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Manufacturing Industry: A Sustainability Perspective on Cloud and Edge Computing

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ABSTRACT –

The problem is investigated through an analysis of the industrial use cases and sustainability of cloud and edge computing technologies. The study is carried out as a review of the literature, and industry-published materials are also employed to comprehend the demands of the market for these technologies. The findings suggest that manufacturing may achieve notable sustainability gains by leveraging cloud and edge computing for data analysis, automation, and cross-organizational cooperation. These consist of enhanced productivity, safety, quality, flexibility, and scalability as well as increased resource and energy efficiency. It is also possible to save costs and decrease waste and downtime. Studies indicate that cloud computing is a more energy-efficient and environmentally friendly option than localized servers. When opposed to centralized data centers, edge computing solutions provide reduced latency. Additionally, edge computing lowers expenses and energy usage by minimizing the quantity of data that has to be sent.

The decentralization of cloud centre provides low-latency computing capabilities. This makes it possible to host latency-sensitive apps that need more processing power than edge devices can provide. Furthermore, for non-compute-intensive application and centre can result in considerable energy and cost reductions. Applications requiring high computational latency and tolerance should be housed in bigger, centralized data centers with more processing power and energy efficiency.

Keywords: Industry4.0, Industrial Internet od Things, Cloud manufacturing, Smart manufacturing, Sustainability

1. Introduction

An integral component of any modern civilization, the manufacturing sector is today heavily reliant on non-renewable resources and a major contributor to global warming. Massive sensor and system counts will be present in smart manufacturing settings, continuously generating fresh data that can be processed and evaluated to be of value (frank et al.2019). The majority of data is being handled in huge, centralized cloud data centers, necessitating long-distance transit. High energy usage and higher latency are the results of this. But as IoT grows, computing solutions are becoming more dispersed; in 2018, centralized data centre has to 10% of generated data of created data; by 2025, Gartner (2018) projects that this percentage will climb to 75%.Edge computing, or processing data closer to the source, is essential for allowing new use cases in latency-critical smart manufacturing, such enhanced robots and real-time process modifications. Additionally, by lowering the requirement for data transfer, edge computing may dramatically lower energy consumption connected to data management.

According to research it has to develop edge computing for cloud for the future shake, the most computationally demanding tasks, like advanced big data analysis, will be handled by centralized data centers, while the majority of industry-generated data will be processed and analyzed either locally either in remote edge data centers or by the data-generating devices. By reducing overall energy usage, this kind of ecosystem will make data use more sustainable and provide real-time analysis capabilities with minimal latency.

1.1 Problem and objectives (Research)

The present work is very useful and contribution by business initiative of Nokia Competitive to business Finland. Enhancing the sustainability of data use using edge computing technologies is one of the primary objectives of the Competitive Edge project. The aim of the study to give solutions for cloud , edge and industries to get better results and sustainability. In addition to identifying suggestions for further research on the subject, this study will provide an overview of industry and research findings addressing the sustainability of edge cloud solutions. All of these findings will be pertinent to Nokia's edge cloud computing research and development.

The primary inquiry for the research is: -

In what ways can the industrial sector foster sustainability via the application of edge and cloud computing?

Two sub questions are used to illustrate this viewpoint:

- What are the features of cloud and edge computing sustainability?
- Are there advantages to building edge clouds in order to decentralize cloud resources?

This work provides answer to value to manufacturing cloud computing, edge computing which provide particular terms to foster sustainability to all concerns.

2. Research methodology

It includes case studies, research evaluations, and theoretical frameworks that have been published in scholarly publications. Academic databases are queried using keyword combinations to locate literature on the subjects covered in this thesis. Many publications that discuss computer solutions concentrate on providing software-level structures and specifics. The focus of this thesis is on the effects of using computing solutions rather than the specifics of how they are implemented. As a result, information about implementation techniques and software-level architectures is not provided. Publications on cloud and edge computing in industrial and sustainability contexts are given special attention. Furthermore, only insofar as they are necessary or supportive of cloud and edge computing solutions or use cases related to smart manufacturing are additional technologies and concepts discussed.

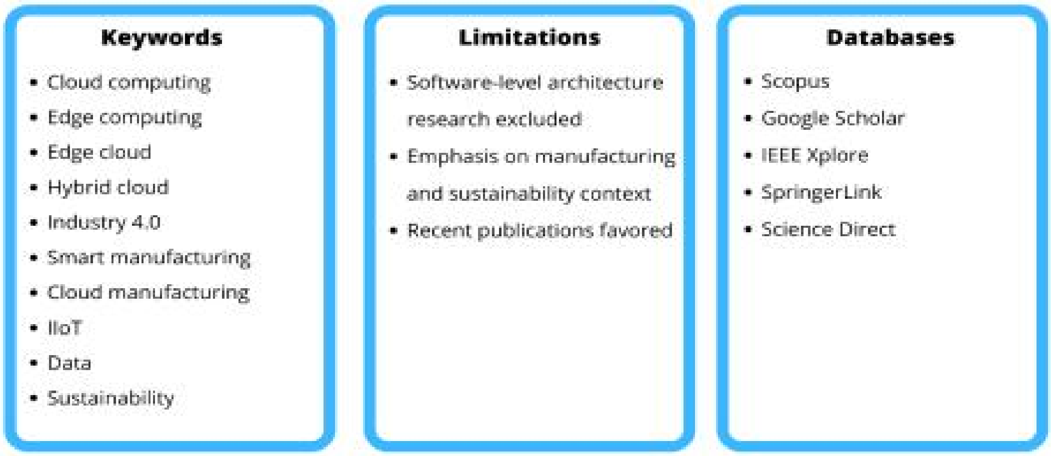

Figure 1: Employed restrictions, keywords, and database queries

The five chapters that make up this thesis each have a distinct function. Figure 2 displays the structure.

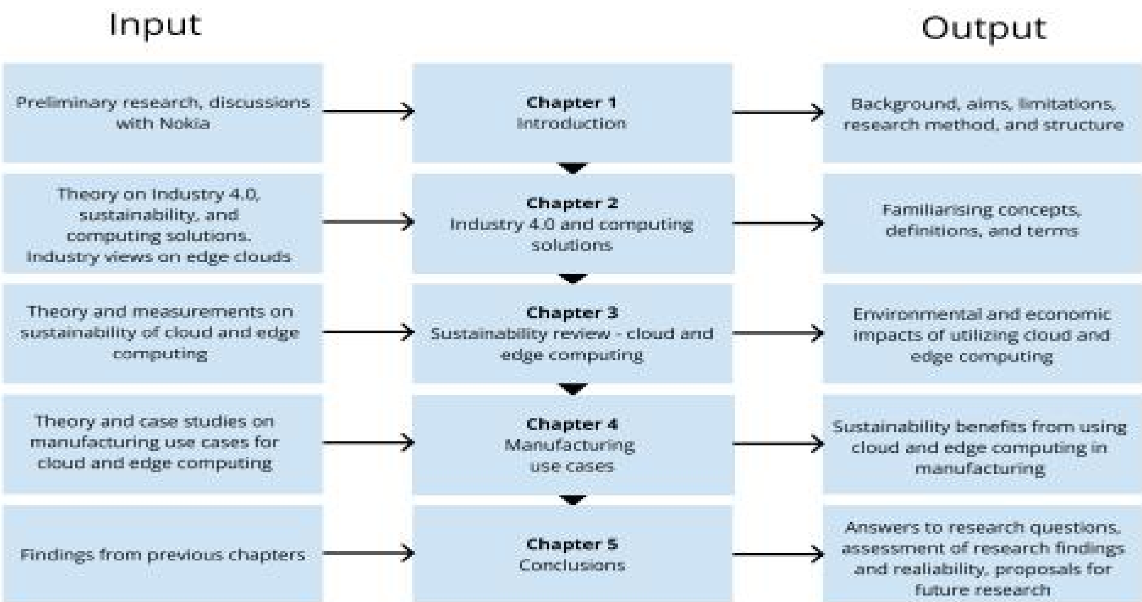

Figure 2. Thesis structure

2.1 Industry 4.0 and computing solutions

The internet of things, or IoT, or the network of internet-connected gadgets, is the primary cause of the ongoing increase of data (Bajic et al. 2019). Industry 4.0 ecosystems with networked data generating units are shown in Figure 4 together with cloud computing and big data analytics.

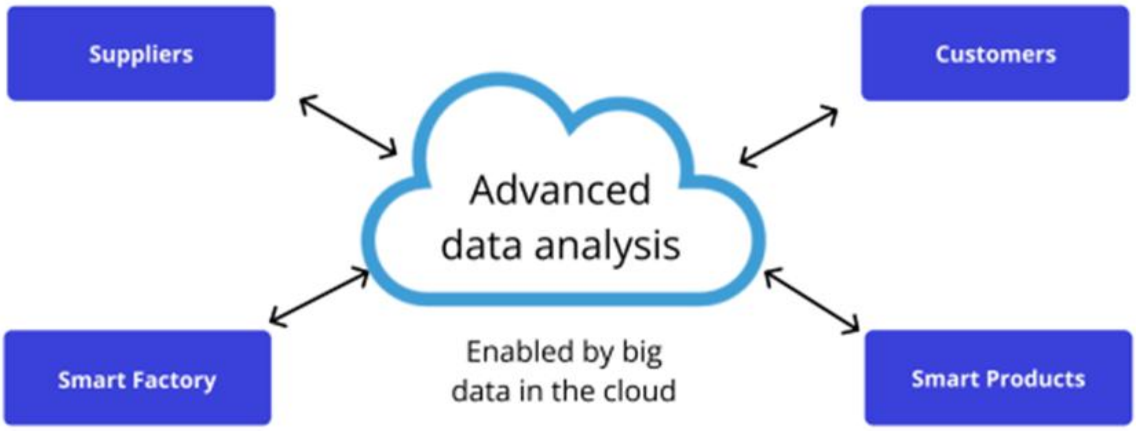

Figure 3: Industry 4.0's use of big data and cloud computing (Velasquez & Estevez 2018)

Big data generated by robots and sensors in smart factories may be processed and stored thanks to cloud computing. However, because of the considerable latency brought on by lengthy data transmission distances, cloud computing may not be the best analytical option for making real-time modifications to industrial processes. Edge computing is thus also used, as seen in Figure 4.

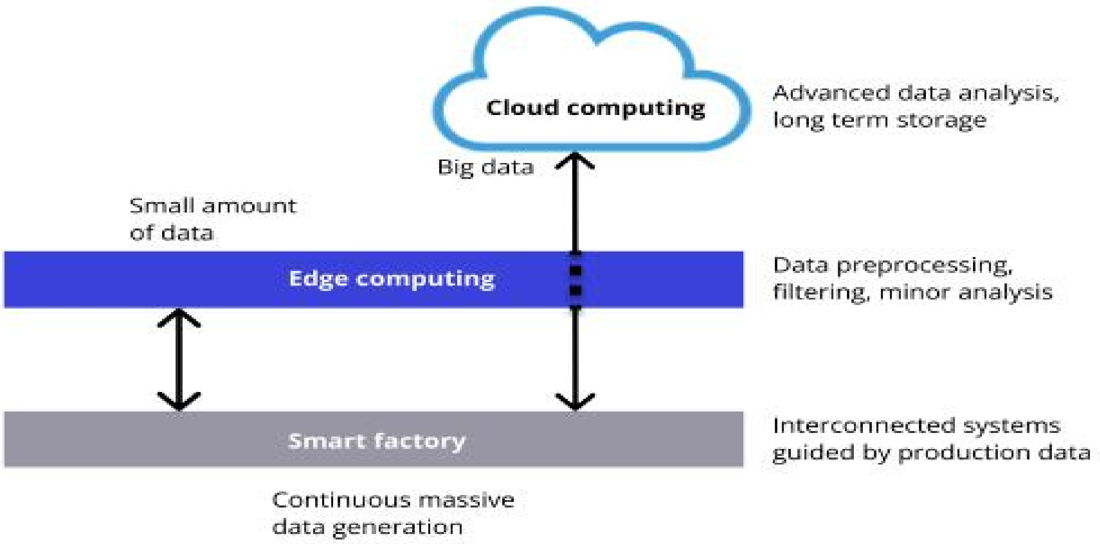

Figure 4: Solution computation in an intelligent plant.

This makes data transmission more affordable and energy-efficient (Eriksson 2020). Typically, the information sent to the central cloud is retained for intricate examination, necessitating substantial computational resources (Bajic et al. 2019).

2.3 Cutting-edge computing

Large data centers located all over the world are being consolidated as a result of the recognized value propositions of cloud computing, which include economies of scale via centralization and cost savings by not needing to operate an own data center.

Applications may be hosted directly at the network edge using smart, connected devices if fog nodes close to the data creation point have the computational ability to handle the data completely. (2015, Cisco) The properties of edge and fog computing are shown in Figure 5.

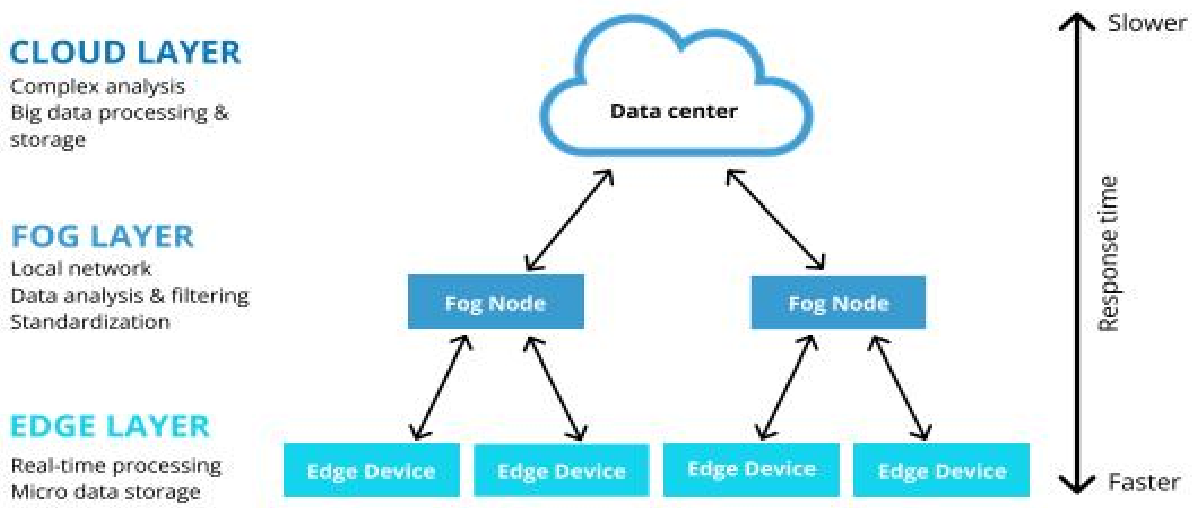

Figure 5 illustrates computing layers. Using data from Yousefpour et al. (2019) and WinSystems (2017)

In summary, fog computing is made up of fog nodes, which are local networks that provide more resources and services than edge devices. Data processing at the edge is becoming more and more common (Gartner 2018). Additionally, as Figure 6 illustrates, a significant rise in global data is anticipated.

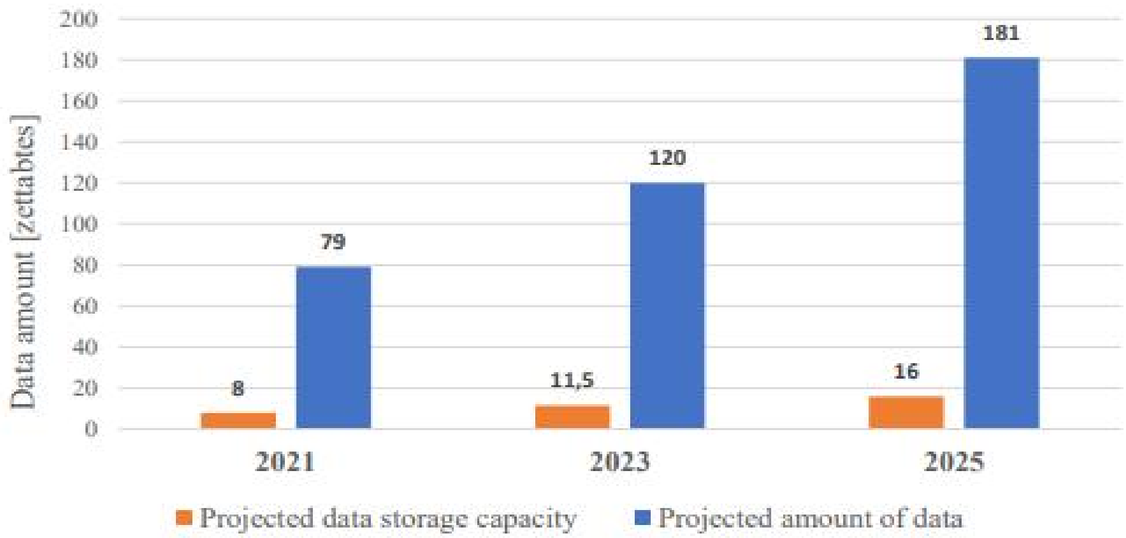

Figure 6. Projected data volume and storage capacity comparison, taken from Reinsel et al., 2021

2.4 Edge Computing with Multiple Access

Using mobile base stations, cloud computing resources are extended to the network edge in Multi-Access Edge Computing (MEC), previously known as Mobile Edge Computing (Abbas et al. 2018). However, more sophisticated functions like processing power, intelligence, and communication capabilities are transferred to the RAN in MEC contexts. (Abbas and colleagues, 2018) Figure 7 shows the design of a simplified MEC environment.

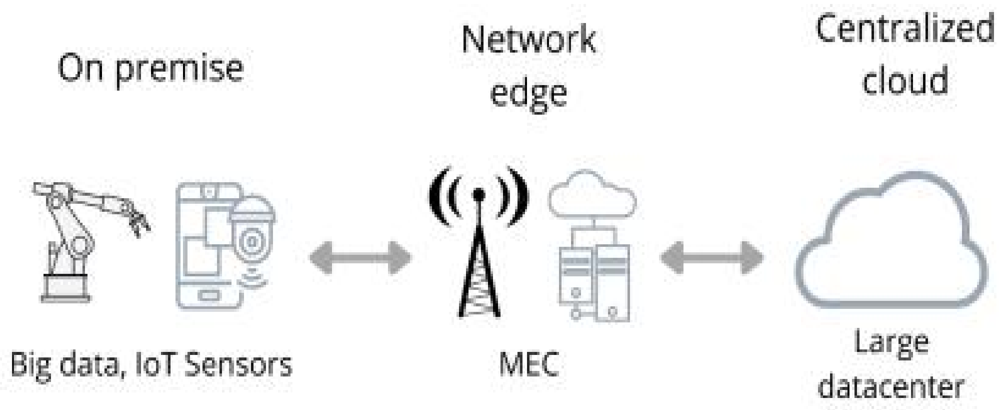

Figure 7 simplified MEC design in is derived from Verizon 2021

2.5 Cloud computing on the edge

Illustrates an overview of cloud and edge computing features in order to approach the idea of edge cloud computing Table 1

Table 1: Cloud and edge computing comparison, taken from Babic et al. (2019).

Characteristic	Cloud computing	Edge computing
Storage capacity	Big data storage	Micro data storage
Data processing	Big data processing	Small amount of data
Computing power	More powerful	Less powerful
Response time	Slow	Fast
Security of data	Less secure	More secure
Cost of data transfer	Higher cost	Barely any
Ease of deployment	Easy with service providers	More difficult
Scalability	Dynamic	More static

The MEC architecture that was previously described would facilitate edge clouds and allow a range of Internet of Things applications that need dependable and fast communication. (2018 Nokia) Figure 8 illustrates one potential approach to building an ecosystem for edge cloud computing.

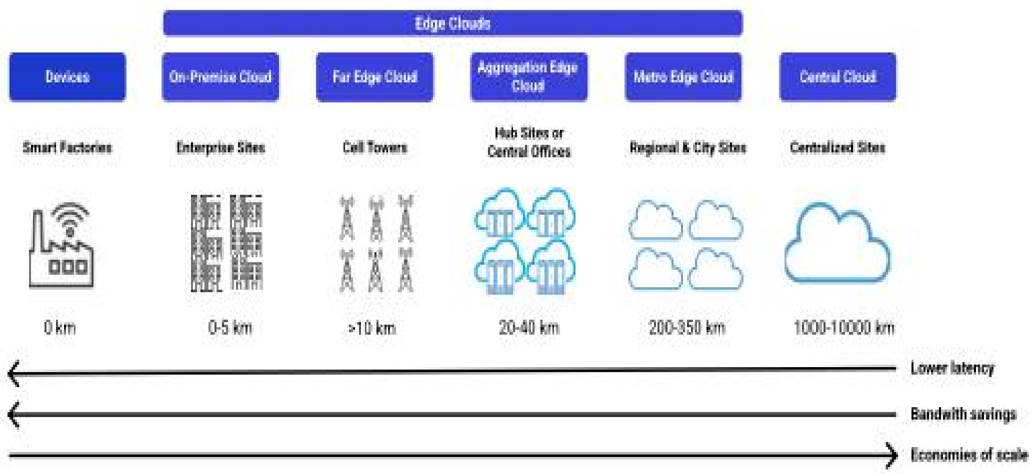

Figure 8. Various edge cloud types, taken from Nokia (2018)

Using the recently presented MEC idea, cellular base stations may therefore be used for some computation and data analysis.

3. Material and Methods

This discusses issues including cloud-created efficiencies, data center energy efficiency, and the advantages of edge cloud datacenter data processing for sustainability.

3.1 The advantages of cloud computing for the environment

Public cloud migrations may reduce worldwide carbon emissions by 59 million tons annually, or 5.9% of all IT emissions, according to Accenture's green cloud research. That's the same as taking 22 million automobiles off the road. Cloud migrations have saved businesses anything from 30 to 40 percent of their total cost of ownership.

As can be seen from Figure 9, the research discovered that moving apps to the cloud using the SaaS model considerably reduces carbon emissions when compared to hosting them in conventional data centers.

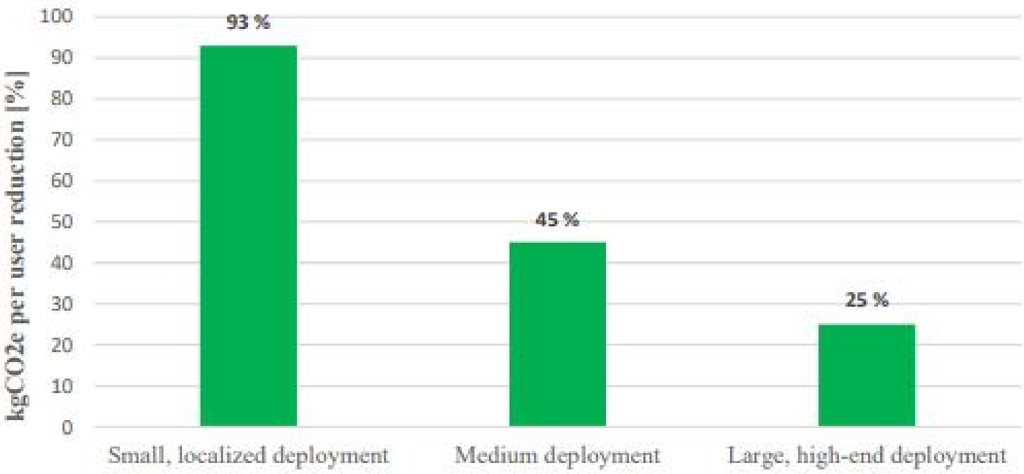

Figure 9. Measurable carbon emission reductions during the Microsoft 2020 SharePoint migration

3.2 Eco-friendly cloud computing

Many techniques, including lowering CPU clock speeds, increasing performance per watt, improving workload management effectiveness, building the ability to operate more effectively in high temperature conditions, and shutting off idle parts, can lower server energy consumption (Hussein et al. 2014; Jing et al. 2013). seven times the processing capacity compared to five years ago. (Kukkonen, 2021)

3.3 Savings on data transport using edge clouds

This paper aims to highlight studies and analysis that investigate whether energy savings from less data transmission are greater than energy consumption from reduced size. Table 2 displays the various sizes of edge data centers that were employed in the aforementioned white paper research to investigate this.

Table 2: Energy efficiency and edge data centers (Eriksson 2020).

Data center name	**Number of servers**	**Power Usage Effectiveness**
Micro	15	2,27
Small	1500	1,85
Regular	15000	1,57

The given names are unique to this research and are not standardized. Three distinct application types were compared for operation in standard, mini, and micro data centers (Figure 10).

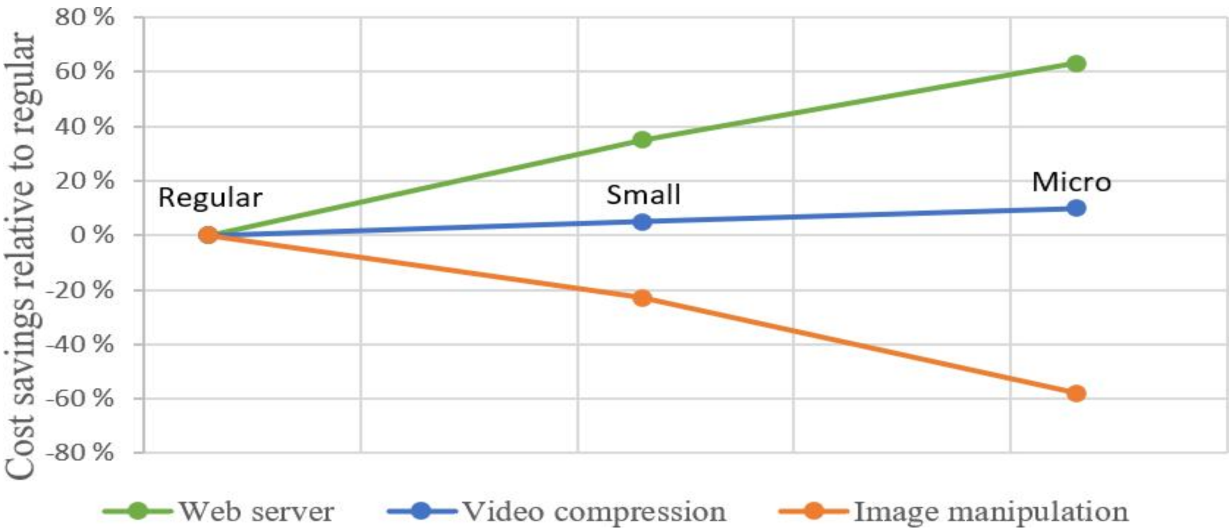

Figure 10: Comparison of energy costs for various kinds of data centers (Eriksson 2020)

4. Results and Discussion

This paper concluding part addresses the research questions and provides a summary of the study's key conclusions. Additionally, this part evaluates the research's plausibility and makes suggestions for additional studies in the areas covered.

Finally, the advantages of decentralizing cloud resources via edge cloud creation were discussed. To determine market need for these technical solutions, a substantial amount of literature on the subjects was reviewed, and industry perspectives were consulted.

How might the use of edge and cloud computing support sustainability in the industrial sector? was the main research topic

Figure 11 below provides an overview of the advantages of cloud and edge computing for sustainability in the manufacturing sector.

What are the features of cloud and edge computing sustainability?

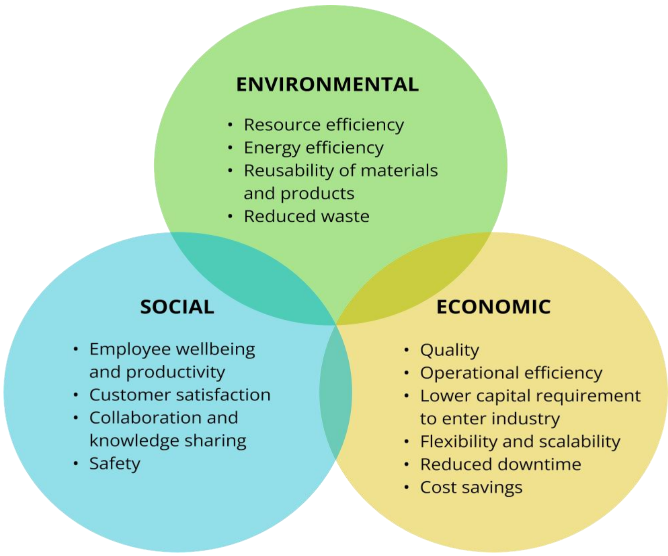

Figure 11. Benefits of Sustainability

The first sub-question looked at edge and cloud computing's sustainability:

Moreover, cloud management technologies facilitate dynamic provisioning refers to the use of just the necessary resources. Studies and industry perspectives suggest that cloud service providers must prioritize data center sustainability as a means of gaining a competitive edge (Mandal et al. 2022; Lacy et al. 2020; Pichai 2020; Walsh 2020; Radu 2017). The objective of green cloud computing is to enhance the sustainability of cloud data centers by reducing their energy usage and carbon emissions. Significant cost and energy savings are possible with edge computing solutions since the majority of the produced data does not need to be sent to a centralized cloud.

The advantages of edge cloud computing were covered in the second sub-question:

Are there advantages to building edge clouds in order to decentralize cloud resources?

The most compute-intensive applications should, wherever feasible, be housed in bigger centralized data centers, according to the research, which supports these results.

5. Conclusion and Future scope

5.1 Conclusion

This research relied on published data rather than doing any sustainability measurements. Reliability relies on the degree of confidence in the accuracy of the measurement reports. Measurements released by the industry were reports from credible multinational corporations including Accenture, Microsoft, and Tietoevry. Academic journals also mentioned the majority of reports. In addition, the results of measurements released by the industry were checked with research publications' findings to avoid drawing conclusions only from unreviewed data. In summary, the approachable methods for doing reliable research have been implemented.

5.2 Future Scope

Current studies comparing the expenses of utilizing public and private clouds might also be beneficial to industry. It would be helpful to do research that offers recommendations for when a private cloud becomes more economically viable. Research on data center power use optimization and its relationship to data center size might also be beneficial to the industry. Some of the problems that may be addressed by further study include:

1) Is it possible to determine the ideal size for an edge data center?
2) How much may data centers' energy efficiency be raised without growing in size?
3) To what extent are the cost and energy reductions made possible by edge clouds application-specific?
4) Which application characteristics—such as the volume of data to be sent or the processing power needed—affect this cost and energy reductions, and how much?
5) Is it feasible to determine the cutoff points at which operating an application in an edge data centervs a centralized one becomes more costly?

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