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LEVERAGING QUANTUM TECHNOLOGIES TO DESIGN A FRAMEWORK FOR A QUANTUM CLOUD SMART ENERGY CENTER IN ENERGY4.0

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Abstract
Industry 4.0 represents the transition in Industry to adapt new technologies which now includes recent advances in Quantum. Energy 4.0 technologies has potential to transform the ways in which global energy and power sources are generated, transmitted along with distribution, maintenance and upgrade . This paper lays the foundation to design the foundations of a Quantum Smart Energy Centre which leverages power of Quantum technologies to automate, manage, integrate, secure, trade while providing sustainable use of Energy Resources optimizing costs and time. It possesses a potential to disrupt the energy sector aligning with the core theme of Deep Tech.
Keywords: Energy 4.0, Quantum Technology, Smart Energy Centre.

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1. Introduction to Quantum Technology and Energy 4.0

The idea of a computational device based on the first exploration of Quantum Mechanics by Charles Bennet, Paul Benoif and Richard Feynman at the start of 1980s. The study of Quantum Technology involves a Qubit which is analogous to a bit in Classical Computing considered as the fundamental unit of computation. The Qubits can be used to store, manipulate and represent data by using multiple bits and operations related with them. The Qubits possess two important properties to achieve this task namely Superposition and Entanglement (QCaD, 2025). In 1982, Richard Feynman was among the first to provide an insight on new kind of computers which could be devised on the foundations of Quantum Physics. He showed how Quantum Systems could be used to do computations and explain simulations pertaining to problems in Quantum Physics. He laid the mathematical framework to solve critical problems for Machines at a faster rate as compared to classical computers. In 1994, Shor's algorithm proposed a polynomial time algorithm on two computationally difficult problems showcasing that quantum computing has the potential to break modern cryptography (Shor, P. W. 1999). In the year 1995, Peter Zoller and Ignacio Cirac proposed a theory which used cold trapped ions in a Quantum Logic Gate (Cirac ,J.I.,& Zoller,P.1995). In 1999, an invention in Quantum Materials sparked an attention when a super conducting resonating circuits was used as Qubits. After this development, there have been many milestone breakthroughs in the area of Quantum Algorithms and Computing, Quantum Cryptography, Quantum Optics Information Theory, Quantum Communication, Quantum Sensing and more recently Quantum Machine Learning. In 1997, IBM developed the first working 3 bit NMR Computer. In 2011 Quantum Computer for $10 M was made commercially available by the

D-Wave. In 2016, IBM provided access to its Quantum Processors by Online Interface called IBM Q Experience. Post 2018 private players like Google and Intel have heavily invested in quantum chips by releasing Bristlecone(72 qubit quantum chip) and Tangle lake (49 Qubit Superconducting chip) making Quantum Technology faster for Commercial access. Recently in December 2024, Google has achieved a technological milestone by developing a Willow (a 105 Qubit Quantum chip) capable of solving a computational expensive problem in 5 minutes as compared to 1025 years taken by a classical supercomputer (Forbes, 2025). In the decade to come, Quantum computing will be used to solve critical problems in areas related to climate change, drug discovery, materials science and financial modelling. The Energy Sector has also started the extensive implementation of the same emerging technologies in their operations that are driving the 4th industrial revolution in the manufacturing sector. The sector currently leverages Industrial Internet of things(IIOT), AI, Cloud Computing to achieve asset monitoring (M. Rebolini, A. Valant and F. Pepe, 2017), smart metering (P. Gordon,2019) , predictive maintenance and the operations of distributed energy resources (P. Darrell,2019). The Energy market today possesses 2 key challenges which involves multiple service providers and consumers competing in the market and the operation/maintenance of grids to the levels beyond the capabilities of current control & monitory systems with exponentially increasing complexities. There is need to keep these systems secure from natural/ Cyber disasters along with ensuring the sustainability for a prolonged utility.

2. Literature Review

2.1 Global Status of Quantum Technologies

Quantum technology represents a major shift in computing, communication, sensing, and cryptography, using quantum mechanics principles. Technologies like quantum computing offer great potential to transform industries including pharmaceuticals, AI, cybersecurity, materials science, and logistics. Global research in quantum technology is accelerating, with nations competing to lead in this progressing field. India has launched several national programs to tap into the planned value of quantum technology. Quantum technology encompasses key areas that includes quantum computing, communication, cryptography, and sensing. These fields are advancing speedily across the world, supported by significant investments from governments, corporations, and research institutions.

2.2 Quantum Computing

Quantum Computing uses quantum bits, that has a multistate existence at once (superposition) and reveal entanglement, allowing for faster problem solving than classical computers. Major key players that includes IBM, Google, Intel, and Microsoft are advancing quantum computing hardware and software. Google’s 2019 "quantum supremacy" milestone showed quantum computers outpacing classical supercomputers in specific tasks. IBM offers cloud-based quantum computing services through IBM Quantum. However, quantum computing faces challenges like quantum bit coherence, rate of errors, and scalable solutions. Researchers are working to develop fault-tolerant computers with quantum technology and efficient algorithms to handle these issues and unlock practical, large-scale applications (Kannan, S., & Kremer, U. 2023, July).

2.3 Quantum Communication

Communication with quantum technologies uses quantum mechanics to ensure secure information transmission. Key Distribution admits two groups to exchange encryption keys securely, with eavesdropping being detectable. China has been a leader in this field, achieving key milestones which include the launch of a first quantum communication satellite, Micius, and establishing the longest quantum communication link (Liao, S., et. al. ,2017). The progress in the field of quantum computing threatens current cryptographic systems, like RSA encryption, which could be easily broken using algorithms such as Shor's. This leads to a growing focus on post-quantum cryptography (PQC), which aims to develop methods for encryption which are immune to quantum threats (Chen, L., et. al. ,2016). .

2.4 Quantum Computing Status in World and India

Countries like the United States, European Union, and China have acknowledged the strategic significance of quantum , committing billions of dollars to research and its development. In the U.S., the 2018 National Quantum Initiative (NQI) Act promotes quantum research across government, industry, and academia. The EU's Quantum Flagship is a 1 billion euros initiative designed to advance quantum technology over the next decade. China has grown its investments in Quantum, leading advancements in quantum communication and satellite technology (European Commission. ,2020). India is emerging as a significant player competitor in quantum technology race, recognizing its transformative potential. In the year 2020, the Indian government launched the National Mission on Quantum Technologies & Applications (NMQTA), investing 8,000 crore rupees (around $1 billion) over 8 years. This initiative is a multi-disciplinary effort focusing on quantum computing, communication, sensors, and materials. It includes establishing research centres of excellence, fostering industry-academia collaborations, and training a skilled workforce to develop a robust quantum ecosystem in the nation (Department of Science and Technology, India, 2020). India has developed international partnerships to enhance its quantum technology capabilities. In 2018, India signed a Memorandum of Understanding (MoU) with the United States to collaborate on quantum technologies, promoting research cooperation, knowledge exchange, developing advanced quantum systems. Additionally, India is working with organizations such as IBM, Microsoft, and European research institutions to strengthen its quantum research initiatives (Srinivasan, V. ,2020) .The incorporation of quantum into energy systems has emerged as a transmuting approach to addressing the complex challenges of modern energy management. This literature review explores the current advancements in using quantum technologies to design a framework for a Quantum Cloud Smart Energy Centre, focusing on applications in energy optimization, grid management, and the integration of renewable energy sources.

2.5 Quantum Computing in Energy Systems Optimization

Quantum computing offers significant potential in solving complex optimization problems inherent in energy systems. Quantum algorithms are applied to optimize energy infrastructure, such as facility location allocation, unit commitment in power systems, and heat exchanger network synthesis. There are advantages of quantum computing over classical methods in handling the intricate nature of energy systems, which involve numerous design and operational constraints (Ajagekar, A., & You, F. 2019) . The scheduling problem of distributed energy resources (DERs) is a critical issue in power systems, influenced by varying viewpoints, procedures, limitations, and goals. This challenge can be addressed through different frameworks. Two prominent and effective solutions are Micro grids and Virtual Power Plants (VPPs), each offering unique advantages and suited for different applications. Micro grids and VPPs have several key similarities, including the capability to integrate demand response (DR), generate distributed renewable energy, and provide storage at the distribution level (Nosratabadi, S. M., et. al ,2017). The computational challenges in modern power systems are apparently expanding every day, and it is anticipated that traditional computers will have to take more efforts to meet the computational demands of future, more complex power grids. In this context, quantum computing (QC) turns up as a budding future-generation solution to address the emerging computational needs of smart grids. QC, although new but a propitious technology, uses the fundamentals of quantum mechanics to process information and perform computations. This prospective field holds potential for overcoming computational limitations, while giving faster and optimal solutions in areas such as simulations, machine learning and optimization. Recent developments in quantum hardware, software, and algorithms have made QC increasingly viable for application across various research domains, including smart grids. A sunstanial research has already been conducted, with efforts continuing to progress. Given that QC is a rapidly evolving area of study, a brief review of the current literature is necessary to understand the new evolutions in QC for smart grid applications (Ullah, M. H., et. al. 2024). The quantum computing applications extends the optimization of smart grids. Shinde et al. (2024) propose the use of quantum algorithms, such as quantum annealing and Grover's method, to enhance energy distribution, load balancing, and resource allocation within smart grids. By processing enormous amount of real-time data, these algorithms can dynamically adapt to change in energy demands, optimizing energy distribution systems. This dynamic adaptability is crucial for the operation of Quantum Cloud Smart Energy Centres (Shinde et.al., 2024).

3. Quantum Cloud Smart Energy Centre

The Energy Sector is undergoing significant changes in the last two decades. Major challenges in the sector include grid distribution, shortage of skilled labour, climate change pose a risk to age old infrastructure affecting future demands. Energy 4.0 is a collection of hardware, software and technologies that improves connectivity, data and computing power to modernize the grids and optimize the performance. According to Essers.T. (2023), the four key problems critical to the Energy Sector can be classified in to 4 major categories which include Optimization, Simulation, Data Processing and Cyber security. In addition sustainable use of Energy Resources possesses a key challenge in future. Technology is extremely critical in contributing towards providing a long term sustainable and economical solution to such problems. Over the last decade technologies like Industrial Internet of things (IIOT), Cloud Computing, Data Analytics and Machine Learning have tremendous applications in Energy Sector. Quantum Technologies is one such Technology in the Deep Tech Ecosystem which revolutionizes the accelerating and optimizing complex tasks in the Energy Sector. According to MIT Energy Initiative, the Future Energy Systems Centre examines the accelerating energy transition as emerging technology and policy, demographic trends, and economics reshape the landscape of energy supply and demand (Mohanty, T. et.al. 2024). We thus propose the Concept of Quantum Cloud Smart Energy Centre. The foundational elements of this centre include

1. Cloud Infrastructure Base to support Quantum Technologies at the Energy Centre
2. Energy Management and Grid Integration using Quantum Technologies.
3. Implementing Quantum Machine Learning and improving energy trading capabilities using Quantum Block Chain.
4. Cyber Resilience to risks arising from Quantum Computing
5. Incorporating Quantum Technologies in Environmental sustainability.

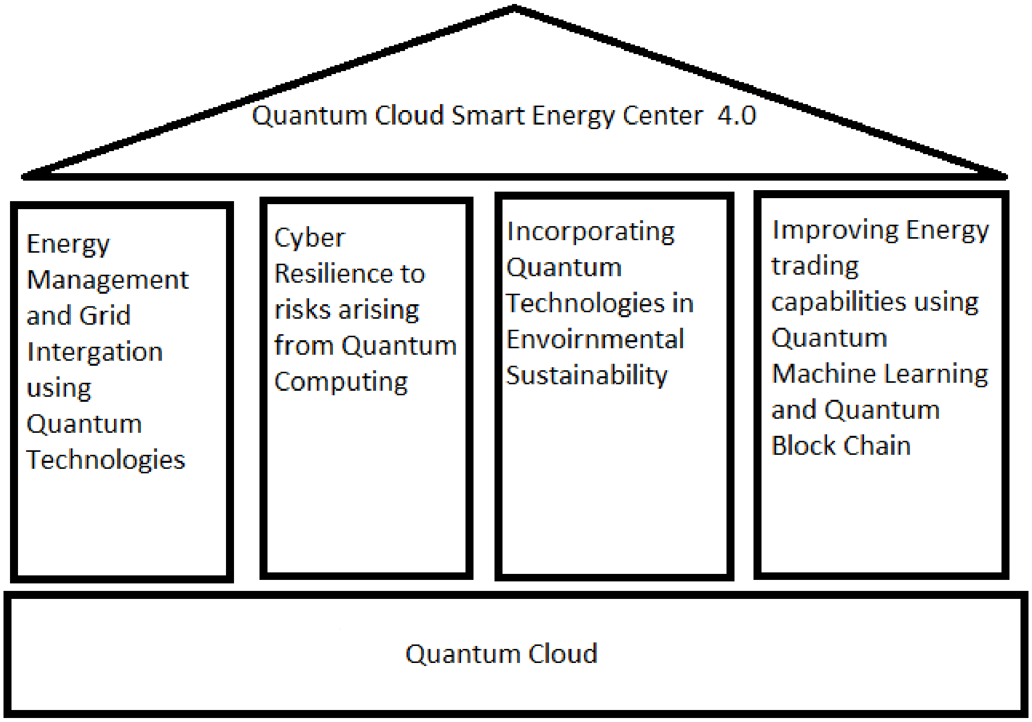

Figure 1: Proposed Quantum Cloud Smart Energy Centre 4.0

3.1 Cloud Infrastructure Base to support Quantum Technologies at the Energy Centre

Cloud Computing has created in revolution in the Software Industry enabling the users to use Software services over the Internet in a affordable economical subscription model. Quantum Cloud Computing is an upcoming area of Computing which provides the facility to run and deploy Quantum Computing Applications not requiring physical infrastructure (Nguyen, H. T. , et.al. 2024). In a recent research by Nguyen, H. T. et.al which discuss the concept of Computing using Quantum Technology as a cloud (QCaaS) provides access to the Quantum Computing resources on the cloud encouraging innovation and promoting the utility of new applications in Energy Sector. In addition Quantum Algorithms as a Service (QAaaS) will help with algorithms providing efficient solutions to many critical problems which include optimizing energy grids and systems, simulation of large and complex energy grids, optimizing energy flows and minimizing efficiencies in the Energy sector. In addition a hybrid approach to Quantum Computing can be utilized. This involves using platforms like IBM Quantum, Azure Quantum and Amazon Bracket which utilize a Hybrid Approach to Traditional- Quantum Computing approach in providing services to Quantum Platforms on a traditional architecture. The above technologies put to use can have three advantages

1. Data Storage and Optimization: The Quantum cloud storage system can help maintain information related to the energy production, storage and utilization which can be processed and analysed to derive insights and in turn help with optimal consumption.

2. Quick Remote Access: The Energy infrastructure can be remotely managed and monitored from any central geographical location using the Quantum Cloud Computing facility with real time data related to the energy performance.

3. **Scalability:** Introducing the Quantum Cloud Computing facility will ensure that energy Centre will be able to scale at faster demands thus improving performance and efficiency of the energy centre.

3.2 Energy Management and Grid Integration using Quantum Technologies.

Machine Learning along with Optimization are two distinct yet interconnected concepts in the field of Data Processing and Analytics. Machine Learning determines a pattern from a known data for future predictions whereas Optimization uses specific algorithms to optimize a Objective function within a set of given constraints. The Quantum analogue of Machine Learning known as Quantum Machine Learning is useful in speeding up computations compared to its classical counter parts. In addition , a new class of Algorithms called as Quantum Variational Algorithms (QVA) is emerging which has variational parameters with optimal value achieved using multiple runs on a Quantum Computer. The applications of Quantum Machine Learning in energy sector include

1. The Quantum version of Fourier Transform and Harrow Hassidim Lloyd (HHL) algorithm can be applied to predict & optimize the behaviour of a Non Linear Micro grid in Energy Centre.(Jing, H., et. al. 2024).
2. The sun is an important source of energy for our planet. However a significant difference is found in the amount of energy trapped at different locations due to its non linear nature. This is influenced by many factors which include weather, geospatial location and photovaltic properties posing critical challenge to accuracy and stability of micro grids. Hybrid Quantum Neural Networks can help forecast photovaltic power with good accuracy over large time intervals and over small datasets. (Shinde, et. al. 2024)
3. A Phasor Measurement Unit measures the voltage and current in an electrical grid. Quantum Optimization Algorithms can help achieve the optimal placement of the Phasor Measurement Units achieving grid stability from voltage and current outages. (Jones, E. B. , et. al. 2024)
4. Demand Side Response strategy enables customers to manage their energy requirements. The Demand Side Response strategy can be implemented using Discount Scheduling Algorithm in Quantum Optimization, by flexibly providing price incentives to its consumers at peak hours to utilize their energy consumptions where the energy provided is in hybrid mode meaning Renewable-Non Renewable mode (Bucher, D. et.al. 2024).

3.3 Implementing Quantum Machine Learning and improving energy trading capabilities using Quantum Block Chain

Peer to Peer (P2P) refers to the trading of energy which occurs in a decentralized manner at a negotiated price between the consumers or organizations that consume energy (Kashyap, P. K. et. al. 2024). This trading will occur locally without any intermediate system , however maintaing transperency and ensuring reliable security will always be a challenge for such systems. The distributed system consisting of transactions and profile information of the microgrids can be created and maintained using Block Chain. However one needs to design the framework for identifying the right amount of energy traded (supply and demand) in such a mechanism. Reinforcement Learning is an agent based Machine Learning technique used to determine optimal decisions using a reward and a penalty based approach. The Quantum Analogue of Reinforcement Learning can be of use in such a problem. The above problem of Energy utility maximization can be formulated as Markov Decision Process (MDP) can be solved using Quantum Reinforcement Learning to determine the optimal price and the amount of Energy traded in P2P. This will have huge benefits in areas or industries where the Energy demands and consumptions are high forcing pressures on Energy grids.

3.4 Cyber Resilience to risks arising from Quantum Computing

The advances in Quantum Crytography over the last decade raises concerns about the possible threats to classical Cryptographic Systems. The foundational work done by Shor (Shor. P.W. , 1999) revealed how the conventional encryption standards like Rivest- Shamir-Adleman (RSA) and Elliptic Curve Cryptography (ECC) are vulnerable to Quantum Computing Attacks (Baseri, Y., et. al. 2024). The major threats include Crytographic breaches, Identity Theft, Financial Fraud, Data Tampering and Cyber Espionage. This has motivated researchers to develop a Post Quantum Cryptography Version whose focus is to secure and safeguard data integrity spread along critical infrastructure which include Energy grids and cloud systems. The proposed Smart Energy centre has a foundation based on Cloud Infrastructure which supports Quantum Technologies. The cloud service provider in this case has two major challenges

- integrating the current cryptographic encryption methods with Quantum Resistant Algorithms
- crypto-agility which ensures your system to adapt to new threats and updates without hardware or software updates.

However at times, a tradeoff occurs between computational efficiency and the security [29]. The Energy sector needs to adopt robust security standards in order to transition to Post Quantum Cryptography. The different Infrastructure layers that are critical to Energy Sector include

1. Application Layer (User Interface) where the users directly interact with the systems via different applications (like dashboards, webapps, reports, visualization etc)
2. Data Acquisition and Processing Layer: where the data is collected via various sources which include smart meters, sensors, weather stations and processed at various levels to achieve standardization. This may also include constructing data pipelines and distributed computing frameworks for large datasets.
3. Business Logic Layer: which deals energy business rules and computations. This includes pricing, demand response Strategies, energy optimization algorithms. It can also include integration with external billing platforms or CRM Systems
4. Cloud Infrastructure Level: which provides the computing infrastructure on cloud platforms. This includes virtual servers, storage, network services and other services required to run applications.

Within the application Layer, Quantum Computing provides immense threat to the Energy sector in terms of safeguarding data and authentication provided to users. The major concerns in the Application Layer encompass frail encryption algorithms, unsecured code and imperfect permission models. The risk due to these concerns can be minimized to an extent by implementing Post Quantum Cryptographic Standards based on Concepts like Lattice,Code, Hashing, Isogeny. Similarly Digital Certificates are issued to set up a trust when communication occurs between Management Systems or two devices in Energy Center. A digital signature is a cryptographic protocol that is used to create unforgeable signatures for electronic messages. A concept of Revocable Quantum Digital Signature is discussed in the Paper by Moriame, et. al. 2023. Similarly a Identity Based Signature (IBS) protocol is proposed by Mohanty, et. al., 2024 which secures the email connection. With regards to the Data Layer, a efficient system which handles cryptographic keys for various tasks related to generation, storage, management and distribution which is resistant to Quantum Attacks can be implemented . Key distribution achieved using Quantum is a secure communication method which involves Quantum Mechanics principles implemented with a cryptographic protocol. One such protocol is proposed by Jasim et al. , 2015. The final Cloud infrastructure level involves various aspects which include updating protocols in the middleware, integrating features which can withstand Quantum Attacks, introducing Hardware modules with Quantum Safe features (crypto4a, 2025) , enhancing encryption at data storage facilities, and implementing Quantum Safe Network Protocols in (Baseri.Y., et. al. 2024). All of these can help improve efficiency in various Energy Centre related applications which include Data Security & Integrity, Authentication and Access Control, Compliance & Reporting, Intra Communication between various Management Systems, Smart Grid and IOT based device Interactions, Software and Hardware Updates. In addition there also needs to be a global compliance standard like NIST particularly drafted for the Energy Sector.

3.5 Incorporating Quantum Technologies in Environmental sustainability.

Sustainable Quantum Computing is an Emerging Area which deals which deals with the amount of Carbon emissions occurring in the life cycle of Quantum Computing (Arora, N., & Kumar, P., 2024). Major challenges in creating such a Benchmark include

- Existence of multiple Quantum Computing Platforms having unique hardware requirements and tailored implementations of algorithms poses challenges to understand resource demands.
- Lack of globally accepted Quantum Computing Benchmarks as opposed to FLOPS metrics used in Classical Computing.
- Constructing a global metric which brings manufacturing, use and application benefits of Quantum to the world.

Hence as a reference, Environmental benchmark for Quantum Computing is set using Life Cycle Analysis (LCA). It uses Equivalent-Carbon or CO2e as the metric for evaluation. The amount of CO2e to be measured is primarily classified in to 2 major categories

1. **Operational Carbon:** CO2e present in sources like water, energy and materials used during the operations.
2. **Embodied Carbon:** This is the amount of Co2e present other than when the product is being used.
3. **Application Centric Carbon:** This is the amount of CO2e optimized for running applications on a computing system. (Kannan, S., & Kremer, U. 2023)

Thus the term Carbon aware Quantum Computing refers to the below identity Carbon Aware Quantum Computing = Operational Carbon+ Embodied Carbon-Application Centric Carbon. The framework makes some critical recommendations on following key points.

1. It recommends to understand the trade off between energy consumption/utilization of the various Quantum Computing Platforms against their performance.
2. Since the Renewable Sources of Energy are non linearly distributed around planet, it is recommended to maximize renewable energy sources in Quantum Computing data centres so as to achieve carbon neutrality.
3. Adapt the current hardware and Software systems in Quantum Computing to run on clean energy sources.
4. Various metals extracted from the Earth's Crust play a vital role in the development of Quantum Computing platforms at various stages like physical qubits, cryogenic cooling, qubit controls and data processing.
5. Promoting replacement and recycling of Quantum Hardware components in an eco-friendly way. Also determining the carbon friendly age of obsolete Quantum hardware aspect relating operational Carbon to Embodied Carbon.
6. Utilizing Quantum Computing to simulate and Optimize complex problems in Energy Sector which include battery chemical and material simulations, energy distribution networks, grid

stability and load balancing problems, fusion energy simulations, carbon capture optimizations and many more.

These Environmental Benchmarks can be implemented as a part of Energy Centre 4.0 thus ensuring sustainable development in Energy Sector with Quantum Technologies.

4 Future Costs and Impacts

We define the term technological problems as that require smart solutions based on a specific technology that is optimal, scalable, distributed, secure, and sustainable. The success of a technology can be measured in terms of two key features

The evolution stages of a Technology in terms of time

- 1- new technology can hardly manage to solve any problem that cannot be solved by classical technology
- 2-new technology can manage to solve a few problems that cannot be solved by classical technology
- 3-new technology can manage to solve a some critical problems that cannot be solved by classical technology
- 4-new technology can manage to solve many critical problems that cannot be solved by classical technology

The different stages that determine the utility of this technology

- 1- denotes the new technology is used by few business and investments are low •
- 2-denotes the new technology is used by Multinational Technology giant companies and they are investing in it
- 3-denotes the new technology is used by Big Sector specific companies and investments are growing
- 4-denotes the new technology is used by almost every investment in the sector and the investments are all time high.

The technology becomes a revolution when it scores high points on both the metrics and it will be made available for commercial use in any Sector. The present state of Quantum Technology (2023) is defined to be Noisy Intermediate scaled Quantum Computing era. This indicates that Computers built with Quantum Technologies have a better edge over traditional Computers in very specific problems. However it is difficult to have complete control over qubits because of which we are not able use Quantum Technologies to solve many complex business problems till the date. The Smart Quantum Technology Smart Centre proposed in this discussion is proposed to lie in era of Quantum Revolution. Quantum Revolution as discussed above is a stage where the Technology is at its peak with evolution and usability. (That is having a perfect score (4,4)). At this stage, the Technological advantages that are utilized to build the smart Energy Centre have been discussed in the previous section 3.

4.1 Cost Impact Matrix

The cross-impact method was originally developed by Theodore Gordon along with Olaf Helmer in 1966. The method provides a forecast to understand the interaction occurring between future events. (Gordon, T. J. ,1994).

Table 1: Cross Impact Matrix related with Quantum Technologies and Energy4.0

	Quantum Technologies	Energy Centre	Energy Technological Problems
Quantum Technologies		Quantum Technologies will be used to enhance Energy Centres (A)	Quantum Technologies will be used to address the technological complex problems in Energy Sector (B)
Energy Centre	The Energy Centre will involve in Research and Development of Quantum Technologies in order attempt its usability (C)		Energy Centres are looking for ways to solve technological problems that are complex and critical to the business (D)
Energy Technological Problems	The Technological critical problems in the Energy Sector thrive the need to create solutions using Quantum Technologies (E)	The Technologically critical problems will remain a challenge to create a smart Energy Centre (F)	

1. (A)-5 (very high) Quantum Technologies could be used to enhance operations at Energy Centres as illustrated in section 3. 2.
2. (B)-5 (very high) Quantum Technologies to play a significant role to solve some other critical problems in Energy Sector. An scenario dealing with optimal positioning of Electric Charging stations is discussed by Sakib, et. al. 2024. Another such example is exploring the option of Computing for Fusion Energy having Science Applications using Quantum Technologies by Joseph, et. al. 2023.
3. (C)-4 (high) The Energy Centre are likely to identify more problems which can enhance their performance in terms of resources, cost and time. Research and Development teams will find ways to accelerate algorithms and improve the design architectures in Quantum Computers. One such work is done by Ueno, et. al. 2024.
4. (D)-3 (moderate) Quantum Computers are able to solve some problems not possible in Classical Computing. However still NP-Hard problems remain a challenge due to hardware limitations, lack of a universal programming language and robust error correction methods, a work due to Younis M.M., et. al., 2024.
5. (E)-2 (low) In this situation Quantum Technologies have been utilized to create solutions to many of the critical problems in the Energy Sector. One such scenario of is discussed in the Ghosh.S. , et al., 2023. Users of the sector could be tempted to use untrusted but readily available Quantum Hardware which can enable stealing of IP address and tampering of Quantum Programs/computations.
6. (F)-2 (low) Here many solutions to major problems have been achieved, however new challenges still remain challenged. For example, energy buying patterns predicted by Quantum Technologies are affected by various factors include socio- economic status and many more.

4.2 Quantum Business Revenue Model

Since the Technology is at a matured stage, a huge amount of money will invested by big Multinational Companies to develop Quantum Computing facilities and make it commercially available at flexible business Models. These flexible Business Models attract other small business to use these technologies which boosting operating revenue. The increase in revenue over the period of time will encourage research and development to take this technology at level where it is more sustainable in revenue, security and environment. However yet some challenges will still need to be addressed for this new technology and it will be a matter of time till sustainable solutions can be found. The overall life cycle of the evolving business model can be seen in the diagram below.

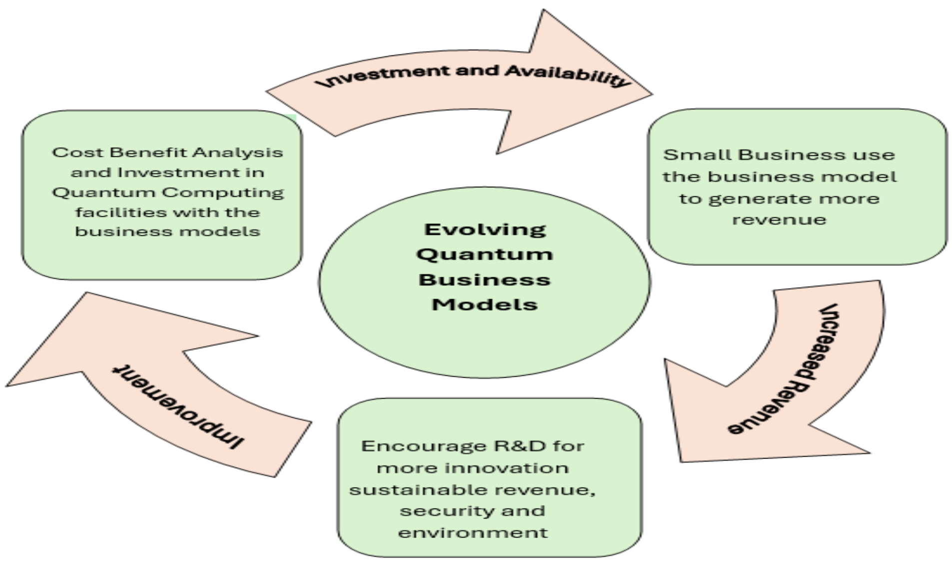

Figure 2: Evolution Cycle of Quantum Business Model

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