ISSN:2320-0790

COMPUSOFT
An International Journal of Advanced Computer Technology

The Strategic Plan Founded on Efficiency of Using Green Computing Techniques in Data Centers

[1]Zahra Ghoreishi Dehkordi, [2]Hassan Ali Shirazi
[1]Asia Pacific University, Kuala Lumpur, Malaysia
[2]Allame Tabatabaei University, Tehran, Iran

Abstract: The ever-increasing costs of supplying energy as a part of total costs of any project and their environmental impacts have turned into a real challenge for IT industry and data centers in particular which are considered information processing and storage centers in IT industry which consume lots of energy. The need to optimize energy consumption is felt due to relatively fixed accessible energy sources, ever-increasing need to develop green data centers and expansion of existing centers. The present study aims at providing a standard strategy to reduce energy consumption and devastating impacts on the environment. This strategy is comprised of three stages of a) assessment, b) analysis and c) solution. Having provided parameters and metrics for the assessment of consumption and utilization extent; it, then, introduces technologies and solutions for and their effects on optimization of energy consumption.

Keywords: Datacenter, Green computing (green IT), Green technology and Efficient Energy Use

I. INTRODUCTION

During the last decade many organizations have directed their ways to be more responsible for the pollutions they cause and minimize their energy consumption (known as green computing) [1]. Allocating IT resources as efficient and effective as possible has always been a great concern for IT managers.

Green computing plays an important role in this field. This study is an effort to improve the utilization of IT resources in order to prevent electricity wastage in data centers.

Green networking concerns about selecting energy-efficient products and networking technologies and aims at reducing resource utilization at any time possible [2].

"Green networking technology contains:

- Implementing virtualization.
- Practicing server consolidation.
- Upgrading older equipment for newer, more energy-efficient products.
- Employing systems management to increase efficiency.
- Substituting telecommuting, remote administration and videoconferencing for travel." [3].

II. RELATED LITERATURE

There are different dominant factors regarding analysis of the efficiency of data centers namely 'consolidation', 'green building', 'server power consumption', ' the related standards', 'equipment lifetime', 'cooling system' and 'renewable resources' in constructing new green data centers or upgrading older ones.

A comprehensive solution addressing existing problems which is made explicit in the four following completing facets should be employed to deal effectively and in details with IT environmental impacts.

'Green use': reduction of power consumed by computers and other information systems and utilization of them in an environmentally friendly way

'Green disposal': refurbishing and reusing old computers and proper recycling of unusable computers and other electrical parts

'Green design': energy efficient and environmentally friendly designs of parts, computers, servers and cooling equipment

'Green manufacturing': manufacturing electrical parts, computers and other relevant sub-systems with minimum or no environmental impacts.

A. Consolidation

The term 'data center consolidation' may bear different meanings from reducing the number of physical servers in an isolated space to reducing the global footprint (environmental impacts) of all infrastructures of a company (including programs, software licenses, servers and so on) [4].

Virtualization is the most prominent sub-solution in this regard.

Critical objectives including security improvement, recovery facilities and compliance are among benefits of the consolidation solution [5].

If the goal of energy efficiency is pursued, it is possible to consolidate more workloads by two techniques namely 'memory compression' and 'request discrimination'. Request discrimination was devised to detect and reject requests which consume the system's resources while having no value for an application (e.g. requests of web crawler applications created by rival companies having espionage objectives). Memory compression is among other applied techniques which turns the processor's power to the capacity of external memory (to overcome the system's underutilization scenario which is caused by memory limitations).

B. Green building

The term data center encompasses all buildings, locations, offices and rooms which host different servers, required telecommunications and communications equipment, cooling and power distribution facilities and provides a kind of data service (e.g. sensitive operation controlling centers or small server rooms located in office buildings).

Numerical calculations reveal that the power dispersion inside the building could be considerably improved through utilization of walls made of concrete, filled by phase-changing materials (PCMs) micro-capsules and used thermal insulating materials in the outside face of walls [6]. Given that the introduced PCMs are newly presented materials and are under testing phase, if these materials are not available at the construction phase, the following points should be meticulously taken into account:

- Utilizing proper thermal insulating materials such as wool glass in walls and ceilings.
- Utilizing double-glazing glasses in all different parts of a data center.
- Utilizing proper silicon insulating materials to cover windows' frames.

C. Server's power consumption

1. Identification: It is necessary to identify and document all operating servers in a data centre, specify their business objectives and measure their power consumption in order to recognize the effects caused by adoption of new solutions. The most recent generations of servers are capable of monitoring their internal power consumption by their internal management facilities. A large part of existing (older version of) installed servers do not possess such a capability.

2. Server farms with appropriate size: These server farms often have large unused capacities. The analysis of patterns of server farm utilization sheds light on the way of estimating the appropriate size. The unused capacity could be shut down; the server farm, however, could still provide sufficient resiliency for agreed service level [7].

3. Shutting down servers at unused time: All servers are not required to operate at 24*7*365 operating style. Each of them could be shut down at specific periods of time in a day. The servers running backup software, for instance, are often merely needed at nights while branch-based servers are often used during the day.

D. Standards and regulations

These standards and regulations including EPEAT, Energy Star 4 and ROHS directive contribute to making designs and classifying data center's hardware and components in terms of environmental criteria. Making use of equipment having abovementioned standards is considered among primary and vital requirements of constructing a green data center.

EPEAT assesses electronic products under 23 compulsory and 28 optional criteria which are divided into 8 different performance groups. Reducing and removing primary hazardous materials, choosing proper raw materials, providing plan regarding the end of life of products (e.g. recycling) and dealing with issues including product's lifetime, energy saving, management of the end of life of equipment, administrative performance and packing are among issues covered by this standard [8].

'Restriction of hazardous substances in electronic and electrical equipment' (ROHS) directive aims at restricting the utilization of certain primary hazardous materials. This directive emphasizes on usage ban of six primary hazardous substances and prevents products having lead, cadmium, mercury, chrome and fire retarding materials more than a certain extent from importing to the markets of developed countries.

E. Equipment lifetime

It seems necessary to be more cautious regarding disposal of old servers, computers, monitors and other hardware components if the environmentally friendly objectives are going to be obtained. The reason lies in the fact that due to utilization of toxic and hazardous substances in construction of these components, their irresponsible disposals could certainly affect the environment. The environmentally friendly solutions known as 3R (i.e. reuse, refurbish and recycle) are now provided to revive them [9].

If servers and components are meeting the requirements, they could be still utilized or delivered to others who can make use of them or their useful components could be utilized in other systems.

Old servers or computers could be refurbished or upgraded to meet new requirements. Instead of purchasing new equipment, an older one could be refurbished or its old components could be changed.

If servers and computers could not be reused or refurbished, they should be disposed in an environmentally friendly manner.

F. Cooling systems

The cooling infrastructure forms a principal part of any data center.

Two new technologies in cooling systems namely in-row cooling and hot and cold aisle containment have contributed a lot in solving the problem. In-row cooling moves the cooling source close to the load as much as possible (through placement and deployment of servers' rows) in order to prevent energy wastage during its transmission beneath the raised floors.

The Environmental Protection Agency (EPA) has introduced several latest choices regarding new cooling technologies and their analyses in its report and claimed that 70-80 percent improvement would be possible in infrastructure efficiency through utilization of these solutions and technologies [10].

1. Traditional cooling solutions: 'Computer Room Air Conditioner' (CRAC) and 'Computer Room Air Handler' (CRAH) are the most used cooling methods which are successfully installed in numbers of data centers. Regardless of their reliabilities, they are not, however, the best cooling choice in terms of their economic conditions with regard to energy issues [11].

Isolation and containment are advantageous regarding energy issues even if they are accompanied by CRAC/CRAH technology. Studies reveled that this solution in comparison to the standard CRAC/CRAH brings about at least 7.3 percent energy savings [12].

Features common to all traditional cooling solution are as follows as cited in www.42u.com(2010):

- Environment cooling (the best dispersion units are installed outside the space dedicated to arranged racks).
- Elevated raised floors (the cooled air is conducted to racks' rows through tracks beneath the raised floors).
- The hot air dispersed from IT equipment would be combined with cold air during its move to CRAC unit exit windows.
- Rows of racks are not orderly arranged by hot and cold air.
- The cooling and conducting equipment and components having higher-than-needed capacities reduce the data center efficiency.

CRAC units, which are designed for continual 24*7*365 operation style, provide the returned heat exchange; in other words, they absorb the heat generated by IT equipment, cool it and send it back to the section [13].

Both solutions have their own specific features which are briefly explained here.

- Specific features of CRAC units :
  - ✓ Operators with refrigerant-based material (DX) which is installed on the raised floor and connected to outer condenser units.
  - ✓ The air is entered to the data center by means of system's fans; the cold air is, then, transmitted to servers and the (hot) air is given out the room.

- Specific features of CRAH units:
  - ✓ Operates with cooled water which is installed on the raised floor and connected to cooling unit of the outer chiller.
  - ✓ The air is entered to the data center by means of system's fans; the cold air is, then, transmitted to servers and the (hot) air is given out the room.
  - ✓

2. Modern cooling solutions: Robert Sullivan introduced a solution named as hot aisle/cold aisle in 2000 to obtain air containment in server room [13]. The data center's cabinets are orderly arranged in

rows in this solution. This is widely accepted as the first step in improving air flow management and utilized in almost all sensitive installations across the globe.

Their benefits are as follows [14]:

- Setting higher temperatures for cooling systems.
- Reducing costs of humidifying/ drying.
- Utilizing physical infrastructure more efficiently.

3. Free cooling solution: The nature would be exploited as a free source of cooling in this solution. Utilizing economization is a technique in which the generated heat is disposed at the outside area of a data center through employing cooling cycles. These systems are constructed in two different ways and essentially have two kinds of economization: water-side and air-side.

The outside air is distributed among cabinets by means of an existing air conducting system while no mechanical activity is needed for heat dispersion. If properly applied, this solution could result in 48 percent energy savings [15].

Water-side economization system utilizes the outside air in combination with chiller system. The outside air as the compressors' substitution cools the water which is, then, pumped to data center's CRAH equipment. There are two kinds of dry and evaporative water-side systems.

4. Liquid-based cooling system: The hot air passes from an air-to-water or air-to-refrigerant thermal exchanger in a liquid-based cooling system which is located close to thermal load. The heat is transferred to the liquid and sent out of the building consequently.

There are various techniques of liquid-based cooling such as a) racks cooled by liquid b) systems founded on pumped refrigerant c) close/open cooling architecture d) close-coupled liquid cooling and e) direct cooling of boards or chips [16].

Direct cooling of racks by normal liquid with cooling water of 7.2 degrees Celsius and without any other optimization in the data center, for instance, could result in 18% energy savings in comparison to CRAH units. If free cooling systems are added to it, 49% energy savings could be expected. The evaporative free cooling system could increase energy savings up to 55% [17].

G. Renewable energy resources

Renewable energies could be driven from different resources including water, wind, sun, tide waves, biomasses and geothermal.

III. RESEARCH METHODOLOGY

Whereas the previous section (review of the related literature) aimed at probing into challenges, gaps and issues regarding the adoption of green technologies, the present section deals with collecting data from practical point of view to be studied along with theories so that a wider understanding could be achieved regarding the formulation of a practical guideline regarding the adoption of green technologies.

Given that there are numbers of different green techniques to be used in a data centre, greening up a data centre requires lots of investments and making decisions in this regard might bring about a couple of risks, IT managers face challenges to select among them. A comprehensive data analysis is, therefore, necessary in this regard. In other words, both qualitative and quantitative data are required to shed lights on the way that IT managers could make up their minds regarding adoption of the most suitable green techniques. The mixed research methodology, therefore, met the aims of the researcher appropriately since it took both primary and secondary sources of data into account.

The present study is of descriptive type. The descriptive statistics was very beneficial in evaluating the relationship between the determinants discussed in this study and the possibility of constructing or upgrading data centers through adoption of green technologies. A descriptive statistics could, furthermore, contribute to the analysis of different responses regarding the use of determinants in data centers which finally makes it possible to develop a comprehensive and reliable guideline.

A. Data collection and analysis

The most relevant and recent data should be collected through literature review which includes but not limited to articles, papers and books; otherwise, it encompasses primary data which could be collected through questionnaires and interviews with professionals, experts and industry practitioners to obtain real life information about their experiences. This phase plays a critical role in adding validity, reliability and creditability to the results obtained from the research which could be generalized globally for most cases as such through the proposed guideline. In the present study, the related literature was meticulously reviewed and data were gathered through holding interviews with three IT professionals in Iran and questionnaires sent electronically to fifty IT practitioners in Malaysia. In the present study, pie charts were resorted to regarding the analysis of data collected through questionnaires. Data gathered from interviews were, however, analyzed qualitatively by the researcher.

B. Discussion

Regarding all effective factors in construction of a data center and all solutions illustrated in the related literature section and data gathered through questionnaires and interviews, a guideline for designing and constructing a green data center would be developed. The proposed data center would be fast, secure and economical and employs new technologies and equipment to achieve high security, integrity, reliability and availability. It tries to centralize all servers, security and communication infrastructures and other electronic equipment. Besides observing all dimensions related to energy saving and eco-sustainability, the proposed data center tries to optimize its communication infrastructures. The proposed data center is founded on the adoption of new solutions and technologies to achieve the desired elements such as reducing energy consumption and minimizing harmful impacts on the environment in construction of a green data center. Regarding questionnaires and interviews, it was revealed that there are still some companies (40 percent) which resort to traditional cooling systems; they, however, believe that CACS and HACS are very effective cooling systems while they are not fully aware of the benefits of liquid-based cooling system. In terms of consolidation, they (more than 80 percent) considered virtualization one of the most effective solutions and most companies (more than 70 percent) applied memory compression to solve their placement problems. Making use of renewable energy resources was among the questions asked. Hydro sources due to their accessibility were among the most utilized sources (35 percent). Furthermore, most companies (more than 80 percent) paid enough attention to recyclable logos when they wanted to purchase IT equipment and they (more than 70 percent) were eager to use PCMs and silicon insulating materials in their data center's buildings. A majority of participants (81 percent) declared that they are taking distance from 24*7*365 operating style to reduce the power consumed by servers. They (68 percent) were also cognizant of EPEAT, ROHS and Energy Star standards and made their attempts to observe these regulations. Most of them believed that Energy Star was a more effective standard. The interviews revealed as well that companies took environmental issues seriously and declared that despite the initial capital, adhering to green IT techniques could bring about long-term economic benefits for their companies.

IV. THE PROPOSED PATTERN

The proposed pattern is comprised of three levels namely assessment, analysis and solution. These levels are successive and should be implemented respectively. The results obtained from any level are considered a prerequisite for the next level.

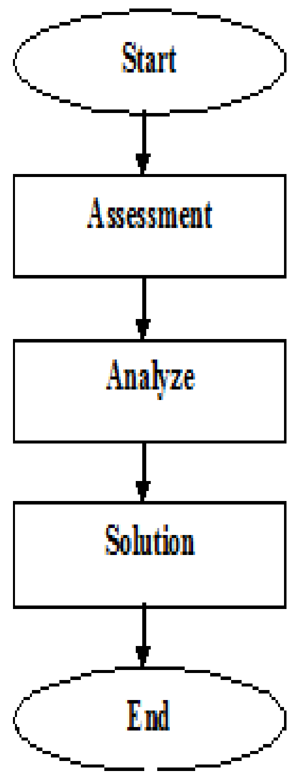


Fig.1. the proposed pattern of designing and constructing a data center

Different levels of the above mentioned pattern are as follows.

Assessment phase: the required information for designing a green data center is gathered at this step. The main source of information is the client of the data center who declares its requirements and facilities. At first, all existing information regarding systems, networks, the performance of employees and the interaction with the final potential users are meticulously examined to achieve a comprehensive estimation of their requirements and systems.

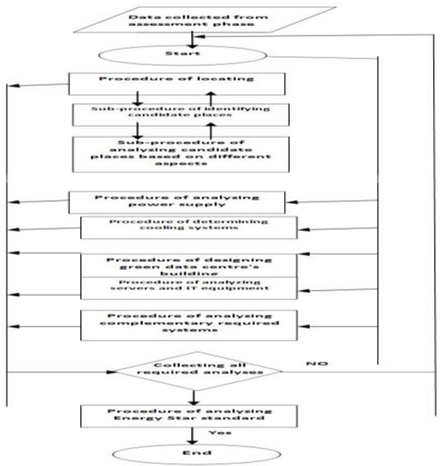


Fig. 2 shows a general overview of different stages of this phase in a flowchart

Analysis phase: according to the data gathered at the previous phase, different aspects of constructing a data center are analyzed. It seems necessary that the analyses cover all dimensions of designing a data center and be able to reply all questions regarding the solutions and required equipment for construction of a data center.

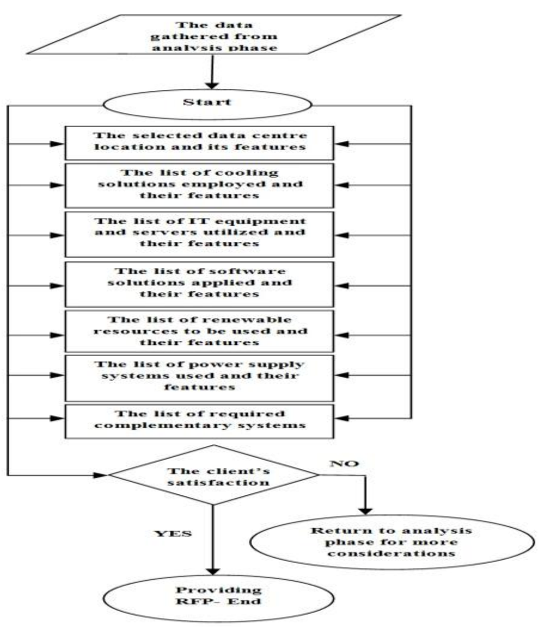


Fig. 3 different stages of implementing analysis phase

Solution phase: based on the findings obtained from the analyses at the previous phase, the client would be informed the considered solutions and technologies for construction and putting into operation of a data center. At the end of this phase, it is expected that the request for proposal (RFP) of the project is provided and the project enters the phase of list of materials (LOM). Fig. 4 shows a general overview of the solution phase in a flowchart.

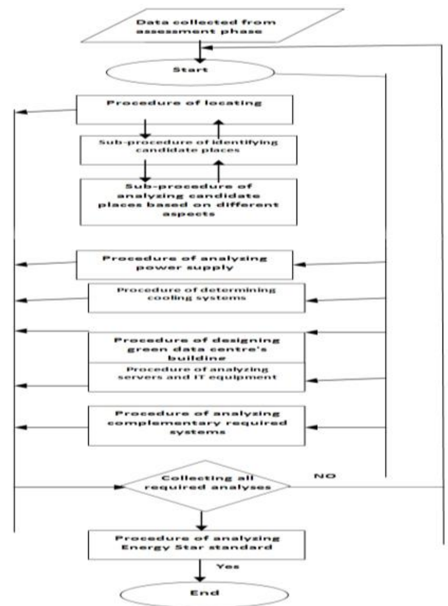


Fig. 4 different stages of implementing analysis phase

Among the three aforementioned levels, the second one, i.e. the analysis phase, is of paramount importance since all effective factors are analyzed at this level and the best final solutions are provided here. What follows is a list of elements which should be taken into account at this level to make possible the development of a practical guideline for constructing new data centres or upgrading older ones.

The procedure of analyzing power supply resources

Given that green data centers are highly dependent on energy, the sources of supplying them are of very importance. This procedure, therefore, focuses on different dimensions of these resources. Renewable and clean energy resources take highest priorities in this regard.
Although their utilizations are very important, these resources, unfortunately, could not always supply all power required in a data centre particularly when

high capacities are needed. Having analyzed renewable energy resources, this study would therefore concentrate on nationwide power supply grids and emergency power supply resources as well. Fig. 5 shows this procedure in a flowchart.

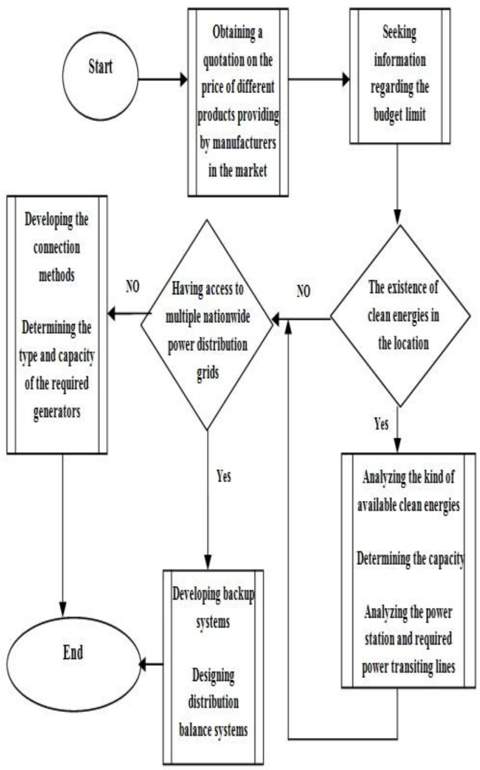


Fig. 5 the procedure of analyzing energy resources

The procedure of analyzing cooling system

Regarding the fact that cooling operation might consume up to fifty percent of a modern data center's power, the analysis and selection of proper solutions and technologies in this regard plays a crucial role in reduction of operation costs and power consumed. Making use of information gathered from previous phase and the client's requirements, the attempt is made in this procedure to analyze and determine the cooling system. Fig. 6 shows this procedure in a flowchart.

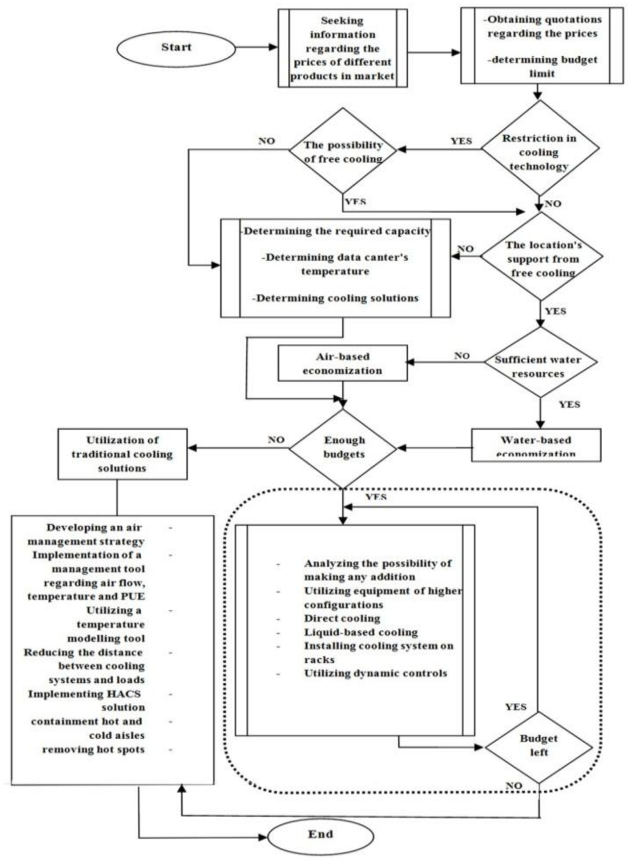


Fig. 6 The procedure of analyzing cooling system

The procedure of analyzing a green data center's building

The data center's building accommodates all IT equipment, servers, communication networks and other backup systems. As illustrated in literature review, adoption of new technologies in constructing and running these buildings might lead to energy saving. They should be designed in a way to accommodate new equipment required by clients over the time. Fig. 7 shows this procedure in a flowchart.

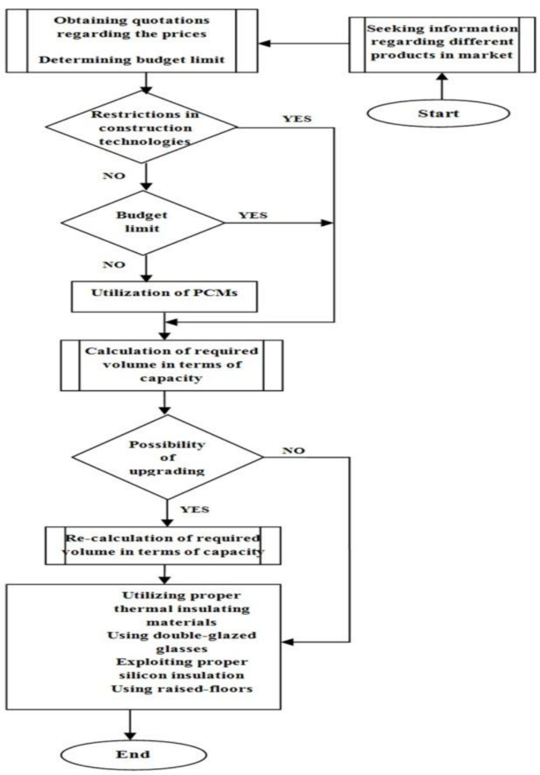
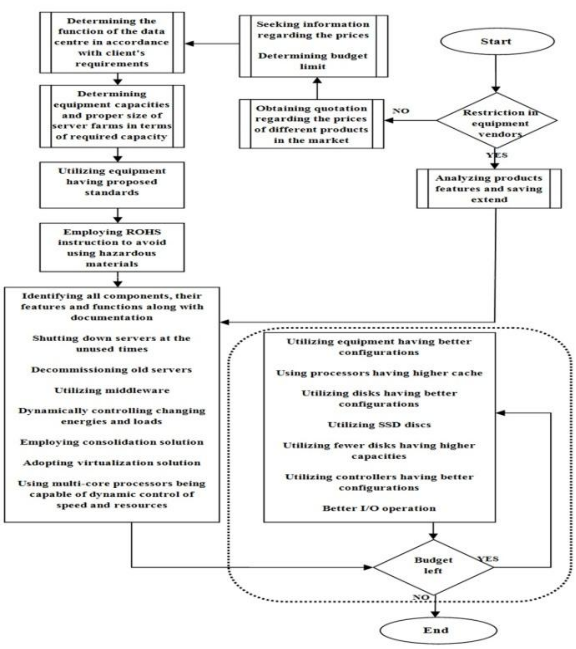


Fig. 7 the procedure of designing and analyzing a



data centre's building

Fig 8 Procedure of Analyzing the servers and IT equipment

The procedure of analyzing servers and IT equipment

Given that all activities required for providing various services in a data centre are done by IT equipment and servers and other systems including cooling and power supply ones are merely implemented to support these equipment, the importance of carrying out proper analyses prior to any decision regarding selection of equipment and technologies would be clear.

These equipment consume the highest quantity of power in any data center; adoption of any solution which leads to reduction of power consumed by these equipment could be, therefore, very effective in total power consumed by the data center. Server and storage equipment take the highest rank in this regard and network equipment takes the next position. The highest emphasis is, therefore, placed on reduction of power consumption in servers.

The proposed procedure regarding analysis of servers and other IT equipment examines the adoption of several common solutions in selection of all equipment after seeking information regarding the equipment prices and existing solutions in the market. The most effective solutions would be then analyzed and provided proportionate to the allocated budget. Fig. 8 shows this procedure in a flowchart.

The procedure of analyzing a data center in terms of Energy Star

A data center should be further analyzed in terms of conformity with the latest version of Energy Star (i.e. version 4.0) and remedied if necessary. This standard is implemented to reduce and optimize power consumed by all components of a data center. Fig. 9 shows this procedure in a flowchart.

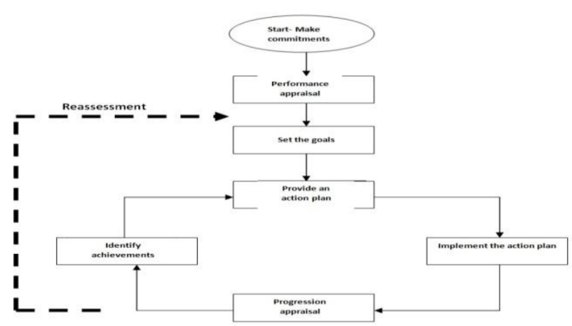


Fig. 9 the procedure of analyzing a data center in terms of Energy Star

So far all implemented operations at assessment and analysis phases aimed at developing a comprehensive report (of RFP type) based on the client's requirements which not only meets the client's preferences and brings economic profits but enjoys the highest rate of energy efficiency and is thoroughly environmentally friendly. The provided report which is a classification of all data gathered from assessment and analysis phases in a clear and understandable frame would be then submitted to the client. If there is any ambiguity or insufficient information, it is necessary to get back to the assessment and analysis phases to remove them. This process should be reiterated until the client's satisfaction is met.

V. CONCLUSION

Regarding environmental issues including global warming, energy efficiency and reduction of power consumption in data centers and fossil fuel rises and swings, the attempt was made in this study to provide a guideline for greening up data centers. Various new technologies were introduced and analyzed in this regard. The effect of each factor was studied and the best elements were introduced. In order to develop a practical guideline regarding the construction of a green data center, the following effective factors were analyzed. The concluding points are summarized here.

Consolidation: Consolidation could lead to the reduction of IT resources which in turn a) reduces power consumption, b) facilitates resource management and c) identifies real requests through utilization of request discrimination solution, as a consolidation sub-solution, which might reduce the loads via removing requests which are not useful for the system such as requests made by thief robots or crawlers.

Server's power consumption: Through analysis of this factor, the servers' power consumption could be instantaneously calculated by means of different solutions. The unused servers would be consequently identified. Therefore, in spite of the traditional thought of having all servers run at all times and having them performed in 24*7*365 operating style, it could be possible to shut down unused servers, decommission old servers and reach the proper size of servers' farm.

Green building: During analysis of data centers' buildings, the researcher concluded that some strategies including use of PCMs, wool glass, double-glazing glasses and silicon insulating materials should be employed in the construction of data centers' buildings to reduce thermal exchange between inside and outside environments which reduces power consumption and improves cooling system's performance.

Standards: Observing EPEAT, Energy Star and ROHS standards are considered prerequisites of constructing a green data center. They firstly improve the performance of the data center which in turn reduces its operation costs and secondly facilitate equipment upgrading and recycling.

Equipment lifetime: In contrast to the traditional thought regarding disposal of old computer equipment, green IT introduces new 3R solutions (reuse, recycle and refurbish) in this regard which considerably reduce harmful environmental impacts.

Renewable energy resources: Given that we are running out of fossil fuels, more attentions should be paid to renewable energy resources as a thoroughly effective factor in achieving goals set in green IT. Their usages could strikingly reduce harmful environmental impacts.

Cooling system: Various cooling solutions were studied in the present study. They were classified into two general categories namely traditional and modern. The disadvantages of traditional ones were examined and the researcher concluded that the move should be towards utilization of modern ones if the objectives of green IT are going to be achieved. New solutions were taken into account and their advantages and disadvantages were illustrated. Liquid-based cooling system was a solution of very high efficiency while it was very expensive at the same time. Free cooling was ranked as a complementary solution. Between two remaining solutions namely containment of hot aisle and cold aisle, the former was more effective since there was no need to move clod air near to loads. It, therefore, reduces power consumption.

VI. REFERENCES

[1] Binder, W. & Suri, N. 2009, "Green computing: energy consumption optimized service hosting," *SOFSEM 2009: Theory and Practice of Computer Science,* 5404**,** 117-128.

[2] Murugesan, S. 2008, "Harnessing green IT: principles and practices," *IT professional,* 10**,** 24-33.

[3] Murugesan, S. 2008, "Harnessing green IT: principles and practices," *IT professional,* 10**,** 24-33.

[4] Torres, J., Carrera, D., Hogan, K., Gavalda, R., Beltran, V. & Poggi, N. 2008, "Reducing wasted resources to help achieve green data centers. parallel and distributed processing," IEEE International Symposium on IPDPS, 2008b. IEEE, 1-8.

[5] Beloglazov, A. & Buyya, R., "Energy efficient resource management in virtualized cloud data centers," Proceedings of the 2010 10th IEEE/ACM

international conference on cluster, cloud and grid computing, 2010. IEEE Computer Society, 826-831.

[6] Le Masson, S. & Nortershauser, D., "New thermal architecture for future green data centres," Telecommunications energy conference (INTELEC), 32nd International, 2010. IEEE, 1-5.

[7] Gandhi, A., Harchol-Balter, M., Das, R. & Lefurgy, C., "Optimal power allocation in server farms," Proceedings of the eleventh international joint conference on measurement and modeling of computer systems, 2009. ACM, 157-168.

[8] Murugesan, S. 2008, "Harnessing green IT: principles and practices," *IT professional*, 10**,** 24-33.

[9] Gehin, A., Zwolinski, P. & Brissaud, D. 2008, "A tool to implement sustainable end-of-life strategies in the product development phase," *Journal of Cleaner Production*, 16**,** 566-576.

[10] Kokkinos, P., Christodoulopoulos, K., Kretsis, A. & Varvarigos, E, "Data consolidation: A task scheduling and data migration technique for grid networks," Cluster Computing and the Grid, 2008. CCGRID'08. 8th IEEE international symposium on, 2008. IEEE, 722-727.

[11] Scofield, B. & Hayden, P., "Keeping cool in the data center: A high-efficiency modular solution," Telecommunications energy conference (INTELEC), 32nd international, 2010. IEEE, 1-5.

[12] Scofield, B. & Hayden, P., "Keeping cool in the data center: A high-efficiency modular solution," Telecommunications energy conference (INTELEC), 32nd international, 2010. IEEE, 1-5.

[13] Nakamura, M., Nakamura, R., Nishida, R., Takeuchi, A. & Tominaga, T., "Energy efficient cooling in data center using optimization approach," SICE Annual Conference (SICE), 2012 Proceedings of, 2012. IEEE, 2103-2108.

[14] Curtis, P. M. 2010. Appendix C, "Airflow management: A systems approach. *maintaining mission critical systems in a 24/7 Environment, Second Edition***,** 441-457.

[15] Niemann, J. 2008., "Hot aisle vs. cold aisle containment," *APC white paper*.

[16] Patterson, D. M. 2008., "Sveven strategies to improve data center cooling efficiency".

[17] Scofield, B. & Hayden, P., "Keeping cool in the data center: A high-efficiency modular solution," Telecommunications energy conference (INTELEC), 32nd international, 2010. IEEE, 1-5.

[18] Scofield, B. & Hayden, P., "Keeping cool in the data center: A high-efficiency modular solution," Telecommunications energy conference (INTELEC), 32nd international, 2010. IEEE, 1-5.