

*Liebert® DSE™ with EconoPhase™:
Highest Efficiency DX Cooling with pumped refrigerant economizer
Product Brief*

Introducing the Liebert® DSE™ from Emerson Network Power

In today's data center, minimizing annual energy usage while maintaining reliability is increasingly important. While chilled-water loops operating at elevated temperatures supported by water-side economizers have helped to decrease energy usage, new innovations are changing how the data center industry thinks about direct expansion (DX) cooling infrastructures with respect to efficiency, scalability and reliability.

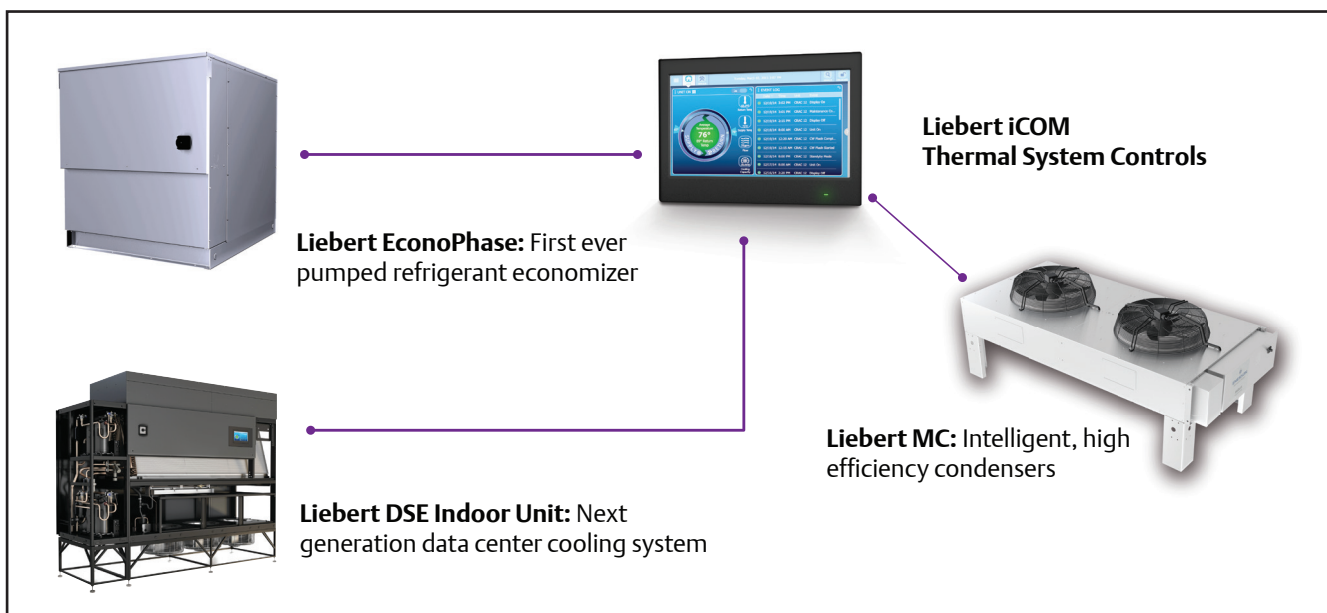
One such next generation DX system, the Liebert DSE from Emerson Network Power, provides the following key benefits:

- Industry-leading energy efficiency among DX systems
- Hassle-free economization with Liebert EconoPhase™
- Precise control and enhanced efficiency through intelligent controls
- Uncompromising reliability and 24/7 support

This product brief will provide a thorough overview of the Liebert DSE system and compare its unique design to comparable DX and chilled-water cooling solutions you may be considering for your data center. It also provides a detailed explanation of the Liebert EconoPhase pumped refrigerant economizer solution and share specific examples for how cooling efficiency can be maximized intelligently in accordance with your data center's ambient climate.

The Liebert DSE direct expansion cooling system comprises four primary components: the Liebert DSE indoor computer room air conditioning (CRAC) unit, the Liebert MCT™ micro-channel outdoor condenser, the Liebert EconoPhase pumped refrigerant economizer, and Liebert iCOM™ thermal system controls. The components operate in harmony to provide the industry's most energy efficient operation for a room-based cooling system.

It is important to note that the Liebert DSE is a complete, integrated system— **not** a collection of disparate components.

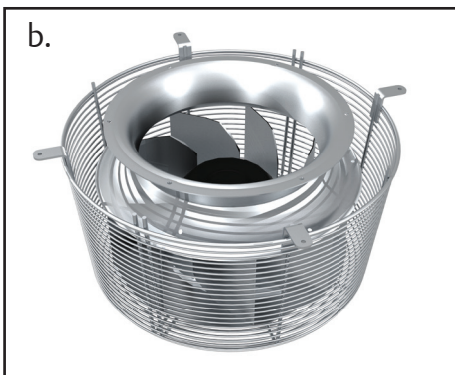


The Liebert DSE direct expansion cooling system comprises four primary components: the Liebert DSE indoor computer room air conditioning (CRAC) unit, the Liebert MC micro-channel outdoor condenser, the Liebert EconoPhase pumped refrigerant economizer and Liebert iCOM control with thermal system manager.

Indoor CRAC Unit Designed with State-of-the-art Technologies

The Liebert® DSE™ indoor unit (DA080, DA085, DA125 or DA150) is equipped with several high-technology components that are designed and controlled to work together to provide a highly efficient and reliable DX system. Key technologies serve the following functions to enhance energy efficiency and performance:

- Digital scroll compressors match cooling to IT load
- Staged evaporator coil reduces compressor power and optimizes economizer performance
- Electronic expansion valve enables part-load and low ambient efficiency
- Electronically commutated (EC) plug fans match airflow to server needs



Digital scroll compressors (a) and EC plug fans (b) optimize the energy efficiency of the Liebert DSE by matching cooling and airflow to the demands of the environment.

To maximize efficiency and control at full and partial loads, the Liebert DSE is equipped with **variable capacity digital scroll compressor** technology and direct-drive, variable-speed EC fans, which are modulated to respond to and match changes in room load. Varying the capacity of the compressors enables them to run at a more efficient operating point than at full capacity. A **staged evaporator coil** inside of the unit enables each refrigerant circuit to operate over large coil surface area, increasing system efficiency. *Alternative coil lacing designs that circulate refrigerant through only one coil slab can result in air passing through dormant coils, resulting in lower circuit efficiency and uneven air distribution across the coils.*

The CRAC's **variable-speed, direct-drive EC fans** enable air volume to be precisely adjusted to match the needs of the server load. The Liebert DSE's indoor unit also is equipped with **electronic expansion valves**, which enable compressors to modulate to a lower head pressure than traditional mechanical expansion valves (TXVs), resulting in lower operating costs during mild temperatures.

Highly efficient Micro-Channel Condenser Design

The Liebert® MC™ condenser integrated into the Liebert DSE system enables the system to achieve higher efficiency, reduced sound levels, reduced refrigerant charge and an overall decreased footprint. As shown in **Figure 1**, micro-channel condensers such as those found in the Liebert DSE system are smaller, lighter (up to 40 percent) and can require significantly less refrigerant charge (nearly 73 percent) than a traditional fin/tube design. This results in a greener design, using less refrigerant and providing a more favorable LEED calculation for refrigerant use.

Because the Liebert MC condenser is equipped with a coil that is only about one 1 inch thick, the condenser is able to achieve lower pressure drop on the air side, resulting in reduced fan power. Micro-channel condenser coils allow for the same heat transfer within a smaller footprint, providing efficiency gains as much as 52 percent compared to traditional fin/tube condensers. Even higher efficiency levels can be realized during low load or lower ambient temperatures, when the fan speed can be reduced, utilizing the condensers' variable speed fans controlled by Liebert iCOM™ controls.

The Liebert® MC™ condenser offers other benefits beyond the intrinsic efficiency gains. The micro-channel coil design eliminates the need for copper/aluminum junctions, improving the condenser's resistance to corrosion and extending the life of key internal components. And the condenser's optimized fan blade design significantly reduces fan noise at full load - lower operating speeds can result in even lower sound levels.

Hassle-free Economization with Liebert EconoPhase™ Pumped Refrigerant Economizer

In addition to the aforementioned components, the integrated Liebert EconoPhase pumped refrigerant economizer – the industry's first – is a key component to maximizing the Liebert DSE™ system's efficiency during lower outdoor ambient conditions. The Liebert EconoPhase economizer is unique from other systems particularly because it is designed to operate without consuming water, eliminating the need for expensive water treatment systems and removing the risk of water leaks by not introducing water into the data center environment. The Liebert EconoPhase also eliminates the risk of outside air contamination and does not require maintenance associated with air-economizers such as damper and louver maintenance.

Changeover between compressor mode and refrigerant economizer mode is almost instantaneous, whereas traditional economizer systems typically operate in economizer mode only when the economizer season is stable—not changing back-and-forth during the night, for example. The Liebert EconoPhase solution is equipped with variable speed pumps controlled to run at the most efficient levels according to heat loads and ambient outdoor temperatures, providing maximum economization with minimum pump power consumption.

The Liebert EconoPhase is also unique in that it is designed with reliability in mind. The Liebert iCOM™ control monitors pump operation to ensure that the pumps do not cavitate - improving system reliability and service life. If free-cooling mode is temporarily disrupted, reliability is maintained by switching to DX operation without interruption. If a Liebert EconoPhase pump needs to be serviced, it can be isolated from the system and replaced without loss of mechanical cooling.

	Fin/Tube	Liebert MC	+/-
Efficiency (COP)	31	47	+52%
Sound Power (dBA)	77.3	73	-4.3 dBA
Refrigerant Charge (lb)	22	6	-73%
Footprint (ft2)	39.8	33.6	-15%
Weight (lb)	670	400	-40%

Figure 1: Breakdown of typical benefits offered by the Liebert MC's micro-channel condenser design, compared to a traditional fin/tube design found in most DX cooling systems.



Liebert® iCOM™ Controls: The Industry's Most Advanced Control System

The Liebert DSE™ is managed by the latest Liebert iCOM intelligent controls, which enable the system to continuously adapt to the data center IT load and outdoor conditions to take full advantage of economization while providing consistent cooling to IT equipment. The controls monitor all cooling system components as well as inlet rack temperatures throughout the data center.

Monitoring inlet temperatures provides two primary benefits: first, it enables the Liebert DSE system to adjust cooling capacity to the exact amount of cooling needed. Second, the inlet rack temperature may be reported back to a building management system and recorded to ensure service level agreements are met.

The Liebert iCOM controls scale the operation of the CRAC to variably modulate the air volume and compressor capacity to precisely match the data center's IT load, enabling the CRAC unit to deliver the right amount of air at the right temperature. Liebert iCOM also monitors the load and outdoor conditions to control the outdoor Liebert MC™ micro-channel condenser, and during cooler temperatures, automatically activates the Liebert EconoPhase pumped refrigerant economizer to provide economization when conditions are optimal to do so.

The system's integrated Liebert iCOM controls also monitor several parameters within each sub-system and coordinate operation to provide efficient and reliable cooling. The Liebert iCOM control system provides hassle-free operation

by automatically transferring between mechanical cooling and economizer operation modes. Built-in diagnostics ensure that system reliability is maintained, and information about system operation is reported.

Comparing Economizer Designs and Efficiency Implications

Traditional direct expansion systems packaged with **water-side economizers** utilize a direct expansion cooling coil overlaid by a closed loop of water/glycol refrigerant solution. When ambient temperatures are low enough, the system's pump moves the water/glycol solution from an outdoor fluid cooler (or drycooler) to the system's indoor economizer coil. While this type of system can provide economization and reduce compressor operation, its efficiency is hampered by the energy required for the pump to move a highly viscous water/glycol solution. In addition, the glycol solution itself—especially a propylene glycol solution—significantly reduces heat transfer of the economizer coil, resulting in very low ambient temperatures required to provide full cooling.

The **Liebert EconoPhase** requires much less power to pump refrigerant than alternative systems that pump glycol. The Liebert EconoPhase maintains full cooling capacity by taking advantage of the two-phase properties of refrigerant. Alternative glycol-based economizers can experience capacity reduction as much as 40 percent compared to full-DX operation resulting in a need to oversize the economizer to reach system rated capacity. Water-side economizers require extra fan power year-round, due to the additional heat exchange that overlays the DX coil. The Liebert DSE system requires no additional economizer coils, keeping air-side pressure drop lower, resulting in lower indoor fan energy consumption¹.

Another option is to use **chilled water air handlers** (CRAHs) in conjunction with a chiller plant and an air-side economizer. In this configuration, the chiller plant produces cold water during warmer times of the year, and outdoor air is brought into the data center when conditions are right. However, some end-users do not wish to change

¹ According to ASHRAE 90.1-2010, data centers are now required to meet mandatory requirements for minimum SCOP (full-load, design day) to achieve a satisfactory efficiency rating per ASHRAE rating Standard 127. The ASHRAE 90.1 requirements also mandate the utilization of economizers in many regions of the United States. This minimum efficiency target for direct expansion cooling systems ranges from 1.8 to 2.6, depending on the cooling capacity, condensing type, and airflow configuration.

The Liebert® DSE™ system combines DX mode operation during warmer temperatures and refrigerant economizer mode during cooler temperatures, resulting in a mechanical power usage effectiveness (PUE) between 1.05 and 1.3.

between mechanical cooling and economizer cooling several times during the year. Instead, they may elect to change to economizer mode only when the system will stay in this configuration for a long period of time (only when the dew point of the outside air is within a certain window: 40°F to 59°F, for example). This can result in missing many partial economizer hours during nighttime or mild “shoulder” months. As such, the efficiency of this particular option is largely dependent of the outdoor ambient climate, and can vary widely depending on geography and environmental conditions.

In addition, air economizer energy savings can be negatively impacted due to the need for powered exhaust fans and the resultant added fan energy to overcome outside air filtration. In addition, some end users are not comfortable introducing outside air into the data center due to contamination concerns.

Other economizer systems involve **chilled water air handlers** (CRAHs) connected to a water-cooled chiller plant, with cooling towers providing water-side economization

during cooler outdoor temperatures. In this case, water is consumed year-round, even during economizer operation, adding additional operating costs. Regular water treatment is required for the **open cooling tower system**. Many end-users do not operate these systems during ‘shoulder seasons’ when the system could changeover during nighttime and daytime. Instead, they prefer to changeover to economizer operation only when the system will stay in that operating mode for an extended period of time. This results in a reduction in economizer use, compared to the Liebert DSE system that automatically changes between economizer mode and DX mode in a matter of a few seconds.

The Liebert DSE system’s combination of DX mode operation during warmer temperatures and refrigerant economizer mode during cooler temperatures results in a mechanical power usage effectiveness (PUE) between 1.05 and 1.3. However, in some climates, economization is not always necessary to meet ASHRAE 90.1 efficiency standards, nor is a fast payback always attainable to justify investment in economizer systems. As such, it is important to note that the **Liebert DSE, even when used solely in the standard direct expansion operating mode, is still capable of exceeding minimum efficiency standards by up to 53 percent¹.**

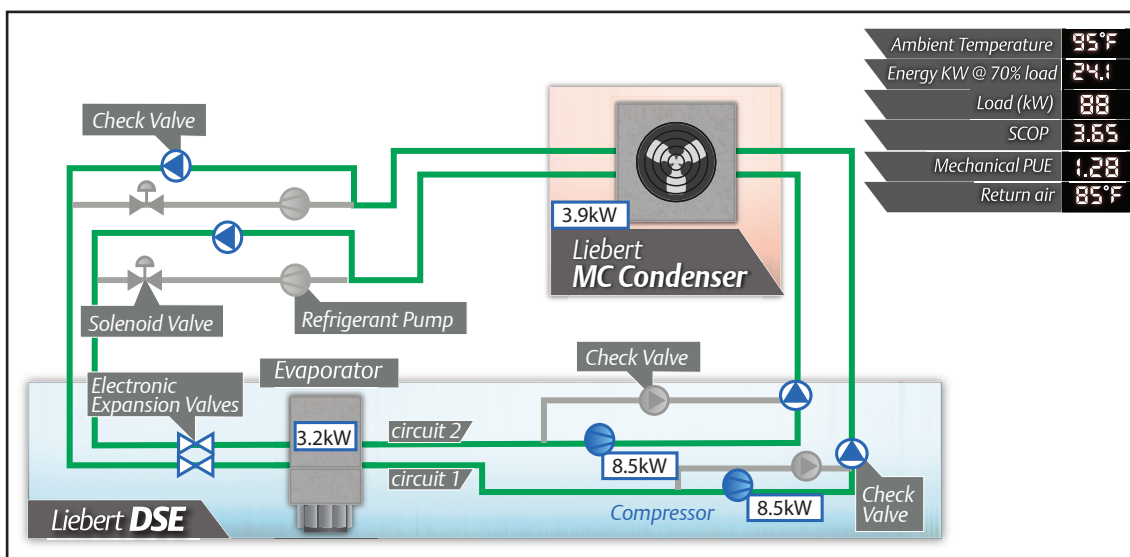


Figure 2: Summer and High Ambient Temperatures: DX-Only Operation

For a load of 88 kW, the cooling system consumes only 24.1 kW of power, resulting in a sensible coefficient of performance (SCOP) of 3.65, or a mechanical PUE of 1.28.

Optimizing Cooling System Operating Modes to Ambient Conditions

The operation of the Liebert DSE and corresponding Liebert EconoPhase™ system is adaptable based on the ambient seasonal temperatures and the overall IT load of the data center. The following examples model a data center operating at 88 kW of load on the system (70 percent load when using a 125kW, DA125 model).

Summer and High Ambient Temperatures: DX-Only Operation

The example in **Figure 2** represents a data center operating at 70 percent load, experiencing ambient outdoor temperatures of 95°F. During warm summer months, the Liebert® EconoPhase™ refrigerant pump system is idled, routing refrigerant instead through the evaporator, dual compressors and outdoor condenser. To maximize efficiency in this scenario, the variable-speed evaporator fans, variable speed condenser fans, and the digital scroll compressors automatically adjust to match the load and optimize energy usage.

However, even in this highly efficient system (which achieves SCOP of 3.65, compared to the industry standard 1.9 at 75°F return air), more than 70 percent of the cooling system’s total energy draw is utilized by the compressors, emphasizing the overarching importance of compressor efficiency or reduced compressor operation— particularly in warm climates.

During cooler parts of the year or at night, the refrigerant economizer may have the ability to provide partial free cooling, offsetting some of the compressor power.

Nighttime and Cooler Ambient Temperatures: Mixed-Mode Operation

During cooler times, such as mild seasons and at night, the refrigerant economizer has the ability to provide partial free cooling, offsetting some of the compressor power usage. Assuming an 85°F return air temperature to the CRAC unit, when the outdoor ambient temperature drops to 65°F (as shown in **Figure 3**), Liebert EconoPhase can begin to reduce energy even further by offering partial economization.

Because the Liebert DSE™ is equipped with a staged evaporator coil, the system’s refrigerant Circuit One is seeing the highest return air temperatures (85°F in this case), meaning the return air is warmer inside than the outdoor ambient air temperature. In this case, the outer cooling coil acts as the primary economizer circuit by using one Liebert EconoPhase pump to provide cool refrigerant to the indoor heat exchanger, essentially pre-cooling the air. The remainder of cooling required is accomplished by the compressor on the second circuit.

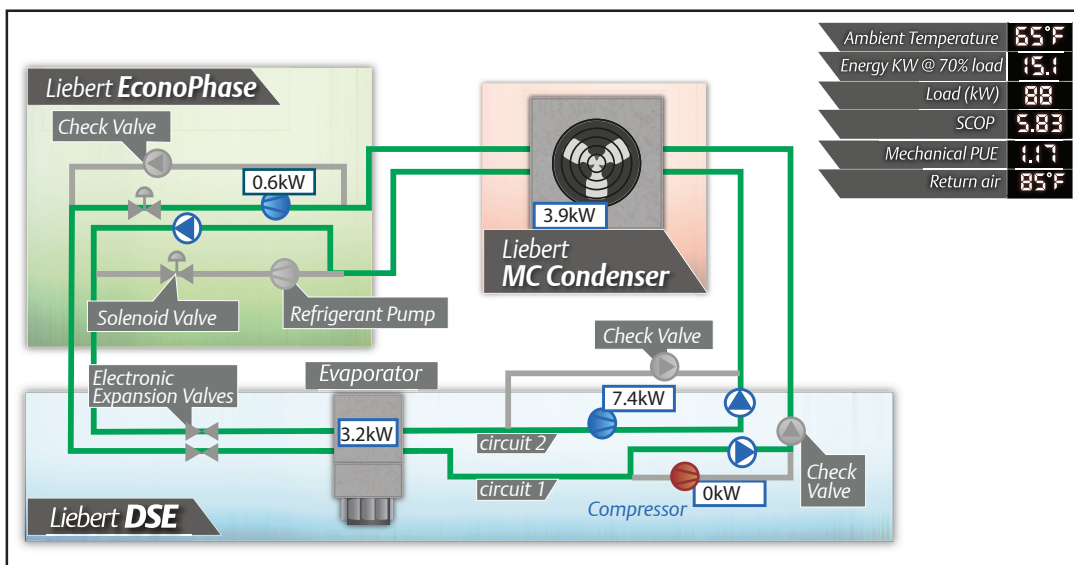


Figure 3: Nighttime and Cooler Ambient Temperatures: Mixed-Mode Operation

The refrigerant bypasses the CRAC’s first compressor, allowing it to idle. Pump One of the Liebert EconoPhase is activated, using only 0.6 kW—a net savings of 6.8kW. The resulting system efficiency is a lower cooling PUE of 1.17, or a system SCOP of 5.83.

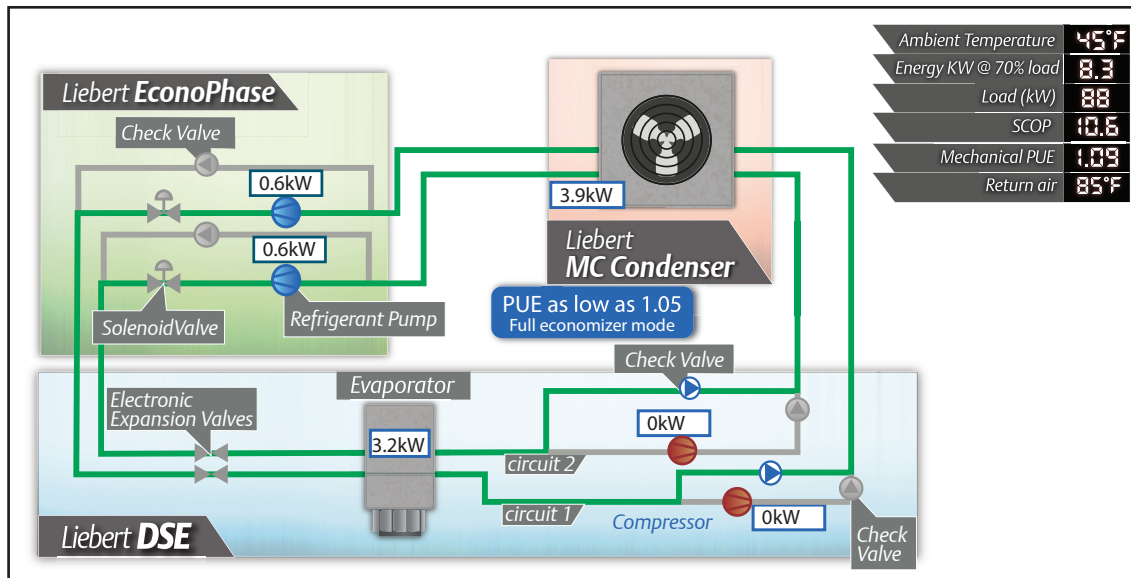


Figure 4:
Cold-Weather
Operation: Pumped
Refrigerant
Economization with
Compressor Bypass

In essence, a total of 14.8 kW of compressor power has been replaced by 1.2 kW of pump power. The result is a cooling PUE of only 1.09, or 9 kW of power for the cooling system for every 100 kW of IT load.

Cold-Weather Operation: Pumped Refrigerant Economization with Compressor Bypass

Finally, as shown in **Figure 4**, when outdoor temperatures are at their lowest (particularly in winter months), the Liebert DSE can leverage the Liebert EconoPhase system to operate at full economization. In this scenario (45°F ambient), all of the Liebert DSE system’s compressors are idled and bypassed, replaced entirely by the Liebert EconoPhase system’s refrigerant pumps. Condenser fans also operate at lower power because colder outdoor air requires less condenser airflow.

This translates to SCOP of 10.7, more than 5.5 times the ASHRAE minimum efficiency requirement at 75°F return air conditions. When operating at full economization at temperatures below 45°F or at lower load, the Liebert DSE is able to achieve a cooling PUE as low as 1.05 and SCOP above 20—nearly ten times the required efficiency targets in ASHRAE 90.1. These efficiency levels also can be realized at higher ambient temperatures by increasing the supply air temperature to the CRAC unit.

Efficiency Profile Based on Outdoor Ambient Temperatures

As these examples have demonstrated, the Liebert DSE is designed to adapt its operation to the ambient environment in order to maximize the efficiency and cooling effectiveness of its DX CRAC unit and pumped-refrigerant economizer. To

better understand and quantify the progression of efficiency gains as outdoor temperatures change, consider the example illustrated in **Figure 5**.

As previously discussed, the Liebert DSE is capable of operating above SCOP of 5.0 during DX operation when operating with 85°F return air to the cooling unit and 80 percent load (assuming outdoor ambient is less than design day temperature). As the ambient temperature decreases, the first stage of economization is automatically activated by the Liebert DSE iCOM™ control system, bringing the SCOP to about 12. Once the ambient temperature reaches approximately 40°F, full economization is realized and efficiency continues to increase as ambient temperatures decrease – with SCOP peaking at about 22 kW/kW, or a cooling PUE of about 1.05.

As this example illustrates, the Liebert DSE transition from mechanical (compressor) cooling to economizer mode is seamless and automatic, capable of moving in and out of economization several times a day, if needed. At these conditions, significant economizer hours can be realized. The system operates as an integrated economizer, meaning it is capable of operating in partial economizer and partial DX mode, if needed.

It is important to note that while this particular example illustrates an 85°F return air application, this scenario scales for other return air conditions. To further illustrate this point, consider **Figure 6**. When operating at 70 percent load with

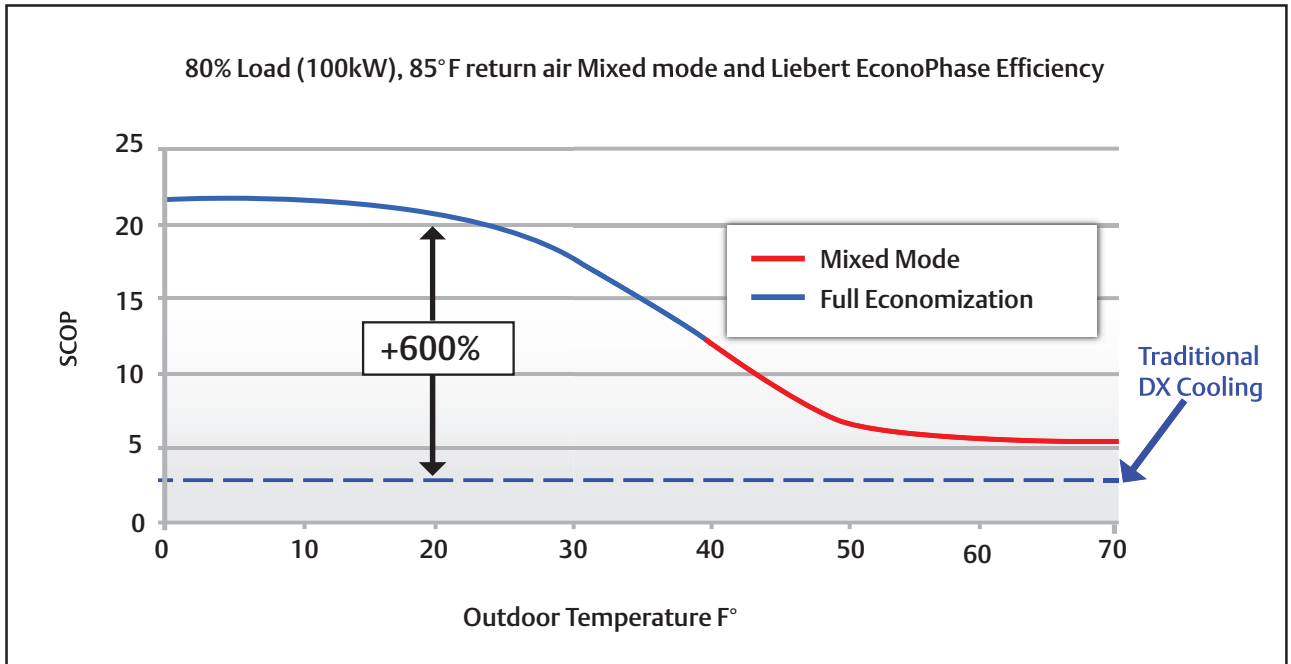


Figure 5: Liebert® EconoPhase™ efficiency progression according to outdoor ambient temperature (operating at 80 percent load).

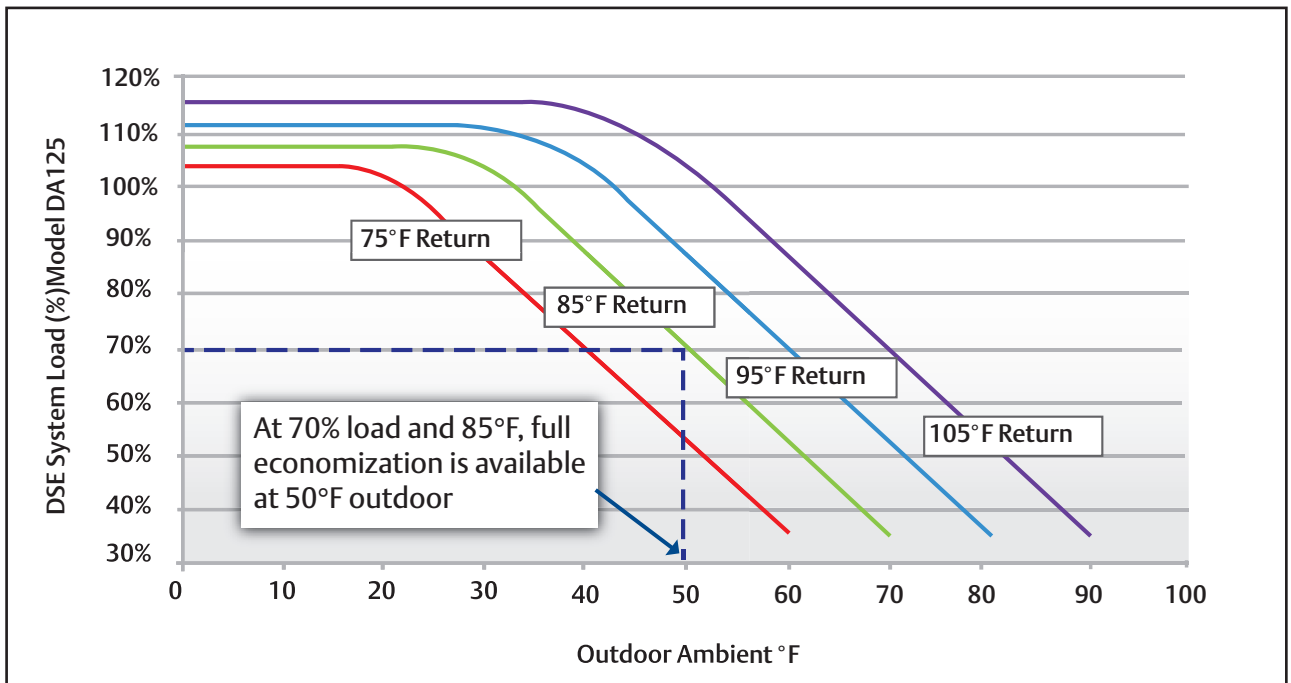


Figure 6: Liebert EconoPhase efficiency progression according to outdoor ambient temperature and system operating load.

return air temperatures of 85°F, 100 percent economization is achieved at an outdoor ambient temperature of 50°F. Increasing the return air to 105°F at 70 percent operating load results in 100 percent economization at just over 70°F outdoor ambient temperature, enabling even more economizer hours.

The key takeaway is that, in order to maximize economization, three factors must be optimized: return air temperature, operating load and outdoor ambient temperatures.

Comparing Efficiency and Total Cost of Ownership

As illustrated by the previous examples, the efficiency of economizer-based cooling systems can vary widely according to the outdoor ambient temperature. This fact is what makes the Liebert® DSE™ system’s flexible and intelligent mixed-mode operating capabilities an ideal choice for maximizing cooling efficiency.

As shown in **Figure 7**, a traditional DX system (red line) starts at about 1.5 cooling PUE on design day, and then levels out to about 1.35 as the ambient temperature drops. By comparison, the Liebert DSE (green line) system starts with a cooling PUE of just over 1.3, and bottoms out at

The Liebert DSE can deliver a payback in less than three years compared to traditional air-cooled DX systems, but without the hassles and risks of other types of economizer systems.

about 1.05, thanks to its ability to dynamically optimize operations according to return air and outdoor ambient temperatures. A chilled water system with air economizer is also shown for comparison (blue line). The cooling PUE for these systems start at about 1.28, and plateau at about 1.2. However, in theory, if air economizers are working perfectly and humidity control is not assumed, the minimum cooling PUE of this system can be as low as 1.13.

While this accurately portrays PUE at a specific outdoor temperature, the annualized PUE depends largely on how many hours the system operates at each temperature. As such, colder climates will log more hours at lower ambient temperatures, resulting in a lower annualized PUE than a climate that does not have as many of these low ambient hours available. However, as previously demonstrated, lower annualized PUE is attainable for data centers in warmer climates by deploying the Liebert DSE and raising return air temperatures.

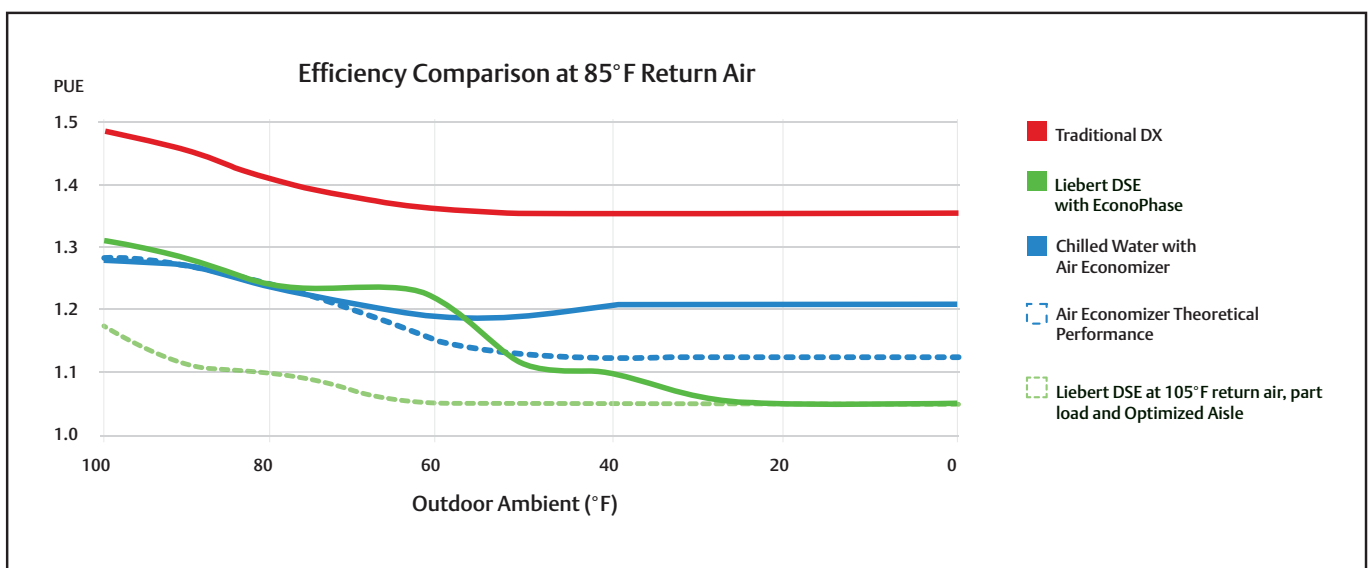


Figure 7: Comparing cooling system efficiency changes based on outdoor ambient temperatures.

Regardless of the system used, an intelligent control system that evaluates room load, room temperature (or supply air temperature) and outdoor temperature must be employed to determine the most optimal operation of system.

When considering total cost of ownership, the Liebert® DSE™ with Liebert EconoPhase™ system also compares very favorably to alternative cooling systems. In order to compare systems, a complete picture of system costs must be known and compared. As shown in **Figure 8**, the Liebert DSE can deliver a payback in less than three years compared to traditional air-cooled DX systems, but without the hassles and risks of other types of economizer systems.

Conclusion

As this brief has demonstrated, the Liebert DSE cooling system from Emerson Network Power represents the industry’s most flexible, reliable and efficient DX solution. The Liebert DSE achieves industry-leading efficiency by offering a modular, end-to-end cooling infrastructure, complete with a high-efficiency indoor CRAC unit, a hassle-free pumped-refrigerant economizer, micro-channel outdoor condensers with variable-speed fan technology and a comprehensive data center intelligence and management system built-in.

Collectively, these components make up a cooling infrastructure capable of delivering the lowest possible total cost of ownership and the highest levels of reliability compared to competitive solutions – all backed by the largest and most experienced sales and support team in the data center industry.

	Traditional Air-Cooled DX	Chilled Water	Chilled Water	Liebert DSE with EconoPhase
Economizer	None	None	Air Economizer	Pumped Refrigerant
Energy Cost	\$416,000	\$276,000	\$251,000	\$231,000
Water Cost	\$0	\$32,000	\$21,000	\$0
Total Utility	\$416,000	\$308,000	\$272,000	\$231,000
Annual Cooling PUE	1.32	1.21	1.19	1.16
Capital Cost	\$1,900,000	\$2,200,000	\$3,100,000	\$2,500,000
Payback	Base	4.9 years	5.6 years	2.7 years
15-Year PV	\$5,200,000	\$4,900,000	\$5,600,000	\$4,100,000

Figure 8: Analysis of total cost of ownership across cooling system options, taking into consideration capital expenditure and operating expenditure for a data center with a 1,500 kW load, \$0.10/kWh utility cost and 40 degree dew point limit, based on Columbus, Ohio weather data. The chilled water systems assume an entering water temperature of 50°F, with a water temperature difference of 12°F.

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