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Power Consumption and Carbon Emission Equivalent for Virtualized Resources – An Analysis

Virtual Machine and Container Analysis for Greener Data Center

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Abstract—The International Energy Agency (IEA) revealed that the worldwide energy-related carbon dioxide (CO2) situation has hit a historic high of 33.1 Giga tonnes (Gt) of CO2. 85% of the rise in emissions was due to China, India, and the United States. The increase in emissions in India was 4.8%, or 105 Mega tonnes (Mt) of CO2, with the increase in emissions being evenly distributed across the transportation and industrial sectors, according to Beloglazov et al (2011). Environmental contamination brought on by carbon emissions is harmful to the environment. As a result, there is an urgent need for the IT sectors to develop effective and efficient technology to eliminate such carbon emissions. The primary focus is on lowering carbon emissions due to widespread awareness of the issue.

Keywords-Virtual Machine; Container; Power; Carbon Emission; Data Center;

I. Introduction

The virtual machine and container analyses have undergone methodical experimentation. In comparison to the virtual machine, it has been discovered that the container is the superior model. As can be seen from the results based on power use and its equivalent carbon emission, this has been examined and proven with the application running on a container as well as the virtual machine. However, while combining both virtual machine and container [1][2] strategies is advised, this study suggests containers as the ideal model for minimising power consumption and carbon emissions/carbon footprint, which is the current requirement of the industry.

The findings were identified using the Powerstat tool. A sample of power consumption utilization of a data center is shown in a graphical representation with an average of 16.5 kW units of power refer Fig. 1 based on the usage, analysis has systematically proved the usage of the container with the read-only operation and virtual machine for read-write operation. Power required for the resources and the carbon emitted have been analyzed with both minimum requirements of the resources and with maximum requirements according to the user request.

II. Literature Survey

Service level agreements, which utilize balancing of load and its scalability of speed increases the usage of electricity consumption and carbon footprint Shu et al.(2014) [3] addresses with the aspects of service level agreements. They have used the technique of Dynamic Voltage Frequency Scaling (DVFS) to adjust the power and speed of computing systems. According to Wu et al. (2014) [4], improved resource allocation with the necessary level of power supply is made to complete the task. When those resources are not needed, it strengthens and improves power backup and allows for the dynamic execution of preferred tasks using the least amount of necessary power. The anticipated model makes use of the benefits of the current DVFS to reduce data centre power and energy consumption. The DVFS regulates the power consumption necessary for the data centre to render the load, whether during peak hours or during routine operations. When the data centre is under a heavy load during peak hours, DVFS is utilised to enable and disable components as needed.

Arroba et al. (2017) [5] follows the use of DVFS technique for balancing the power which saved up-to 41.6 % energy and used a virtual machine for saving energy. They have used CloudSim for experimental analysis. Van Heddeghem et al. (2012) [6] they analyzed the possibility electricity savings nearly 60%–90% by relating the natural resources like sun and wind strategy to data centers where the minimal loaded capacity in the data center is well below the peak level judged by low footprint and high footprint values. Optimum savings nearly 1.5 to 2.5 times are gained by the

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design of the internal working that manages the daily operation of the data center to reduce the amount of carbon emission.

Ren et al. (2012) [7] made an informed decisions with data center operators about sustainable renewable energy and powered IT system design through their architecture and reduce the carbon footprint. Renewable energy can lower the carbon footprint. More than off-site renewables, on-site renewables can be used for reducing the carbon foot during the peak time usage of the data center which can economize the electricity bill. Deng, Liu, Jin, Li & Li (2014) [8] established the load shifting on servers, with one powered by the grid and the other by on-site wind energy. The load transfer between these servers makes use of the renewable energy production based on the practicality of wind energy. Direct Systems for distributing power that use current can minimise system energy consumption and increase the use of renewable energy.

Zhou et al. [9] considered the electrical carbon footprint has spatial and temporal heterogeneity that can be fully utilised to support green cloud running on top of geographically dispersed data centres. It assists in making judgements online regarding capacity right-sizing, server speed scaling, and geographical load balancing by using Lyapunov optimization algorithms. Additionally, it offers a framework for reducing carbon emissions and electricity costs through simulation using actual workload traces and electricity price generation data.

Deng, Wu, Shen & He (2014) [10] reduced the average time and cost of power by ensuring the quality of experience through the performance of eco-aware power management and load scheduling jointly for geographically distributed cloud data centers. The existing system achieved a better result in power cost savings, environment protection, and users quality of experience. Bala et al. (2015) [11] utilized simulation environment that captures the energy consumption of computing and communicating devices of the cloud environment. The device also demonstrated the effectiveness of various green computing tactics over the classical methods of computing with various data center architectures. The amount of energy consumed in a data center was seen as similar to the computing devices.

Zhou et al. (2015) [12] explored the spatial and temporal variability of the carbon footprint for cutting down the carbon emission of the cloud. They achieved a time-averaged electricity cost subjectively close to the finest while upholding the long-term carbon emission budget. Tang et al. (2015) [13] framed power management framework for identifying the physical variation of the hardware. They have achieved a nominal energy cost though with some overheads. Castro-Leon (2016) [14] formulated demand response for addressing power imbalances whereby a power producer sends a restricted request to a power consumer. Direct response adoption becomes more persistent and can expect a rich ecosystem to develop in which restricted watts are traded as easily as generated watts.

Zhou et al. (2013) [15] and Yao et al. (2012) [16] refers to cutting electricity cost using a service level agreement, right-sizing of hardware component and speed mounting of the server for massive energy demand for geo-data centers. Deng, Liu, Jin, Li & Li (2014) [17] provided a taxonomy for using renewable energy in cloud computing data centers from key features like renewable energy, capacity planning, load scheduling and balancing. Deng, Wu, Shen & He (2014) [18] and Chen et al. (2016) [19] identifies the ecological power shifting and its scheduling of load to reduce the time-average eco-aware power cost of cloud data centers along with the quality of experience restriction of user requests. Wind and solar have seen a better approach to the power supply.

Wadhwa & Verma (2014) [20] discussed migration among the same data centers and also minimizing the emission of carbon by virtual machines. Urgaonkar et al. (2010) [21] indicated about a issues due to resource distribution during heavy load and its power utilization and management in a VDC with queuing accessible information system to make online control decisions. Gao et al. (2016) [22] suggested different aspects of ecological metrics, scheduling and monitoring of cloud application for carbon emission in VM's. Zhou et al. (2015) [23] worked with the performance based on average response time while balancing the load and also discuss the policy for violation of rules and resource utilization.

Pierson and others (2019) [24] Utilizing available power and renewable energy, consolidated virtual machine consolidation was used to optimise resource allocation and reduce carbon emissions using locally accessible power. Wang et al. (2017) [25] followed a server-based resource allocation, with a minimized number of the task which helped increasing the energy efficiency. Local migration technique using simulation was analyzed. Basmadjian et al. (2016) [26] recommended considering data centres as demand response prospects since they are significant energy consumers and have the ability to effectively change their power profile. Participating high potential data centres in demand response power adaptation schemes led to better power profiles and energy savings.

Wang et al. (2016) [27] suggested the framework that balances the traffic load and helps the entire process lasting longer. It involves sleep planning and wake-up protocol based on implementation, which supports the estimation of sleep intervals. State changes promote the energy-efficient use of the entire system capital. Pierson et al. (2019) [28] framed a

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technique for consolidating virtual machines for power-efficient resource allocation. With the locally available power, carbon emissions were reduced using renewable energy. Electrical sources profiling required an accurate design that took into account sophisticated elements including ageing, Cloud application phases and degradation patterns, and IT server power and performance modelling and analysis.

Paper	Technique	Outcome
Van Heddeghem et al. (2012)	Renewable energy	Reduced Carbon Footprint
Ren et al. (2012)	Renewable energy, energy storage devices.	Reduced Carbon Footprint
Deng, Liu, Jin, Li & Li (2014)	renewable energy, capacity planning, scheduling, load balancing	Reduced renewable energy source.
Zhou et al. (2013) Zhou et al. (2016)	Lyapunov optimization	Minimized electricity cost and reduced carbon emission.
Deng, Wu, Shen & He (2014)	renewable energy	Achieved power cost savings
Wadhwa & Verma (2014)	VM allocation and migration	Reduced carbon emission and energy consumption
Bala et al. (2015)	DVFS, DNS	Minimized energy consumption
Zhou et al. (2015)	Lyapunov optimization	Minimized electricity cost
Tang et al. (2015)	renewable energy	Minimized electricity cost
Castro-Leon (2016)	Demand response	Better power profiles and energy savings
Basmadjian et al. (2016)	Demand response	Better power profiles and energy savings
Wang et al. (2016)	IOT	Improved resource utilization and energy consumption.
Pierson et al. (2019)	Renewable energy	Reduced carbon emission with accurate power model
Li et al. (2016)	Solar Panels, Distributed battery Systems	Extended battery lifetime and 26% cost savings

a. Survey on Power Consumption and Carbon Emission.

III. VITCC TEST BEST

The analysis of the power consumption and its equivalent carbon emission was tested with the application running both in virtual machine and container. The Experimental setup was implemented using HAProxy in an open-source load-balancer that can support any TCP network. By exploiting the benefits of OpenStack, for creating virtualized environments like virtual machines and containers, HAProxy is by default deployed in OpenStack. The analysis was done for two different phases. It was first tested with the minimal requirements and next was with maximum requirements for ROR and RWR Anusooya et al. (2019) [1] [2] applications. Power consumption is tested with PowerStat tool and its equivalent carbon emission was measured using AVERT online calculator by EPA - the United States Environmental Protection Agency.

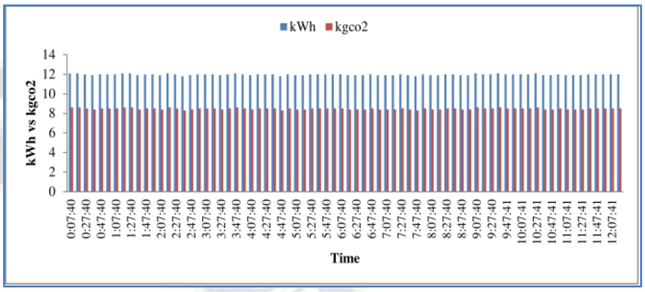

Figure 1. Data Center - Power Consumption vs Carbon Emission.

A. HAProxy

HAProxy(High Availability Proxy) with TCP or HTTP applications offers a fast and reliable HTTP reverse proxy and load balancer. It is particularly suitable for web crawling under very high loads while requiring persistence or processing of layer 7. It supports hundreds of thousands of connections to the latest hardware in realistic terms. Every HAProxy instance configures its front end to allow connections to the VIP address only.

The back end of the HAProxy (termination point) is a list of all load balancing instance IP addresses. HAProxy is used to setup Load Balancing in Openstack. The HAProxy workflow is shown in Fig. 2, the incoming request is captured by HAProxy Request Handler, based on the input from the configuration file the source load balancer is set to virtual machine and container according to the call invoked by the HAProxy request handler. The structure of HAProxy file invokes the setup of load balancer along with the frontend and backend of the application.

Each HAProxy instance configures its front end to allow connections to the VIP address only. The back end of the HAProxy (termination point) is a list of all load balancing instance IP addresses. HAProxy is used for setting up Load Balancing in Openstack. This service already provides us with three Load Balancing algorithms: Round Robin, Source IP and Least Connections. Openstack instances need to be established on top of these instances to set up a Load Balancer. So if a user wants to make any request, it has to be forwarded to the Load Balancer, and then this Load Balancer will forward it to the instances (virtual machine/container).

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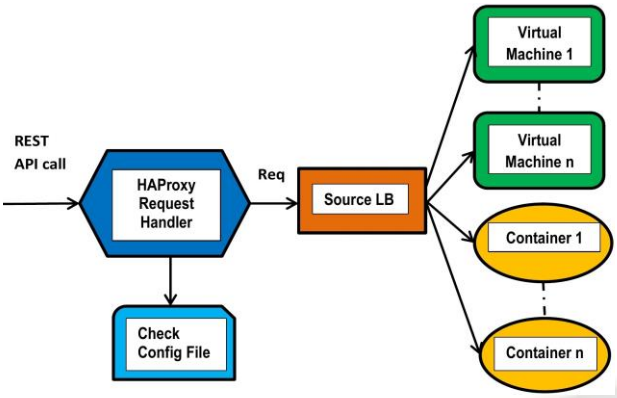

Figure 2. HAProxy Work Flow Design

B. OpenStack

Openstack is an open-source framework for open and private clouds for the creation and management of distributed computing levels. The OpenStack Foundation which operates the Openstack, is a non-profit that drives development as well as community building around the project. A cloud operating system called OpenStack controls the process, storage, and network resources spread throughout a data centre. Its web interface enables administrators to monitor while interacting with clients through a dashboard to offer services.

HAProxy which is a reliable, High-performance TCP/HTTP Load balancer has to be utilized. This enables attempting at different load balancing algorithms and hence check their performance. This HAProxy is by default installed with OpenStack. Applications are implemented by creating instances for virtual machine and container using OpenStack. Fig. 3 shows the experimental setup used for analyzing, it shows the entire representation of OpenStack.

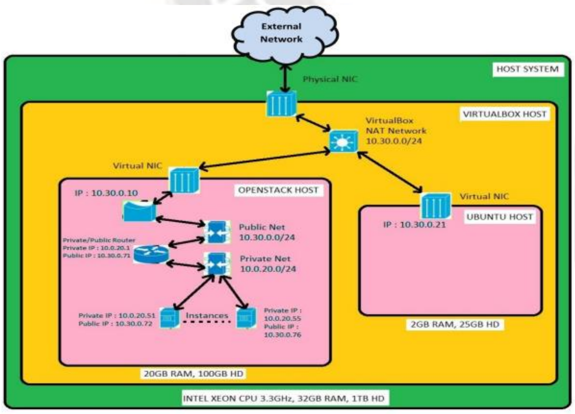

Figure 3. OpenStack Setup

IV. Analysis Tool

A. PowerStat Tool

In this study, the model of power consumption was computed for many categories, including an application running directly on virtual machine vs an application running on top of a virtual machine with a container. This specific software uses various virtual machines and containers in comparison to monitoring power consumption. A Powerstat gadget was used to gauge power usage. Powerstat is a method in the measurement system that is effective and efficient for calculating how much power is being used Fig. 4.

Time	User	Nice	Sys	Idle	IO	Run	Ctxt/s	IRQ/s	Fork	Exec	Exit	Watts
22:38:23	3.9	0	1.8	93.5	0.8	1	1172	429	0	0	0	14.31
22:38:33	1.7	0	2.1	95.6	0.6	1	1006	416	0	0	1	13.95
22:38:43	4.2	0	2.2	93.1	0.6	1	1205	472	5	5	5	14.54
22:38:53	2	0	2.1	95.3	0.6	1	1028	424	0	0	0	14.24
22:39:03	4.6	0	4.7	89.3	1.4	1	1442	612	8	5	5	14.76
22:39:13	2.1	0	2.2	94.7	0.9	1	1089	465	0	0	0	14.44
22:39:23	4.4	0	2	93	0.6	1	1291	492	5	5	7	15.36
22:39:33	2.2	0	2.7	94.4	0.7	1	1197	526	5	5	5	14.83
22:39:43	3.7	0	1.7	93.6	0.9	1	1196	441	5	5	5	14.94
22:39:53	2.4	0	3.1	93.9	0.6	1	1230	549	5	5	6	14.64
22:40:03	4.3	0	2	92.2	1.6	1	1253	456	5	5	5	15.45
22:40:13	2	0	2.3	95.1	0.7	1	1020	439	0	0	1	14.7
22:40:23	4.1	0	2.2	93.2	0.6	1	1271	474	10	10	10	15.02
22:40:33	2.3	0	2.5	94.7	0.6	1	1080	470	5	5	5	14.52
22:40:43	4.1	0	1.8	93.5	0.6	1	1192	441	5	5	5	14.91
22:40:53	2	0	2.7	94	1.4	1	1154	479	0	0	0	14.49
22:41:03	4.8	0	5.7	89	0.6	1	1704	748	7	5	5	15.29
22:41:13	2.1	0	2.3	95	0.6	1	1082	474	1	1	1	14.05
22:41:23	4.1	0	2.3	93	0.6	1	1238	488	0	0	2	14.21
22:41:33	1.9	0	2.1	94.5	1.5	1	1026	426	0	0	[illegible]	[illegible]
22:41:43	4.1	0	1.9	93.5	0.5	1	1173	456				
22:41:53	2	0	2.6	94.7	0.7	1	1056					
22:42:03	4.1	0	1.7	93.3	0.8	[illegible]						
[illegible]	1.7	0	2.4	95.3	[illegible]							

Figure 4. PowerStat Sample Result.

B. AVERT Tool

Using an online Calculator called AVERT by the EPA, the analysis for the examination judgements for determining the amount of carbon emission generated by the hardware component based on the utilization of the electricity was conducted. Evaluation of power in kWh and its consistent carbon engendered by multiplying it by 16.44 pounds.

V. Testing Phase-1

The testing for analyzing the power consumption and its equivalent carbon emission for container and the virtual machine was done in two phases, phase-1 is tested with minimum requirements and phase-2 is tested with requirements.

The containerization can be used if building and using the application is our only task for usage, so that the power consumption can be limited wisely. According to implementation's results, different models' power consumption is drastically reduced when compared to virtual machines. Fig. 5 displays a graphical comparison of an application operating on 4 VMs and 1 container. This analysis took 20 seconds to complete, and the Powerstat software was used to display the power use in watts. One application will be run and compared to one virtual machine while the same programme was run in 4 containers per one application.

When less energy is consumed, power consumption will also gradually drop, as shown by the chart, making containers the best option for cutting down on carbon emissions. When utilising the virtual machine and container, there is a very

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noticeable difference, according to observations of more than 4 virtual machines and 4 containers, each with similar applications. The utilisation of a virtual machine demonstrates the consumption of roughly 4 times as much power in watts, although the container just needs a little amount of electricity. The container is well acknowledged as the best option for a particular application type. For a specific kind of application, perhaps the limitation is not checked. The Water Shower Model (WSM) [Anusooya et al. (2019)] [1] [2] , which is the best method based on the successful results, is used to assess the container for Read-Only Request (ROR).

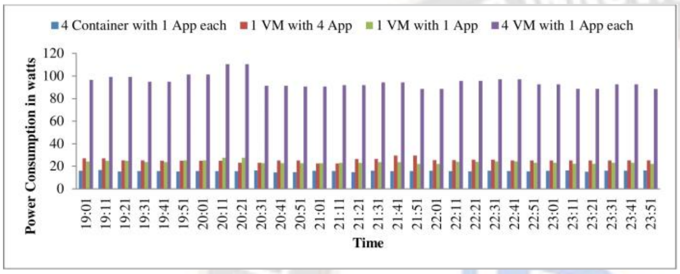

Figure 5. Power Consumption for Container vs Virtual Machine

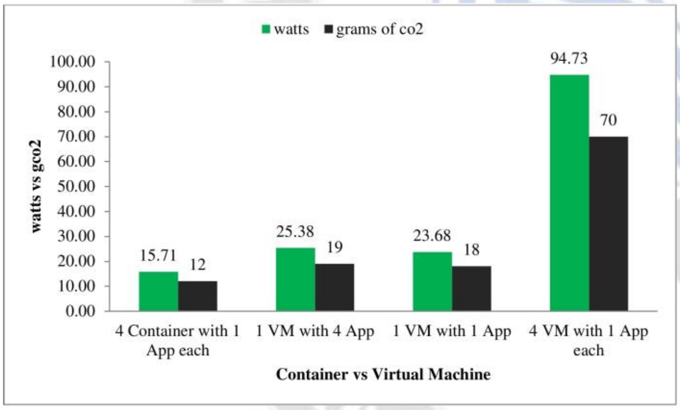

Figure 6. Average Power Consumption vs Carbon Emisison

The visual representations mentioned in Fig. 6 the average carbon emission equivalent in kgco2 for power use in watts. Four containers with one application each emit 12 grams of CO2, but four virtual computers with the same application each emit 7 grams of CO2. Due to the Powerstat tool's computation of the power usage for approximately 480 seconds as in 8 minutes, this carbon emission equivalent was only taken into account for 8 minutes during a very limited day.

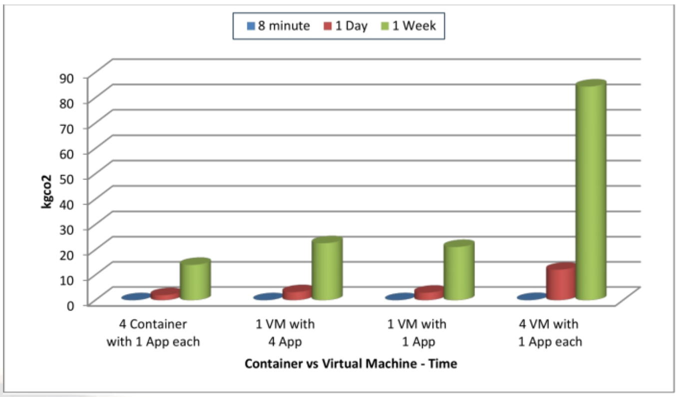

Figure 7. Comparision between Container vs VM for carbon emisison in time intervals.

The same application, which was calculated for 1 Day at 1440, was equivalent to 2 kg of CO2 for 4 containers with 1 application each, 3.2 kg for 1 virtual machine with 4 applications each, 3 kg for 1 virtual machine with 1 application, and 12.1 kg for 4 virtual machines with 1 application each, which is a significant amount. The same has been produced for calculating the carbon emission level over time in kilograms of CO2. The amount of carbon output is very high when it is cumulatively monitored, as studied and noted in Fig. 7.

VI. TESTING PHASE-2

In the above Phase-1 testing, the analysis was made as the container used minimum power emitting less carbon compared to the virtual machine. Based on the analysis, the request received from the user was considered as ROR and RWR operation to minimize the usage of power and reduce the emission of carbon which is the need of the IT industry. Even though the container and the virtual machine have already been in use in the IT industry, it was identified based on the request received from the user during peak time or normal time of usage. Considering the effective usage of the technology container is recommended but limited to the necessity of the application.

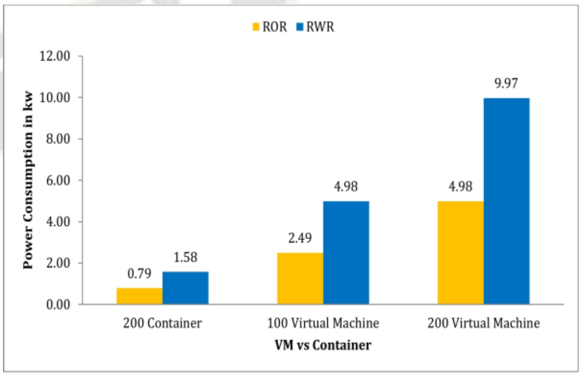

Figure 8. Average Power Consumpton in kw for ROR and RWR

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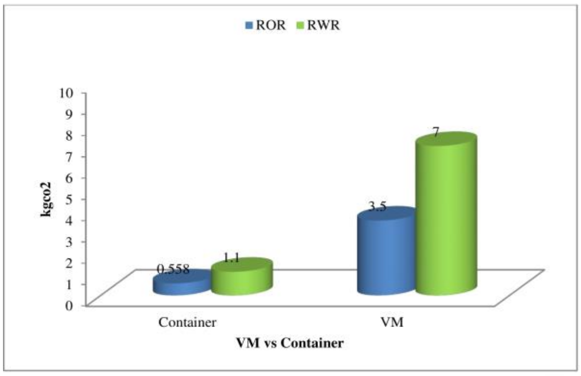

Figure 9. Carbon Emission equivalent in kgcco$_2$ for ROR and RWR

The testing was done for fulfilling the maximum requirement of the industry. The Read-Only Request - ROR and Read Write Request - RWR is tested with a sample of 100 and 200 virtual machines and 200 containers. Testing was done with the above-mentioned tools for identifying the power utilized and its equivalent carbon emission. Testing was done also for ROR application like the examination result publication portal and for RWR application tested with Moodle portal where both read and write operation taking place. The observed result is shown in Fig. 8 and Fig. 9. Experimental analysis was done with ROR and RWR for power consumption and its equivalent carbon emission and the result proved that container used less power when compared with the virtual machine, which is huge.

VII. CONCLUSION

The amount of carbon footprint marked was compared with Read-Only Request - ROR and Read Write Request - RWR with multiple containers and virtual machines was done. Refer to Figure 5.8 and 5.9, where ROR uses 4.19 kW of power and emits 2.9 kgco$_2$ when comparing with container and virtual machine and for RWR 8.39 kW of power and emits 5.9 kgco$_2$. The analysis and recommendation of virtual machine over container showed the usage of technologies in an efficient and optimized as very important in this current culture of using technology. The right technology stands better for reducing the hazardous to the environment, which is most important. The inference of using virtual machine and container, where VM uses much power and as well emits its equivalent carbon emission which is very huge on the other side the container uses less power with emission of comparatively low carbon which is the awful need for the productivity. *"The less the power, the less the carbon emission."*

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