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Review

Cloud Computing and Energy Efficiency: Mapping the Thematic Structure of Research – Supplementary Materials

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Table S1. Reference list and key research finding 2009-2015 (ranked by the number of citations).

No.	Reference	Citations (N)	Key Research Findings
1.	Beloglazov et al., 2012 [1]	1627	An architectural framework and principles for energy-efficient cloud computing were proposed. The study presented open research challenges, resource provisioning as well as allocation algorithms for energy-efficient management of cloud computing environments. The findings proved that the proposed cloud computing model enables serious cost savings and offers high potential for the improvement of energy efficiency under dynamic workload scenarios.
2.	Berl et al., 2010 [2]	439	Based on the literature analysis, a comprehensive review of the methods and technologies currently applied for energy-efficient operations of computer hardware and network infrastructure was held. Moreover, the key research challenges arising while energy-saving techniques are extended for use in cloud computing environments have been identified.
3.	Beloglazov et al., 2011 [3]	410	The review of the causes and problems of high energy consumption was done. The study was aimed at mapping the research field considering the taxonomy of energy-efficient design of computing systems covering the hardware, operating system, virtualization as well as data center levels. As the result of the conducted analysis, the advancements in energy-efficient computing and future design and development efforts were presented.
4.	Lee and Zomaya, 2012 [4]	365	Task consolidation as an effective method enabling an increase of resource utilization and resulting in energy consumption reduction was discussed. The study focused on two energy-conscious task consolidation heuristics aimed at maximizing resource utilization and explicitly taking into account both active and idle energy consumption. The proposed heuristics assign each task to the resource on which the energy consumption for fulfilling it is

			explicitly or implicitly minimized without the performance degradation of that task.
5.	Miettinen and Nurminen, 2010 [5]	277	The analysis of the critical factors affecting the energy consumption of mobile clients in cloud computing was made. Based on the analysis, measurements regarding the central characteristics of contemporary mobile handheld devices that define the basic balance between local and remote computing have been proposed. The study argues that the trade-offs are highly sensitive to the exact characteristics of the workload, data communication patterns and technologies used. Furthermore, it debates the implications for the design and engineering of energy efficient mobile cloud computing solutions.
6.	Mastelic et al., 2015 [6]	142	In-depth analysis of the infrastructure supporting the cloud computing paradigm in terms of energy efficiency was done. A systematic approach for analyzing energy efficiency of most important data center domains, including server and network equipment, cloud management systems and appliances consisting of software utilized by end users was defined. The proposed approach was applied for analyzing the relevant literature on state-of-the-art practices in data centers and their equipment. Finally, the challenges existing in the research field as well as future research directions have been pointed out.
7.	Mi et al., 2010 [7]	119	An online self-reconfiguration approach for reallocating virtual machines in large-scale data centers was developed. The proposed approach precisely predicts the future workloads of the applications with Brown's quadratic exponential smoothing. Then, based on such a prediction, it follows a genetic algorithm to efficiently find the optimal reconfiguration policy. The study proves the proposed approach may effectively switch off more unnecessary running physical machines comparing with current approaches without a performance degradation of the whole system.
8.	Boru et al., 2015 [8]	117	The issues of data replication in cloud computing data centers were studied. Within the adopted research framework, both energy efficiency and bandwidth consumption of the system were considered. The results of the study allow for unveiling performance as well as energy efficiency trade-offs and in turn governing the design of future data replication solutions.
9.	Zhang et al., 2013 [9]	108	The scheduling policy for collaborative execution in mobile cloud computing was investigated. The problem studied referred to minimizing the energy consumed by a mobile device, while meeting the time deadline. The authors formulated minimum-energy task scheduling as a constrained shortest path problem on a directed acyclic graph and adapted the canonical 'LARAC' algorithm to solving this problem approximately. Numerical simulation conducted within the study confirmed that a one-climb offloading policy is energy efficient for the Markovian stochastic channel, in which at most one migration from mobile device to the cloud takes place for the collaborative task execution.
10.	Goudarzi and Pedram, 2012 [10]	93	The problem of energy-efficient virtual machines placement in a cloud computing system was investigated. The approach that creates multiple copies of virtual machines and then uses dynamic programming and local search to place these copies on the physical servers was proposed. The conducted study confirmed that the

			proposed algorithm reduces the total energy consumption by up to 20% while compared with previous works.
11.	Kaur and Chana, 2015 [11]	91	The need for energy efficiency is highlighted by debating the dual role of cloud computing as a major contributor to increasing energy consumption as well as the way to reduce energy wastage. The conducted study presents in-depth analysis of existing energy efficiency techniques in cloud computing. Furthermore, it supplies the taxonomies for the evaluation of the works existing in the research field.
12.	Chen et al., 2015 [12]	88	The problem of inadequacy of scheduling approaches for real-time tasks running in uncertain cloud environments was addressed. The authors proposed an interval number theory to discuss the uncertainty of the computing environment as well as a scheduling architecture to diminish the uncertainty effect on the task scheduling quality for a cloud data center. The novelty of the study refers to the scheduling algorithm (PRS1) which dynamically exploits proactive and reactive scheduling methods, for scheduling real-time, aperiodic, independent tasks. The authors offered three strategies to scale up and down the system's computing resources in line with the workload to advance resource utilization as well as reduce energy consumption for the cloud data center.
13.	Horri et al., 2014 [13]	77	The new QoS-aware virtual machines consolidation approach for cloud environments, adopting a method based on resource utilization history of virtual machines was offered. The algorithms suggested by the authors were implemented and evaluated with the use of CloudSim simulator. The study findings confirm the improvement in QoS metrics as well as energy consumption. Furthermore, the study proves that there is a trade-off between energy consumption and quality of service in the cloud environment.
14.	Dabagh et al., 2015 [14]	68	The key resource allocation challenges were investigated to offer particular solutions aimed at reducing the energy consumption by cloud data centers. Special attention of the researchers was paid to power management techniques exploiting the virtualization technology in order to save energy.
15.	Kliazovich et al., 2013 [15]	63	The problem of communication demands in terms of solutions for energy efficiency and job scheduling is addressed. In the study, a novel scheduling solution, named e-STAB is offered. The proposed solution considers traffic requirements of cloud applications providing energy efficient job allocation as well as traffic load balancing in data center networks. The study results validation, gained from the Green Cloud simulator, highlights the benefits and efficiency of the offered scheduling methodology
16.	Ye et al., 2010 [16]	62	A study on the energy efficiency is conducted from the performance point of view. Firstly, a virtual machine based energy-efficient data center architecture for cloud computing is proposed. Then, the potential performance overheads caused by server consolidation as well as live migration of virtual machine technology are examined. The study results prove that both analyzed technologies may effectively implement energy-saving goals with little performance overheads. Therefore, the study concludes claiming that efficient consolidation and migration strategies may advance the energy efficiency.

17.	Abrahamsson et al., 2013 [17]	60	The research focused on the examination of the steps needed for creating a Raspberry Pi cluster consisting of 300 nodes, namely considering setting up and configuring the hardware and the system software, and then monitoring as well as maintaining the system. The study debates potential use cases for the analyzed cluster, pointing out an inexpensive and green test bed for cloud computing research as well as a robust and mobile data center for operating in adverse environments.
18.	Shiraz et al., 2015 [18]	58	A novel distributed Energy Efficient Computational Offloading Framework (EECOF) aimed at processing of intensive mobile applications in MCC was proposed. The framework offered in the study concentrates on leveraging application processing services of cloud data centers with minimal instances of computationally intensive component migration at runtime. The validation of the offered framework showed that due to employing EECOF, the size of data transmission over the wireless network medium was reduced by 84 %. Furthermore, the energy consumption cost was reduced by 69.9 % in offloading different components of the prototype application.
19.	Dong et al., 2015 [19]	50	A model of task scheduling for a cloud-computing data center aimed at analyzing energy-efficient task scheduling was examined. The authors proposed the assignments of tasks to servers as an integer-programming problem with the goal function minimizing the energy consumed by the servers of the data center. The study results confirm that the use of a greedy task scheduler limits the constraint service time while minimizing the number of active servers. Simulation results proved that the "server energy consumption of the proposed most-efficient-server-first scheduling scheme is 70 times lower than that of a random-based task-scheduling scheme".
20.	Shu et al., 2014 [20]	49	A novel, improved clonal selection algorithm based on time cost and energy consumption models in cloud computing environment was proposed. The authors of the proposed approach analyzed its performance with the use of the CloudSim toolkit. The results obtained shows that the proposed approach has immense potential due to the fact that it offers significant advancement in the aspects of response time and makespan, shows high potential for the improvement in energy efficiency of the data center, an may effectively meet the service level agreement requested by the users.
21.	Cui et al., 2013 [21]	46	A survey on the universal energy estimation model for mobile devices was done. While conducting the study, considerable attention was paid to a low-power design of the WNIC (i.e., Cellular and WiFi). Conducted analysis enabled providing a comprehensive summary of recent work on transmission energy savings as well as pointing out the future research avenues.
22.	Fallahpour et al., 2015 [22]	45	An energy-efficient manycast routing and spectrum assignment (EEM-RSA) algorithm in elastic optical networks supporting cloud computing applications, adapted for both static and dynamic scenarios, was proposed and examined. The simulation results find that thanks to applying the proposed energy-aware heuristic algorithm, the network energy consumption is reduced at the cost of increasing the blocking probability. The results proved also that by designating the shortest path, instead of the path with the lowest power consumption, the blocking probability is reduced, while boosting the energy consumption. Consequently, the authors proposed an intermediate solution, referred to as blocking-aware

			energy-efficient manycasting, compromising between the power consumption and blocking probability performance metrics
23.	Guazonne et al., 2011 [23]	45	A framework allowing automatic management of computing resources of cloud infrastructures to simultaneously achieve suitable QoS levels as well as reduce the amount of energy used for providing services as much as possible was offered. Simulations done by the authors prove that the proposed approach is able to dynamically adapt to time-varying workloads (without any prior knowledge) and to significantly reduce QoS violations as well as energy consumption while comparing to traditional static approaches.
24.	Itani et al., 2010 [24]	44	An energy-efficient protocol for ensuring the integrity of storage services in mobile cloud computing was proposed. The offered approach applies the concepts of incremental cryptography and trusted computing in order to design secure integrity data structures which protect the customer data whilst highly reducing the mobile client energy consumption as well as efficiently supporting dynamic data operations. The authors analytically examined and experimentally implemented the designed approach to demonstrate the energy savings it provides on mobile clients.
25.	Sarathchandra Magurawalage et al., 2014 [25]	43	A new system architecture for mobile cloud computing, including a middle layer sitting between mobile devices and their cloud infrastructure or clones was introduced. The study proposes an offloading algorithm with the main purpose referring to deciding whether to offload to a clone or a cloudlet. The decision-making considers the energy consumption for task execution as well as the network status whilst satisfying certain task response time constraints. Finally, the study proposes a data caching mechanism at cloudlets to further improve the overall MCC performance. Simulation results confirm the effectiveness and efficiency of the offered system architecture and offloading algorithm from the response time and energy consumption perspective.
26.	Song et al., 2012 [26]	43	An energy efficiency model and measuring approach for cloud computing was examined. The study explains a mathematical expression of energy efficiency and examines energy efficiency measuring approaches. The authors conduct a series of experiments to verify the correctness of the proposed model. Study results prove that the proposed energy efficiency model and measuring approach may precisely evaluate the energy efficiency cloud systems and lay the foundation for energy efficiency optimization.
27.	Luo et al., 2012 [27]	42	The relationship between infrastructure components and power consumption of the cloud computing environment was examined. The study discusses the issue of matching the task types and component power adjustment methods and offers a resource scheduling algorithm of cloud computing based on energy efficient optimization methods. The results of the study confirm that, for jobs which do not fully utilize the hardware environment, using the proposed algorithm may significantly reduce energy consumption.
28.	Subirats & Guitart, 2015 [28]	36	A mathematical formulation for the design of a CPU utilization estimator used to calculate current and future energy efficiency at different levels (virtual machine, node, infrastructure and service levels) was proposed. The study shows that the correct adjustment

			of the estimators' configuration parameters leads to considerable precision improvements.
29.	Jain et al., 2013 [29]	36	Various ideas related to green cloud computing approach were examined. Based on the statement that "more processor chips generates more heat, more heat requires more cooling and cooling again generates heats and thus we come to a stage where we want to balance the system by getting the same computing speed at decreased energy consumption", the authors of the study search for particular solutions aimed at the expansion of green cloud computing concept.
30.	Zhou et al., 2015 [30]	34	A virtual machine deployment algorithm labelled three-threshold energy saving algorithm (TESA), based on the linear relation between the energy consumption and (processor) resource utilization aimed at improving the energy efficiency of large-scale data centers was proposed. According to the offered approach, virtual machines on lightly loaded host or virtual machines on heavily loaded host are migrated to another host with proper load. Instead, virtual machines on properly loaded host or on moderately loaded host are kept constant. The study concludes with pointing out five kinds of virtual machine selection policies and provides five avenues for further research.
31.	Ragona et al., 2015 [31]	33	A model and comprehensive analysis for computational offloading between wearable devices and clouds in realistic setups was offered. The research addresses the issue that despite continuous improvement of hardware, the lifetime of mobile devices and their capabilities still remain a concern. The authors note that in these circumstances, mobile cloud computing may augment the capabilities of wearable devices by helping to execute some of the computing tasks in the cloud. They argue that computational offloading enables preserving battery power at the cost of more intensive communications with the cloud.
32.	Baker et al., 2013, [32]	33	A high-end autonomic meta-director framework aimed at finding the most energy efficient route to the green data center by utilizing the linear programming approach was developed. The authors of the study formalize the proposed framework by the situation calculus, and then evaluate it against the shortest path algorithm with the minimum number of nodes traversed.
33.	Xiang et al., 2014 [33]	32	The issue of energy-efficient link selection and data transmission scheduling for delay-tolerant and data-intensive applications in MCC was addressed. The authors formulate the problem as a discrete-time stochastic dynamic program focused on optimizing both system throughput and energy consumption. In order to solve the formulated stochastic dynamic program, they offer a scalable approximate dynamic programming (ADP) algorithm which does not require the statistics of exogenous stochastic information (e.g., data arrival). Study results prove that the proposed ADP algorithm may reduce the average energy consumed for delivering a packet by a maximum of over 40 percent while comparing with alternative minimum-delay and SALSA policies.
34.	Liu et al., 2013 [34]	31	An optimization model for task scheduling in order to reduce energy consumption in cloud-computing data centers was proposed. The introduced approach was formulated as an integer programming problem aimed at minimizing the cloud-computing data center energy consumption by scheduling tasks to a minimum number of servers while keeping the task response time

			constraints. The authors offer the most-efficient server-first task-scheduling scheme to minimize energy expenditure as a practical scheduling scheme. They model and simulate the offered scheduling scheme for a data center with heterogeneous tasks. The study simulation results prove that the proposed task scheduling scheme reduces server energy consumption on average over 70 times whilst comparing with the energy consumed under a (not-optimized) random-based task-scheduling scheme.
35.	Tesfatsion et al., 2014 [35]	28	The research combining three management techniques that may be applied to control cloud data centers in an energy-efficient manner, namely changing the number of virtual machines, the number of cores, and scaling the CPU frequencies. The authors describe a feedback controller determining an optimal configuration to minimize energy consumption whilst meeting performance objectives. The potential of the offered approach is evaluated in a video encoding scenario. Study results confirm that the combined approach achieves up to 34% energy savings if compared to the constituent approaches (core change, virtual machine change, CPU frequency change policies) whilst meeting the performance target.
36.	Ma et al., 2012 [36]	27	A comprehensive survey of recent work on low-power design of location based applications (LBAs). The study highlights that one increasingly widespread type of applications in mobile cloud environments that is location based applications (LBAs) present some inherent limitations surrounding energy what implies the need for the research devoted to energy-efficient solutions in the field.
37.	Mukherjee et al., 2014 [37]	25	The technology of mobile cloud computing based offloading strategies are proposed as the solution leading to significant energy saving of a femtocell device. The study provides three cases where either data processing, or data encryption and hardware authentication or both are offloaded to the cloud. Then, the power consumption models of the femtocell in these three cases are introduced. Simulation results of the study show that all proposed cases reduce the power consumption of the femtocell.
38.	Wang et al., 2012 [38]	23	A new energy-efficient multi-job scheduling model based on Google's massive data processing framework was developed. In order to solve the proposed model, a practical encoding and decoding method for the individuals was designed as well as an overall energy efficiency function of the servers as the fitness value of each individual was constructed. The study findings prove that the proposed model is effective and efficient.
39.	Djemame et al., 2014 [39]	21	The study highlights the need to provide novel methods and tools in order to support software developers focused on energy efficiency optimizing as well as minimizing the carbon footprint resulting from designing, developing, deploying and running software in clouds, whilst maintaining other quality issues of software to adequate and agreed levels. A cloud architecture aimed at supporting energy efficiency at service construction, deployment, and operation was investigated, supplemented with its implementation and evaluation plans.
40.	Mastelic & Brandic, 2015 [40]	21	Recent trends in cloud computing regarding the energy efficiency and its supporting infrastructure were examined. The study provides in-depth analysis of the approaches found in literature and in practice covering servers, networking, cloud management systems as well as appliances (user software). Furthermore, it

			debates the benefits and trade-offs related to applying particular energy-efficiency techniques, as well as discusses existing challenges and future research avenues.
41.	Yao et al., 2013 [41]	21	An energy efficient task scheduling strategy (EETS) aimed at determining what kind of task with certain amount of data should be chosen to be offloaded under different environment was discussed. The authors evaluated the scheduler with the use of an Android smartphone. The study results prove that the proposed approach may achieve 99% of accuracy in terms of choosing the right action to minimize the system energy usage.
42.	Balakrishnan & Tham, 2013 [42]	19	The research is an attempt to apply DVFS in mapping and scheduling stages by combining both the task-resource and resource-frequency assignments in a single problem. The authors aim at estimating the worst-case global slack time for each task-resource assignment, distributing it over the TIG and slowing down the execution of tasks using dynamic voltage and frequency scaling. The optimal slowdown advances the computation time of TIG without exceeding its worst-case completion time. Furthermore, the study models the code offloading as a Quadratic Assignment Problem (QAP) in Matlab-R2012b and solves it using two-level Genetic Algorithm (GA) of the global optimization toolbox. The effectiveness of the discussed model was proved by a simulation. The study results confirmed that there is an average energy savings of 35% in a mobile device.
43.	Wang et al., 2012 [43]	19	The solutions focused on the improvement of the energy efficiency of servers in a data center by appropriate task scheduling strategies were examined. Based on MapReduce, Google's massive data processing framework, a new energy-efficient task scheduling model was proposed. In order to solve the model offered, the authors put forward an effective genetic algorithm with practical encoding as well as decoding methods and specially designed genetic operators. Meantime, in order to accelerate the proposed algorithm's convergent speed and enhancing its searching ability, a local search operator was introduced. The study results prove that the proposed algorithm is effective and efficient.
44.	Adhikary et al., 2014 [44]	18	A mechanism for cluster formation based on network vicinity among the data servers was proposed. The authors developed two distributed and localized intra-cluster and inter-cluster virtual machines scheduling algorithms based on energy calculation, resource requirement as well as availability. The scheduling algorithms offered in the study manage virtual machines to reduce the energy consumption of the servers and networking devices. The study results prove that the proposed distributed virtual machines scheduling algorithms may conserve huge amount of energy compared to state-of-the-art works
45.	Cao et al., 2012 [45]	18	A power-saving approach based on demand forecast for allocation of virtual machines was developed. Firstly, the study introduces the forecast of demands of next period with Holt-Winters' exponential smoothing method. Secondly, it applies a modified knapsack algorithm to find the appropriate allocation between VMs and hosts. Thirdly, it introduces a self-optimizing module that updates the values of parameters in Holt-Winters' model and determines the reasonable forecast frequency. The study results prove that the proposed approach may considerably reduce the frequency of switching hosts on/off.

46.	Moreno & Xu, 2011 [46]	18	A dynamic resource provisioning mechanism to overallocate the capacity of real-time cloud data centers based on customer utilization patterns was introduced. The authors analyze the impact of proposed mechanisms on the trade-off between energy efficiency and SLA fulfilment. The study focuses on exploiting the resource utilization patterns of each customer to decrease the waste produced by resource request overestimations. The proposed approach considers SLA deadlines, predictions based on historical data, and dynamic occupation to determine the amount of resources to overallocate for each host. Furthermore, a compensation mechanism to adjust resource allocation in cases of underestimation is discussed. Simulation results show meaningful improvements in energy-efficiency whilst SLA-deadlines are slightly impacted.
47.	Wang et al., 2014 [47]	16	A comprehensive survey of recent work on low-power design of LBAs was provided. The authors investigated LBAs and different locating sensing technologies used today as well as the methods for energy saving with existing locating technologies. They also discussed cloud-based schemes that try to develop new energy-efficient locating technologies by leveraging the cloud capabilities of storage, computation and sharing. The study concludes with pointing out the future research directions.
48.	Ravi & Peddoju, 2013 [48]	16	A novel framework in which application execution is offloaded to both cloud and mobile ad hoc cloud to reduce communication overhead was developed. Distributed/Parallel execution of tasks was introduced in order to reduce the waiting time of the mobile device, provided the cost of offloading is less, compared to cost of executing the application in device. Seamless service provisioning is achieved in this approach by measuring the signal strength of the wireless medium. While the signal strength threshold is reached, interim results are obtained from the device to which the task is offloaded.
49.	Sarji et al., 2011 [49]	16	Two energy models based on a statistical analysis of a server's operational behavior to minimize energy consumption in data centers at cloud computing providers were proposed. The main difference between the two models offered refers to energy and time required to put the server in an operational mode from a sleep mode or from an off state. Due to this, the decision is a tradeoff between energy savings and the required performance according to the SLA between the client and the cloud provider. The study results are based on "actual power measurements taken at the server's AC input, to determine the energy consumed in the idle state, the sleep state, the off state and in the case of switching between any two of these states".
50.	Tzanakaki et al., 2014 [50]	15	An infrastructure and architectural approach based on the orchestrated planning and operation of Optical Data Center networks and Wireless Access networks was proposed. The study presents "a novel formulation based on a multi-objective Non Linear Programming model that considers energy efficient virtual infrastructure planning over the converged wireless, optical network interconnecting DCs with mobile devices, taking a holistic view of the infrastructure". The modelling results indicate trends as well as trade-offs related to end-to-end service delay, resource requirements and energy consumption levels of the infrastructure across several technology domains.

51.	Uchechukwu et al., 2012 [51]	14	Formulations and solutions for Green Cloud Environments (GCE) aimed at minimizing their energy consumption under new models by considering static and dynamic portions of cloud components, to reduce severe environmental impacts were proposed. The authors examine energy consumption patterns, in particular they make use of measurable metrics based on runtime tasks to compare rationally the relation existing between energy consumption and cloud workload and computational tasks, as well as system performance. The study results may be integrated into cloud computing systems in order to monitor energy consumption and support static and dynamic system level-optimization.
52.	Owusu & Pattinson, 2012, [52]	14	The issue of the energy efficiency of cloud computing is addressed. The authors investigate previous contributions in the field of the energy efficiency of cloud computing, introduce a working definition of cloud computing as well as highlight the significance of cloud computing , as a disruptive technology.
53.	Jung et al., 2011 [53]	14	A scheme to enhance energy efficiency and QoS of realtime network applications on smartphone was proposed. The scheme offered reduces energy consumption and increases the successful interaction rate between the client at the smartphone and the busy server of a realtime network application through deploying a surrogate of the client at the smartphone in the cloud computing environment.
54.	Tian et al., 2013 [54]	12	An online energy-efficient scheduling of virtual machines for cloud data centers was investigated. The authors schedule all of the requests non-preemptively in their start-time-end-time windows, subjecting to physical machine capacity constraints, such that the total busy time of all used physical machines is minimized (called MinTBT-ON for abbreviation). They highlight it as the fundamental scheduling problem for parallel jobs allocation on multiple machines having significant applications in power-aware scheduling in cloud computing, optical network design, customer service systems as well as other related areas. The study discusses also offline scheduling in order to minimize busy time in the special case where all jobs have the same processing time and can be scheduled in a fixed time interval.
55.	Liao et al., 2012 [55]	12	An energy-efficient resource provisioning technology with service level agreement (SLA) consideration for virtual machine scheduling was introduced. The study claims that in line with SLAs, the resource manager could consolidate virtual machines onto the physical machine to meet customers' SLA requests. The study experimental results prove that the developed approach outperforms other proposed ones in power consumption.
56.	Abdelsalam et al., 2009 [56]	12	A pro-active energy efficient technique for change management in cloud computing environments was presented. The authors formulate the management problem into an optimization problem which aims at minimizing the total energy consumption of the cloud. The developed approach is pro-active in the sense that it takes prior SLA (Service Level Agreement) requests into account whilst determining time slots in which changes should take place.
57.	Tian & Yeo, 2015 [57]	11	The fundamental scheduling problem was addressed in the study. The authors discuss the case in which "there are n deterministic jobs to be scheduled offline on multiple identical machines, which have bounded capacities. Each job is associated with a start-time, an end-time, a process time, and demand for machine capacity. The

			goal is to schedule all of the jobs non-preemptively in their start-time-end-time windows, subject to machine capacity constraints such that the total busy time of the machines is minimized". The authors refer to this problem as minimizing the total busy time for the scheduling of multiple identical machines (MinTBT). They highlight the significance of this issue as having important applications in power-aware scheduling for cloud computing, optical network design, customer service systems, and other related areas. The study concludes with presenting how its results are applied in cloud computing to improve the energy efficiency.
58.	Borgetto & Stolf, 2014 [58]	10	The virtual machine allocation and reallocation inside a cloud in order to save energy while maintaining the resources required by users was examined. The authors emphasize that such actions have to be made to minimize the number of hosts powered on, whilst limiting concurrent migrations of virtual machines, and in a reasonable computational time. They suggest to effectively consolidate virtual machines with an approach handling the reallocation, migration and host management problems. The proposed approach has been implemented in OpenNebula, and then experimentally compared with its default approach.
59.	Xiang et al., 2015 [59]	9	The problem of energy-efficient downlink and uplink data transmission between mobile devices and clouds was addressed. The study aimed at minimizing the time average energy consumption of a mobile device while ensuring the stability of both device-end and cloud-end queues. In order to accomplish this goal, an online control framework named EcoPlan under which mobile users can make flexible link selection and data transmission scheduling decisions to achieve arbitrary energy-delay tradeoffs was proposed. The study real-world trace-driven simulation results show the effectiveness of EcoPlan, along with its superior energy-efficiency over alternative WiFi-prioritized, minimum-delay and SALSA schemes.
60.	Lin et al., 2013 [60]	9	The resource allocation for energy-efficient cloud computing in a heterogeneous environment was modeled as a constraint satisfaction problem (CSP). Through solving the constraint satisfaction problem, the optimized allocation scheme minimizing energy consumption in virtualized cloud data centers was gained. Based on the optimized allocation scheme, the authors introduced an energy-efficient resource allocation algorithm, dynamic power (DY), taking into account the heterogeneity of resources. The performance of the proposed algorithm was evaluated using Choco. The study results prove that, while comparing with first-fit decreasing (FFD), best-fit decreasing (BFD) as well as minimizing the number of physical machines (MinPM), the developed algorithm (DY) has less energy consumption.
61.	Valentini et al., 2013 [61]	9	The issues of cloud computing, energy models, and task consolidation algorithms were addressed in the study. The authors used two energy-conscious heuristics for task consolidation: MaxUtil, aiming to maximize resource utilization, and Energy-Conscious Task Consolidation (ECTC) that takes into account both active and idle energy consumption. The study debates the complementarity approach and the related mathematical model. The study concludes with the simulation results.
62.	Gondhi & Kailu, 2015 [62]	8	The solutions to minimize power consumption related to cloud computing and its operating cost were investigated. A prediction based faster energy efficient virtual machine consolidation scheme

			was proposed that results in faster VM consolidation to improve quality of service as well as performance whilst reducing energy consumption.
63.	Saab et al., 2013 [63]	8	The factors affecting the power consumption due to offloading were investigated. The authors proposed a decision model as well as verified its correctness by real implementation on an Android device. The study results indicate that the developed partitioning scheme successfully results in energy savings at the mobile handset and surpasses the energy efficiency of both fully local and fully remote execution.
64.	Okada et al., 2015 [64]	7	The issue of an energy efficient initial virtual machines placement was examined. The study introduces three new algorithms to solve the above said problem, one based on the First Fit Decreasing algorithm, and the other two based on the Best Fit Decreasing algorithm. The proposed algorithms are compared with other algorithms in the literature. The study results indicate a reduction of power consumption up to 3.24% and a reduction of execution time in several orders of magnitude.
65.	Jeong & Park, 2013 [65]	7	The use of grid infrastructure for server virtualization in which existing servers are used rather than bringing in new servers was discussed. Server virtualization service is provided using scheduling algorithms for distributed servers or resources in grid computing. In order to overcome the performance limitations resulting from using existing servers, mathematical models of Meta and Sleep Servers under the grid infrastructure environment were applied in order to provide server virtualization service with high availability.
66.	Ren & Zhang, 2010 [66]	7	The architecture of networked green manufacturing on cloud computing to support service-oriented IT resources outsourcing was presented. The study also investigated the issue of the dynamically-scalable resource utilization mechanism for networked manufacturing. The discussed approach may provide effective support for manufacturing resource virtualization as well as deliver a variety of services to distributed manufacturing enterprises. What is more, IT resources of network, computing, and storage may be shared concurrently and scheduled dynamically that are adaptive to practical resource demand of collaborative manufacturing tasks. The study concludes pointing out that a great amount of IT resources can achieve high efficient utilization in networked manufacturing as well as result in reduced energy consumption to benefit green manufacturing.
67.	Kumar et al., 2015 [67]	6	The resource allocation problem in cloud computing as a linear programming problem, with the objective to minimize energy consumed in computation was addressed. The resource allocation problem has been treated using heuristic approaches, particularly two phase selection algorithms were used 'FcfsRand', 'FcfsRr', 'FcfsMin', 'FcfsMax', 'MinMin', 'MedianMin', 'MaxMin', 'MinMax', 'MedianMax', and 'MaxMax'. The study simulation results prove in the favor of MaxMax.
68.	Aldulaimy et al., 2015 [68]	6	A model identifying common patterns for the jobs submitted to the cloud was proposed. The offered approach is able to predict the type of the job submitted, and accordingly, the set of users' jobs is classified into four subsets. The job classification is aimed at finding a way to propose useful strategy which enables to improve energy efficiency. The core idea of the developed strategy is to

			place virtual machines of the jobs of different types in the same physical machine whenever possible, based on Knapsack Problem. Such a strategy reduces the number of active physical machines leading to a major reduction in the total energy consumption in the data center. The simulation results confirm that the presented strategy outperforms both Genetic Algorithm and Round Robin from an energy efficiency perspective.
69.	Anan & Naser, 2015 [69]	6	The study focused on the design and implementation of an energy efficient computing framework for green cloud datacenters leading to the improvement of energy efficiency, operational costs reduction as well as meeting required Quality of Service (QoS). A dynamic migration algorithm was developed in order to minimize the cost of energy in consideration of SLAs. The proposed approach applies one of the most promising technologies in the area of server virtualization research, namely Software Defined Networking (SDN) using OpenFlow technology. The study results indicate that the efficiency of the resource usage and reduced power consumption of the cloud can coexist with Service Level Agreements (SLAs) while keeping the cost of penalties as well as power consumption to a minimum.
70.	Sharma & Javadi, 2015 [70]	6	The study highlights reliability and energy efficiency as two big challenges in cloud computing systems that need careful attention and investigation. Therefore, the review of existing techniques for reliability and energy efficiency was hold. Then, the research gaps to combining these two metrics for resource provisioning in cloud computing environments were identified and discussed.
71.	Wajid et al., 2013 [71]	6	The requirements for energy efficient and CO_2 aware cloud computing to allow the conception and development of new techniques and approaches in this area were discussed. The research is based on a case study approach for energy efficient cloud sourcing focused on building on these requirements.
72.	Zhang & Fu, 2011 [72]	6	Macropower, a coarse-grain power and energy profiling framework was proposed. The developed framework provides a combination of hardware and software tools which achieve energy profiling at server granularity. The authors implemented a prototype of macropower and tested it in a cloud testbed. The study analyzes profiled data as well as quantifies the impact of system configurations on the server/cloud power usage. This in turn is valuable for autonomic and energy-efficient management of cloud resources.
73.	Panda & Jana, 2015, [73]	5	A energy saving task consolidation (ESTC) minimizing the energy consumption by utilizing the idle period of the resources in a cloud environment was proposed. ESTC achieves it by assigning few tasks to all available resources in order to overcome the idleness of the resources. Moreover, it calculates the energy consumption on arrival of a task to make the scheduling assessment. The authors performed several experiments in order to measure the performance of ESTC and compared it with the recent energy-aware task consolidation (ETC) algorithm. The study results indicate that the developed algorithm outperforms ETC in terms of energy consumption as well as the total number of task completion.
74.	Shidik & Ashari, 2014 [74]	5	The issue of efficient electrical energy consumption in the cloud computing area, in particular by improving virtual machines selection policy in dynamic virtual machines consolidation was discussed. The study presented the procedure of overall strategy

			for dynamic VM consolidation that includes four basic phases: (1) host overloading detection, (2) VM selection, (3) host underloading detection, and (4) VM placement. The approach proposed by the authors focuses on the VM selection policy, where the idea of the proposed method is by minimalizing time to select or decide virtual machine in overloaded host that are required to migrate constantly based on VMs position. The method refers to "selecting position VMs that will be migrated with constant selection at first, center or last VMs position when overloaded host has been detected with Local Regression algorithm". The performance of the proposed approach was assessed by measures energy consumption, SLAV, SLATAH, and PDAM parameter with real-world workload data from PlanetLab VMs. The study results indicate promising improvement in energy efficiency and acceptable SLA while comparing with other VMs selection policy technique.
75.	Goyal et al., 2015 [75]	4	The resource allocation problem was addressed. The study covers an energy consumption analysis of Greedy, Round Robin and Power Aware Best Fit Decreasing scheduling algorithms on a private academic cloud. The research provides an insight into the working of different scheduling scenarios for cloud computing as well as exemplifies the potential for the improvement of energy efficiency of PABFD algorithm under academic workload.
76.	Selmy et al., 2014 [76]	4	The necessity of energy efficient solutions required to minimize energy consumption of data centers was addressed. The authors claim that in datacenters, the number of physical machines can be reduced using virtualization by consolidating virtual machines onto shared servers and enabling them to migrate according to migration policy. Hence, virtual machines migration and selection policies to boost cloud computing environment energy efficiency and performance were investigated and discussed.
77.	Lin et al., 2014 [77]	4	The resource allocation problem in a heterogeneous cloud data center as a constraint satisfaction problem (CSP) was addressed. Aiming at solving constraint satisfaction problem, the authors propose an optimal resource allocation scheme including a virtual machine provision algorithm and a virtual machine packing algorithm. Performance studies indicated that the proposed new scheme outperforms the existing binpacking based approaches in terms of energy consumption in heterogeneous cloud data centers.
78.	Kim & Mvulla, 2013 [78]	4	An approach to remove hardware over-provisioning implementing task buffers and scheduler, in terms of energy consumption, based on workload shaping technology was proposed. The authors designed a mechanism wherein tasks with fast execution are routed to fast and high energy consumption machines and slow tasks to slow and low energy consumption machines. The proposed approach may efficiently shape workloads as well as manage the optimal number of active virtual machines and physical machines, in terms of energy consumption. To assess the offered approach, the authors generated synthetic workload data and evaluated it both in simulating and actual cloud environment. The study results show that the developed approach outperforms in terms of energy consumption other solutions that do not use workload shaping methodology.
79.	Widmer et al., 2013 [79]	4	The issue of the formation of green virtual organizations (GVOs) was discussed. The authors approach the formation of green virtual organizations problem from a game-theoretic perspective

			providing well suited models for analyzing sourcing strategies of service customers. In particular, they study the social welfare by examining the economic as well as ecological efficiency of the GVOs as a whole. The study contributes to the field through providing an agent-based GVO formation mechanism that optimizes the social welfare of service providers and customers. The results of the study show the efficacy of the proposed artifact in a set of simulation experiments.
80.	Wang & Wang, 2011 [80]	4	A new energy-efficient multi-task scheduling model based on the Google's massive data processing framework was proposed. In order to solve the offered model, the authors designed a practical encoding as well as decoding method for the individuals, and constructed an overall energy efficiency function of the servers as the fitness value of the individual. To accelerate the convergent speed and enhance the searching ability of the proposed algorithm, a local search operator was introduced. The experimental results indicate that the developed algorithm is effective and efficient.
81.	Chen et al. 2015, [81]	3	The agent models, mobile energy consumption models and data transmission models were investigated under different connection environments. The authors propose a novel terminal energy efficient scheduling method (AGILE) that compares energy consumption in cloud execution and mobile execution according to the actual wireless environment, and based on comparison it makes energy-efficient decisions. The study highlights extensive experiments conducted to assess the performance of the AGILE under different wireless channels as well as the performance impact on different parameters. The experimental results demonstrate that the developed approach may save mobile devices' energy effectively.
82.	Liu et al., 2013 [82]	3	The issue of establishing an architecture of resource sharing among mobile devices was discussed. The study provides an energy efficient method that establishes resource sharing overlay networks in wireless mobile networks. Theoretical models and a heuristic algorithm were presented. The study simulation results proved the effectiveness of the proposed models and heuristic algorithm.
83.	Wen, 2013 [83]	3	The location-aware cloud storage (CS) selection to implement a remote data backup as a strategic to tackle energy efficiency was discussed. The study developed network, access distribution, delay, and energy consumption models as well as proposed a remote backup mechanism. The related methods, including weighted access percentage CS (WAP), approximation method (AM) and group-based heuristic (GBH) were assessed to show how the control variable affect the green cloud computing networks.
84.	Kachris & Tomkos, 2013 [84]	3	The rise of optical interconnection networks in cloud computing infrastructures as a novel alternative to current networks based on commodity switches were discussed. Some of the most recent and promising optical interconnects architectures for high performance data centers that had appeared recently in the research literature were examined. Moreover, a qualitative categorization of these schemes based on their main features such as performance, connectivity, and scalability were presented and discussed in terms of providing green cloud infrastructures with reduced power consumption. The study provides also a case study of an optical interconnection network based on high-bandwidth optical OFDM

			links as well as shows the reduction of the energy consumption that it may achieve in a typical data center.
85.	Szymanski, 2013 [85]	3	The technologies to achieve low-latency energy-efficient communications in Global-Scale Cloud Computing systems were explored. The study investigates the use of a recently-proposed Future-Internet network, that uses a QoS-aware router scheduling algorithm combined with a new IETF resource reservation signaling technology, in order to achieve improved latency and energy-efficiency in cloud computing systems.
86.	Song et al., 2013 [86]	3	An energy efficiency measurement model was proposed to address the large-scale computing problem through two metrics: 'energy as well as 'efficiency'. The proposed model provides the definition and mathematical expression of the improved energy efficiency measurement and has been proved reasonable through experiments.
87.	Fu et al., 2015 [87]	2	The offloading policy for energy efficient mobile cloud computing was investigated. In order to minimize the energy consumption on the mobile device and the cloud, the authors propose a general optimization framework based on the characteristic of applications. In particular, for delay-sensitive applications, they formulate a delay-constrained optimization problem to reduce the energy consumption on the mobile device whilst meeting the time constraint. For delay-tolerant applications, they work out a stability-constrained optimization problem to reduce the energy consumption in the cloud while satisfying the queue stability. Based on the optimization framework, the study presents the offloading policy of typical mobile applications being computation intensive, including video transcoding, object recognition, image retrieval and virus scanning. The offered offloading policy may reduce the energy consumption on mobile devices and the cloud, which provides guidelines for the design of green mobile cloud.
88.	Panagiotou et al., 2015 [88]	2	An efficient virtual machine allocation mechanism for cloud data center environments was proposed. The authors discussed the virtual machine allocation policy and then performed a series of experiments based on CloudSim 3.0.3 simulator. Experimental results proved that the developed scheme is very efficient in terms of energy consumption and QoS (decreased SLA violations) compared to LrMmt provisioning mechanism.
89.	Verma & Katti, 2015 [89]	2	The comparative study among various optimized resource utilization techniques aimed at mitigating the problems such as resource underutilization, high energy consumption, and large CO_2 emissions was held. The authors address the problems related to the consumption of electrical energy by large scale data centers resulting in high operating cost and release of large amounts of CO_2 and highlights the need for solving it.
90.	Sofia & Kumar, 2015 [90]	2	The idea of green computing in the cloud called green cloud was discussed. The study examines various techniques aimed at reducing energy consumption in cloud as well as evaluates the CPU energy with power consumption. Moreover, it debates memory consumption techniques and presents the results for that. Finally, it compares the memory consumption with power consumption and shows the obtained results.
91.	Liu et al., 2015, [91]	2	A combined service subscription and delivery (CSSD) algorithm able to guide the users to subscribe to services reasonably, based on introducing the Lyapunov optimization method was proposed.

			The offered algorithm may also determine whether to deliver the data and to whom data is sent in the current time unit based on the queue backlog and the channel state. The findings from the study confirm effectiveness of the tested CSSD algorithm.
92.	Wang & Luo, 2015 [92]	2	Min-EnergyFlow algorithm that explores a transferring path in order to achieve the minimum energy and time consumption as well as improve customers' satisfaction was proposed. Firstly, "the study combines mobile terminal and mobile cloud computing service domain as a whole, then analyzes long-term returns of a mobile cloud computing service domain and obtains the best mobile virtual cloud computing resource allocation between different mobile cloud computing service domains. Finally, the cloud computing service domain decides to receive, transfer, or refuse the mobile terminal service requests". Simulation results indicate that, on the basis of the users' interest in mobile cloud computing, the proposed algorithm advances the energy consumption effectiveness of mobile cloud computing network and mobile customers satisfaction.
93.	Cai & Zhang, 2014 [93]	2	A simple model of energy efficiency–QoS (E-Q) focused on capturing some key aspects of energy minimization while meeting the specified constraints on performance and/or QoS was proposed. Based on the developed E-Q model, the authors provide an algorithm enabling the physical nodes to satisfy the performance's need for any set of jobs with a minimum-energy schedule and in the cloud. Experiment results prove the effectiveness of the offered algorithm while comparing with previous work, which can achieve objective optimization both on energy consumption and QoS.
94.	Joyee De et al., 2013 [94]	2	The issues regarding energy efficiency as well as the security in the cloud were addressed. The study provides a framework based on a layered data approach together with user selected security policies. The authors developed a mathematical model in order to depict the energy consumption while performing a security-enhanced computation in the cloud. The proposed model shows the potential energy saving in the event of user or organization specified policy for secure computing and data storage in the cloud.
95.	Kliazovich et al., 2012 [95]	2	A simulation environment, named GreenCloud, for advanced energy-aware studies of cloud computing data centers was proposed. GreenCloud provides a detailed fine-grained modeling of the energy consumed by the elements of the data center, such as servers, switches, and links.
96.	Saponara et al., 2012 [96]	2	The role of energy-efficient cloud-server-on-chip (CSoC) solutions aimed at reducing the total cost of ownership and the ecological impact of cloud computing data centers was investigated. The study describes "a green cloud computing platform, based on a multi core architecture with upcoming 64-b ARM processors of the ARMv8 family, interconnected by a service-aware Network on Chip (NoC) ensuring cache coherency" that can reduce costs (due to energy consumption and extra cooling systems) as well as increase system reliability (by avoiding thermal issues) of cloud data centers.
97.	Kumar & Parthiban, 2015 [97]	1	The design of a data center selection framework for submission of tasks to a data center with minimal energy consumption was presented. A proposed framework aims at selecting a data center for tasks submission with minimum total energy consumed by the

			servers, computer room air conditioning units and other IT equipment like routers, switches. Study results were simulated with the use of Google Cloud Trace logs as well as cloud analyst tool. The proposed approach was compared with shortest distance first and round robin methods. The performance analysis of the developed framework indicates that it is an efficient way for tasks submission to a data center as it concentrates on minimizing the energy consumption which in turn reduces operational expenditures of the cloud environment. Moreover, the comparisons of the proposed approach with other algorithms show that it consumes far less energy.
98.	Arani & Moghadasi, 2015 [98]	1	The issue of reduction of energy consumption of mobile devices was addressed in the study. A new approach to reduce energy consumption based on Learning Automata in mobile cloud computing was proposed by the authors. Simulation results prove that the proposed approach significantly saves energy consumption through determining the appropriate location for application.
99.	Afianian et al., 2015 [99]	1	The problem of security architecture for outsourcing data in mobile cloud computing was discussed. The authors introduce a cipher key using a selfie picture taken by the user. Further they employ "a method of key management such that in case of missing one file, there would be no way of reconstructing the file while relieving the user from key management complexities". Study results indicate that thanks to proposed method's low-energy consuming nature, it can be confidently used in mobile cloud computing.
100.	Zheng & Cai, 2015 [100]	1	An energy efficient statistical live virtual machines placement scheme in a heterogeneous server clusters was proposed. The developed scheme supports virtual machines request scheduling and live migration to minimize the number of active servers in order to save the overall energy in a virtualized server cluster. The offered virtual machines placement scheme incorporates all the virtual machines operation overheads in the dynamic migration process. Moreover, it takes into account other important factors related to energy consumption, as well as it is ready to be extended with more considerations on users demand. The authors conducted extensive evaluations based on HPC jobs in a simulated environment. The obtained results confirm the effectiveness of the proposed scheme.
101.	Armstrong et al., 2015 [101]	1	An energy efficient interoperable cloud architecture realized as a cloud toolbox that aimed at reducing the energy consumption of cloud applications holistically across all deployments models was investigated. The proposed architecture supports energy efficiency at service construction, deployment, and operation and interoperability through the use of the Open Virtualization Format (OVF) standard. The authors consider the practical experience during implementation as well as present an initial performance evaluation of the architecture. The study results indicate that the implementing cloud provider interoperability is feasible and incurs minimal performance overhead during application deployment when compared to the time taken to instantiate virtual machines.
102.	Heydarikiya et al., 2014 [102]	1	The role of communication fabric was discussed. The study presents a scheduling solution, named e-STAB, that takes into account traffic requirements of cloud applications providing energy efficient job allocation as well as traffic load balancing in data center networks. The authors claim that effective distribution

			of network traffic improves quality of service of running cloud applications by reducing the communication-related delays and congestion-related packet losses. The validation results gained from the GreenCloud simulator indicate the benefits and efficiency of the proposed scheduling methodology.
103.	Kantarci & Mouftah, 2013 [103]	1	A detailed survey of the existing mechanisms aimed at designing the Internet backbone with data centers and the objective of energy-efficient delivery of the cloud services was hold. The survey is followed by a case study where Mixed Integer Linear Programming (MILP)-based provisioning models and heuristics are applied in order to guarantee either minimum delays or maximum power saving cloud services where high performance data centers are assumed to be located at the core nodes of an IP-over-WDM network. The study concludes with summarizing the surveyed schemes with a taxonomy including the cons and pros as well as providing the research challenges and opportunities.
104.	Tafani et al., 2013 [104]	1	A survey of the most popular energy-conservation and 'green' technologies that can be applied at data centers and network level in order to overcome these issues was done. The authors illustrate the state-of-the-art strategies for the development of energy-efficient data centers. In particular, they debate principles and best practices for the energy-efficient data center design focusing on hardware, power supply specifications, and cooling infrastructure. They also discuss the problem through the lens of the network energy consumption, analyzing several approaches achieving power efficiency for access, as well as core networks. Moreover, the authors provide an insight to recent development in energy-efficient virtual machine placement and dynamic load balancing. The study concludes with providing the reader with a novel research work for the establishment of energy-efficient lightpaths in computational grids.
105.	Han & Cai, 2013 [105]	1	The issue of improving the energy efficiency of the data center was addressed. The policies for setting the speed of the processor for both goals of minimizing the total energy cost and meeting the specified QoS performance were studied. The authors propose a model of speed scaling with weighted power energy, the QoS parameters may be induced to a qualitative concept as the weighting factor of energy consumption. Based on the model, they offer a resource allocation policy based on the cooperative game theory for energy-efficient management of clouds. The simulation results indicate the efficiency of the proposed method.
106.	Bărbulescu et al., 2013 [106]	1	The issue of energy efficiency in terms of cloud computing was addressed. The possibility of using cloud computing and grid computing for calculations of finesse in energy efficiency was investigated. The study examines some of the basics of cloud computing with aim of introducing cloud computing in distributed system.
107.	Whittington et al., 2015 [107]	0	The ways of improving the energy usage of cloud computing environments through better resource management and consolidation were investigated. The methodology proposed by the authors focuses on critically reviewing and comparing the existing methods that are available in relation to schedulers as well as allocation policies through a simulated environment and experimentation. The described experiments confirm the energy efficiency of the identified schedulers and allocation policies in the CloudSim environment. The study results point out which policy

			performs the best at energy reduction while maintaining the service level agreement (SLA), which is a valuable source of information for future energy efficiency control in real world cloud computing environments.
108.	Wen et al., 2015 [108]	0	The issue of mobile cloud computing treated as an effective solution to extend capabilities of resource-poor mobile devices by application off-loading was discussed. The authors emphasize that it is not always energy-efficient to off-load mobile applications to the cloud for execution. They argue that the stochastic nature of wireless channels and various profiles of mobile applications (e.g., task topology and time deadline requirement) present challenges for making decision on application off-loading.
109.	Prathibha et al., 2015 [109]	0	The issue of the energy consumption patterns in the field of cloud computing was addressed. The complete investigation of the energy consumption patterns and enhancements with DVFS technique in order to facilitate the support for optimization of the green cloud environment was first presented and then applied for scheduling tasks of workflow application was done.
110.	Pandolfo et al., 2015 [110]	0	An algorithm named ε-PUC-Fit, aimed at improving energy efficiency in cloud computing environments through dynamic consolidation of virtual machines was proposed. The developed algorithm was evaluated through simulations based on real-world workload traces. The study results indicate that, under certain conditions, the ε-PUC-Fit algorithm outperforms other algorithms such as the First-Fit algorithm and a variant of the Best-Fit algorithm.
111.	Liu et al. 2015, [111]	0	The issue of energy-efficient scheduling for wireless uplink in MCC was addressed. Through introducing Lyapunov optimization, the authors introduce a scheduling algorithm that may dynamically choose channel to transmit data based on queue backlog and channel statistics. Then, they prove that the proposed scheduling algorithm can make a tradeoff between queue backlog and energy consumption in a channel-aware MCC system. Simulation results indicate that the offered scheduling algorithm may reduce the time average energy consumption for offloading compared to the existing algorithm.
112.	Asha & Rao, 2014 [112]	0	The survey of the techniques and solutions aimed at improving the energy efficiency of computing resources was presented. The study discusses methods used to evaluate and model the energy consumed by these resources, and presents the techniques operating at a distributed system level, trying to improve aspects such as resource allocation.
113.	Szymanski, 2014 [113]	0	An Enhanced-Internet network supporting 'ultra-low-latency' energy efficient communications for cloud services was presented. The demonstrated Enhanced-Internet combines various technologies: (1) two non-interfering traffic classes, the Guaranteed-Rate (GR) and Best-Effort (BE) classes, (2) a flowbased resource-reservation signaling protocol for the GR class, (3) a QoS-aware low-jitter router scheduling algorithm with 100% bandwidth-efficiency, and (4) aggregation and smoothening of cloud traffic, to achieve exceptionally low latencies and high energy efficiencies. The Enhanced-Internet supports ultralow latency machine-to-machine communications, for automated financial trading systems. It improves the efficiency of the current infrastructure, thereby reducing energy costs. Study results prove a

			saturated Enhanced-Internet network supporting one thousand traffic flows, each receiving essentially-perfect service, with very low latencies and very high energy-efficiencies.
114.	Owusu et al., 2014 [114]	0	The issue of energy efficiency of cloud computing was discussed. Previous contributions to the discussion on the energy efficiency of cloud computing were outlined. The study investigates the energy efficiency of cloud computing through simulations.
115.	Davlea & Teodorescu, 2014 [115]	0	An integrated system for energy management provided through cloud computing was discussed. The presented system includes a network of autonomous addressable, distributed modules, for metering the energy consumption as well as a module for energy consumption forecast.
116.	Guo & Yu, 2014 [116]	0	In order to solve massive data processing inefficiencies, redundant business systems and data silos and other issues, a scheduling model of migrating technology based on efficiency optimization virtual machine to meet the massive data efficiently scheduling requirements was proposed. The study results indicate that the improved algorithm may effectively advance the efficiency of cloud computing massive data scheduling, with high feasibility as well as applicability.
117.	He et al., 2014 [117]	0	The study "uses an improved particle swarm optimization, that is, when the optimal solution did not change for two generations, traversing through the chaotic particle method for local optimization to accelerate access to global optimal solution". Comparing the proposed algorithm with other scheduling algorithms by simulatin, the authors prove that better scheduling scheme may be achieved, and they confirm the effectiveness and practicality of the algorithm.
118.	Li et al., 2014 [118]	0	The issues of rapid growth in the cloud computing centers worldwide posing serious challenges to both hardware and software designers on the energy efficiency were discussed. The study examines particular challenges and potential promises on the part of data processing in cloud computing centers.
119.	Chung et al., 2013 [119]	0	A smartphone with both WLAN and cellular interfaces was considered. The authors propose an efficient offloading decision scheme for energy conservation. "In the proposed scheme, whether offloading is required or not and which wireless interface is more appropriate for offloading are decided based on the estimated local execution time of a task". The study results indicate that the proposed offloading scheme may decide offloading and choose an appropriate wireless interface efficiently
120.	Sun et al., 2012 [120]	0	A novel energy consumption model by a heuristic virtual machine scheduling mechanism to maximize cloud system energy efficiency was put forward with a brief survey of high energy efficiency suitable for large-scale distributed virtual computing environments. The proposed model includes: modeling the general energy consumption model and virtual machine live migration cost model for mobile clouds, managing high energy efficiency virtual machine live migration by a heuristic virtual machine scheduling mechanism in cloud data center, as well as designing the heuristic virtual machine scheduling algorithm in a mobile clouds. Theoretical and experimental study results prove that the heuristic virtual machine scheduling algorithm has high potential in dealing with the high energy-high performance trade-off, provides high

	energy efficiency for the data center as well as minimizes energy consumption in mobile clouds.

Source: Own study based on data retrieved from the Scopus database (20 May 2020).

Table S2. Reference list and key research findings 2016-2020 (ranked by the number of citations).

Rank	Reference	Citations (N)	Key Research Findings
1.	You et al., 2016 [121]	167	An innovative solution that easily integrates two technologies: mobile cloud computing and microwave power transfer was presented to enable "computation in passive low-complexity devices such as sensors and wearable computing devices".
2.	Hameed et al., 2016 [122]	139	To identify challenges associated with energy efficient resource allocation, existing hardware and software-based techniques presented in the literature were summarized against the proposed research dimension taxonomy namely: resource adaption policy, objective function, allocation method, allocation operation, and interoperability.
3.	Guo et al., 2016 [123]	131	An energy-efficient dynamic offloading and resource scheduling (eDors) policy was provided to reduce energy consumption and shorten application completion time. It was shown that the computing workload of a task, the maximum completion time of its immediate predecessors and the clock frequency and transmission power of the mobile device were the main factors influencing the computation offloading selection. Experimental results in a real testbed demonstrated that the eDors algorithm can effectively reduce the energy-efficiency cost by optimally adjusting the CPU clock frequency of smart mobile devices based on the dynamic voltage and frequency scaling technique in local computing, and adapting the transmission power for the wireless channel conditions in cloud computing.
4.	Kandavel and Kumaravel, 2019 [124]	87	This work misused exponential weighted mean moving average to foresee gadget speed as per load on mobile gadget. The proposed work was contrasted with two kinds of framework: "Fixed CPU Speed framework where CPU speed of mobile gadget is fixed all through all offloading choices, and Oracle which accept to know definite speed of mobile gadget ahead of time". Assessment of all frameworks was conducted by "utilizing manufactured outstanding tasks at hand".
5.	Liu et al., 2018 [125]	85	An energy efficient OEMACS for virtual machine placement in cloud computing was developed. The optimal virtual machine placement was achieved with the minimum number of active servers and by switching off the idle servers. Experimental results showed that OEMACS achieved the "objectives of minimizing the number of active servers, improving the resource utilization, balancing different resources, and reducing power consumption".
6.	Li et al., 2016 [126]	77	A dynamic energy-efficient virtual machine migration and consolidation algorithm based on a multi-resource energy-efficient model was developed. In the algorithm, a method of double threshold with multi-resource utilization to trigger the migration of virtual machines was designed. The modified particle swarm optimization method was introduced into the consolidation of virtual machines to avoid falling into local optima which is a common defect in traditional heuristic algorithms. Comparing with the popular traditional heuristic algorithm the modified best fit decrease, the algorithm reduced the number of active physical nodes and the amount of virtual

Rank	Reference	Citations (N)	Key Research Findings
			machines migrations. It showed better energy efficiency in data center for cloud computing.
7.	Sharma et al., 2016 [127]	65	A review of existing techniques for "reliability and energy efficiency and their trade-off in cloud computing" was presented. The "classifications on resource failures, fault tolerance mechanisms and energy management mechanisms in cloud systems" were discussed. Various challenges and research gaps in trade-off between reliability and energy efficiency were identified.
8.	Fiandrino et al., 2017 [128]	49	A framework of "new metrics able to assess performance and energy efficiency of cloud computing communication systems, processes and protocols" was proposed. The suggested metrics were evaluated for the most common data center architectures including: fat tree three-Tier, BCube, DCell and Hypercube.
9.	Agitha and Kaliyamurthie, 2019 [129]	47	The proposed algorithm "can be presented to be minimal since from the time limit vector and loading off data information vector are fixed in the constraints to the overloading data". The numerical results showed that the "given redundant algorithm compress good performance than older method in part of energy absorption and efficiency".
10.	Dashti and Rahmani, 2016 [130]	47	The modification of particle swarm optimization to "reallocate migrated virtual machines in the overloaded host" was proposed. Simulation results demonstrated that whenever simulation conditions were close to the real environment, this method was able to save as much as 14% more energy and the number of migrations and simulation time significantly reduced.
11.	Terefe et al., 2016 [131]	37	An energy-efficient multisite offloading policy algorithm was proposed as the efficient solution to the multisite partitioning problem. Numerical simulations showed that the algorithm "considers the different capabilities of sites to distribute appropriate components such that there is a lower energy cost for data transfer from the mobile to the cloud". A multisite offloading execution using this algorithm achieved "a greater reduction on the energy consumption of mobiles when compared to a single site offloading execution".
12.	Guo et al., 2019 [132]	35	An energy-efficient dynamic offloading and resource scheduling policy was provided to "reduce energy consumption and shorten application completion time". The results showed that the algorithm can "effectively reduce an energy-efficiency cost by optimally adjusting CPU clock frequency of SMDs in local computing, and adapting the transmission power for wireless channel conditions in cloud computing".
13.	Liu et al., 2016 [133]	30	An offloading decision method was investigated to "minimize the energy consumption of mobile device with an acceptable time delay and communication quality". Simulation results showed that "considerable energy can be saved via the proposed method in various mobile cloud scenarios".
14.	Vakilinia et al., 2016 [134]	30	A platform for virtual machine placement/migration was proposed to "minimize the total power consumption of cloud data centers" Adaptation and scalability of the proposed

Rank	Reference	Citations (N)	Key Research Findings
			platform resulted in a notable performance in virtual machine placement and migration processes.
15.	Bui et al., 2017 [135]	28	An energy-efficient solution for "orchestrating the resource in cloud computing" was proposed. This approach can achieve "a significant result in reducing the energy consumption as well as maintaining the system performance".
16.	Jiang et al., 2016 [136]	27	A robust routing algorithm was proposed to "reach the higher network energy efficiency, which is based on optimization problem". Simulation results showed that the algorithm was effective and feasible to achieve energy-efficient networks for cloud computing.
17.	Malekloo et al., 2018 [137]	24	An energy-aware and quality of service-aware multi-objective ant colony optimization approach for virtual machine placement and consolidation was proposed. The results showed that this approach outperforms the other tested approaches in terms of energy savings, reduction of resource wastage at the CPU, reduction of communication cost in terms of energy induced by traffic load exchanged between virtual machines, and minimization of the number of virtual machine migrations and SLA violations.
18.	Wajid et al., 2016 [138]	24	An eco-aware approach was described that relies on "the definition, monitoring and utilization of energy and CO_2 metrics combined with the use of innovative application scheduling and runtime adaptation techniques to optimize energy consumption and CO_2 footprint of cloud applications as well as the underlying infrastructure". The experimental and validation results showed the "potential of the eco-aware approach to significantly reduce the CO_2 footprint and consequent environmental impact of cloud applications".
19.	Mebrek et al, 2017 [139]	23	The study of the fog computing suitability assessment as a solution for the increasing demand of the internet of things devices was presented. The focus was on the energy consumption and the quality of service as "two important metrics of the performance of the fog". A modeling of these two metrics in the fog was presented. The problem was expressed as constrained optimization and solved efficiently using evolutionary algorithms.
20.	Demirci, 2016 [140]	20	A detailed survey of recent works in the literature was provided which have employed "machine learning to offer solutions for energy efficiency in cloud computing environments". A comparative classification of the proposed methods was presented. This survey was enriched by studying non-machine learning proposals to energy conservation in data centers, and also how machine learning has been applied towards other objectives in the cloud.
21.	Vakilinia, 2018 [141]	19	The joint optimization of power consumption of servers, network communications and cost of migration with workload and server heterogeneity subject to resource and bandwidth constraints through virtual machine placement were developed. The results showed that "optimization achieves significant power savings compared to the heuristic algorithms".

Rank	Reference	Citations (N)	Key Research Findings
22.	Ye et al., 2017 [142]	19	An energy-efficient KnEA point-driven evolutionary algorithm was proposed. Experimental results show that the proposed model is reasonable, and the algorithm "outperforms its counterparts on this type of problem in terms of energy saving, load balance, and robustness".
23.	Ahmad et al., 2017 [143]	17	A system architecture based on the hierarchical resource sharing mechanism for mobile cloud computing was presented. It was shown that the "proposed system architecture helps in minimizing handover delay, packet loss, average queuing delay, and device lifetime in a network".
24.	Eshratifar and Pedram, 2018 [144]	16	The efficiency of offloading only some parts of the computations in deep neural networks to the cloud was investigated. The simulation results showed that the framework can achieve "1.42× on average and up to 3.07× speedup in the execution time on the mobile device. In addition, it results in 2.11× on average and up to 4.26× reduction in mobile energy consumption".
25.	Cao et al., 2017 [145]	16	A low-rate distributed denial-of-service attack-aware energy-efficient multipath TCP solution was proposed for multi-homed mobile cloud computing systems. The simulation results showed that this solution outperforms the baseline multipath TCP in terms of quality of service and energy-savings in a multi-homed mobile cloud computing network environment.
26.	Zhao et al., 2016 [146]	16	The "joint optimization of radio and computational resources for multiple users in mobile cloud computing" was studied and a heuristic strategy, based on the latency constraint and the application type of each mobile terminal, for resource allocation of low computational complexity was proposed. Numerical results showed that "proposed task offloading strategy can significantly reduce the total energy at the mobile terminal side by 40% with 3 mobile terminals in the system, compared with the non-offloading mobile computing scheme, while at the same time satisfying the delay constraints". Moreover, it performed fairly close to the optimum.
27.	Choudhary et al., 2016 [147]	15	A technique for "optimizing virtual machine placement by live migration using dynamic threshold values ensuring a deadlock free resource allocation focusing on multidimensional resources" was proposed. The aim was to "improve the overall utilization of computing resources thus reducing the energy consumption of datacenter".
28.	Jiang et al., 2016 [148]	14	The energy-efficient problem with quality of service constraints in "large-scale cloud computing networks was studied". Simulation results showed that this approach can "significantly improve energy efficiency of cloud computing networks".
29.	Wen et al., 2017 [149]	13	To minimize the energy consumption of a data center, an "energy-efficient virtual resource dynamic integration" method was proposed. The experiments showed that the suggested method can reduce the energy consumption of the data center and ensure the quality of service of the cloud applications developed on the virtual machines.
30.	Li et al., 2016 [150]	13	By introducing "heterogeneous energy constraints of heterogeneous physical servers in cloud computing, an energy-efficient resource scheduling model for heterogeneous physical

Rank	Reference	Citations (N)	Key Research Findings
			servers based on constraint satisfaction problems" was presented. Experimental results showed that "compared with DynamicPower and MinPM, the proposed algorithm not only improves the performance of resource allocation, but also reduces energy consumption of cloud data center".
31.	Abu Sharkh and Shami, 2017 [151]	12	A novel mathematical optimization model to "solve the problem of energy efficiency in a cloud data center" was introduced. Proposed solutions were evaluated "in terms of a number of critical metrics, namely, energy used per server, energy used per served request, acceptance rate, and the number of migrations performed".
32.	Ahn et al., 2017 [152]	11	An energy efficient job scheduling scheme for offloaded computation in a mobile cloud computing environment was proposed. That scheme "can induce the maximal social utility". To provide a novel solution for mobile cloud computing "an insightful discussion as a guide for further research and the deployment of partial computation offloading in a cloudlet environment" was presented.
33.	Stavrinides and Karatza, 2019 [153]	10	An "energy-efficient, quality of service-aware and cost-effective scheduling strategy for real-time workflow applications in cloud computing systems" was presented. The simulation experiments revealed that this approach "outperforms the other examined policies, providing promising results".
34.	Jiang et al., 2016 [154]	10	Combining the sleeping redundant links algorithm with the minimum criticality routing algorithm, a Robust Energy Efficiency Routing Algorithm (REERA) used for cloud computing networks was proposed. Comparing REERA with open shortest path first-based algorithm, the simulation results showed that REERA outperforms open shortest path first-based algorithm, and REERA "can realize the energy-efficient routing algorithm under the premise of network robustness constraints".
35.	Atiewi et al., 2016 [155]	10	A review of various "energy-efficient task scheduling methods in a cloud environment and a brief analysis of various scheduling parameters considered in these methods" were presented. The results showed that the "best power-saving percentage level can be achieved by using both DVFS and DNS".
36.	Wu and Wang, 2018 [156]	9	The scheduling of the "precedence-constrained parallel application to minimize time and energy consumption efficiently" was presented. The comparative results showed the Pareto solution set by the proposed algorithm was able to "dominate a large proportion of those solutions by both the heuristic methods" and the bi-objective genetic algorithm.
37.	Lin et al., 2017 [157]	9	A "game-theoretic approach to data traffic management to obtain a distributed and energy-efficient solution, where each edge router is acting as a strategic player" was adopted. Simulation results showed "notable challenges for operators to plan, design, and operate a multimedia content network to optimize energy consumption, network delay, and load balance over a diurnal cycle".
38.	Khattar et al., 2019 [158]	8	Classification of heuristics-based optimization methods and the dynamic power management techniques was carried out. The survey showed the "research trends based on regions, journals,

Rank	Reference	Citations (N)	Key Research Findings
			conferences, etc., in the domain of energy efficiency in cloud computing".
39.	Askarizade et al. 2019 [159]	8	Through virtualization technique a hybrid technique for resource management was applied. The results showed that the proposed KMGA technique "could provide a good trade-off between effectively reduce energy consumption of datacenters and sustained quality of service". Moreover, it "minimized the number of virtual machine migrations and make-span, in comparison with particle swarm optimization and genetic algorithms in similar hybrid techniques".
40.	Zhang et al., 2017 [160]	8	The energy saving issue for virtual machine selections on an overloaded host in a cloud computing environment was presented. Experiments with CloudSim were conducted and results showed that the proposed algorithm can effectively reduce energy consumption while satisfying the constraints of service level agreement.
41.	Zheng et al., 2017 [161]	8	An energy efficient virtual network embedding approach for cloud computing networks was proposed, in which power savings are "introduced by consolidating resources in the network and data centres". Simulation experiments showed that the proposed algorithm can effectively increase virtual networks acceptance ratio and "reduce energy consumption when large quantities of virtual networks arrive and depart over time".
42.	Muthu Pandi and Somasundaram, 2016 [162]	8	An application virtualization and desktop virtualization in cloud environment was presented. Based on the identified gap between server consolidation and optimization, an experimental setup was created and the CPU usage, memory usage, disk and network usage parameters were continuously monitored. Based on the parameters which help to reduce the energy consumption in data center, the power consumption was calculated.
43.	Jararweh et al., 2018 [163]	7	A general host overloading detection algorithm was proposed based on "logistic regression model and median absolute derivation". The proposed algorithm is scalable and can be used with any virtual machine placement and migration algorithms. An extensive evaluation procedure was used with dynamic workload to proof the efficiency of the proposed algorithm. The archived results showed that the "proposed algorithm outperforms all other known host status prediction techniques".
44.	Singh et al., 2017 [164]	7	The major techniques available in the literature for energy saving in cloud computing such as "energy efficient hardware, energy efficient scheduling, consolidation, energy efficient network and clustering servers" were discussed.
45.	Goyal et al., 2016 [165]	7	An energy efficient hybrid technique was proposed to "lessen energy consumption in cloud computing". It not only met energy efficiency requirements but also ensured quality of service to the user by "minimizing the service level agreement violation". The proposed technique results were validated with higher efficiency. The results of proposed technique/policy were compared with energy efficient cloud and power aware cloud.
46.	Sharma et al., 2019 [166]	6	A failure-aware virtual machine consolidation mechanism was proposed, which takes the occurrence of failures and the hazard rate of physical resources into consideration before performing

Rank	Reference	Citations (N)	Key Research Findings
			virtual machine consolidation. The results demonstrated that by using the combination of checkpointing and virtual machine migration with the proposed mechanism, the energy consumption of cloud computing system is reduced by "34% and reliability is improved by 12% while decreasing the occurrence of failures by 14%".
47.	Mekala and Viswanathan, 2019 [167]	6	An "energy-efficient resource ranking and utilization factor-based virtual machine selection approach" was proposed. The experiments evaluated the ability of the proposed approach to "diminish energy consumption without violation of service level agreements".
48.	Jangiti et al., 2018 [168]	6	The key technologies and techniques which "support and enhance the energy efficiency of cloud computing infrastructure and make cloud a sustainable model' were reviewed. Virtualization, elasticity, and energy-efficiency were considered as three important attributes of cloud and its infrastructure. The interdependencies of these techniques were studied.
49.	Alsadie et al., 2018 [169]	6	The concept of mapping appropriately sized virtual machines to a "group of tasks in a data center, in order to reduce its power consumption" was employed. The experimental results showed an improvement of 8.42% in power consumption compared to representational techniques using fixed-sized virtual machines in the field. The proposed approach also achieved an improvement of "62% in the number of instances of virtual machines created for hosting the task workload, while maintaining a low task rejection rate".
50.	Zhang et al., 2018 [170]	6	A "cloud-based architecture of virus scanning as a service for resource-poor mobile devices" was presented. The results showed that "it is possible to achieve the penalty function, i.e., the combination of the energy consumption and the missed detection error cost, arbitrarily close to the minimum but at the cost of increasing the queue length".
51.	Bermejo et al., 2017 [171]	6	The "resource management and resource allocation techniques, which contribute to the reduction of energy consumption without compromising the cloud user and provider constraints" were presented.
52.	Panigrahi et al., 2017 [172]	6	An "energy efficient emergency management system" was proposed. The simulation results indicated that this system was "suitable for emergency conditions where, mobile devices do not find any suitable networks". That means this system "also works in the absence of any network by considering wireless mesh network technology".
53.	Ahamed et al., 2016 [173]	6	The "compartment isolation technique" was introduced to improve the system security during the consolidation process. The "security-based selection and placement algorithms" were also presented. The comparative analysis of this improved security approach shows that "utilizing the proposed method will reduce the security risks without impacting the overall power consumption in data centers".
54.	Pallavi et al., 2019 [174]	5	An "energy efficient mobility management in mobile cloud computing system for 5G heterogeneous networks" was proposed. The simulation results showed that the proposed

Rank	Reference	Citations (N)	Key Research Findings
			system "helps in minimizing delay, packet loss rate and energy consumption in a heterogeneous network".
55.	Guo et al., 2017 [175]	5	The "energy-efficient and delay-guaranteed workload allocation problem in an internet of things-edge-cloud computing system" was investigated. The theoretical analysis and simulation results were conducted to demonstrate the efficiency of the proposal for energy efficiency and delay guarantee in the system.
56.	Zhou et al., 2018 [176]	5	A new algorithm energy efficiency optimization of virtual machine migrations was proposed. The experimental results showed that, as compared with double threshold algorithm, the suggested algorithm "saves 7% energy consumption and reduces 13% SLA violations".
57.	Zhang et al., 2018 [177]	5	The application of simultaneous wireless information and power transfer technique to a multi-user computation offloading problem was considered for mobile-edge cloud computing, where energy-limited mobile devices harvest energy from the ambient radio-frequency signal. The simulation results revealed that the proposed algorithm "can converge within a few iterations and yield minimum system energy cost".
58.	Tang et al., 2018 [178]	5	An energy consumption optimization problem was modeled, while taking into account task dependency, data transmission and some constraint conditions such as response time deadline and cost, and solved it by genetic algorithms. A series of simulation experiments were conducted to "evaluate the performance of the algorithm and the results showed that [the] proposal is more efficient than the baseline approach".
59.	Bahrami et al., 2016 [179]	5	A novel light-weight data privacy scheme for tiny computing devices was presented. The experimental results showed that the proposed scheme did not "introduce radical additional power consumption, and the scheme maintained data privacy while the smart devices outsource data to a mobile cloud computing system".
60.	Bianchini et al., 2016 [180]	5	Green and energy efficient cloud computing were presented. "Public clouds allow their customers to outsource the management of physical resources, and rent a variable amount of resources in accordance to their specific needs. Private clouds allow companies to manage on-premises resources, exploiting the capabilities offered by the cloud technologies, such as using virtualization to improve resource utilization and cloud software for resource management automation. Hybrid clouds, where private infrastructures are integrated and complemented by external resources, are becoming a common scenario as well, for example to manage load peaks'.
61.	Fayyaz et al., 2016 [181]	5	Simulation results showed a "substantial reduction observed in the overall power consumption of the cloud data centers".
62.	Chou et al., 2016 [182]	5	The framework of a smart decision support system that integrates "smart grid big data analytics and cloud computing for building energy efficiency" was presented. The proposed framework "serves as a start-up creation in an application of big data analytics and cloud computing technology for sustainable building energy efficiency".

Rank	Reference	Citations (N)	Key Research Findings
63.	Zhang et al., 2019 [183]	4	The energy efficiency advantages were presented achieved by "selectively cooperative transmission and associated power consumption model". Simulation results showed that the proposed algorithm can effectively reduce the energy consumption of baseband and improve the energy efficiency of the system.
64.	Sarvabhatla et al., 2018 [184]	4	An "optimized energy efficient offload decision making" algorithm was presented, which "maximizes energy saving while preserving stringent time interval requirements of user applications in the 5G system". The results showed that the algorithm "minimizes energy consumption in various data inputs and result output scenarios and achieves 97% of accuracy while offloading the code to cloud".
65.	Sarkar et al., 2018 [185]	4	A game theory-based energy efficient transmission policy for mobile cloud computing was proposed. The simulation results showed that this policy "helps to minimize the energy consumption of mobile devices as compared to the existing approaches".
66.	Pham et al., 2017 [186]	4	The resource allocation problem for reducing the energy consumption was proposed. "ECRA-SA algorithms were designed to solve it and were evaluated through CloudSim simulation tool compared with FFD algorithm". The experimental results showed that the proposed ECRA-SA algorithm "yields a better performance than FFD algorithm".
67.	Goyal and Saini, 2016 [187]	4	A fault-tolerant energy efficient framework for application offloading with minimal energy consumption and response time was presented.
68.	Panda and Jana, 2019 [188]	3	An energy-efficient task scheduling algorithm was presented to "address the demerits associated with task consolidation and scheduling". The experimental results were compared with recent algorithms, namely "random, round robin, dynamic cloud list scheduling, energy-aware task consolidation, energy-conscious task consolidation and MaxUtil". The proposed algorithm provided an "elegant trade-off between energy efficiency and make span than the existing algorithms".
69.	Alla et al., 2019 [189]	3	An "efficient energy-aware tasks scheduling with deadline-constrained in cloud computing" was proposed. The experimental results validated that the "proposed approach can effectively achieve good performance by minimizing the make span, reducing energy consumption and improving resource utilization while meeting deadline constraints".
70.	Pati et al., 2018 [190]	3	An energy optimal scheduling policy for mobile cloud computing was proposed. The simulation results indicated that this approach "performs better as compared to the existing approaches such as eTime and ThinkAir".
71.	Vinh et al., 2016 [191]	3	Different mobile cloud computing architectures were investigated and "their performance over energy efficiency by examining different approaches: OSGi, overlay, and container based solutions".
72.	Liu et al., 2016 [192]	3	A scheduling algorithm was proposed by introducing the Lyapunov optimization, which can "dynamically choose users to

Rank	Reference	Citations (N)	Key Research Findings
			transmit data based on queue backlog and channel statistics". The Lyapunov analysis showed that the proposed scheduling algorithm can "make a tradeoff between queue backlog and energy consumption in the channel-aware mobile cloud computing system". The simulation results verify the effectiveness of the proposed algorithm.
73.	Akbari et al., 2016 [193]	3	An incorporating weighted linear prediction technique and M/M/1 Queuing Theory for "enhancing the energy efficiency of cloud data centers" was presented. The effect of various workloads on energy consumption of the cloud system was simulated using CloudSim or similar software.
74.	Lu and Sun, 2019 [194]	2	Based on the concepts and principles of load balancing, a novel energy-efficient load balancing global optimization algorithm, called resource-aware load balancing clonal algorithm for task scheduling, was proposed to deal with the problem of energy consumption in green cloud computing. Simulation studies showed that the proposed algorithm "can effectively reduce energy consumption in green cloud computing, and its exploration and exploitation abilities can be enhanced and well balanced".
75.	Han et al., 2019 [195]	2	A virtual machine relocation method was suggested to improve the "energy efficiency by increasing the density of virtual machines using the Knapsack algorithm". Through the proposed method, it was possible to achieve efficient virtual machine relocation in a short period by improving the Knapsack algorithm. The effective "resource management method of cloud cluster for big data analysis" was proposed.
76.	Sharma et al., 2018 [196]	2	Multi-objective virtual machines migration at the cloud data center was presented. The CloudSim based experimental results demonstrated the superiority of the proposed multi-objective virtual machines migration technique in terms of energy efficiency and also reduced the service level agreement violation over state-of-the-art virtual machines migration techniques such as interquartile range, and random virtual machines migration techniques at the cloud data center.
77.	Mohanapriya et al., 2018 [197]	2	A power efficient scheduling and virtual machine consolidation algorithm was proposed, which emphasizes on the software level by taking the flexibility of the virtualization technology. It consists of two phases, virtual machine scheduling phase, and virtual machine consolidation phase. The experimental evaluation was performed using WorkflowSim and the proposed algorithm "achieved significant energy conservation and resource utilization".
78.	Sharma et al., 2017 [198]	2	A mathematical model of both reliability and energy consumption in cloud computing systems was provided and their interplay was analyzed. Moreover, a formal method was proposed to calculate "the finishing time of tasks running in a failure prone cloud computing environment using checkpointing and without checkpointing". The results of experiments demonstrated that "by considering both reliability and energy factors during resource provisioning and virtual machine

Rank	Reference	Citations (N)	Key Research Findings
			allocation, the reliability and energy consumption of the system could be improved by 23% and 61%, respectively".
79.	Acharya and D'Mello, 2017 [199]	2	A dynamic load balancing policy based on the performance, resource utilization and the power consumption was implemented. The results obtained after the simulations with various combinations of the datacenters clearly indicated that the proposed method "results in effective reduction in response time and power consumption and improved resource utilization by comparing with the considered existing mechanisms".
80.	Daraseliya and Sopin, 2017 [200]	2	A cloud computing system was considered, in which "a server does not switch off immediately, as it remains empty but after a certain time". A mathematical model of a cloud computing "system with switch on/off periods" was developed and its energy efficiency metrics were analyzed.
81.	Malik et al., 2017 [201]	2	A survey of "load balancing algorithms along with their limitations" was presented and a "framework for an energy efficient resource allocation and load balancing for heterogeneous workload in cloud computing along with the validation of the framework using CloudSim toolkit" was proposed.
82.	Balakrishnan et al., 2016 [202]	2	A methodology for "estimating the energy consumption of tasks by considering processor and memory usage" was proposed. The proposed approach used "energy consumption during computation as well as memory access as its metric to conceive the offloading decision". The proposed energy model was simulated and the results were concluded that there was a "considerable amount of energy saving in mobile devices due to computation offloading to nearby mobile devices or cloud resources".
83.	Iqbal et al., 2016 [203]	2	The energy utilization of a server was observed using SNMPv3 and ways to improve the energy efficiency were suggested based on the data collected. The power consumption of the system varied with different loads on the host application. Data were extracted about the CPU state of the server. This allowed for a more rigorous comparative analysis and results showed that energy efficiency can be improved under different circumstances.
84.	Bahwaireth et al., 2016 [204]	2	The energy efficiency in mobile cloud computing was presented since it is the "most important design requirement for mobile devices". Techniques and prototypes in mobile cloud computing were presented to reduce power consumption and increase resources efficiency and utilization.
85.	Niu et al., 2016 [205]	2	The energy efficiency and spectral efficiency were treated as one joint optimization function. Simulation results confirmed the analytical properties and showed the advantage of tradeoff scheme compared with energy efficiency-based or spectral efficiency-based design.
86.	Yadav et al., 2016 [206]	2	An algorithm for energy optimization having quality of service and SLA as constraints was proposed.
87.	Shobana and Radhika, 2016 [207]	2	A survey of "mobile cloud computing research with energy efficiency" was presented. An overview of various cost models

Rank	Reference	Citations (N)	Key Research Findings
			was conducted including the scheme of classification based on the major issues. Moreover, various approaches to overcome these issues were described. The offloading methods and the analysis of mobile cloudlet-cloud experiment with the results were also presented.
88.	Kitanov and Janevski, 2016 [208]	2	A model for fog and cloud hybrid environment service orchestration mechanisms for 5G network was evaluated in terms of energy efficiency per user for different payloads.
89.	Singh and Kaushal, 2016 [209]	2	An algorithm was proposed which "profiles the overall energy consumed based on: max utilization of host after allocation, creation history of virtual machine, and the difference in power consumed by host before and after allocation". The framework for the implementation of the proposed algorithm was conducted in CloudSim. The results showed that reducing the total number of virtual machine migrations affected the overall energy consumption in the cloud.
90.	Devaraj et al., 2020 [210]	1	A new load balancing algorithm was proposed as a hybrid of firefly and improved multi-objective particle swarm optimization technique. The simulation outcome showed that the proposed model "exhibited an effective performance" when compared with other methods. From the simulation outcome, it was understood that the "algorithm yielded an effective result with the least average response time of 13.58ms, maximum CPU utilization of 98%, memory utilization of 93%, reliability of 67% and throughput of 72% along with a make span of 148".
91.	Khorsand and Ramezanpour, 2020 [211]	1	An energy-efficient task-scheduling algorithm was proposed based on "best-worst and the technique for order preference by similarity to ideal solution methodology". The performance of the proposed and existing algorithms was evaluated 'using several benchmarks in the CloudSim toolkit and statistical testing through ANOVA, where the evaluation metrics include the makespan, energy consumption, and resource utilization".
92.	Abed et al., 2019 [212]	1	A secure energy-efficient platform was introduced that reduces the energy consumption and maintains privacy. The results showed that the "platform depends on the rate of sensing, frequency of sending data, data size, location and number of sleeping sensors, and smartphone battery capacity".
93.	Xu and Buyya, 2019 [213]	1	A brownout-based software system was proposed for container-based clouds to handle overloads and reduce power consumption. The results showed the currently implemented policies in this software system "can save about 10%-40% energy than the existing baselines while ensuring quality of services".
94.	Usman et al., 2019 [214]	1	A comprehensive review of the state-of-the-art nature-inspired algorithms suggested for solving the energy issues in the cloud datacenters was presented. This review supports the researchers and professionals in cloud computing datacenters in "understanding literature evolution towards to exploring better energy-efficient methods for cloud computing datacenters".
95.	Sanjay et al., 2019 [215]	1	The given algorithm decreased the consumption of energy by "decreasing the working states of multiple physical machines"

Rank	Reference	Citations (N)	Key Research Findings
			and reduced the task rejection rate and made span. The results were demonstrated using the CloudSim simulator.
96.	Xu et al., 2019 [216]	1	The performance of the proposed scheme was "evaluated in terms of scheduling strategies under different system configurations and user traffic". The results indicated the feasibility of the proposed scheme.
97.	Ali et al., 2019 [217]	1	A taxonomy of "huge energy consumption problems and its related solutions" was prepared. The authors covered "all aspects of energy consumption by cloud datacenters" and analyzed "many more research papers to find out the better solution for an efficient energy consumption".
98.	Singh and Dhir, 2019 [218]	1	A hypercube based genetic algorithm was proposed for efficient virtual machine migration for energy reduction in cloud computing under quality-of-service constraint. Experimental results of comparisons between the proposed method with the existing solutions showed a "marked reduction in energy consumption of cloud computing environment".
99.	Carvin et al., 2018 [219]	1	A novel 3D neural network predictor model was proposed to estimate the workload. The experiment was carried out using six different processors using Cloud SIM Tool. ENNEGCC 3D avoided unwanted status change in server thus greatly reduced the power consumption.
100.	Jin et al., 2018 [220]	1	To obtain the "resource management strategy in deterministic scenarios", a deterministic strategy algorithm was proposed based on the adaptive group genetic algorithm. Based on the deterministic model, a stochastic model was established that involved a stochastic optimization problem with chance constraints. Experiments showed that the deterministic strategy algorithm obtained "approximate optimal solutions with low algorithmic complexity with respect to the problem size", and the stochastic strategy algorithm saved "more energy than other algorithms while satisfying the chance constraints".
101.	Pasha and Khan, 2018 [221]	1	A conveyed and versatile protocol was used for "economical, efficient and effective task offloading in these networks which address the adaptability of vehicular clouds". The results obtained by extensive simulations were presented to assess and contrast its performance with existing protocols.
102.	Daraseliya et al., 2018 [222]	1	A cloud computing system with three different mechanisms was considered for increasing the energy efficiency of cloud computing systems. Four mathematical models of the cloud computing system were developed "in terms of the queuing system and derived the system of equilibrium equations, which makes it possible to obtain the energy consumption indicators".
103.	Diouani and Medromi, 2018 [223]	1	The existing energy efficient methods in the green cloud computing fields were tackled and the green cloud solution was put forward for data center dynamic resource management. The proposed approach aimed to reduce the infrastructure energy consumption and maintained the required performances.
104.	More and Ingle, 2018 [224]	1	The different strategies for energy-efficient cloud computing were analyzed along with the motivation for it. A mathematical model for energy efficient cloud was discussed which gives the

Rank	Reference	Citations (N)	Key Research Findings
			"basic equation of calculating energy consumed at cloud by considering different activities of the virtual machine". An experiment with the MATLAB simulator for investigating interrelationships between cloud entities and energy consumption using fuzzy logic was carried out. Different research issues were discussed along with methodologies and techniques to be adapted for achieving them.
105.	Liu et al., 2018 [225]	1	A new energy-efficient failure detector was proposed specifically for vehicular cloud computing. It did not only provide acceptable failure detection service, but also saved the battery consumption of a roadside unit. Through the comparative experiments, the results showed that "the failure detector has better performance in terms of speed, accuracy and battery consumption".
106.	Megharaj and Mohan, 2016 [226]	1	The migration of the extra tasks from overloaded virtual machine to suitable virtual machine instead of migrating the entire overloaded virtual machine was described. The implementation of proposed methodology was done using CloudSim tool, and comparative analysis was conducted to evaluate the proposed method with a traditional load balancing algorithm in terms of energy consumption and time.
107.	Zhang et al., 2016 [227]	1	A platform for "sharing and scheduling the distributed resources from embedded devices and Linux servers including computational resources, scale-out storages, and various data to accomplish collaborative processing tasks" was described. The result showed that the platform "can achieve more efficient utilization of resources when sharing the heterogeneous cluster among diverse frameworks".
108.	Dinita et al., 2016 [228]	1	The results of positive experiments were presented "on the efficiency and security potential of an optimized and novel approach to an autonomous management distributed system […] running in a cloud computing environment".
109.	Long and Ji, 2016 [229]	1	To address the issue of "high energy consumption and low efficiency of cloud computing", a power-efficient immune clonal optimization algorithm was proposed based on "dynamic load balancing strategy and immune clonal selection theory in green cloud computing". The experimental results showed that the algorithm performed much better than the clonal selection algorithms and differential evolution in terms of the quality of solution and computational cost.
110.	Jasuja and Kaur, 2016 [230]	1	The hybrid of metaheuristic optimization algorithms was used. The hybrid of algorithms was expected to produce better results "in terms of number of migrations and energy consumption". This hybrid can be implemented using various tools like CloudSim embedded with either Eclipse IDE or Netbeans.
111.	Torrens et al., 2016 [231]	1	A prototype of the platform together with workload and thermal management algorithms was implemented and the algorithms in a simulation based model of a real data center were evaluated. Results showed significant energy savings potential, "in some cases up to 40%, by integrating workload and thermal management".

Rank	Reference	Citations (N)	Key Research Findings
112.	Ding et al., 2020 [232]	0	A q-learning based task scheduling framework was proposed for energy-efficient cloud computing. Simulation experiments confirmed that implementing proposed queueing system in a cloud can "help to reduce the average task response time". Moreover, this approach is the "most energy-efficient as compared to other task scheduling policies".
113.	Mc Donnell et al., 2020 [233]	0	Gossip contracts were proposed as a "new multi-agent framework for crafting decentralized co-operation strategies". A gossip contracts-based dynamic virtual machine consolidation strategy was developed and compared to two popular strategies: Sercon and ecoCloud. The gossip contracts-based strategy performed best with respect to SLA violations, and was similar to or outperforms other strategies with respect to power consumption.
114.	Hu et al., 2020 [234]	0	The "coexistence and synergy between edge and central cloud computing in a heterogeneous cellular network" was studied, which contains a multi-antenna macro base station, multiple multi-antenna small base stations and multiple single-antenna user equipment. The simulation results showed that proposed solution can achieve great performance gain over conventional schemes using edge or central cloud alone.
115.	Wu et al., 2020 [235]	0	A novel scheme was provided with the "two-level hybrid adaptive model" to predict virtual machines load based on the strong regularity of command line applications, and elastically configured the CPU and memory resource for virtual machines. Extensive experiments demonstrated that the elastic allocation strategy can improve the virtual machines performance and resource utilization.
116.	Radhamani and Dalin, 2020 [236]	0	The crossover and mutation process of genetic algorithm was utilized to optimally select the migration virtual machines and choose the destination physical machines. Thus, this genetic algorithm based load optimization algorithm optimally and efficiently maps the migration of virtual machines to the destination physical machines.
117.	Elashri and Azim, 2020 [237]	0	Two algorithms were proposed for "making an efficient offloading decision for soft and weakly hard (firm) real-time applications while guaranteeing the schedulability of tasks". Different experiments were performed and the "technical and economic feasibility of using offloading were investigated to perform various processes that require different computational power". Experimental results showed that "significant power can be saved by offloading the resources of the power-intensive applications into the cloudlet for weakly hard real-time tasks and cloud for soft real-time tasks".
118.	Sharma et al., 2020 [238]	0	Energy efficiency in mobile cloud computing was discussed. A modified best fit decreasing algorithm was used to "sort the users as per their task". To minimize energy consumption and completion time required for completing the tasks, the artificial bee colony optimization algorithm was used with a supervised learning technique support vector machine. It was analyzed that "energy consumption and completion time are reduced by 36.12% and 8.12% respectively".

Rank	Reference	Citations (N)	Key Research Findings
119.	Li et al., 2020 [239]	0	An adaptive wireless resource allocation strategy of computation offloading service was studied under "a three-layered vehicular edge cloud computing framework". Numerical results showed that the "designed algorithm can gain above 80% execution time conservation and 62% conservation on energy consumption, and it exhibits fast convergence and superior performance compared to benchmark solutions".
120.	Rajabzadeh et al., 2020 [240]	0	In the proposed model, "monitoring the status of resources and analyzing the obtained data have led to proper placement and consolidation of virtual machines through targeted migrations at the right time". The results of simulations obtained from various scenarios in CloudSim indicated the proposed model has led "to energy savings up to 14.3%, 19% and 21% on low load, average load and high load, respectively, compared to the best understudy algorithm, while the SLA violation has also led to a decrease in all three modes".
121.	Khan et al., 2019 [241]	0	A study on "optimizing the power and energy efficiency of physical and virtual machines in a cloud computing environment" was described. The findings provided "a good understanding of how different workloads affect power and energy efficiency of both physical and virtual machines".
122.	Karthikeyan et al., 2019 [242]	0	A novel offloading algorithm was proposed to enhance the security in the mobile cloud computing by combining AES, SHA and Diffie-Hellman key exchange techniques. The simulation results showed that the proposed algorithm "provides better security when compared with other security algorithms and exhibits better energy efficiency".
123.	Wang, 2019 [243]	0	In order to adapt to the complex use environment of multi-load parallel in cloud computing, a decoupling method in a virtualization environment was proposed, which can "optimize the energy allocation strategy of distributed systems and effectively improve the efficiency of cloud resources".
124.	Mebrek et al., 2019 [244]	0	A novel system design was proposed in which the energy consumption and the delay were considered. Simulation showed the effectiveness of the proposed solutions compared to works from the literature.
125.	Patel and Bhadka, 2019 [245]	0	Virtual machine placement issues were described by offering the modified salp swarm algorithm. The simulation result demonstrated that the proposed method outperforms effectively other presented approaches in "optimal virtual machine placement in cloud computing environment with maximal resource use, minimal energy consumption, minimum SLA violation and reduced migration cost".
126.	Satyanarayana and Kalbani, 2019 [246]	0	A new method was provided to reduce the energy consumption in the mobile cloud computing.
127.	Vijaya Kumari et al., 2019 [247]	0	From the presented algorithm and experiment work the conclusion was that "the number of physical systems to be used should be directly proportional to the number of virtual machines which can be launched on a physical system till the threshold capacity of the physical system is reached". This reduces the energy consumption in the data center.

Rank	Reference	Citations (N)	Key Research Findings
128.	Jiang et al., 2019 [248]	0	An adaptive scheme was presented for "scheduling randomly arriving heterogeneous tasks in mobile cloud computing to minimize energy consumption while satisfying quality-of-service requirements". Simulation results demonstrated the effectiveness of the proposed method.
129.	Zhao et al., 2019 [249]	0	To solve the high power consumption problem, a power-aware task scheduling method was proposed for a heterogeneous cloud platform. Results demonstrate that this method "consumes 23.9-6.6% less total power consumption in comparison to the state-of-the-art".
130.	Deepa and Dheeba, 2019 [250]	0	The present state of cloud computing research was described by examining literature and identifying current study trends.
131.	Liu et al., 2019 [251]	0	The results showed that the "power consumption of the migration strategy based on the artificial bee colony algorithm was lower than the other two strategies, and there were fewer failed virtual machines under the same number of requests, which meant that the service quality was higher".
132.	Kandavel and Kumaravel, 2019 [252]	0	It was described "image information offload as of mobile to remote server, which at that point procedures image and changes over it to suitable, good low goals image on solicitation through new mobile customers. This change lessens mobile gadget energy utilization pretty downloading equal lofty goals imagery".
133.	Kumari et al., 2019 [253]	0	The job scheduling in the cloud environment was described. Various job scheduling algorithms were discussed for load balancing and improving the compilation time. The simulation has been made using Matlab on virtual machines.
134.	Zhao et al., 2019 [254]	0	A novel energy-aware task scheduling strategy was proposed based on "a sleep-delay timer and a waking-up threshold". The presented strategy was "efficient under the network environment with a heavy load of big data streams".
135.	Din et al., 2019 [255]	0	A hierarchical system architecture for mobile cloud computing based on a novel 5G system architecture was presented. Simulation results showed that "the proposed scheme outperforms the existing cloud computing example scenario regarding cost and time".
136.	Biswal and Prakash Sahoo, 2019 [256]	0	It is proposed that renewable energy sources available in the environment should be chosen to avoid high electricity cost. "Load provided by the user was routed to a suitable data center, so that the electricity cost will be minimized and utilization of renewable energy sources will be maximized".
137.	Deiab et al., 2019 [257]	0	A survey of approaches and techniques for energy efficiency in cloud computing was provided.
138.	Pallavi et al., 2019 [258]	0	An energy efficient mobility management in mobile cloud computing system for 5G heterogeneous networks was proposed. The simulation results showed that "the system helps in minimizing delay, packet loss rate and energy consumption in a heterogeneous network".
139.	Son et al., 2019 [259]	0	The virtual machine energy efficient placement scheme based on fuzzy-AHP system was proposed for sustainable cloud

Rank	Reference	Citations (N)	Key Research Findings
			computing. The energy efficiency for the proposed scheme was proved by using static virtual machine energy efficient placement schemes.
140.	Li et al., 2019 [260]	0	A combined forecasting approach of cloud computing resource load based on wavelet decomposition was proposed, which combined the grey model and cubic exponential smoothing model. That proposal demonstrated to be "efficient for forecasting the cloud computing resource load and helping to reduce energy consumption".
141.	Asha and Raghavendra Rao, 2019 [261]	0	Technologies like virtualization, migration, and dynamic voltage and frequency scaling and workload consolidation were used to "reduce energy consumption and power without affecting the progress rate of jobs". The proposed mechanism was compared with existing systems in various dimensions.
142.	Khan and Shrestha, 2019 [262]	0	A study on "optimizing the power and energy efficiency of physical and virtual machines in a cloud computing environment" was done. Findings provided a good understanding of how different workloads affect power and energy efficiency. The methods and frameworks provided can be used "in any cloud environment and of any size in order to investigate and improve energy efficiency".
143.	Zhu et al., 2019 [263]	0	The independent task scheduling problem in a cloud data center was considered. Experimental results showed that the proposed heuristic "clearly outperforms the other algorithms".
144.	Babu et al., 2019 [264]	0	A systematic methodology for "exploring the energy efficiency of most significant data center domains" was stated, including the "utility server and network hardware equipment, as well as cloud management systems and the corresponding appliances consisting of a software package that can be predominantly utilized by end users". This approach was "utilized for analyzing the already available scientific implementation and industrial literature investigations on state-of-the-art practices in the data centers and their equipment".
145.	Agarwal, 2019 [265]	0	The comparison between cloud computing and green cloud computing was done. The use of green cloud computing in "reducing the carbon emission induced in the environment by the ever-increasing usage of data centers and their increasing numbers" was described.
146.	Huang et al., 2019 [266]	0	An energy-efficient computation offloading method of multimedia workflow with multi-objective optimization was described. An offloading method based on cloudlet using differential evolution algorithm was proposed to "optimize the energy consumption of the mobile devices with time constraints". Massive experimental evaluations and comparison analysis validated the efficiency of proposed method.
147.	Xu et al., 2019 [267]	0	Considering the "similarity of the accessibility data of strong interactive users and the predictability of user behaviour data", it was proposed "a link prediction method based on the maximization of user interaction behaviour in a specific environment for the mobile cloud computing". The evaluations

Rank	Reference	Citations (N)	Key Research Findings
			showed that it can "reduce mobile energy consumption significantly by around 20%".
148.	Arya et al., 2019 [268]	0	This research emphasized on "computational offloading or augmented execution to augment the performance and energy efficiency of resource-demanding mobile applications in the cloud-assisted environment".
149.	Scionti et al., 2019 [269]	0	An allocation algorithm was presented aimed at reducing the overall energy consumption. The results of simulations on a state-of-the-art framework were also presented. When compared with well-known and broadly adopted allocation strategies, the proposed approach results in a tangible energy-saving, thus demonstrating energy efficiency superiority.
150.	Reza Dibaj et al., 2018 [270]	0	The similarities between the cloud infrastructures and smart cities were discusses, as well as their respective business models. A "comprehensive survey of the cloud pricing mechanisms" was provided and the "challenges that it deals with, to shed light on the potentiality of improving the sustainability and pricing mechanisms on the cloud or any similar state-of-the-art technologies".
151.	Verma and Katti, 2018 [271]	0	A resource request based heuristic was proposed "for offloading the overloaded servers to optimize power consumption efficiency".
152.	Kalpana and Swathikha, 2018 [272]	0	A "comprehensive analysis for an energy-efficient computational offloading research" was conducted and "a distinct pattern which concludes whether to offload or not to offload" was highlighted.
153.	Jayasimha et al., 2018 [273]	0	The "comparison of cloud and cloud computing, cloud type providers, component performance through secured shell" was made and "various levels of energy consumptions in the cloud" were identified. The different techniques used to "reduce the power consumption in the server and workload consolidation using various parameters" were considered.
154.	Saroha et al., 2018 [274]	0	A review on "long term, medium term, virtual machine and gang scheduling for energy efficiency in cloud computing environment" was presented. The existing research in the field of cloud computing was explained.
155.	Kavitha and Phani Krishna, 2018 [275]	0	"It was noted strength consumption and make span associated with the resources allotted need to be taken into consideration and first rate beneficial useful resource allocation regulations had been surveyed based totally on the special parameters and the related gaps were discussed".
156.	Sun et al., 2018 [276]	0	A task scheduling algorithm was proposed, which "can improve the real-time performance and energy consumption of cloud resource scheduling and allocation". Simulation results showed the efficiency of this algorithm.
157.	Pham et al., 2018 [277]	0	The resource allocation problem was discussed to reduce the energy consumption. An algorithm was designed to "solve and evaluate through CloudSim simulation tool compared with an FFD algorithm". The experimental results indicated that the

Rank	Reference	Citations (N)	Key Research Findings
			proposed algorithm "yields a higher performance in comparison with an FFD algorithm".
158.	Verma et al., 2018 [278]	0	An energy-efficient mechanism for computation in mobile devices was proposed. The simulation results indicated that the execution time of applications is improved by the mechanism as compared to "without using cloudlet layer".
159.	Park et al., 2018 [279]	0	The impacts of in-house information technology capital and data processing and hosting services outsourcing which is closely related to cloud computing on client industry's energy efficiency were examined. Based on a two-stage stochastic frontier approach, it was found that capital and outsourcing played a complementary role in reducing energy consumption.
160.	Pham et al., 2017 [280]	0	A desktop delivery scheme was proposed that takes into account both quality of experience and energy consumption on mobile devices. The experimental results demonstrated that the proposed scheme "can provide good display quality of different kinds of service to mobile clients with low energy consumption".
161.	Yamini and Germanus Alex, 2017 [281]	0	Resource consolidation algorithm was used to maximize the resource utilization with the minimum cost. Based on experimental results, the proposed algorithm "reduces the power consumption, improves the resource utilization and also […] reduce[s] the user's cost".
162.	Mondal et al., 2017 [282]	0	A variety of energy-efficient job scheduling algorithms were reviewed and comparison analysis of various pre-existing algorithms for scheduling jobs to provide energy efficiency in green cloud computing was performed.
163.	Gupta and Kaur, 2017 [283]	0	A fuzzy based map reduce technique for multi-core systems was proposed. The use of triangular membership function reduced the potential overheads of map-reduce technique. Thus "proposed technique has quite significant improvement over available techniques".
164.	Rehani and Garg, 2017 [284]	0	A multi-objective workflow scheduling algorithm in cloud computing was proposed, which "optimizes three conflicting criteria: makespan, reliability of task execution and energy consumption". The simulation results showed that the algorithm was "significantly better than the considered algorithms in terms of makespan, reliability and energy consumption in real world scenarios where reliability and energy consumption are important issues".
165.	Muthu Pandi and Somasundaram, 2017 [285]	0	Energy efficiency in virtual infrastructure is studied to contribute to green cloud computing.
166.	Körner et al., 2017 [286]	0	A toolbox was presented that provides libraries and components which can be used to "develop energy efficient cloud software on all three layers of the usual could stack". Power consumption can be reduced by deploying energy efficient software in the cloud.
167.	Sriprasadh, 2016 [287]	0	Clustering the multiple servers into a single server is an emerging technique for environment friendly computing. This makes "power consumption and resource segregation at a single point" what "enables a multiple user can access multiple server

Rank	Reference	Citations (N)	Key Research Findings
			in single server mode". "This provides cost consumption and energy consumption that will provide a green computing environment".
168.	Parekh et al., 2016 [288]	0	The algorithm for "balancing load in cloud" was provided. The load can be of Memory, CPU or Network.
169.	Joy et al., 2016 [289]	0	The different energy and power models were discussed and the main challenges to build a model for green cloud with the help of SLAs were identified.
170.	Singh and Agnihotri, 2016 [290]	0	The "efficient allocation strategy of the independent computational jobs among different virtual machines in a datacenter is a distinguishable challenge in the cloud computing domain and finding out an optimal job allocation strategy guided by a good scheduling heuristic for such an environment is an Mape-k loop problem". Different heuristic approaches were used for better result and worst fit in Mape-k was implemented and evaluated the results.
171.	Suciu et al., 2016 [291]	0	The concept of creating a cyber-physical energy system was presented that will "change organizations' way of consuming energy, by making them aware of their use". The presented concept considers "the security of the whole system and the easy integration with the existing electric network infrastructure".
172.	Aldmour et al., 2016 [292]	0	The cost of the power consumption, execution time, and file size for the core cloud, and the local node were calculated to denote an input to the execution decision.
173.	Kaur and Sachdeva, 2016 [293]	0	A new approach of energy productive scheduling of tasks was presented to "reduce the wastage of power in datacenters so that resources can be properly used". "The cloudlets submitted to the cloud provider were executed in an energy efficient DVFS approach".
174.	Kannan and Rajendran, 2016 [294]	0	An energy saving mechanism was used in order to reduce the energy consumption. Cloudsim toolkit was used to create the cloud data center and analyze the efficiency of the mechanism.

Source: Own study based on data retrieved from the Scopus database (20 May 2020)

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