ISSN No. 0976-5697

Volume 5, No. 3, March-April 2014

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

The Analysis of Constructing a Green Data Center in Iran

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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 saving 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 new data centers and expansion of existing centers. The present study aims at applying some green techniques and solutions in the construction of a green data center to reduce energy consumption and devastating impacts on the environment. A three-phase strategy is introduced in this regard which is comprised of a) assessment, b) analysis and c) solution. The present study takes one special country, Iran, into account; however, the steps presented could be taken in the construction of a green data center in any given country.

Key terms: Data centre, 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].

II. RELATED LITERATURE

A. Green building:

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 [3].

B. 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, for instance, 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 [4].

C. IT equipment:

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 [5].

D. Cooling systems:

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 [6].

a. ***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 [7].

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 [8].

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 [9].

b. ***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 [10]:

a) Setting higher temperatures for cooling systems
b) Reducing costs of humidifying/ drying
c) Utilizing physical infrastructure more efficiently

c. 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.

d) 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 [11].

d. 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 [12].

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% [13].

E. Renewable energy resources:

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

III. THE PROPOSED PATTERN

What follows is the proposed pattern which 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 prerequisites for the next level. Fig. 1 shows the proposed pattern in a flowchart.

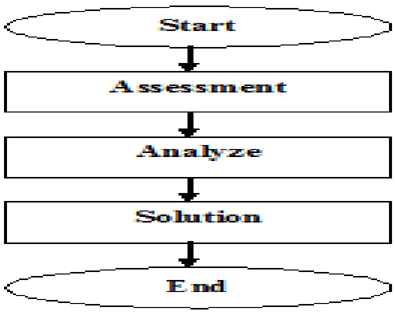

Figure.1 The proposed pattern of designing and constructing a data center

Different levels of the abovementioned 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.

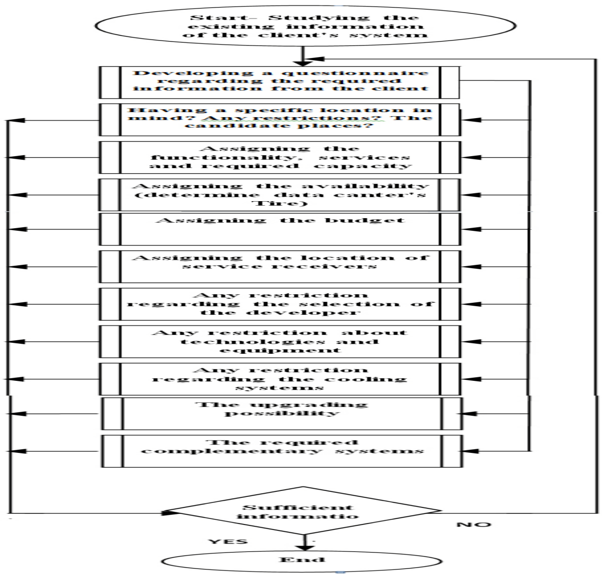

Figure. 2 shows a general overview of the assessment phase in a flowchart.

Fig. 2 different stages of implementing assessment phase

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

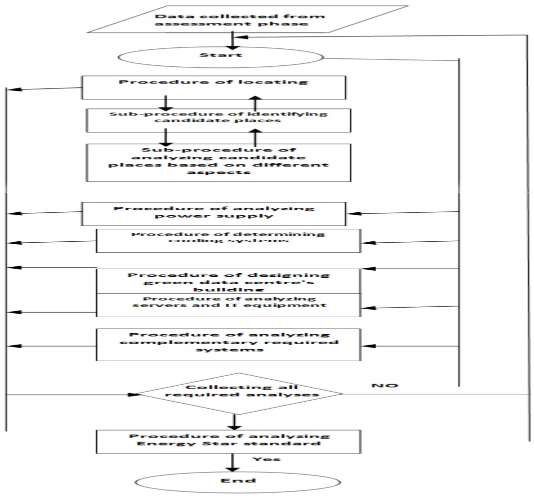

Figure. 3 different stages of implementing analysis phase

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).

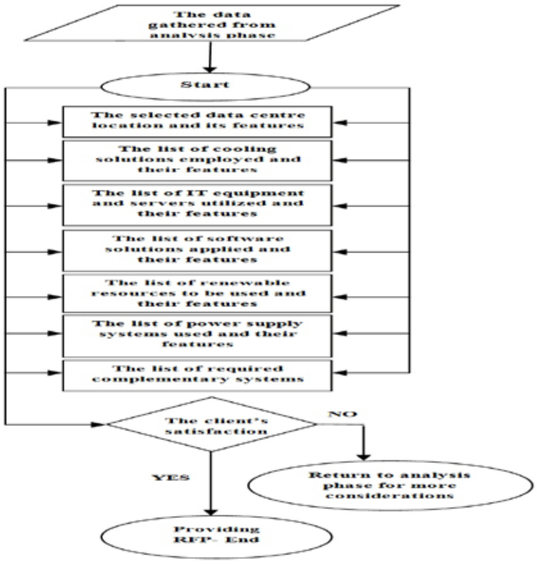

Figure. 4 shows a general overview of the solution phase in a flowchart.

Fig. 4 different stages of implementing solution phase

A. The assessment phase:

At first, the data presented by the company regarding the employees, systems and the current network status of the company is reviewed.

The physical status: the main office which is a fifty-storey building is located in Tehran and several smaller offices are also located in this city. The company has an office in almost all large cities of the country; however, there is no office abroad.

Employees: there are 1500 employees (with different recruitment status) in this company. Six hundred employees work in the main office and the rest are scattered all around the country.

Table 1 shows the company's current status regarding its networks and systems.

Number of available PCs	Approximately 1300
Number of servers	Nearly 30
Number of server rooms	One in the main office
The network's core switches	2
Network access switches	30
Server switches	3
VoIP equipment	To provide services for the employees of the main office
Communication wide web infrastructure	1) The system's connection with other centers and organizations in Tehran 2) The system's connection with internet provider companies to prepare the required internet connection for the employees of the main office 3) MPLS connection with the company's offices located in other cities

Table 1 the current status of the client's networks and systems

What follows is the analysis of responses provided by the client:

a. The objectives behind the construction and equipment of the data center: The client aims at constructing a data center and optimizing its communication infrastructure. S/he is fully aware of the advantages of utilizing a fast, reliable, safe and economical processing and communication system and employing new equipment and technologies to provide availability, reliability, integrity and safety, centralize all servers, communication and security infrastructures and other electronic equipment and observe all environmental and energy saving issues.
b. The client's technical objectives: The technical objectives are consisted of the following issues: scalability, availability, performance, security and management.
c. The services required by the client:
    a) Architectural and designing services including plans and equipment operational and technical features
    b) The optimum location of the construction of the data centre (there is no restriction in construction of the data centre)
    c) The physical infrastructure of the data centre and NOC monitoring room
    d) The required security systems
    e) The required features regarding all equipment
    f) The required solutions regarding IT equipment cooling, power supply and operation
    g) The possibility of upgrading at least for the two next years
    h) Availability and development possibility in designs
d. The client's responses to the raised questions:
    a) There is no locating restriction in construction of the data centre. The designer is in charge of selecting the location and providing the required justifications
    b) Tier 2 is deemed proper for designing and constructing this data centre with regard to the conditions and facilities
    c) The service receivers are mainly the company's own employees and the only outside users are those who visit the company's website.
    d) The client imposes no restriction regarding the technologies to be employed and the vendor of equipment and cooling systems to be used. The final employer, however, has to provide required services and guarantees. There should be no restriction imposed by the original vendor.

B. The analysis phase :

Different effective factors in the construction of a green data centre would be analyzed at this stage. These factors are as follows:

a. ***Locating:*** The selection of the location of a data center is considered one of the most important decisions to be made regarding the construction of a data center. Any negligence in this regard could lead to irreparable losses for the owner. Even the most advanced technologies could not compensate the imposed operation costs. Numbers of factors might take roles in locating a data center. Latency, for instance, is an effective factor in any data center locating. In other words, the distance between all main target markets for the provided services and the location of a data center should be kept reasonable.

b. ***Other factors to be taken into account are:*** natural disasters, power supply sources including access to energy resources, closeness to distribution grids, cheapness, availability and sustainability, access to clean energy sources, access to water resources since it plays an important role in water-based cooling systems, being in proper temperature conditions, access to fast communication networks since it could reduce latency and costs of getting connected to grids.

c. ***Locating procedure:*** This procedure is designed with regard to different factors contributing to proper locating of any data centre. These factors including having access to renewable energy sources or cold air required for new cooling solutions could lead to energy saving and data centre's pollutants reduction. This procedure is used if only the location has not been already selected by the client. Fig. 5 shows a general overview of this procedure.

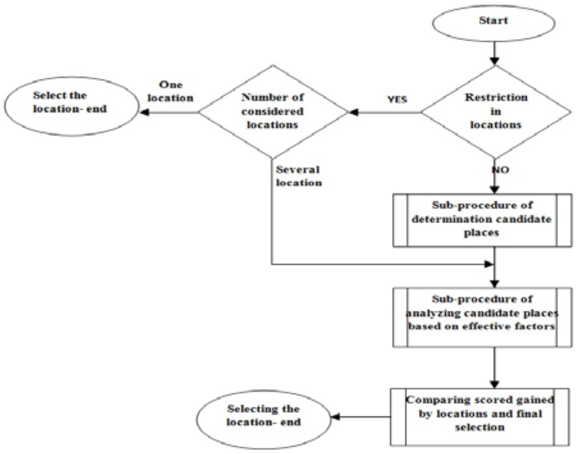

Figure. 5 the procedure of locating from analysis phase

a) ***Locating sub-procedure:*** This sub-procedure as a part of locating procedure is applied provided that there is no restriction regarding the selection of data centre's location. Under this condition, it provides a list of advantageous locations according to the client's provisions and facilities and effective factors in construction of a data centre. If the client poses any restriction, this procedure would be void of any usage. Fig. 6 shows a general overview of this sub-procedure in a flowchart.

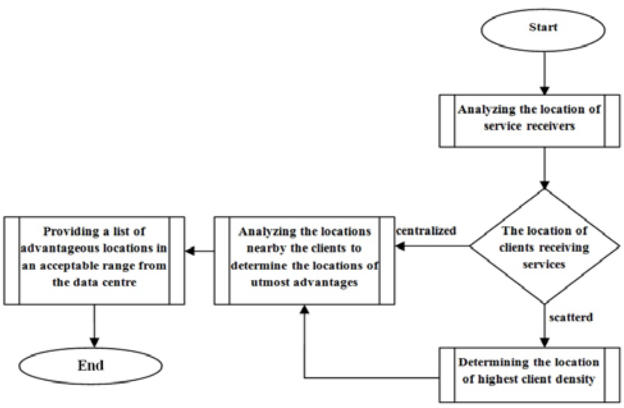

Figure. 6 the sub-procedure of locating candidate places

b) ***The sub-procedure of analyzing candidate locations:*** This sub-procedure is considered a part of locating procedure which aims at examining and analyzing candidate advantageous locations in terms of aforementioned effective factors. Fig. 7 shows this sub-procedure in a flowchart.

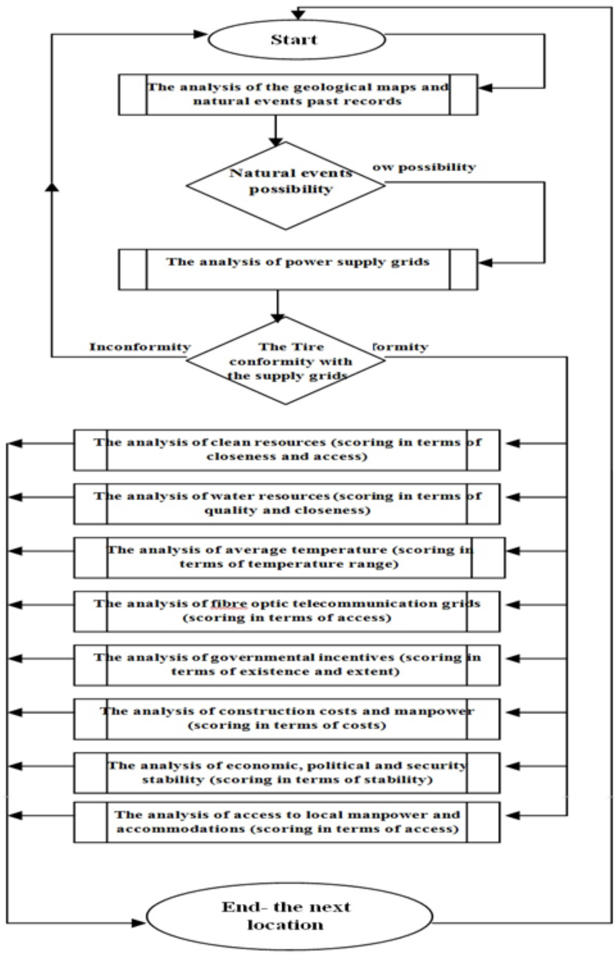

Figure. 7 the sub-procedure of analyzing candidate places

c) Weighing up the effective factors: In order to study the effectiveness of any of these factors in any of these locations and their impacts on the sub-procedure outcome, it seems necessary to meticulously weigh up each of them. The total score gained by each location determines the best and exact location of constructing a data centre. This section, therefore, deals with the way different effective factors in selection of the data centre's location are weighed up. Each of candidate locations gains a series of scores and it is taken for granted that the location of highest score would be finally presented as the selected location for the client.

There are ten important elements in locating a data centre which are discussed in the following. The total score of 100 was allocated to a perfect location of a green data centre. A particular weight is allocated to each of these ten elements according to their effectiveness.

There are two exceptional elements which play critical roles in a data centre's performance. They are influential enough to jeopardize the whole project. The sub-procedure of analyzing the location of a data centre, therefore, designed in a way that automatically removes and stops analyzing candidate locations lacking any of these factors. These two factors are namely: a) the potential of occurring natural disasters and b) inconformity of the client's required tier with the number of available power distribution grids. Other elements, however, do not put the whole project in jeopardy. These factors and their allocated weights are as follows:

(a). The likelihood of occurring natural disasters including earthquake, flood, whirlwind, landslide, seasonal typhoon and so on (the allocated weight: ∞). The devoted weight bears the meaning that if any of the abovementioned events is likely to happen in the location, it would be totally discarded from the list of locations. In the present analysis, however, 20 score is dedicated to this factor.

(b). Inconformity of the client's required tier with the number of available power distribution grids (the allocated weight: ∞). Data centres are divided into four tiers (tier 1 to tier 4) in terms of their availabilities. Tier 4 as the most expensive and equipped tier of a data centre, which is only used for vital functions, due to overabundance in its all sections including power supply section requires at least two power distribution grids (with different resources) to minimize power failure likelihood. Under these circumstances, the selected location must have the aforementioned access to the power distribution grids; otherwise, the location would be removed from the list before any further analysis. The dedicated weight is 20 in this analysis.

(c). Access to renewable energy resources (the allocated weight: 12). A striking score is allocated to the access and amount of renewable energies in this sub-procedure since their usages for supplying power for green data centres are of very importance. The highest weight would be 12 which is gained if all power consumed in a data centre is supplied by these sources.

(d). Access to water resources (the allocated weight: 7). Sufficient and proper water resources could play a prominent role in new cooling solutions and might result in saving energies required for cooling. It could be used as a resource in hydro economization cooling solution. Rivers, seas and lakes are among these resources.

(e). The location's average temperature range (the allocated weight: 7). Free cooling is now widely used in new data centres. The cold air outside the data centre which is of lower temperature than the air inside it could be used to cool the IT equipment. Therefore, the lower the average temperature ranges, the higher the scores.

(f). Access to fibre optic communication grids (the allocated weight: 5). The closeness of the location of a data centre to these grids reduces the latency of sending and receiving data and results in saving initial capital regarding making these connections. There is no relationship between this factor and the operation costs and the extent of power consumed.

(g). The existence of tax-based and governmental incentives (the allocated weight: 10). Most governments have provided incentives to create jobs and attract domestic and international investments particularly in advanced industries including IT and data centres. These incentives are of different types from allocating cheap lands to issuing permits, supplying cheap power and exempting taxes. If these opportunities are available, the maximum benefits and utilizations could be taken through proper assessments. Given that these incentives are of different kinds and various amounts, it seems necessary to carry out a comprehensive analysis at first regarding their related regulations and quantities and economic savings gained by them.

(h). The analysis of construction costs, material prices, manpower and availability features (the allocated weight: 6). More detailed studies are required in this regard since the costs of constructions vary in different places. The analyses in this regard should take different factors into account. The material prices, access roads, the costs of importing equipment and the average wage level are among the factors to be considered.

(i). The analysis of political, economic and security stability in the location (the allocated weight: 3+3+3=9). Given that huge investments are required to be made in construction of any data centre and it is important to prevent them from stopping providing services, it seems necessary that the selected location be stable in terms of economic and political status and enjoys a proper security condition. The lack of any of the abovementioned factors could strikingly jeopardize the project of constructing the data centre. Three scores are allocated to each of these factors.

(j). The analysis of access level to the professional manpower and the accommodation conditions (the allocated weight: 4). Access to professional manpower in the construction location could reduce the operation and implementation costs of a data centre. If the construction location is far from the nearby cities, investments should be made in providing accommodation for the employees.

Given that there was no restriction imposed by the client regarding the construction location, it is necessary to carry out the locating procedure step by step. In accordance with the introduced procedure, a list of proper locations should be provided at first. The sub-procedure of locating candidate locations should be, therefore, carried out. The locations of highest intensity of service receivers should be identified at first. Given that the data centre's users and service receivers are mainly the company's employees, the location of service receivers would be of scattered type. According to the data provided by the client, the company's main office and other offices in Tehran have the highest density of users. The locations two to three hundred kilometres far from Tehran are considered the candidate locations. A list of advantageous locations in this range is, then, provided.

Iran's map should be looked at to determine different advantageous locations. Iran's map is shown in Fig. 8, retrieved from www.mrud.ir.

Figure. 8 the map of Iran

The area around Tehran which is to be analyzed for the data centre locating is shown in Fig. 9, retrieved from www.mrud.ir. This map illustrates cities, roads and water resources. As the map reflects, the emphasis is put on Tehran western and northern areas; the reason lies in the fact that the southern areas are warmer and there are fewer water resources in eastern areas. These factors play crucial roles in new cooling solutions and energy savings; the abovementioned areas, therefore, were totally discarded from the list of candidate locations. Having analyzed the locations more meticulously and regarding various effective locating factors, the researcher selected the following locations for further analysis (their advantageous over other locations are pointed to as well):

(a). Tehran (closeness to the location of highest intensity of service receivers, access to facilities and professional manpower)
(b). Arak (cold climate)
(c). Zanjan (cold climate, being windy)
(d). Qazvin (cold climate, access to facilities, being windy)
(e). Manjil (cold climate, sufficient wind source)
(f). Taleqan (cold climate, access to water resource of Taleqan dam)
(g). Abhar (cold climate)
(h). Hamedan (cold climate)

Figure. 9 the area around Tehran

The sub-procedure of 'analyzing candidate locations in terms of effective factors' should be, then, carried out. At first, the possibility of occurring natural disasters in the selected locations should be studied. Given that none of them are located near the country's large rivers, the possibility of occurring water-driven natural disasters is similarly low in these locations. The most effective factor in this regard is the possibility of being located in earthquake zones. The country's earthquake zone map should be, therefore, looked at. Fig. 10 shows the country's earthquake zone map.

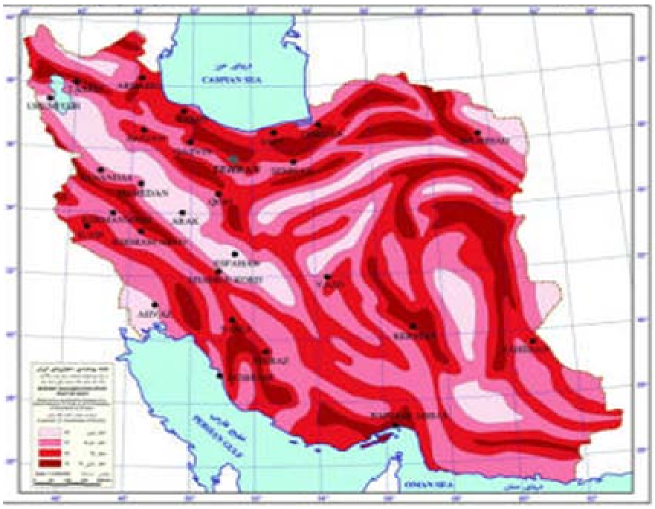

Figure. 10 The map of earthquake zones in Iran (Jafari, 2010)

As the map indicates, Tehran, Manjil and Taleqan are located in zones of high earthquake potential. These locations are, therefore, removed from the list of candidate locations. Qazvin and Zanjan are located in zones of high earthquake potential as well and are not, hence, considered proper places for constructing the data centre. Southern areas of Qazvin (Qazvin Plain) and northern areas of Zanjan, however, are located in zones of medium earthquake potential. These locations, therefore, remain in the list but obtain lower scores of 16. Hamedan and Abhar are located in earthquake zones of medium potential while Arak is located in a low potential one. They obtain the score of 20.

Regarding the analysis of having access and being close to nationwide power transmission and distribution grids, it seems necessary to check the maps circulated by the Ministry of Energy and Tavanir Company. One of these maps is shown in Fig. 11, retrieved from www.mrud.ir.

Figure. 11 the map of electrical power distribution and transmission grids in Iran

Given that the client has selected Tier 2, the need to have access to more than one distribution grid is not felt and it suffices to be close to a 63kv distribution post. All cities in the country possess such a facility and all candidate locations have this feature in common. All remaining locations obtain the complete score in this regard.

Regarding the analysis of access extent to renewable energy resources, the related circulated maps should be looked at. There are various kinds of renewable and clean energy resources. Water resources might lead to the highest outcome but dams should be constructed in this regard. Given that the proposed data centre is not large enough to invest such an amount of money, the access to this resource is not considered an advantage in our analysis. The wind sources take the second position in terms of capacity and outcome. Their utilizations are now localized in the country and several power stations are now generating wind energy. Fig. 12 shows the extent of wind resources across the country. It is worth mentioning that solar energy resources are sufficiently available across the country. However, regarding the current technology level and the power extent needed for running a large or medium-size data centre, this resource does not produce the desired outcome and does not bring economic benefits due to the very large required piece of land. If the data centre was a small one, this resource could be utilized. Other renewable energies including biomass and tide waves are not available in the country and the only identified geothermal resource is located in Azarbayjan province which is not under the scope of the candidate locations in this study.

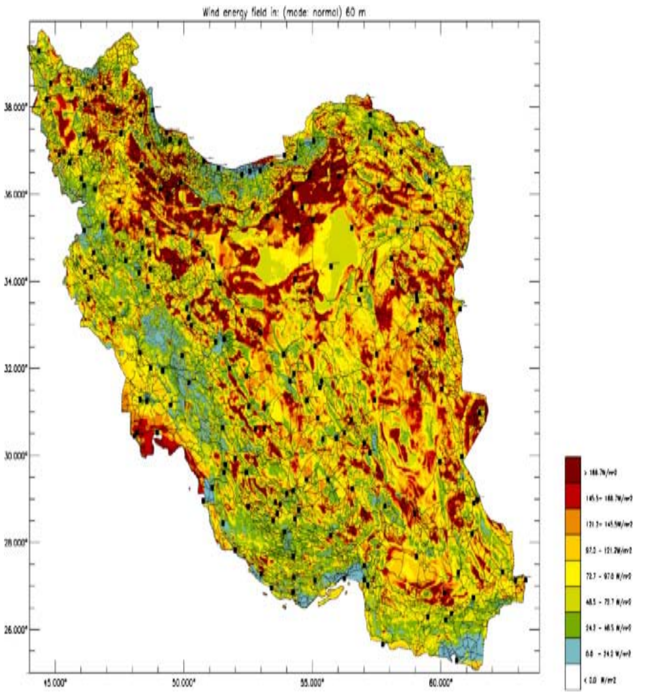

Figure. 12 the map of wind resources in Iran (Alamdari et al., 2012)

As Fig. 12 shows, among the candidate locations Qazvin Plain (in southern part of Qazvin), northern areas of Zanjan, Abhar and northern areas of Arak have considerable access to wind resources while Hamedan does not. These locations but Hamedan gains the complete score in this regard. Table 2 indicates the scores gained by different locations regarding the access to renewable energy resources.

Table 2 the scores related to access to renewable resources

Location	Access to renewable energy resources
Qazvin plain	12
Northern area of Zanjan	12
Abhar	8
Hamedan	3
Arak	9

Water resource and meteorology maps are required for the analysis of average temperature status and access level to water resources. Fig. 13, 14 and 15 respectively show the country's average temperature status, water resources and average rainfall.

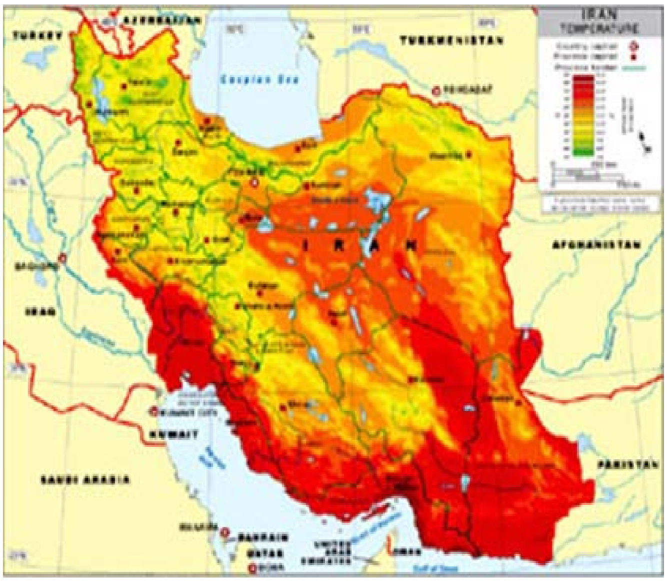

Figure. 13 the map of average temperature in Iran (Tabari et al., 2011)

Fig. 7 shows, Qazvin Plain has access to Shahroud River and sufficient underground water resources. Zanjan has access to Qezelozan River as well. Hamedan has access to water resources stemmed from Alvand Mountain while Arak and Abhar do not have reliable and stable access to water resources.

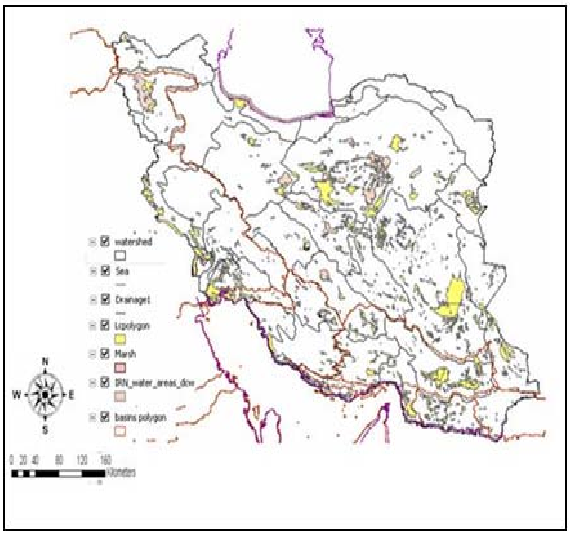

Figure. 14 the map of water resources in Iran (Sowers et al., 2011)

The annual rainfall level has a direct impact on the environmental temperature and the extent of available water resources. As Fig. 15 demonstrates, all candidate locations enjoy similar rainfall level that is 300 to 400mm annually.

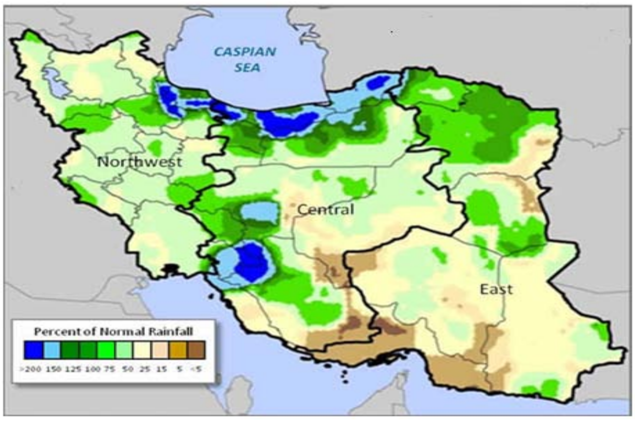

Figure. 15 the map of average rainfall in Iran (Amiri and Eslamian, 2010)

Table 3 shows the scores gained by remaining locations in terms of access to water resources and annual average temperature.

Table 3 the scores related to access to water resources and average temperature

Location	**Access to water resources**	**Annual average temperature**
Qazvin Plain	7	6
Northern area of Zanjan	7	7
Abhar	2	5
Hamedan	6	7
Arak	1	7

National fibre optic network map is required for the analysis of access level to fibre optic networks which reduces the construction costs. According to the Infrastructure Company and Ministry of Communications, the national fibre optic length has reached over 120 thousand kilometres which covers all cities across the country. Fibre optic cables are also laid over all main power distribution and transmission grids (400kv grids) which are jointly utilized by the Ministry of Energy and the Infrastructure Company. All locations but Abhar possess 400kv power grids and fibre optic ones consequently. The scores gained are, therefore, as follows:

Table 4 the scores related to access to nationwide fiber optic grids

Location	**Access to fiber optic grids**
Qazvin Plain	5
Northern area of Zanjan	5
Abhar	2
Hamedan	5
Arak	5

Given that none of the abovementioned locations is placed in free or special economic zones (which are often located in border lines to attract international investments and create jobs), no economic incentive or tax exemption belongs to them. They, therefore, gain no score in this section.

These locations are all located in Iran and due to their relative similar distances from Tehran enjoy equal conditions regarding construction and material costs, manpower and access facilities. The equipment import tariff is similar as well. Therefore, they all but Abhar gained an equal score in this section. The reason lies in the fact that Abhar is not a province centre. One score was, however, reduced from them since they are a bit far from Tehran. Regarding access roads, all locations but Abhar are province centres and there are highway accesses to them. All locations but Abhar, therefore, gain an equal score in this regard. The scores gained are represented in Table 5.

Table 5 the scores related to state incentives, construction costs and access roads

Location	Access to incentives	Construction costs, access facilities
Qazvin Plain	0	5
Northern areas of Zanjan	0	5
Abhar	0	3
Hamedan	0	5
Arak	0	5

Given that all cities are close to each other and located in one country, the same scores were gained by them in terms of political, economic and security stability. Table 6 shows the scores obtained by the candidate locations.

Regarding IT professional manpower, Qazvin is considered first class, Hamedan, Arak and Zanjan are regarded second class and Abhar is recognized third class.

Table 6 also shows the scores gained in this regard.

Location	**Political stability**	**Economic stability**	**Security stability**	**Access to professional manpower**
Qazvin Plain	3	2	3	4
Northern area of Zanjan	3	2	3	2
Abhar	3	2	3	1
Hamedan	3	2	3	2
Arak	3	2	3	2

Table 6 Political, economic and security stabilities, access to professional manpower

According to the discussions made, the total scores gained by the locations were calculated which are presented in table 7.

Table 7 total scores gained by candidate locations

Location	**Total score**	**Considerations**
Tehran	0	Removed due to earthquake possibility
Manjil	0	Removed due to earthquake possibility
Taleqan	0	Removed due to earthquake possibility
Qazvin Plain	83	
Northern area of Zanjan	82	
Abhar	71	
Hamedan	76	
Arak	77	

As table 6 demonstrates, Qazvin Plain gaining 83 scores is the best location to construct the green data center. The advantages which could be taken are as follows:

(a). Relatively low earthquake potential

(b). Excellent access roads to Tehran, good facilities and access to professional experts
(c). Excellent access to power transmission and distributing grids having high capacity, excellent access to fiber optic network
(d). Access to clean and renewable wind energy resource
(e). Access to Shahroud River and sufficient underground water resources
(f). Average temperature in range of 10 to 13 degrees centigrade.

a. ***Energy resources:*** The energy resources would be analyzed according to the proposed sub-procedure illustrated in Fig. 5. Regarding the wind resources in the construction location, wind turbines having high capacity could be employed to utilize this resource. There are now large turbines being capable of generating 1.5mw electricity. At first, the information should be sought from system providers regarding the costs of constructing a wind power station and its related transmitting installations proportionate to the data center's needs.

The selected location is an ideal place since it is located near Shahid Rajaei Power Station and in meeting point of West and Tehran distribution and transmission grids. Given that Tier2 is preferred by the client for this data centre, no need is felt to have access to more than one distribution grid. At the second stage, therefore, the costs of constructing a low capacity electrical post (proportionate to the data centre's needs) would be merely analyzed. It is necessary to determine the method of getting connected to the distribution grids and estimate the capacity of the required electrical post in terms of consuming power at this stage. The capacity of the related generators required for supplying emergency power should be determined as well.

b. ***Cooling system:*** At first, the costs of putting into operation, maintenance and power consumption of all available and provided solutions would be analyzed. A budget limit would be then determined. All costs should be proportionate to this budget limit.

Given that no restriction is imposed regarding the cooling technologies and solutions, the possibility of utilizing free cooling solution would be studied. Water-based free cooling system would be selected for this data centre with regard to the low temperature average and sufficient water resources. This would strikingly reduce the costs of cooling operation. This technology would be used along with the computer room air handler (CRAH) cooling system (as the main cooling system when the temperature does not allow the utilization of free cooling system). CRAH is preferred over computer room air conditioner (CRAC) since there is a good access to water resources required for chillers and the cost of providing; installing and maintaining chillers and their power consumptions are lower than those required for compressors utilized in CRAC systems.

Hot aisle would be used for racks inside the data centre to prevent hot air pollution. Hot aisle was preferred over cold aisle since it enjoys more advantages and higher efficiency. The combination of HACS and free cooling would considerably reduce power consumption in cooling section.

The following solutions regarding cooling operation would be employed provided that there is sufficient budget:

(a). Utilizing equipment having higher configurations
(b). Installing cooling system on racks
(c). Using dynamic controls

Direct and liquid-based cooling systems are not, however, utilized due to their novelties and high prices. The following complementary solutions would be also considered in the cooling system:

(a). Developing an air management strategy
(b). Reducing the distance between cooling systems and loads
(c). Containment of cold and hot aisles
(d). Eliminating the hot air pollutions
(e). Removing hot spots

c. ***The building:*** Regarding the restrictions on available technologies and obstacles for their imports, use of phase changing materials (PCMs) for constructing walls is neglected.

The infrastructure area and the desired size of building by the client would be analyzed in the following. Regarding the client's request for expansion possibility for at least next two years, constant decrease of spaces occupied by IT equipment and improvement of servers due to the ever-increasing technology advancements, only thirty percent would be added to the calculations made about the size of building and compulsory items are strictly and meticulously implemented:

(a). Installing raised floors and over-heads in all operational sections of the data center
(b). Making use of proper insulating materials such as wool glass in walls and ceilings
(c). Using double-glazing glasses in all sections of the data center
(d). Utilizing proper silicon insulations to cover windows frames

d. ***IT equipment:*** According to the proposed procedure, all restrictions imposed by the client regarding equipment and technologies should be studied; however, there is no restriction imposed by the client in the proposed data center. Information would be, therefore, sought and analyzed regarding the prices of available equipment and technologies in the market. The budget limit for purchasing, installing and putting into operation IT equipment would be determined at the end of this stage.

The selected equipment would be then restricted to those having introduced standards and been made in accordance with ROHS directive. The green data centre's function would be figured out according to the client's requirements and gathered data from the assessment phase. Regarding the information provided by the client, the data centre in this model aims at storing data and hosting the company's website which has lots of visitors. The data centre's function is, therefore, bilateral and is a combination of storing and processing tasks.

The size of servers' farms would be analyzed according to the client's requirement. Server management applications (middleware) and dynamic controlling solution would be, furthermore, utilized in this data centre.

It seems necessary to determine the related technologies and solutions according to the allocated budget with regard to the bilateral function of the data centre. The list of selected solutions is as follows on the assumption that a medium budget is dedicated to the project:

i. Compulsory equipment and technologies
   (a). Identifying all components, their features and functions along with documentation
   (b). Shutting down servers at unused times
   (c). Decommissioning old servers
   (d). Utilizing server management applications (middleware)
   (e). Dynamically controlling loads and changing energies
   (f). Adopting consolidation solution
   (g). Employing virtualization solution
   (h). Making use of multi-core processors capable of dynamically controlling speed and resources

ii. Optional equipment and technologies
   (a). Utilizing disks of higher configurations
   (b). Better I/O operation
   (c). Making use of controllers of higher configurations
   (d). Using fewer disks having higher capacities

e. Energy Star standard: The power usage effectiveness (PUE) rate is considered 1.5 in the proposed model to not only improve efficiency and reduce power consumption but reach the Energy Star standard.

The action plan would be, then, developed to achieve the goals set. The action plan aims at decreasing PUE index and increasing energy efficiency as much as possible. Given that the data centre was fundamentally designed and maximum possible elements were utilized regarding the green data centre solutions and technologies, the procedure's circle won't be reiterated more than one time and the goals set regarding PUE metric and Energy Star standard would be achieved if the proposed solutions are adhered to.

C. The solution phase :

The results obtained from two previous phases namely assessment and analysis are classified and submitted to the client through a comprehensive report at this stage.

IV. CONCLUSION

Different techniques and strategies in terms of green computing namely 'locating', 'clean energy resources', 'cooling systems', 'green building', 'IT equipment' and 'Green Standard' including Energy Star were introduced and analyzed. A three-phase strategy was introduced by the researcher. A step-by-step study was, then, carried out and the best location for constructing a green data centre in Iran was identified. Different strategies and techniques were applied to the selected location to optimize the performance of the data centre and achieve the aim of constructing a green data centre. It is worth noting that although the study was carried out in Iran, the proposed pattern could be applied to any other location.

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