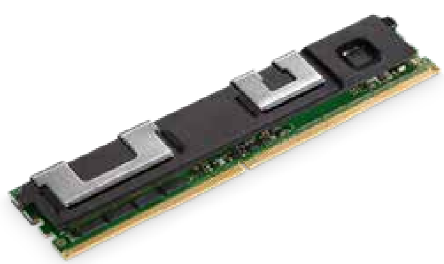
PRODUCT BRIEF

Data Center
Intel® Optane™ DC Persistent Memory

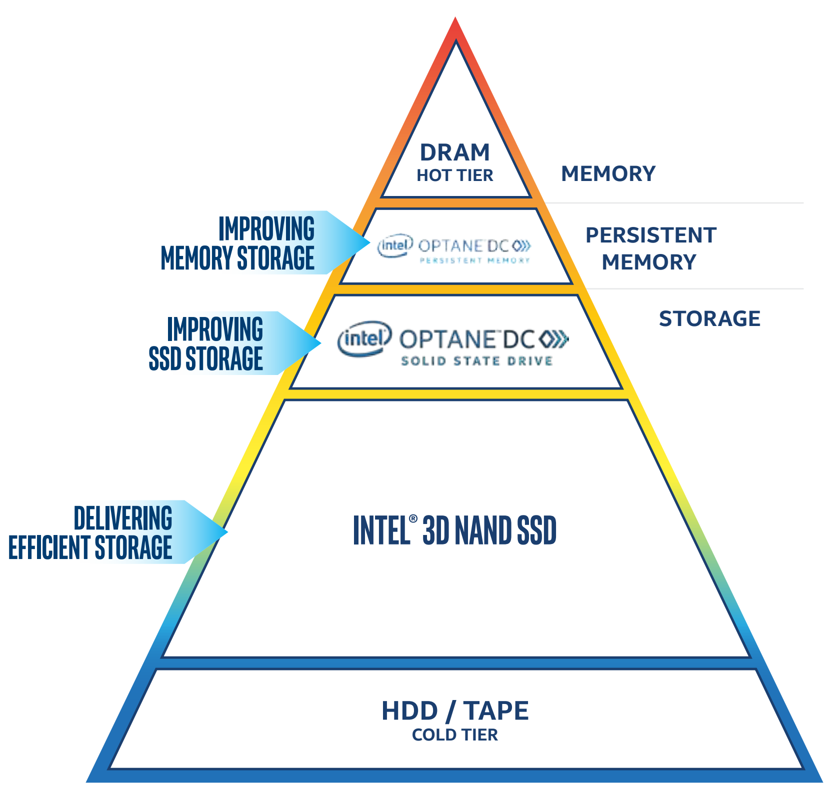
The Challenge of Keeping Up With Data



Every Day, the Amount of Data Created Across the World is Exploding to New Levels

Every day, the amount of data created across the world is exploding to new levels. Businesses thrive on this data to make critical decisions, gain new insights, and differentiate services. The demand for memory capacity is growing at an insatiable rate and there is a need to keep larger amounts of data closer to the CPU.
The technology that dominates traditional main memory, DRAM, is fast to access, but small, expensive, and volatile. Storage is large, cheap, persistent, but is slow to access. There is a huge latency and bandwidth penalty as you jump from RAM based memory and disk based storage. The ever increasing amount of data and the need to access more of it quickly have further magnified the gap. Intel's breakthrough product, Intel® Optane™ DC persistent memory, is disrupting the traditional memory-storage hierarchy by creating a new tier to fill the memory-storage gap providing greater overall performance, efficiency, and affordability.

INTERNET TECHNOLOGY COMPLETES THE HIERARCHY



Introducing Intel® Optane™ DC Persistent Memory

The new Intel Optane DC persistent memory introduces a new category that sits between memory and storage and will deliver the best of both worlds through the convergence of memory and storage product traits. Intel Optane DC persistent memory is available in capacities of 128 GiB, 256 GiB and 512 GiB and is a much larger alternative to DRAM which currently caps at 128 GiB. With this new flexible tier of products, designers and developers will have access to large capacity and affordable memory that is both flexible (volatile or non-volatile) and serves as a high-performance storage tier. They will also have the option of application managed memory which is vital to optimize system performance. The low, consistent latency, combined with high bandwidth, Quality of Service (QoS) and endurance of this unique Intel technology will mean more capacity and more virtual machines (VMs) for cloud and virtualized users, much higher capacity for in-memory databases without prohibitive price tags, super-fast storage, and larger memory pools. Ultimately, Intel can deliver higher system performance with larger memory that is 3X the performance of NVMe-SSD, with much higher endurance than NAND SSDs for write-intensive workloads.

The persistent memory modules are DDR4 socket compatible and can co-exist with conventional DDR4 DRAM DIMMs on the same platform. The module fits into standard DDR4 DIMM slots on 2nd Generation Intel® Xeon® Scalable processors. Deigned with and optimized for the 2nd Generation Intel Xeon Scalable processors, a user can have up to one Intel Optane DC persistent memory per channel and up to six on a single socket providing up to 3 TiB of Intel Optane DC persistent memory which means an 8 socket system could access up to 24 TiB of system memory. The module is compatible with 2nd Generation Intel® Xeon® Gold and Platinum processor SKUs.

Intel Optane DC persistent memory is big, affordable, and persistent which makes extracting more value from larger data sets than previously possible. This new technology can solve issues for customers and launch a revolution in the data center. Finally an affordable alternative to expensive DRAM, that can deliver HUGE capacity and can accommodate demanding workloads and emerging applications like in-memory databases (IMDB). When deployed, Intel Optane DC persistent memory can help improve TCO via not just memory savings, but broadly via reduced SW licensing costs, node reduction, power efficiencies, and other operational efficiencies.

Not only can Intel Optane DC persistent memory bring cost savings, it can improve infrastructure consolidation making your servers do more. Intel Optane DC persistent memory can spur major infrastructure consolidation. The increase in memory size from Intel Optane media provide the opportunity to consolidate workloads that have been spread across several nodes, leaving CPUs underutilized, to concentrating and consolidating workloads on fewer nodes, ultimately saving on the deployments necessary and maximizing CPU utilization. Each Node does more, and the CPU can do more.

Intel Optane DC persistent memory brings an entirely new memory tier that has new properties of performance and persistence, and architects and developers are using it as a springboard for innovation taking advantage of new usages around restart and replication, groundbreaking performances from breaking system bottlenecks that used to severely constrain workloads, and making use of what could be considered the world's tiniest, but fastest storage device sitting on a memory bus.

Operational Modes

The Intel Optane DC persistent memory has two operating modes: Memory Mode and App Direct Mode. With distinct operating modes, customers have the flexibility to take advantage of Intel Optane DC persistent memory benefits across multiple workloads.

Memory Mode – Memory Mode is great for large memory capacity and does not require application changes which makes Intel Optane DC persistent memory easy to adopt. In Memory Mode, the Intel Optane DC persistent memory extends the amount of available volatile memory visible to the Operating System. DRAM is used as Cache for the Intel Optane DC persistent memory. The CPU memory controller uses the DRAM as cache and the Intel Optane DC persistent memory as addressable main memory. Virtualization can benefit from Intel Optane DC persistent memory in Memory Mode because there is larger memory capacity which provides more VMs and more memory per VM at a lower cost compared to DRAM. Workloads that are I/O bound can also benefit from using Memory Mode as the Intel Optane DC persistent memory provides larger memory capacity which supports larger databases and at a lower cost compared to DRAM. With increased capacity there is greater VM, container, and application density which increases the utilization of the 2nd Generation Intel Xeon Scalable processors. The data in the Intel Optane DC persistent memory when used in Memory Mode is volatile as it is handled with a single encryption key that upon power down is discarded making the data inaccessible.

App Direct Mode – In App Direct Mode, software and applications have the ability to talk directly to the Intel Optane DC persistent memory, which reduces complexity in the stack. There is the option of having App Direct Mode use legacy storage APIs. This allows it to act like an SSD and can boot an OS. The operating system sees Intel Optane DC persistent memory and DRAM as two separate pools of memory. It is persistent like storage, byte addressable like memory, cache coherent which extends the usage of persistent memory outside the local node, and consistent low latency supporting larger datasets. The power of persistent memory adds business resilience to systems with faster restart times because data is retained even during power cycles. Memory bound workloads benefit from Intel Optane DC persistence with its large capacity and higher endurance and greater bandwidth compared to NAND SSDs.

Dual Mode – a sub-set of App Direct, can be provisioned so that some of the Intel Optane DC persistent memory is in Memory Mode and the remaining is in App Direct Mode. In Dual Mode, applications can take advantage of high performance storage without the latency of moving data to and from the I/O bus.

Security

Intel Optane DC persistent memory has 256-AES hardware encryption so you can rest easy knowing your data is more secure. While in Memory Mode the Intel Optane DC persistent memory encryption key is removed when powered down and is regenerated at each boot. This means data is no longer accessible. In App Direct Mode data is encrypted using a key on the module. Intel Optane DC persistent memory is locked at power loss and a passphrase is needed to unlock and access the data. The encryption key is stored in a security metadata region on the module and is only accessible by the Intel Optane DC persistent memory controller. If repurposing or discarding the module, a secure cryptographic erase and DIMM over-write is utilized to keep data from being accessed.

Extract More Value from Larger Data Sets Than Previously Possible

With the advent of larger persistent memory capacities, larger datasets can exist closer to the CPU for faster processing which mean greater insights. Higher capacities of Intel persistent memory create a more affordable solution which is accelerating this industry-wide trend towards IMDB. Delivered on the 2nd Generation Intel Xeon Scalable processors, large memory-bound workloads will have significant performance increase for rapid data processing.

With Intel persistent memory, customers will have large capacity memory to choose from which means that they can support bigger datasets for analysis. An additional benefit here is that the CPU can read/write cache lines to Intel persistent memory, which means overhead of constructing the data into 4 KB blocks to be written to disk is eliminated. Intel persistent memory will offer many of these benefits through App Direct mode with higher reliability as Intel Optane DC persistent memory can handle more petabytes written than NAND SSDs. Customers can also benefit from the module's native persistence which provides quicker recovery and less downtime compared to DRAM all at a much lower cost.

Many mission critical databases and enterprise apps store large amounts of data in working memory. If a server goes down, either planned or not, it can take hours to re-load the memory array, increasing the downtime. Application downtime can be measured in thousands of dollars per minute. Since Intel Optane DC persistent memory retains data during power cycles, these types of applications can be returned to service orders of magnitude faster. This means enterprises, cloud, and communication service providers can consistently meet their SLAs and avoid expensive system redundancy costs. An example is SAP HANA which can realize a 13x faster restart time at a 39% cost savings.[1,2,3,4,5]

Scale Delivery of More Services to More Customers at Compelling Performance

Virtual machines are requiring bigger amounts of data. Having larger memory capacity near the CPU means that customers can support more virtual machines and more memory per virtual machine all at a cost lower than typical DRAM. Before Intel Optane DC persistent memory, the memory system was constrained and the CPU was underutilized. Consequently, this severely limits performance. Now Intel Optane DC persistent memory enables more virtual machines (VM), or larger VMs at a lower HW cost per VM. With Microsoft Windows Server 2019/Hyper-V, customers can realize 33% more system memory, 36% more VMs per node all at a 30% lower hardware cost.[1,2,6,7]

Drive Application Innovation and Explore New Data-intensive Use Case with this Best-in-Class Product

With Intel Optane DC persistent memory introducing a new tier of memory, with its compelling new characteristics, and the ability to have direct load load/store access to it, developers are able to drive new innovation and capabilities.

Rapid adoption is easier and customers are able to take full advantage of the Intel Optane DC persistent memory

MORE CAPACITY, GO FASTER, SAVE MORE

for **SAP HANA**

	DRAM ONLY	DRAM+ intel OPTANE DC PERSISTENT MEMORY	
MORE CAPACITY	3 TB DRAM	+ 6 TB INTEL® OPTANE™ DC PERSISTENT MEMORY	= 9 TB TOTAL
GO FASTER MINIMIZE DOWNTIME	RESTART TIME 20 MINS	RESTART TIME 90 SECONDS	13X Faster Restart[1,2,3,4]
SAVE MORE COST/DB TERABYTE	~$62,495 USD	~$38,357 USD	39% Cost Savings[5]

Pricing Guidance as of March 1, 2019. Intel does not guarantee any costs or cost reduction.
You should consult other information and performance tests to assist you in your purchase decision.

capabilities with a growing global ecosystem of ISVs, OSVs, virtualization providers, database and enterprise applica-tion vendors, data analytics vendors, open source solutions providers, Cloud Service Providers, and HW OEMs, Standards bodies such as the Storage Network Industry Association (SNIA), ACPI, UEFI, and DMTF.

Programming Model

The software interface for using Intel Optane DC persistent memory was designed in collaboration with dozens of companies to create a unified programming model for persistent memory. The Storage Network Industry Association (SNIA) formed a technical workgroup which has published a specification of the model. This software interface is independent of any specific persistent memory technology and can be used with Intel Optane DC persistent memory or any other persistent memory technology.

The model exposes three main capabilities:

- The management path allows system administrators to configure persistent memory products and check their health.
- The storage path supports the traditional storage APIs where existing applications and file systems need no change; they simply see the persistent memory as very fast storage.
- The memory-mapped path exposes persistent memory through a persistent memory-aware file system so that applications have direct load/store access to the persistent memory. This direct access does not use the page cache like traditional file systems and has been named DAX by the operating system vendors.

When an independent software vendor (ISV) decides to fully leverage what persistent memory can do, converting the application to memory map persistent memory and place data structures in it can be a significant change. Keeping track of persistent memory allocations and making changes to data structures as transactions (to keep them consistent in the face of power failure) is complex programming that hasn't been required for volatile memory and is done differently for block-based storage.

The Persistent Memory Development Kit (PMDK – http://pmem.io) provides libraries meant to make persistent memory programming easier. Software developers only pull in the features they need, keeping their programs lean and fast on persistent memory.

These libraries are fully validated and performance-tuned by Intel. They are open source and product neutral, working well on a variety of persistent memory products. The PMDK contains a collection of open source libraries which build on the SNIA programming model. The PMDK is fully documented and includes code samples, tutorials and blogs. Language support for the libraries exists in C and C++, with support for Java, Python*, and other languages in progress.

Turn Your Data from a Burden to an Asset

Intel® Optane™ DC persistent memory represents a groundbreaking technology innovation. Delivered with the next-generation Intel® Xeon® Scalable processor, this technology will transform critical data workloads—from cloud and databases, to in-memory analytics, and content delivery networks.

WINDOWS SERVER* 2019/HYPER-V - MULTI-TENANT VIRTUALIZATION

Workload – Windows Server 2019/Hyper-V with OLTP Cloud Benchmark

	DDR4 DRAM ONLY	DDR4 DRAM+ Intel Optane DC Persistent Memory — Memory Mode	
DO MORE	768 GB DDR4 DRAM 22VMS	192 GB DDR4 DRAM +1 TB INTEL® OPTANE™ DC PERSISTENT MEMORY 30VMS	UP TO 33% more memory[1,2,6] UP TO 36% more VMs per node[1,2,6]
SAVE MORE	~$1,588 USD/VM	~$1,108 USD/VM	UP TO 30% lower HW cost per VM[7]

Pricing Guidance as of March 1, 2019. Intel does not guarantee any costs or cost reduction.
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INTEL OPTANE DC PERSISTENT MEMORY DATA SHEET

PRODUCT FAMILY	Intel® Optane™ DC Persistent Memory					
FORM FACTOR	Persistent Memory Module (PMM)					
DCPMM SKU[1]	128 GiB		256 GiB		512 GiB	
USER CAPACITY	126.4 GiB[8]		252.4 GiB[8]		502.5 GiB[8]	
MOQ	4	50	4	50	4	50
MM#	999AVV	999AVW	999AVX	999AVZ	999AW1	999AW2
PRODUCT CODE	NMA1XXD128GPSU4	NMA1XXD128GPSUF	NMA1XXD256GPSU4	NMA1XXD256GPSUF	NMA1XXD512GPSU4	NMA1XXD512GPSUF
MODEL STRING	NMA1XXD128GPS		NMA1XXD256GPS		NMA1XXD512GPS	
TECHNOLOGY	Intel® Optane™ Technology					
LIMITED WARRANTY	5 years					
AFR	≤ 0.44					
ENDURANCE 100% WRITES 15W 256B	292 PBW		363 PBW		300 PBW	
ENDURANCE 100% WRITES 15W 256B	91 PBW		91 PBW		75 PBW	
ENDURANCE 100% READ 15W 64B	6.8 GB/s		6.8 GB/s		5.3 GB/s	
ENDURANCE 100% WRITES 15W 256B	1.85 GB/s		2.3 GB/s		1.89 GB/s	
ENDURANCE 100% READ 15W 64B	1.7 GB/s		1.75 GB/s		1.4 GB/s	
ENDURANCE 100% WRITES 15W 64B	0.45 GB/s		0.58 GB/s		0.47 GB/s	
DDR FREQUENCY	2666, 2400, 2133, 1866 MT/s					
MAX TDP	15W		18W			
TEMPERATURE (TJMAX)	≤ 84 oC (85 oC shutdown, 83 oC default) media temperature					
TEMPERATURE (TAMBIENT)	54 oC @ 2.4m/s for 10W					
TEMPERATURE (TAMBIENT)	49 oC @ 2.4m/s for 12W					
TEMPERATURE (TAMBIENT)	44 oC @ 2.7m/s for 15W					
TEMPERATURE (TAMBIENT)	N/A		40 oC @ 3.7m/s for 18W			

NOTES: [1]GiB = 2^{30}; GB = 10^{9}

Learn more at intel.com/optanedcpersistentmemory

[1] Performance results are based on testing as of Jan 30, 2019 and may not reflect all publicly available security updates. No product or component can be absolutely secure.

[2] Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to www.intel.com/benchmarks.

[3] Columnar store entire reload into DRAM for 1.3TB dataset is 20 mins. Entire system restart before is 32 Minutes and with DC PMEM it is 13.5 Minutes (12 mins for OS + 1.5 mins).

[4] 13x Faster Restart Time: Baseline Config (DRAM Only): System: Lightning Ridge (4s); CPU: Intel® Xeon® 8280M; CPUs per node: 4-socket @ 28 core / socket; Memory: 6 TB (48 x 128 GB DDR4 @ 2666 MT/s; Network: 10 GbE Intel X520NIC; Storage: 60x Intel SSD DC S4600 SATA 480 GB TB; BIOS: WW48'18; OS or VM version: SUSE 15; WL Version: Intel IT workload; SAP HANA* database size: 3TB; Security mitigations: Variants 1,2,3 enabled; Date costs projected: March 1, 2019.

Intel Optane DC persistent memory & DRAM Config: System: Lightning Ridge (4s); CPU: Intel® Xeon® 8280L; CPUs per node: 4-socket @ 28 core / socket; Memory: 9TB (248 x 256 GB Intel® Optane™ DC persistent memory, 24 x 128 GB DDR4 @ 2666 MT/s; Network: 10 GbE Intel X520NIC; Storage: 90x Intel SSD DC S4600 SATA 480 GB TB; BIOS: WW48'18; OS or VM version: SUSE 15; WL Version: Intel IT workload; SAP HANA* database size: 3TB; Security mitigations: Variants 1,2,3 enabled; Date costs projected: March 1, 2019.

[5] Baseline Config (DRAM Only): # of systems: 5; Memory Sub System Per Socket: DRAM – 1536 GB (12x128 GB); CPU SKU|# per system: 8280M (CLX, Plat, 28core)|4; Storage Description|Total Storage Cost: # of HDD/SDDs|$36,000; SW License Description|Cost per System: SW Cost (per/core or per system)|$0; Relevant Value Metric:15.00; CPU Cost: 4x8280M (CLX, Plat 28core): $52,048; Memory subsystem: Total Capacity (DRAM only): 6144 GB (1536 GB/Socket): $91,834; Storage: #of HDD/SDDs: $36,000; RBOM: Chassis; PSUs; Bootdrive, etc: $7,603; SW Costs: $0; Total System Cost: $187,485; Total Cost: 5 Systems x $187,485: $937,424; Cost/TB: $62,494.95.

Intel Optane DC persistent memory & DRAM Config: # of systems: 5; Memory Sub System Per Socket: 2304 GB (6x256 GB DCPMM + 6x128 GB DRAM, 2-2-2 App Direct Mode; CPU SKU|# per system: 8280L (CLX, Plat, 28core)|4; Storage Description|Total Storage Cost: # of HDD/SDDs|$54,000; SW License Description|Cost per System: SW Cost (per/core or per system)|$0; Relevant Value Metric:30.00; CPU Cost: 2x8280L (CLX, Plat 28core): $71,624; Memory subsystem: Total Capacity (Intel Optane DC persistent memory+DRAM): 9216 GB (2304 GB/Socket): $96,917; Storage: #of HDD/SDDs: $54,000; RBOM: Chassis; PSUs; Bootdrive, etc: $7,603; SW Costs: $0; Total System Cost: $230,144; 5 Systems x $230,144: $1,150,720; Cost/TB: $38,357.32.

[6] Baseline Config (DRAM Only): Nodes: 1; Sockets: 2; CPU: Cascade Lake B08272L; Cores/socket, Threads/socket: 26, 52; HT: ON; Turbo: ON; BKC version: WW42'18; Intel Optane DC persistent memory FW version: 5253; System DDR Mem Config: slots/cap/run-speed; 24 slots/32 GB/2666 MT/s; Total Memory/Node (DDR, Intel Optane DC persistent memory) 768 GB, 0; Storage – boot: 1x Samsung PM963 M.2 960 GB; Storage application drives: 7 x Samsung PM963 M.2 960 GB, 4x Intel SSDs S4600 (1.92 TB); Network: Intel X520SR2 (10 Gb); PCH LBG QS/PRQ-T-B2; OS: Windows Server 2019 RS5-17763; Workload & version: OLTP Cloud Benchmark.

Intel Optane DC persistent memory & DRAM Config: Nodes: 1; Sockets: 2; CPU: Cascade Lake B08272L; Cores/socket, Threads/socket: 26, 52; HT: ON; Turbo: ON; BKC version: WW42'18; Intel Optane DC persistent memory FW version: 5253; System DDR Mem Config: slots/cap/run-speed; 12 slots/16 GB/2666 MT/s; System Intel Optane DC persistent memory Config: slots/cap/run-speed: 8 slots/128 GB/2666 MT/s; Total Memory/Node (DDR, Intel Optane DC persistent memory) 192 GB, 1 TB; Storage – boot: 1x Samsung PM963 M.2 960 GB; Storage application drives: 7 x Samsung PM963 M.2 960 GB, 4x Intel SSDs S4600 (1.92 TB); Network: Intel X520SR2 (10 Gb); PCH LBG QS/PRQ-T-B2; OS: Windows Server 2019 RS5-17763; Workload & version: OLTP Cloud Benchmark. Running 4 vCPUs per VM, 32 GB memory per VM.

[7] Baseline Config (DRAM Only): # of systems: 1; Memory Sub System Per Socket: DRAM – 284 GB (12x32 GB); CPU SKU|# per system: 3276 (CLX, Plat, 28core)|2; Storage Description|Total Storage Cost: # of HDD/SDDs|$7,200; SW License Description|Cost per System: SW Cost (per/core or per system)|$0; Relevant Value Metric:22.00; CPU Cost: 2x8276 (CLX, Plat 28core): $17,348; Memory subsystem: Total Capacity (DRAM only): 768 GB (384 GB/Socket): $8,993; Storage: #of HDD/SDDs: $7,200; RBOM: Chassis; PSUs; Bootdrive, etc: $1,300; SW Costs: $0; Total System Cost: $34,931.

Intel Optane DC persistent memory & DRAM Config: # of systems: 1; Memory Sub System Per Socket: 2 GB (4x128 GB DCPMM+6x16 GB DRAM, 2-2-1, Memory Mode; CPU SKU|# per system: 3276 (CLX, Plat, 28core)|2; Storage Description|Total Storage Cost: # of HDD/SDDs|$7,200; SW License Description|Cost per System: SW Cost (per/core or per system)|$0; Relevant Value Metric:22.00; CPU Cost: 2x8276 (CLX, Plat 28core): $17,348; Memory subsystem: Total Capacity (Intel Optane DC persistent memory+DRAM): 1024 GB (512 GB/Socket): $7,306; Storage: #of HDD/SDDs: $7,200; RBOM: Chassis; PSUs; Bootdrive, etc: $1,300; SW Costs: $0; Total System Cost: $33,244.

[8] PV FW 1.2.0.5355

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