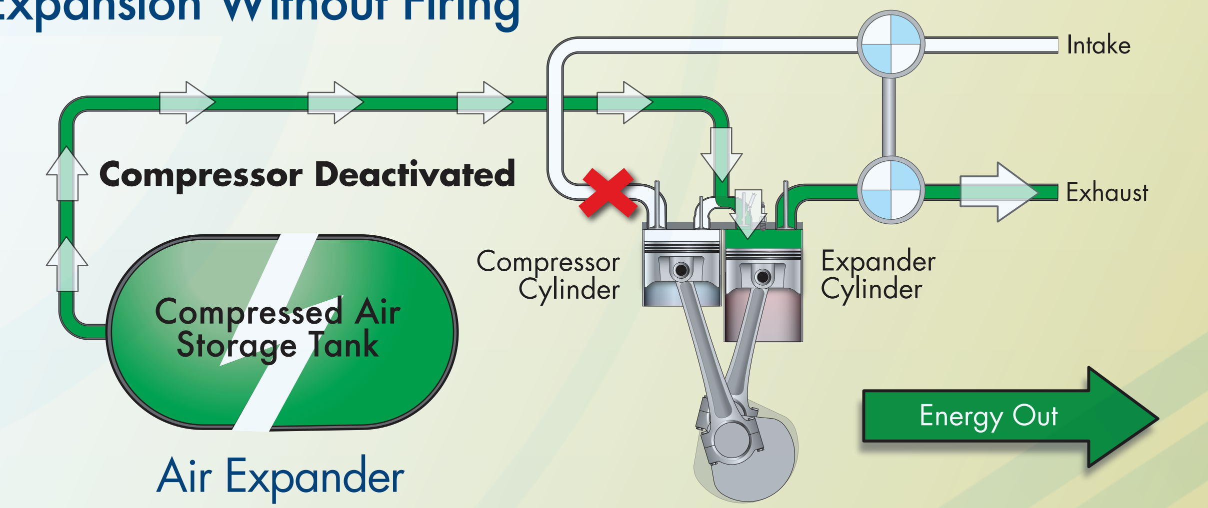
For decades, the power generation industry has recognized the advantages of using compressed air energy storage to store significant amounts of energy at relatively low costs. By using stored compressed air to produce energy, power companies are able to generate on-peak electricity using excess, off-peak generating capacity.

Excess Energy to Storage



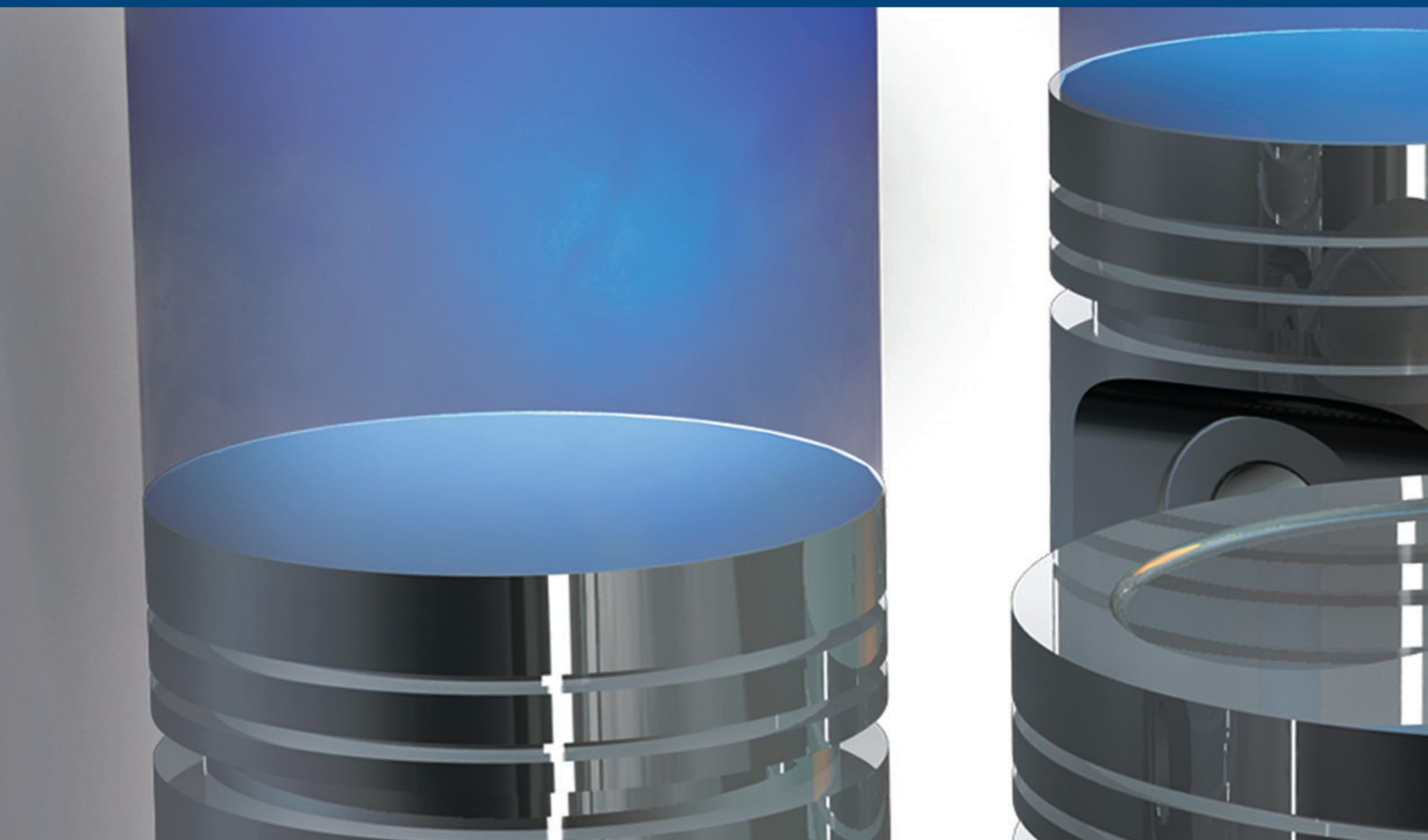
Air Compressor

Expansion Without Firing



Air Expander

SCUDERI GROUP



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