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Capacity Planning for Green Data Center Sustainability

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***Abstract*—Business demands for powerful computing resources are increasing the workload in data centers, hence raising the complexity of managing the data center. What the impact of data centers on the environment is now a particular concern. Although there are now efforts to realize Green data centers through harnessing Green technologies, their sustainability remains an issue. Data center management includes planning its capacity. However, capacity planning for data center efficiency has only focused on measurements of power and cooling (part of infrastructure operation), which are insufficient to ensure the sustainability of the data center. In fact, a more thorough set of components must be considered. Therefore, this study proposes a capacity planning framework to derive practical solutions for Green data center management and thus ensure the sustainability of the Green data center. To this end, the components for Green data center sustainability and capacity planning were determined using Content Analysis and the findings verified by Green data center experts.**

***Keywords*—capacity planning; green data center; green technology; sustainability.**

I. INTRODUCTION

GHG (greenhouse gas) emissions are negatively impacting the environment. One of the sources emitting high levels of GHGs and requiring massive power consumption is the data center [1]. Data centers are among the highest consumers of electricity in the world due to their massive reliance on the usage of the Internet of Things (IoT), Internet traffic, digital content, and big data to increase processing ability. In 2011, as much as 1.4 metric CO_2 (carbon dioxide), which translates to an electricity bill of RM714 billion, was attributed to the data centers in Malaysia alone [2]. A 4% increase in total electricity consumption in the U.S. was reported from 2010 to 2014, where 1.8% of this consumption or an estimated 70 billion kWh was attributed to data centers, and this number is set to increase to 73 billion kWh in 2020 [1]. The environment is increasingly impacted by the increased power needed to operate data centers [1], [3]. Furthermore, data center efficiency will also be affected if its power usage were not controlled, as this could lead to increased cost and operational issues [4]. Therefore, there is a need for technology, especially data centers, to be more environmentally conscious, and this has paved the way for research and initiatives into Green data centers.

Green IT [5], Green computing, and Green data centers [6] are some of the Green initiatives developed and adopted to ensure a more environmentally friendly and greener data center. These initiatives aim for organizations to be more environmentally conscious by implementing governing mechanisms such as assessment tools and best practices, legislation, policies, standards, and guidelines. The threat of technology to the environment has also led to the development of Green technology guidelines and Green Policies [7], [8]. Despite the existence of these policies and guidelines, none are targeted towards data center characteristics, which are more specialized; most focus on general management of IT. Existing works on Green data centers establish the data center's environmental efficiency by emphasizing on cooling and power usage measurements, but sustainability is not addressed. Sustainability has become a key challenge in data center management due to the full-tilt growth in demand for data processing and storage and the all-out transformation of business operations into digital information management [9]. Seeing how sustainability is increasingly required in technological operations, sustainability strategies to ensure a more cost- and performance-effective data center operation have been implemented in major IT companies [10]. These strategies stem from the awareness that power is being wasted due to data centers not optimizing IT resources [11]. The performance of Green data centers can be controlled and managed to become more sustainable and environmentally efficient through proper planning of the centers' resource capacity. It is important to note that a holistic reference is required for planning on this scale. [12]. Previous works have yet to consolidate Green data center components with

sustainability concepts, as they tend to focus more on power consumption and cooling [2], [8], [7], [13]–[16], and are therefore lacking the holistic reference mentioned above.

To address the gap in the field of study, this work proposes a capacity planning framework to ensure Green data center sustainability. Sustainable concepts and Green technology components for data centers are consolidated in this framework. Official documentations underwent a comprehensive Content Analysis as part of the framework development process so that data center sustainability and environmental efficiency elements could be defined and identified. The capacity planning framework for Green data center sustainability is then verified via expert review.

The organization of this article is based on the following format: the groundwork for the concepts of this study are first discussed followed by an outline of the process for developing the framework. Then, an analysis of the findings is conducted. Lastly, the work is concluded with implications and future work.

II. MATERIAL AND METHOD

A. *Capacity Planning*

Capacity planning in the IT context is defined as a process to determine the best solution for IT infrastructure to fulfill the needs of future business demands [17]. The practice of establishing a complete capacity planning plan could increase the efficiency of IT operations and cost-effectiveness.

Capacity planning encompasses IT service management aligned with business needs, and capacity management in the Information Technology Infrastructure Library (ITIL). The organization demands maximum IT opportunities with minimal cost, which requires a good capacity plan. This enables a balance between business productivity and IT cost in the organization [18]. From the industrial practitioner's perspective [19], capacity planning is defined as business planning that is translated into requirements for IT infrastructure resources to meet future expectation within the organization's budget. Planning focuses on the entire IT infrastructure including its related resources (hardware, software, technical and workforce support) and its environment (location, space). Concurrently, it must also consider the business aspects and organizational governance. Hence, the capacity planner needs to holistically understand both the IT and business aspects to avoid any ICT project execution breakdown.

B. *Data Center Capacity Planning*

Capitalizing on the advantages of IT without overspending is essential. An essential tool for achieving this objective—and to optimize data center management and operation—is capacity planning [18] Capacity planning for data center environment enables:

- Estimation of the time for existing data center infrastructure that will no longer meet the service level.
- Determination of the infrastructure elements that will cause any future catastrophe
- Analysis of cost-effectiveness in selecting the right services (e.g., choosing between Public or Private cloud services).
- Recommendation on re-purposing obsolete infrastructure to optimize data center operation.
- Determination of workloads that can be consolidated for maximum utilization.
- Preparation for forecasted and unexpected business workload.
- Envisaging the most cost-effective operational configuration before proposing new technology or applications.
- Optimization of virtual and physical machines.
- Transfer of workloads into new IT infrastructure.
- Ensuring the disaster recovery solution will have sufficient capacity.
- Ensuring the successful implementation of server consolidation.

Successful capacity planning significantly improves data center performance and availability; hence supporting efforts to establish a green and efficient data center [11], [20]. Existing research on green data center capacity planning has been focusing on several issues:

- Power and energy consumption through energy footprint from implemented virtualization that enables flexibility for capacity management in a data center [15]
- To improve data center performance and availability from the maximum utilization of energy storage resources via an investigation into battery-aging affects data center sustainability. Green data center power costs and energy have been proven to reduce, and supply/demand power mismatch eliminated, with the use of energy storage devices [14]
- Power and workload management for minimizing long-term cost due to uncertain workload demand is a capacity planning problem that is also being addressed [21]
- Energy source selection (Green and Brown energy) for constructing a Green data center to meet cost, emission, and service availability requirement [13]

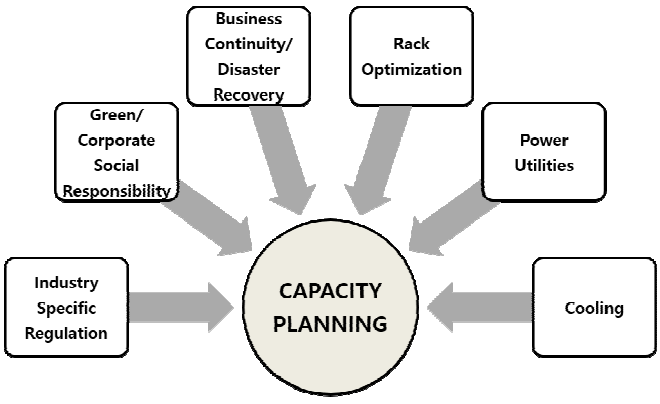

Fig. 1 Standard Components for Data Center Capacity Planning [22]

Research in capacity planning for data centers has been mainly focusing on the energy and cooling management perspective for data center optimization, as presented in Fig. 1. However, a holistic perspective that includes all the Green elements and principal components in a data center is still required when planning the capacity for an effective and efficient data center.

C. Green Data Center

One of the key parameters that change business and IT workloads is the data center, which is dynamic because it consistently requires increased capacity for IT services, infrastructure, and facilities. The two main components for operating a data center are IT facilities (storage, servers, and networks) and site infrastructure (lighting, uninterruptible power system (UPS), power distribution unit (PDU), and cooling system) [12], [17]. Without these two components, the data center will not be able to successfully process high system transactions as part of meeting user and business requirements, as interruptions would emerge. The data center thus consumes a massive amount of power because its IT equipment must always be operating optimally [12], [23].

Once a data center can reduce environmental impact and energy cost, as well as efficiently and effectively utilize resources, it is certifiably Green [24]. Most strategies to produce an efficient data center have focused on power consumption and cooling measures. However, many other factors are involved such as optimal performance through sustainability, proper performance standards for components, utilization of space, essential player collaboration, manufacturer operation optimization, and the right infrastructure to promote dynamic adaption to new technology [25]. In short, apart from the factors of power and cooling, factors involving environmental health and safety ((PCFE) are also crucial for establishing a Green data center [3].

The move towards a data center that is greener requires significant expenditures [26]. To solve this issue, organizations do not need to implement Green initiatives all at once; this can be done progressively, beginning with measures that are elementary and free, at no cost [11]. Enhancing services and infrastructure are part of the efforts that are being looked into in current studies on Green data center development and transition [6], [26]. A Green data center can be built using two primary methods that complement each other; first, the data center is designed using Green equipment; second, Green best practices are implemented as part of the daily operations in the new data center [6]. Previous studies have reported the advantages of using both methods including enhanced thermal control and cooling management, better utilization of data center resources, reduced power usage, and improved management of data center infrastructure [6], [27], [28].

D. Data Center Green Metric and Benchmarking

It is impossible to recognize the Green impact from data center operations (based on resource usage and type) without a proper method to measure it [4]. Therefore, having a form of measurement is paramount to ascertain whether or not the Green initiatives applied in data centers are successful [29]. In answer to this issue, a recognized body consisting of qualified IT professionals, known as The Green Grid, developed specific measurement metrics for data centers.

To measure the environmental impacts of data center operation, a set of measurements were developed, namely the Green performance metrics [12]. Benchmarking and execution environments are performed using these performance metrics. The benchmarking of data centers is divided into two categories: data-center level and server level. The former is done to assess the Green status of the data center, whereas the latter measures power consumption due to server operation performance. The United States Department of Energy Office of Energy Efficiency & Renewable Energy, the National Renewable Energy Laboratory (NREL), and Lawrence, Berkeley National Laboratory (LBNL) are at the forefront of Green data center benchmarking and practices [1], [30]. For an in-depth view of performance metrics and benchmarking concepts, the reader is referred to [31].

The Green Grid developed the PUE (Power Usage Efficiency) metrics, which is a globally accepted metrics [32]. This metric is the ratio of total data center power consumption to total electricity consumed by IT equipment, where a ratio of less or equal to 1.6 is considered efficient [2]. Nevertheless, this metric alone is insufficient for measuring data center energy usage and functionality level as a whole, so additional metrics must also be taken into account [33]. Therefore, the current metrics for measuring the Green status of data centers should be further improved. This can be done through the identification and specification of requirements for effective and efficient utilization of all resources in data centers with the aim of reducing GHG emissions and improving the future of Green technologies [33].

E. Green Data Center Sustainability

When discussing sustainability, the concepts of economy, corporate, and environment also come into play [9]. The needs of future stakeholders must not be compromised when satisfying organizational needs; this is termed corporate sustainability. Organizational needs are met by applying the correct solution and ethical practices [9]. The data center that utilizes IT resources efficiently with minimum energy consumption throughout its life cycle, to protect the environment, is deemed environmentally sustainable. [24]. By going Green, and giving value to the community, besides gaining a good reputation and receiving benefits that are tangible and intangible, the data center would also be economically sustainable [24]. IT organizations are now aware of the importance of sustainability and have even taken up strategic measures towards this end. However, the data center involves many parts of a whole, so measuring its sustainability is a complex undertaking [34]. Complexity mainly arises because costs must be reduced and energy consumption managed while ensuring the business continues to expand [12]. This case is relevant to the field of IT in general, but differs according to context. Hence, IT management stakeholders must have the same understanding of sustainability even though different IT components are involved [35].

The Malaysia National Green Technology Policy is a sustainability strategy initiative that integrates the concept of

Green technology such as the economy, environment, energy, and society [8]. Via this policy, renewable energy is promoted as an acceptable and environmentally friendly source, and this is part of the concept of sustainability. Sustainability initiatives are also part of the 2011–2015 strategic plan of the United States Environmental Protection Agency (EPA) [36]. Google has opted to rely on wind energy for some of its operations, besides recycling gray water for cooling purposes and reusing or recycling machines, as part of practicing these strategic plans, which measure IT infrastructure sustainability through optimal operational performance [37]. Another tech giant that claims to have used 100% green energy for its power consumption since 2014 is Microsoft, placing it as the United States' second largest renewable energy user [38]. To address the many components of IT in an organization, various sustainability components for ensuring Green technology must be defined.

Data centers, however, have unique, different, and specialized IT components. Hence, the Green state or environmental efficiency, and sustainability of data centers can only be monitored and measured using a specially defined set of components that must first be established.

F. *Sustainability for Green Data Center Framework*

Practical solutions for sustainable Green data center management and operation are founded on the Sustainability for Green Data Center Framework [31]. The capacity planning framework in this study—for Green data center sustainability—adapts the framework mentioned above. Extensive analysis of international and national Green initiatives was performed to derive Green data center components and sustainability concepts that are then integrated into the framework, as shown in Fig. 2.

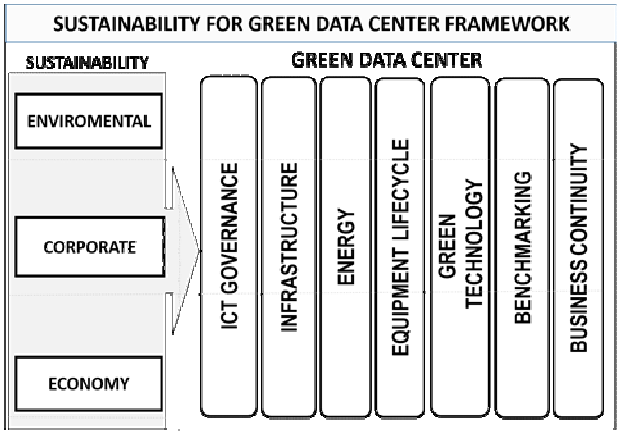

Fig. 2 Framework for the Sustainability of a Green Data Center [31]

The framework in Fig. 2 shows that efficient and effective management and operation of a Green data center can be achieved by utilizing the sustainability concepts that cover Environmental, Corporate and Economy aspects. Meanwhile, the components for a Green data center are critical aspects in developing, managing, and operating the Green data center in order for it to be environmentally efficient and sustainable. These include ICT Governance, Infrastructure, Energy, Equipment Lifecycle, Green Technology, Benchmarking, and Business Continuity.

G. *Research Design*

This study adopted a qualitative approach, where the Content Analysis method was employed to analyze data collected from 11 official documentation referred in [3], with the aim of defining the components for the design of the capacity planning framework to achieve sustainable Green data centers. The framework was then validated using an expert review.

1) Framework development: The Sustainability for Data Center Framework from a prior study was adapted for the development of the Capacity Planning framework in this study, which aims for the Sustainability of a Green Data Center [31]. The proposed framework includes the relevant components related to Green data center management obtained from official documentation. Capacity planning models and frameworks with the objectives of Green IT sustainability, data centers, and sustainability were also referred to for the development of the framework [22], [39], [40]. Fig. 4 shows the proposed framework in more detail.

2) Verification of Framework: The Green data center components and sustainability strategies incorporated in the framework are verified via an expert review consisting of three experts. There are two steps involved in the process of verification:

- Determination of expert characteristics: To select the right experts, each expert must be examined based on the following characteristics: certification and qualification, current job scope, expertise area, and duration of expertise (must have worked in a related field and work sector for at least eight years). This study employed three experts: a Senior IT Manager former trainer for data center courses from the National Institute for Public Administration (INTAN), Bukit Kiara; a Data Center Management Consultant from the Malaysian Administrative Modernization and Management Planning Unit (MAMPU), ICT; and a Data Center Consultant-cum-Chief Executive Officer for Novartis Sdn. Bhd.
- Interview: The interview conducted with the identified experts followed a semi-structured format, in which the questions were designed to verify the components and elements in the framework.

III. RESULTS AND DISCUSSION

The two-part study findings describe the developed framework in the first part, whereas the second part outlines the verification of the framework from the expert review analysis.

A. *Framework for Capacity Planning to ensure Green Data Center Sustainability*

Fig. 3 shows the main components defined in the Sustainability for a Green Data Center Framework, which form the basis for the development of the capacity planning framework in this study [31]. This framework has six Green Data Center components consisting of ICT Governance.

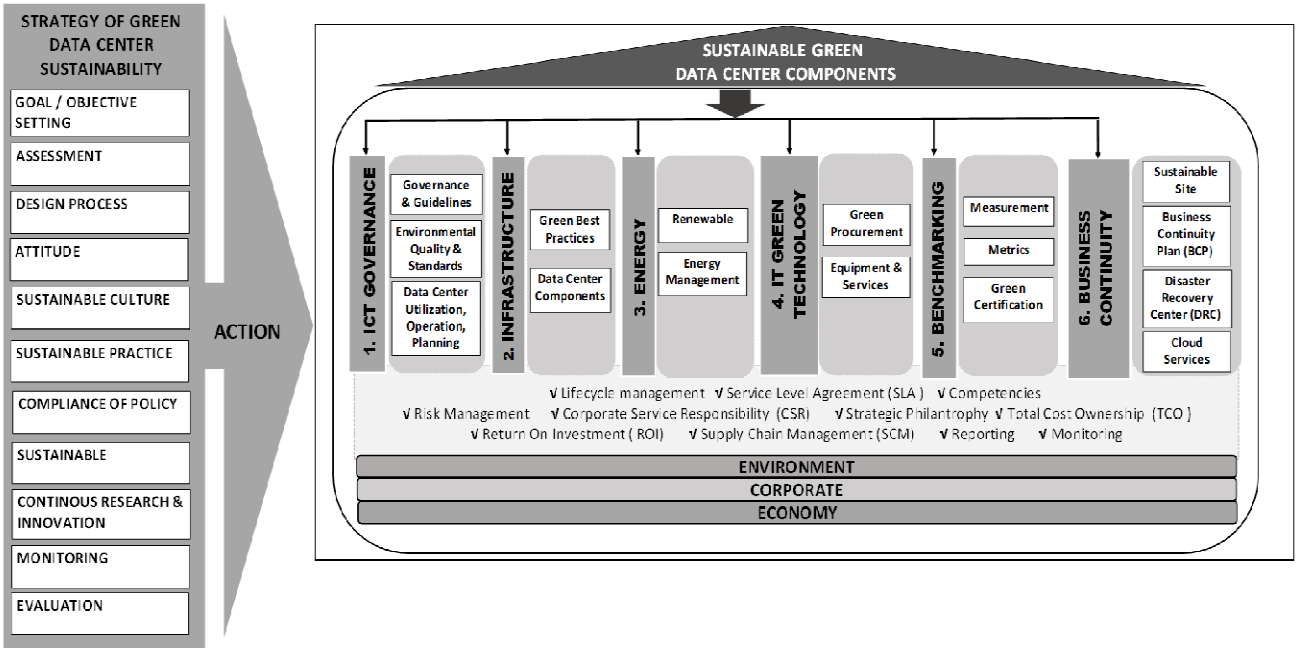

Fig. 3. Capacity Planning Framework for the Sustainability of a Green Data Center

Infrastructure, Energy, IT Green Technology, Benchmarking and Business Continuity. The components are relevant across the three sustainability pillars defined in [31]. In order to drive the sustainability components, a set of 11 strategies for data center sustainability was established.

The strategies ensure appropriate actions are taken for a Green data center to preserve or sustain its green status. The strategies incorporate Environment, Economy, and Corporate, the three main pillars of sustainability, with the management and operation component of the Green data center.

Ten sustainability elements have been defined in the framework that reflects the three sustainability pillars. The

Analysis from the expert reviews resulted in the redefinition and redesign of several components and elements for clarity. The result is discussed in three subparts to distinctively highlight the findings according to the main aspects of the framework. The subparts discuss the strategies for Green data center sustainability, sustainability component elements, and verification of the elements for a Green data center.

3) Green Data Center Elements: The verified framework has seven Green Data Center components. One of the changes is the definition of the Infostructure component that was redefined from the part of the Infrastructure component. The Infostructure component consists of data management, backup solution, and data lifecycle elements. A Green data center must have these elements to ensure sustainability. Competent human capital must also be part of the framework, as emphasized by experts in this field. The Human Capital component was initially embedded in the ICT Governance component. Human capital competency that effectively practices Green practices is crucial for the successful sustainability of a Green data center. Meanwhile, the Equipment Lifecycle component was redefined as the Lifecycle Management component and repositioned as part

elements consist of lifecycle management, service level agreement (SLA), competencies, risk management, corporate service responsibility (CSR), strategic philanthropy, total cost ownership (TCO), return on investment (ROI), supply chain management (SCM), and reporting. The elements are mapped to the Green data center components that support the sustainability pillars in Green data center operations. These sustainability elements were adapted from different IT perspectives regarding the environment, economy, and corporate relevant to the Green data center.

B. Framework verification result

of the sustainability elements. Finally, the Green Technology component was redefined as a generic component that is relevant to all the other Green Data Center components. The redefinition of the components also affects the Green elements. Table I presents the set of elements for the redefined Green Data Center.

TABLE I
REDEFINED GREEN DC COMPONENTS

Key Component	Green Elements
1. ICT Governance [9], [10], [12], [16], [24], [41]	Environmental Quality & Standards, Operation & Planning, Governance and Guidelines, Data Center Utilization, Green Procurement
2. Infrastructure [16], [24]	Data Center Site Facilities, ICT equipment and Services, Power Management, Design of Network, Cooling, Monitoring, Data Center Building, Lighting, Air Management, Space Management, Security
3. Infostructure [2], [16]	Data Management, Backup Solution, Data Lifecycle
4. Human Capital [2]	Training Roadmap, Certification, Certified Personnel
5. Energy	Energy Management and Usage,

Key Component	Green Elements
[2]	Renewable Energy
6. Benchmarking [12]	Measurement, Metrics, Green Certification
7. Business Continuity [12]	Business Continuity Plan (BCP), Disaster Recovery Center (DRC), Sustainable Site, Cloud Services

To ensure business goals are supported through data center performance, Green IT administration is specified under **ICT Governance**. To this end, this element establishes best practices such as how to plan, implement, deliver, support, budget, and monitor resources. It also guides the development of related policies [2], [9], [16]. The components in a data center and their efficient operation are grouped under **Infrastructure** [2], [12], [16]. **Infostructure** construes the importance of data management in conducting multiple levels of confidentiality in valuable organizational data [2], [16]. Personnel that is competent and has specific knowledge of handling Green data center operations are grouped under **Human Capital** [2]. The correct management of resources and renewable resource consideration is defined in **Energy** [2], [16]. Unwanted hardware in the data center is considered for recycling, refurbishing, or reuse in **Equipment Lifecycle** [24]. System, equipment, or products that are energy efficient, improve the environment and health, and are safe to consume, are defined as **Green Technology** [12]. By the aim of reducing energy use in data centers through the measurement of performance and identification of greenness and potential opportunities towards this end, a set of performance metrics, known as **Benchmarking,** are formulated [12], [24]. In the event of a natural disaster, the continuation of business is foremost. Therefore, cloud services, Disaster Recovery (DR), and building design requirements that meet the standards in the detailed Disaster Recovery Plan (DRP) and Business Continuity Plan (BCP) is considered as part of **Business Continuity** [11], [12].

4) Elements for sustainability components: The elements to ensure green data center sustainability were reevaluated. Duplicated elements were eliminated and simplified. Three additional elements were emphasized for consideration as sustainability elements. The elements are the 3R concepts, change management, and maintenance while the element of monitoring was repositioned as part of the strategy components. Descriptions of all the redefined elements are presented in Table II.

TABLE II
SUSTAINABILITY ELEMENTS

Sustainability Elements	Description
1. Lifecycle Management [9], [24]	Keep tracks of the data center equipment lifecycle to reduce downtime while optimizing the performance of the data center availability. It assists in strategic decision making by putting in place a set of business practices that integrate financial, contractual, maintenance, and inventory functions to support the lifecycle management for the data center environment.
2. Service Level Agreement (SLA) [24]	An official commitment that has been agreed upon in the contract between a service provider and a client. Data center SLA covers aspects of the service quality, availability, and responsibilities.
3. Competencies [2], [10], [24]	Personnel-related to Green data center management and operation shall attain relevant training, education, skills, and experience to be competent. The organization should provide recognized certification and training associated with Green data center implementation and operation. The courses are customizable to the organizational requirement.
4. Strategic Philanthropy [10], [24]	Knowledge sharing on best practices implementation in Green data centers could help the organization to become aware of the opportunities and impact of implementing Green initiatives.
5. Risk Management [12], [24]	Prepare for uncertainty in data centers. The organization needs a contingency plan such as BCP and DRP to support the business continuity component in a Green data center.
6. Corporate Social Responsibility (CSR) [10], [24]	The organization should support the sustainability culture and commit to ethical conduct. The practices in a Green data center preserve the environment and people.
7. Reporting [2], [9], [10], [24]	Reporting helps the organization to benchmark their Green data center performance based on the consistent use of standard measurement and continuous monitoring.
8. Total Cost Ownership (TCO) [10], [12], [24], [40]	TCO helps the organization to select the best ICT product for green data center efforts that meet the technical, environmental, and dynamic, and effective cost requirements.
9. Return On Investment (ROI) [10], [12], [24], [40]	The ROI analysis frequently uses the TCO analysis output as input. This analysis helps organizations to form the right decisions that consider both costs and income.
10. Supply Chain	Supply chain management

Sustainability Elements	Description
Management (SCM) [24], [40]	concepts are crucial for gathering information about, analyze, make recommendations, and follow up on changes made to increase ROI. These concepts can be applied to the introduction of any asset in the design and building of a data center within the data center supply chain.
11. 3R Concept (Reduce, Refurbish, Recycle) [9], [10], [24]	The 3R concepts enable the disposal of e-waste from the data center in an environmentally sound way.
12. Change Management [24]	Any changes to the data center need to be recorded and informed. This is to ensure the effectiveness of each new or updated implementation in Green data center management and operation.
13. Maintenance [12]	Maintenance involves managing the data center's physical infrastructure to utilize its resource consumption and increase efficiency and availability fully.

The specifications for each Green data center sustainability concept are translated from the redefined elements. Capacity planners will be able to define Green data center sustainability using these elements as a comprehensive reference.

5) Sustainability Strategies for a Green Data Center

The components for the capacity planning framework must be consolidated with the elements in a Green Data Center to ensure Green data center sustainability. To this end, specific strategies are devised, as outlined in Table III. The strategies are formulated according to ICT sustainability strategies relevant for a Green Data Center.

TABLE III
THE STRATEGY OF SUSTAINABILITY COMPONENTS

Strategy of Sustainability	Description
1. Goal Setting [39]	Sustainability and Green principles drive the overall approach. Goal setting is crucial to determine the organization's aim and actions for Green data center sustainability.
2. Assessment [12], [39]	Determining the sustainability factor that needs attention in the planning and implementation phase. It applies to all Green data center components. The data center needs to quantify total power usage to meet Green standard benchmarking. Assessment enables organizations to identify their needs in order to sustain their Green data center state from multiple aspects.
3. Design Process [10], [12]	Designing resource-efficient infrastructure and ICT equipment to promote energy savings and minimize potential negative environmental impacts over its entire lifecycle. Development of a sustainability plan is also part of the design process.
4. Sustainable Practice [9], [10], [30], [41]	Adapting Green business principles and processes by changing individual attitude towards sustainable and Green practices in data center management and operation.
5. Sustainable Culture [10], [12]	Sustainability actions must be considered after the adoption of innovation or obtaining Green status recognition.
7. Compliance of Policy [9], [10], [24]	Ensuring every decisions, process, and practice adheres to established standards.
8. Sustainable Technology [24], [41]	Indicated as Green technology that promotes energy and resource efficiency according to the aspects of the environment, economy, and corporate with the aim of achieving Green data center sustainability.
9. Continuous Research and Innovations [10], [24]	Promote sustainability innovations across organizations internally and externally.
10. Consolidation [9], [24]	Enable sharing of resources to manage and operate Green data centers effectively and efficiently.
11. Awareness [2], [11], [42]	Educate, encourage, and enlist personnel by sharing the best Green practices carried out in Green data center operations. Promotes Green practices through the 3R concepts of reducing, reuse, and recycle.
12. Tools Usage [12], [24]	Competent personnel using the right tools at the right time in a Green data center.
13. Monitoring [2], [9], [10]	Audit and monitor resource consumption in the Green data center.
14. Evaluation [12]	Measure the impact of operations to improve efficiency.

Three additional elements for strategy consisting of awareness, consolidation, and tool usage, are established, while the element of attitude was embedded in the element of sustainable practice and sustainable culture

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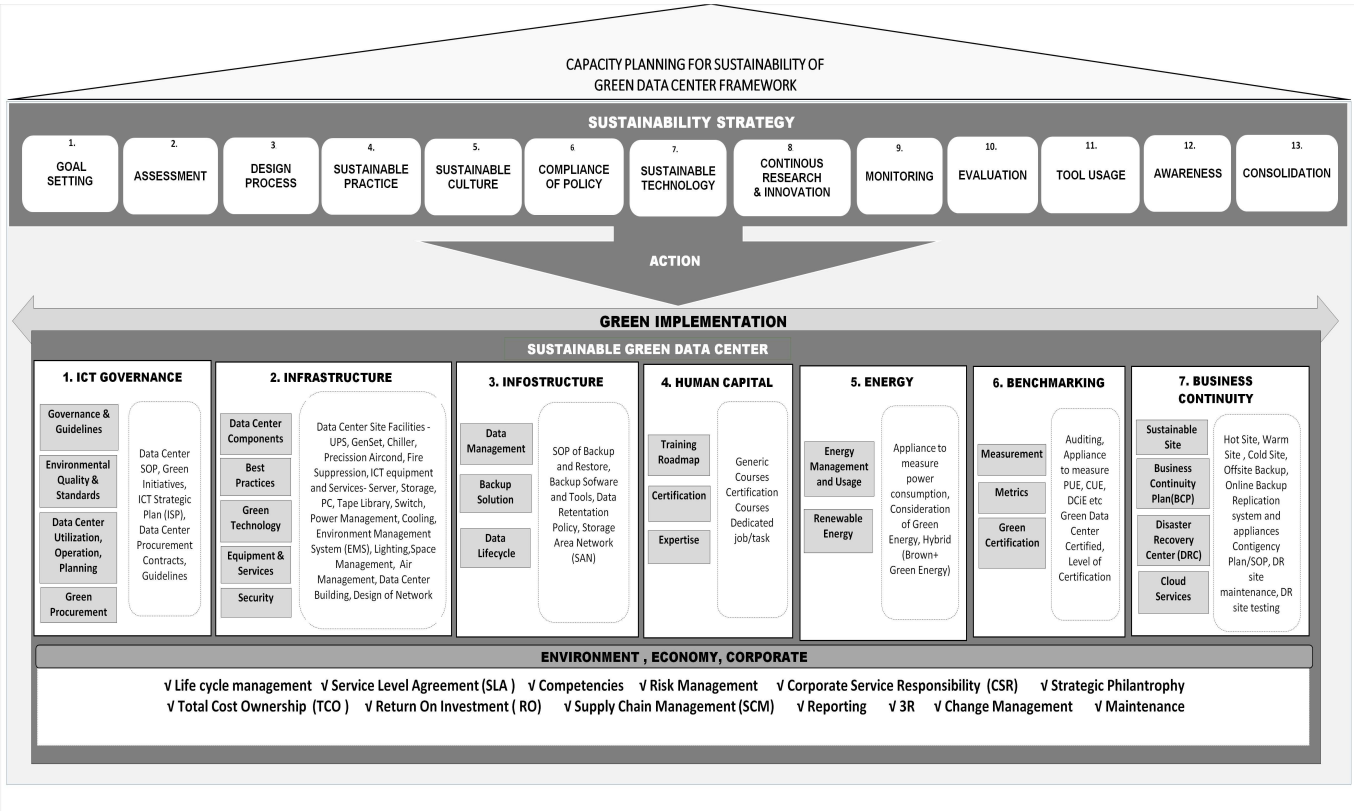

Fig. 3 Verified Sustainable Green Data Centre Capacity Planning Framework

The redesigned framework incorporates the redefined Green data center sustainability elements and components consolidated with sustainability strategies. The verified Green Data Center Sustainability Capacity Planning Framework is presented in Fig. 4.

IV. CONCLUSIONS

To efficiently manage and utilize the computing resources in a data center, two critical criteria emerge—sustainability and Green technology. Existing efforts that address these criteria have mainly focused on energy management and power consumption issues. This study proposed a holistic and thorough approach to address appropriate strategies to ensure Green data center sustainability effectively. This was done by proposing a Capacity Planning framework for the Sustainability of a Green data center that has been verified by experts from Public and Private Sectors. A data center capacity plan was described in this framework, in which the components for Green data center and a set of defined elements beyond the common technical components for sustainability were established. This verified framework would assist practitioners and guide them in Green technology capacity planning. The environment, economy, and corporate perspectives were taken into account in this framework, which also serve as a reference for developing practical solutions in the strategic management and operations of a sustainable Green data center.

This work will be further continued in the future to include the practical scope in which capacity planning for a data center in Malaysia will apply the framework proposed in this study for validation purposes. The case study method will be employed for the validation process. The results of this study can potentially provide an imminent solution to data center managers to properly plan for resource capacity and employ an updated method to achieve a sustainable and environmentally efficient data center.

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