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IBM **IT Economics Consulting & Research**

2020 marks the 20th anniversary of Linux® on IBM Z® and IBM contributions to the Linux open source community. In 1999, IBM first announced its support for the open source Linux operating system. Since that time IBM has invested considerable financial, technical, and marketing resources to foster the growth, development, and use of Linux technology, and has made significant contributions to the community on which Linux relies.

Even before Linux was cool, IBM was one of the earliest champions of open source, backing influential communities like Linux, Apache, and Eclipse. IBM began pushing for and helped establish open licenses, open governance, and open standards. IBM supported Linux with patent pledges, a $1 billion investment of technical and other resources, and helped to establish the Linux Foundation in 2000.[1]

IBM has been a major contributor to the Linux kernel, ranking in the top ten corporate contributors and having maintainers for a wide range of Linux-kernel subsystems.[1] IBM has partnered with key Linux distributors such as Red Hat®, SUSE and Canonical to exploit IBM Z and LinuxONE hardware technology to deliver Linux-based enterprise IT computing. And with the journey to the cloud, IBM has brought significant contributions to OpenStack® and Cloud Foundry. IBM also open sourced its serverless platform implementation called OpenWhisk.[2]

With the growing use of containers with cloud, IBM became an active contributor and advocate for open governance of Docker and became a founding sponsor of the Open Container Initiative in 2015. Shortly after IBM also helped launch the Cloud Native Computing Foundation to provide an open governance model for Kubernetes[2], the foundation for the Red Hat OpenShift® Container Platform on IBM Z, LinuxONE and other architectures.

What makes Linux on IBM Z secure

Workloads that access sensitive data are typically placed on IBM Z or LinuxONE to minimize the possibility of a security event. Both Integrated Facility for Linux (IFLs), that are processors dedicated to Linux workloads on IBM Z that support the Linux operating system for IBM Z, IBM z/VM® with IBM Wave for z/VM, KVM and container technologies, and LinuxONE, provide unique security benefits to lower the risk of a data or privacy breach. Linux on IBM Z and LinuxONE are certified with Hardware Security Module (HSM) Crypto Express cards at the highest level 4 of FIPS 140-210[3]. HSMs are hardened, tamper-resistant hardware devices that secure cryptographic processes by generating, protecting, and managing keys used for encrypting and decrypting data and creating digital signatures and certificates. IBM Z pervasive encryption with HSM-based key management[4] enable extensive encryption of data in-flight and at-rest to substantially simplify encryption, and reduce costs associated with protecting data.

IBM Z and LinuxONE also provide IBM Secure Service Containers[5], a combination of hardware, firmware, and software technologies, that are primarily extensions to IBM Processor Resource/System Manager (PR/SM) logical partitioning technologies which are Common Criteria Enterprise Assurance Level (EAL) 5+ certified for separation and isolation.

IBM Z and LinuxONE Cryptographic coprocessors deliver high throughput for cryptographic functions in crypto workloads[6] and cryptography for Linux guests on z/VM[7]. z/VM also provides security features for virtualized workloads such as Lightweight Directory Access Protocol (LDAP) and the Resource Access

[1] https://www.ibm.com/opensource/story/#section-before-open
[2] https://www.ibm.com/downloads/cas/EANR1VPJ
[3] *https://csrc.nist.gov/publications/detail/fips/140/2/final*
[4] https://www.ibm.com/downloads/cas/3V7EY7N9
https://www.ibm.com/blogs/systems/security-considerations-for-critical-environments
[5] https://www.ibm.com/support/pages/node/6019450
[6] https://www.ibm.com/security/cryptocards/hsms
[7] http://www.redbooks.ibm.com/redbooks/pdfs/sg248447.pdf

Control Facility (RACF®). RACF provides access control and auditing functionality for the z/OS® and z/VM operating systems.

IBM Data Privacy Passports can encrypt eligible data, and then grant, control, and revoke access to it, even as it moves off the system of record within an enterprise.[8]

Security capabilities on Linux on IBM Z and LinuxONE are centralized, meaning that administrators can monitor and efficiently manage security tasks from a single point of control for their entire IFL and LinuxONE enterprise. Centralized administration significantly simplifies the complexities of security encryption and compliance.

Enterprise Hybrid Cloud Elasticity with Linux on IBM Z

Seamless scale up

Linux on IBM Z and LinuxONE provide seamless scaling for hybrid cloud environments to meet the elasticity demands of enterprises. LinuxONE III can simultaneously run hundreds of workloads, by using up to 190 processors[9], along with on-chip acceleration for compression and encryption. Resources within an LPAR can be dynamically assigned to different workloads depending on the demand of the moment. Shared Memory Communication[9] allows for better efficiency at scale, performance and improves price/performance.

LinuxONE III offers up to 40TB of memory to allow for more in-memory workloads and in-line analytics for a richer transactional experience. On-chip accelerated compression enables use of pervasive encryption with almost zero overhead[10] for Linux workloads. IBM Dynamic Partition Manager (DPM) facilitates system administration with extended hardware configuration capabilities. DPM is designed to help non-mainframe centric system administrators to easily manage a system running Linux-only workloads without having to learn about defining Logical Partitions (LPARs). With DPM an administrator, can create a new partition including I/O configuration within 10 minutes through a single management endpoint[11], making management of Linux workloads easy and fast.

Containerization

LinuxONE takes advantage of Red Hat OpenShift Container and Kubernetes technology for IBM Cloud Paks™ that enable businesses to use containerized IBM middleware and common software services for development and management. Red Hat OpenShift, an open source container application platform based on the Kubernetes container orchestrator for enterprise app development, provides a common integration layer designed to reduce development time and operational expenses.

Red Hat OpenShift allows containerized workloads to be densely packed enabling easier management, and reducing operations expenses. DevOps automation across the application delivery lifecycle brings higher productivity and efficiencies resulting in higher business values. Red Hat OpenShift and Cloud Paks[12] enable LinuxONE to provide an efficient and cost-effective platform for PaaS (Platform as a Service).

[8] https://www.ibm.com/products/data-privacy-passports
[9] https://www.ibm.com/downloads/cas/ZV0EVLAK
[10] IBM testing with an OLTP banking application simulation running on z15 T01 showed less than a 0.5% change in performance with encryption and compression enabled on a 3 GB database. Results were achieved using Rational Performance Tester (RPT) to drive transactions in a 50,000 user simulated retail banking environment using a CICS v5.4 application that was colocated with Db2 v12 in one LPAR configured with 8 CPs, 1 zIIP and 32GB of memory on a z15 T01. Encryption and compression of Db2 were enabled (3 GB size database) and disabled (3.7 GB size database) from the IBM Data Facility Storage Management Subsystem (DFSMS) for the tests. Unencrypted tests resulted in an average of 10,108 TPS per utilized processor while the encrypted test resulted in an average of 10,059 TPS per utilized processor for a difference of 0.49%. Testing was performed in an IBM lab. Results will vary.
[11] https://www.vm.ibm.com/education/lvc/LVC0309.pdf
[12] https://www.ibm.com/downloads/cas/QWB9X1GE

Administration simplification

Not only do containers simplify DevOps, they can also help reduce wasted physical resources by enabling the deployment of more workloads in containers with less unused CPU, memory and IO that can occur in an x86 virtual machine server farm thus decreasing administration server efforts. IBM internal tests show that transaction workloads on x86 can be delivered at over four times the throughput and in half the response time using an IBM Cloud Pak container environment versus a virtual machine environment.[13]

LinuxONE also helps reduce server administration efforts with concurrent replace, repair, and upgrade functions for processors, memory, drawers, and I/O. These capabilities avoid downtime and accelerate recovery in the event of a hardware failure.

LinuxONE can alleviate administration overhead with fewer physical servers to manage, meaning less hardware maintenance, less network management, and simpler software patching. Additionally, centralized servers such as LinuxONE and IBM Z simplify the task of workload provisioning and deprovisioning by leveraging available capacity within the same physical server.

Mission critical ready with Linux on IBM Z

Availability

Customers expect services to be always "on" and accessible 24 hours x 365 days a year, regardless of planned downtimes for routine maintenance. Application outages can result in client dissatisfaction and revenue loss. LinuxONE is designed to deliver 99.999%[14] availability, enabling enterprises to be able to provide almost non-stop commerce through a combination of highly reliable software such as IBM GDPS®[15], that automates day-to-day IBM Z and LinuxONE management and disaster recovery processes and hardware capabilities such as Redundant Array of Independent Memory (RAIM) memory modules and transparent CPU sparing. RAIM protects the server from single-channel errors such as sudden control, bus, buffer, and massive dynamic RAM (DRAM) failures. LinuxONE CPU sparing is designed to prevent hardware cores from affecting the availability of critical workloads by enabling an available spare core to replace a lost core instantly.[7] Capacity Backup (CBU) for IFLs and LinuxONE can also be used for high availability in the event of a system or site outage.

Redundancy

Increasingly, business critical workloads that require 24x7 availability are often placed on IFLs on IBM Z or LinuxONE to leverage built-in redundancy and resiliency.[16] Capacity Backup (CBU) allows hardware engines to be used for disaster recovery (DR) without incurring additional software charges if a server is temporarily unavailable.[17] Unlike a distributed architecture DR environment in which DR servers must remain online (and incur license costs), a CBU environment can remain offline and be brought up in minutes in the event of an outage. Additionally, IFLs and LinuxONE hardware used for disaster recovery environments cost less than hardware for production environments, resulting in increased disaster recovery savings. Both Linux on IBM Z and LinuxONE can leverage IBM GDPS® and IBM Spectrum Scale™ for near-continuous availability and disaster recovery solutions. IBM Spectrum Scale is a cluster file system that provides concurrent access to a single file system or set of file systems from multiple nodes.

[13] Internal IBM tests were performed to replicate conditions in observed customer environments for transaction workloads running in virtual machines versus IBM Cloud Pak for Applications containers on x86 servers. Workloads were run to simulate a variance in CPU demand with a peak-to-average ratio of 7 to 1 on 16-core Cascade Lake x86 servers configured with 128 GB memory as well as a separate server for Control Plane functionality. Software included RHEL, x86 hypervisor, OpenShift containers, and an OLTP application driven by JMeter. The OCP environment required 15,536 MHz to deliver a total of 2,676 TPS collectively over 33 containers with a per-container average of 81 TPS and a response time of 3 milliseconds and a CPU consumption of 5.81 MHz per TPS. Using identical workloads 8 VMs required 3,911 MHz to deliver a total of 627 TPS with a per VM average of 78 TPS and a response time of 6.4 milliseconds and CPU consumption of 6.24 MHz per TPS.
[14] https://www.ibm.com/support/z-content-solutions/journey-to-linuxone/
[15] https://www.ibm.com/it-infrastructure/z/technologies/gdps
[16] ITIC 2019 Global Server Hardware, Server OS Reliability Survey Mid-Year Update for LinuxONE and IBM Z found 0% annual unplanned server downtime of >Four Hours in 2019, https://itic-corp.com
[17] https://www.ibm.com/it-infrastructure/z/software/pricing-resources, Backup, Disaster Recovery, and Capacity Backup Upgrade video https://www.youtube.com/watch?v=XPvd5OJTJ-Y

Bandwidth

Many IT organizations keep their critical system of record data on IBM Z and use other platforms for their applications. If the data on z/OS® is used from applications on distributed servers, latency increases as the data is accessed by an off-platform environment. Overall application performance is reduced since the data must constantly access the system of record over TCP/IP. These applications are best collocated with the data on the same physical server as the system of record. Applications can run on IFLs on the same IBM Z server and leverage Shared Memory Communication D (Direct Memory Access (SMC-D)) through HiperSockets™[18], a hardware feature that provides high-speed LPAR-to-LPAR communications within the same physical server through memory.

Shared Memory Communication R (Remote Direct Memory Access (SMC-R))[19] can enable applications to communicate within the same server or across different physical servers using a RoCE (RDMA over Converged Ethernet) network adapter. Both HiperSockets and Shared Memory Communication R enable speed, greater bandwidth and lower latency compared to accessing the data over TCP/IP from distributed servers.

The Open Systems Adapter (OSA), a network controller for IBM Z and LinuxONE, also provides high speed communication within and across servers. When OSA is used for communication within the same physical server, TCP/IP requests can be processed swiftly since they occur locally using the memory on the OSA card.[20]

Linux on IBM Z enables sustainability

More than ever governments, industries and boardrooms are seeking to limit the amount of greenhouse gas emissions. New environmental standards, organizations and legislations have increased to actively address the impact of human activity on the environment. For businesses in many nations, compliance with environmental directives is required to avoid financial penalties. Contribution to global sustainability is also viewed by many businesses as a competitive advantage. Their clients prefer to do business with organizations that take action to minimize their greenhouse gas emissions.

Most data center facilities consume up to 10 to 50 times the energy per floor space of a typical commercial office building[21], so for many businesses an energy efficient IT solution is an essential step towards achieving carbon footprint reduction.

LinuxONE offers a solution to growing greenhouse gas emissions with its ability to run many workloads in a dense, energy-effective environment. Workloads on IFLs on IBM Z and LinuxONE consume less energy compared to distributed server environments[22], reducing data center carbon footprint and improving Power usage effectiveness (PUE). Consolidating x86 workloads onto a fewer physical servers also lowers floor space costs.[23]

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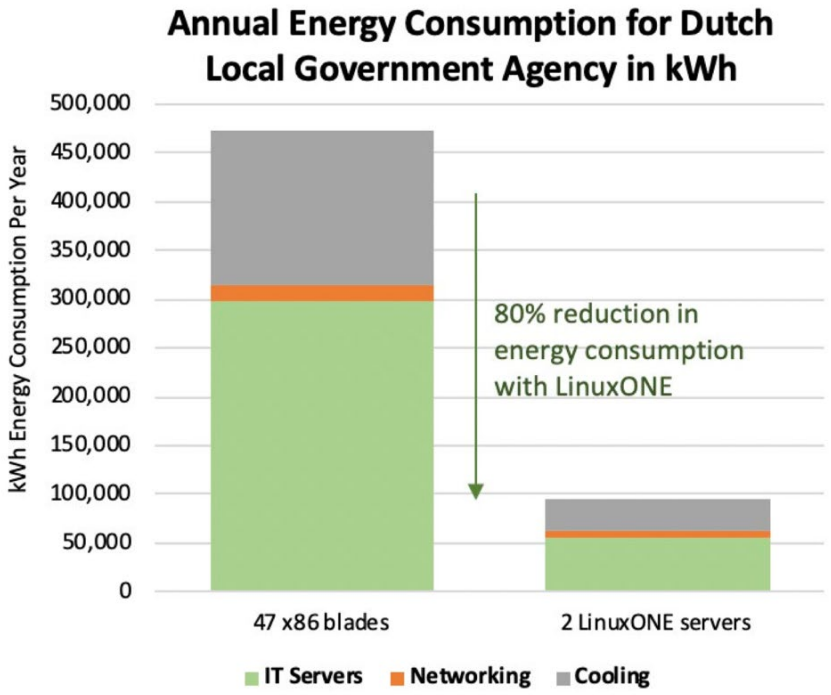
[18] .HiperSockets, http://www.redbooks.ibm.com/redbooks/pdfs/sg246816.pdf
[19] https://www.ibm.com/support/knowledgecenter/en/SSLTBW_2.3.0/com.ibm.zos.v2r3.halz002/smc_ovw.htm
[20] http://www.redbooks.ibm.com/redbooks/pdfs/sg248851.pdf
[21] U.S.DepartmentofEnergy,https://www.energy.gov/eere/buildings/data-centers-and-servers
[22] Compared LinuxONE III LT1 model consists of 3 CPC drawers containing 108 IFLs, and one I/O drawer to support both network and external storage. Power consumption for the LinuxONE III LT1 is estimated using the Power Estimation Tool for 8561 https://www01.ibm.com/servers/resourcelink/hom03010.nsf/pages/pet8561v2150?opendocument assuming a "Normal" workload. x86 systems ran at various CPU utilizations according to 15 customer surveys, representing Development, Test, Quality Assurance, and Production levels of CPU utilization and throughput. Three workloads were tested, consisting of a mix of leading databases and application servers. Each workload ran at the same throughput and SLA response time on LinuxONE and x86. Power consumption on x86 was measured while each system was under load. LinuxONE III LT1 performance data and number of IFLs were projected from actual LinuxONE Emperor II performance data including a performance improvement of 10% on LinuxONE III LT1. Compared x86 models were 78 2-socket servers containing a mix of 8-core, 12-core and 14-core Xeon x86 processors. External storage is common to both platforms and is not included in power consumption. Assumes LinuxONE and x86 are running 24/7/365. Power consumption may vary depending on factors including configuration, workloads, etc. Energy cost savings are based on a U.S. national average commercial power rate of $0.10 per kWh basedonU.SEnergyInformationAdministration(EIA)data,https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a. Individualratesmayvary.Savingsassumesapowerusageeffectiveness(PUE)ratioof1.66tocalculateadditionalpowerfordatacentercooling.PUEisbasedonIBMandtheEnvironment-Climateprotection-Datacenterenergyefficiencydata,https://www.ibm.com/ibm/environment/climate/datacenter_energy.shtml
[23] Actual floor space covered by the systems includes doors and covers.The LinuxONE III LT2 consists of two CPC drawers containing 64 IFLs, and one I/O drawer containing 7 FCP and 3 OSA adapters versus 4 x86 racks, each occupying 16 2U slots to run the comparable workloads, consisting of a mix of databases and application servers. Each workload ran at the same throughput and SLA response time on LinuxONE and x86. x86 systems ran at various CPU utilizations according to 15 customer surveys, representing Development, Test, Quality Assurance, and Production levels of CPU utilization and throughput. 16 x86 2U form factor servers populated a standard 32U rack. Other 10 2U slots contained PDU, network switches, SAN switches and allowed space for air circulation. External storage floor space is not included. LinuxONE III LT2 performance data and number of IFLs was projected from actual LinuxONE Rockhopper II performance data including a 3% lower throughput using MIPS ratio on LinuxONE III LT2 versus LinuxONE Rockhopper II with high availability. Assumes LinuxONE and x86 are running 24x7x365 with 42 Development, Test, Quality Assurance, and Production servers and 9 High Availability servers. Compared x86 models were all 2-socket servers containing a mix of 8-core, 12-core and 14-core Xeon x86 processors.

As distributed server environments grow to meet new business demands, floor space can become a significant expense, particularly when an IT organization has reached the physical limits of its data center and is considering a move to a larger facility.

In an effort to comply with the Netherlands' Supreme Court decision to reduce greenhouse gas emissions by 25% compared with 1990 levels by the end of 2020[24], one Dutch local government organization replaced part of its x86 server IT infrastructure with a LinuxONE environment.
By moving its Linux applications from 47x86 blades to 11 IFLs on LinuxONE, energy consumption for the organization is projected to be reduced by 80%, resulting in 946 fewer metric tons of CO2 emissions over five years.[25]

Learn more about consolidation of data and applications onto IBM Z or LinuxONE to contribute to a more environmentally sustainable IT environment and to fewer greenhouse gas emissions.



Reduce IT costs

Whether large or small, companies are seeking solutions to simplify IT operations and reduce cost. For many, consolidating workloads onto denser, centralized computing platforms is an effective way to decrease IT expense.

[24] Supreme Court of the Netherlands' decision, https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:HR:2019:2006

[25] Energy savings are based on a carbon footprint assessment conducted by the IBM IT Economics team for a government agency in the Netherlands using four blade centers with a total of 47 blades at 8.5 KW (4.5 KW for blades and 4 KW for the chassis based on vendor published KW rates) for an estimated annual server energy consumption of 297,840 kWh versus two LinuxONE Rockhopper I servers with 6 IFLs each at 3.1 KW each, consuming an estimated total of 54,312 kWh annually. Network energy consumption of 2 KW for the blades (two for each blade center for a total of eight) and 1 KW for the LinuxONE servers (two switches for each server), based on vendor published KW rates for networking switches, results in an estimated 17,520 kWh for the blade centers and 8,760 kWh for the LinuxONE servers. Cooling energy consumption is estimated by using an efficiency factor based on the server's architecture and is proportional to the networking and servers' power consumption. In this assessment both blade centers and LinuxONE servers use a data center power utilization effectiveness rate of 1.5 as the factor to calculate cooling consumption, resulting in an estimated 157,680 kWh for the blade centers and 31,536 kWh for the LinuxONE servers. The assessment uses a kWh to CO2 factor of 505.2 grams of CO2 for 1 kWh based on Netherlands CO2 emissions intensity from electricity generation from the European Environment Agency, https://www.eea.europa.eu . Findings from IBM IT Economics assessments will vary according to each client environment.

Consolidation saves

Consolidating x86 workloads onto a fewer physical servers can lower software costs, administration, networking, energy and floor space costs. Linux on IBM Z and LinuxONE workload consolidation capabilities can mean fewer software licenses, less hardware maintenance, less network management, simpler software patching and lower facilities costs. Analysis of forecasted total ownership costs for numerous financial institutions found that their Java™ workloads on LinuxONE provided on average a 60% lower TCO over five years than on compared x86 servers.[26]

For another customer, a large insurance company in Asia Pacific, moving to LinuxONE from x86 servers brought significant efficiencies to its IT operations. The company was experiencing significant growth, and as its x86 data center grew, physical floor space charges and hardware costs increased, energy bills became higher, and its IT staff struggled with server administration complexities.

The company initiated an assessment of its current operations to find more effective scaling for new workloads. Analysis discovered that workloads running on 55 x86 servers could be consolidated onto one IBM LinuxONE system with a dramatic decrease in energy and floorspace usage. Floor space could be reduced by 86% and annual energy consumption could drop by 62%[27]. These savings enable the company to address their challenges of rapid growth with much denser workload consolidation, a smaller data center and simpler administration for its staff.

In a subsequent phase of IT transformation, the company moved the remaining databases and application server workloads from over thousands of x86 servers to just ten LinuxONE servers. The move to LinuxONE simplified IT administration, decreased facility costs and improved IT security.

Cost savings factors

Typically, Linux workloads running on centralized servers such as Linux on IBM Z or LinuxONE require fewer per core licenses due to per core pricing. For most IT organizations the decrease in software costs (fewer cores means fewer licenses) is the greatest savings factor. Another savings driver is energy efficiency.[28] Workloads on LinuxONE consume less energy compared to distributed server environments, reducing data center carbon footprint and improving Power usage effectiveness (PUE). Consolidating x86 workloads onto a fewer physical servers also lowers floor space costs.[29]

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[26] Financial institutions in different geographies requested analysis of Java x86 workloads for consolidation onto LinuxONE. The assessments involved business critical workloads running in production and non-production environments for IBM Java application server middleware running on different types of x86 and distributed servers. TCO costs included migration, hardware, software, networking, energy, floor space and people costs. TCO savings with IFLs or LinuxONE ranged from 43% to 80% over five years with an on average savings of 60%. Each client engaged the IT Economics team to evaluate the distributed workloads and the proposed IFL or LinuxONE environment for the consolidation. For each assessment, IT Economics consultants met with the client to discuss consolidation planning and execution, analyzed the client's current total cost of ownership, and provided a projected total cost of ownership with workload consolidation based on estimated core consolidation ratios for the client's workloads based on workload sizing estimates from IBM internal testing and comparable client workload data. For additional information on x86 workload analysis contact the IBM IT Economics team, IT.Economics@us.ibm.com.

[27] Energy savings are based on a workload consolidation assessment conducted by the IBM IT Economics team for an Asia Pacific insurance company running Linux workloads on 55 x86 servers with 3,264 x86 cores versus one LinuxONE Emperor II system with 170 IFLs. Analysis estimates total cost of ownership costs such as hardware, software, labor, floorspace and energy with 38.3 KW for the sized LinuxONE versus 101.6 KW for the x86 environment. The KW numbers are calculated using IBM and vendor published server KW rates, and multiplied by 2 for networking and cooling energy consumption based on the client's data center power utilization effectiveness (PUE) of 2, resulting in an estimated reduction from 335K kWh for LinuxONE versus 5.54M kWh for x86. Floor space in use for the 55 x86 servers in the assessment is 42.57 square meters versus an estimated 6.11 square meters for the LinuxONE server. Findings will vary according to individual client environments.

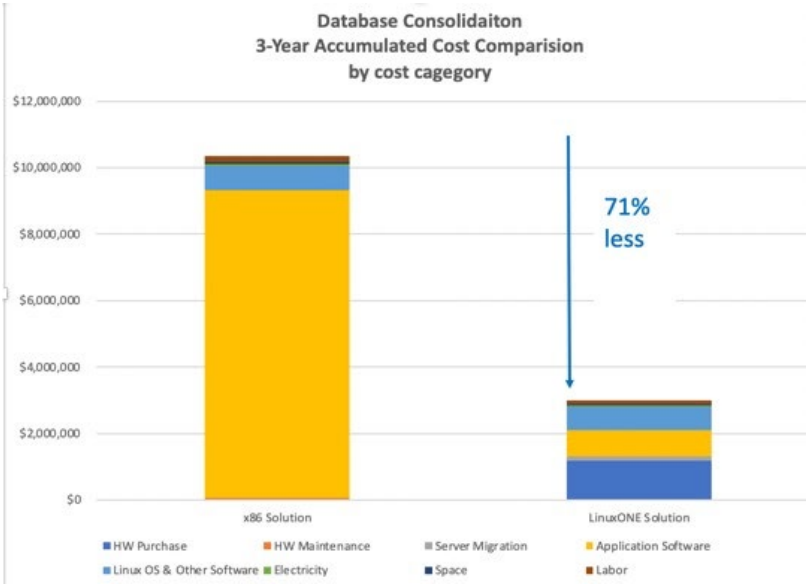
[28] A single frame LinuxONE III or z15 saves an estimated 50% in power consumption per year than compared x86 systems running workloads with the same throughput. Compared LinuxONE III LT1 model consists of 3 CPC drawers containing 108 IFLs, and one I/O drawer to support both network and external storage. Power consumption for the LinuxONE III LT1 is estimated using the Power Estimation Tool for 8561 https://www01.ibm.com/servers/resourcelink/hom03010.nsf/pages/pet8561v2150?opendocument assuming a "Normal" workload. x86 systems ran at various CPU utilizations according to 15 customer surveys, representing Development, Test, Quality Assurance, and Production levels of CPU utilization and throughput. Three workloads were tested, consisting of a mix of leading databases and application servers. Each workload ran at the same throughput and SLA response time on LinuxONE and x86. Power consumption on x86 was measured while each system was under load. LinuxONE III LT1 performance data and number of IFLs were projected from actual LinuxONE Emperor II performance data including a performance improvement of 10% on LinuxONE III LT1. Compared x86 models were 78 2-socket servers containing a mix of 8-core, 12-core and 14-core Xeon x86 processors. External storage is common to both platforms and is not included in power consumption. Assumes LinuxONE and x86 are running 24/7/365. Power consumption may vary depending on factors including configuration, workloads, etc. Energy cost savings are based on a U.S. national average commercial power rate of $0.10 per kWhbasedonU.SEnergyInformationAdministration(EIA)data,https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a. Individualratesmayvary.Savingsassumesapowerusageeffectiveness(PUE)ratioof1.66tocalculateadditionalpowerfordatacentercooling.PUEisbasedonIBMandtheEnvironment-Climateprotection-Datacenterenergyefficiencydata,https://www.ibm.com/ibm/environment/climate/datacenter_energy.shtml

[29] *A LinuxONE III LT2 or z15 single frame system requires* ***75%*** *less floor space than compared x86 2U servers in racks, running the same workloads and throughput.* Actual floor space covered by the systems includes doors and covers.The LinuxONE III LT2 consists of two CPC drawers containing 64 IFLs, and one I/O drawer containing 7 FCP and 3 OSA adapters versus 4 x86 racks, each occupying 16 2U slots to run the comparable workloads, consisting of a mix of databases and application servers. Each workload ran at the same throughput and SLA response time on LinuxONE and x86. x86 systems ran at various CPU utilizations according to 15 customer surveys, representing Development, Test, Quality Assurance, and Production levels of CPU utilization and throughput. 16 x86 2U form factor servers populated a standard 32U rack. Other 10 2U slots contained PDU, network switches, SAN switches and allowed space for air circulation. External storage floor space is not included. LinuxONE III LT2 performance data and number of IFLs was projected from actual LinuxONE Rockhopper II performance data including a 3% lower throughput using MIPS ratio on LinuxONE III LT2 versus LinuxONE Rockhopper II with high availability. Assumes LinuxONE and x86 are running 24x7x365 with 42 Development, Test, Quality Assurance, and Production servers and 9 High Availability servers. Compared x86 models were all 2-socket servers containing a mix of 8-core, 12-core and 14-core Xeon x86 processors.

As distributed server environments grow to meet new business demands, floor space can become a significant expense, particularly when an IT organization has reached the physical limits of its data center and is considering a move to a larger facility.

Not only can workload consolidation lower software and data center costs, it can lower administrative overhead. Fewer physical servers can mean less hardware maintenance, less network management, and simpler software patching and for most organizations, workload growth is inevitable.

In a three year cost comparison model for a database workload, IBM LinuxONE III LT2 delivers a 71% lower TCO versus compared x86 servers.[30] Even when accounting for workload migration costs to move deployed x86 workloads to LinuxONE, overall cost savings was significant given the cost of software and other factors in a distributed server environment.



Which workloads consolidate well? Organizations opting for workload consolidation to relieve cost and IT complexity tend to look for the following types of workloads.

- **Workloads with per core pricing** Linux workloads that have a software license price per unit of compute power (processor or socket) are strong candidates for consolidation on LinuxONE from a financial perspective. In general, distributed servers require considerably more processor cores to run the same Linux workloads than LinuxONE. IBM internal tests and data from client environments show core consolidation ratios ranging from 10 to 32.5 distributed cores to one IFL, yielding dramatically lower software.
- **Workloads with variable resource requirements** Linux workloads with activity fluctuations are very well suited for LinuxONE and IFLs. Centralized servers provide compute elasticity, or resource sharing, so that memory, CPU and I/O can be allocated to workloads with diverse timeline requirements over a 24-hour period.
- **Workloads with I/O demands** LinuxONE leverages FICON®[5] or FCP protocols designed to enhance data transfer and to increase sustained CPU utilization through advanced workload management capabilities.
- **Workloads with high availability requirements** Business critical workloads that require 24x7 availability are often placed LinuxONE to leverage built-in redundancy and resiliency. Capacity Backup (CBU) on LinuxONE allows hardware engines to be used for disaster recovery without incurring additional software charges if the production server is temporarily unavailable.

[30] An IBM IT Economics model was used to examine one time charge and maintenance costs over three years for hardware, software, floor space, energy, migration and labor and networking costs for a commercial database running on five 48-core Cascade Lake x86 production servers and an additional six non-production servers for devtest and QA versus 19 IFLs on one LinuxONE III LT2 server for production and non-production workloads. Both scenarios include DR hardware and software costs for one nine IFL LinuxONE III LT2 and five 48-core Cascade Lake x86 servers. LinuxONE pricing, where applicable, is based on U.S. prices as of 07/01/2020 from our website and x86 hardware pricing is based on IBM analysis of U.S. prices as of 07/01/2020 from IDC. Software, floor space, energy, migration and labor costs are based on data from IBM IT Economics assessments for clients. For additional information on the use case model, contact the IBM IT Economics Team at IT.Economics@us.ibm.com

- **Workloads with high security requirements** Workloads that access sensitive data are typically placed on LinuxONE to minimize the possibility of a security event. LinuxONE provides unique security benefits to lower the risk of a data or privacy breach
- **Workloads headed toward the cloud** Both new cloud native and existing workloads targeted for modernization for the cloud are good fits for IFLs on IBM Z or LinuxONE using IBM Cloud Paks.

What about Linux in your organization?

Most businesses already have some amount of Linux workloads running in their datacenter or are looking to leverage Linux and open source software to mitigate costs. If your organization is interested in examining the with Linux for on-prem and cloud solutions, contact the IBM IT Economics team for a no-charge assessment at IT.Economics@us.ibm.com. The analysis can help your organization identify savings and operational efficiencies based on your specific IT environment (infrastructure, workloads, costs) and business objectives.

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