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Article

Emerging Technologies in Smart Water Grids: Enhancing Urban Water Distribution Systems

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Abstract: Urban water distribution systems are under increasing pressure due to rapid urbanization, ageing infrastructure, water scarcity, and climate change. Traditional water networks often struggle with inefficiencies such as leakage, poor demand forecasting, and limited operational visibility. To counter this, smart water grids have become an innovative one and have used technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Advanced Metering Infrastructure (AMI), and analytics of big data to facilitate real-time monitoring, real-time control, and data-driven decision making. In this paper, I will discuss the major technologies that drive smart water grids, their potential real-life use in cities, and the many advantages associated with them, such as better efficiency of functioning, sustainability and customer experience. It also critically analyses the technical, financial, regulatory and organizational barriers to its overall establishment. The paper concludes by referring to a prospective discussion on how smart water grids can facilitate the shift toward more resilient and sustainable urban water systems.

Keywords: Smart Water Grids, Urban Water Management, Internet of Things (IoT), Artificial Intelligence (AI), Water Distribution Systems

1. Introduction

The cities across the world are experiencing an increasing burden on their water system amid an ever-increasing global population, and prompted by the process of urbanisation, it has become a matter of extreme concern, to say the least. Most urban water distribution systems that were designed decades ago are not able to cope with the growing water demand, deteriorating infrastructure and the demands of climate change. Loss of water, poor water management, ageing pipeline and unpredictable consumption patterns have become major issues of concern to water utilities. Such difficulties are complicated by the increase in the occurrence of extreme weather phenomena, resulting in floods, droughts, and heat waves that put additional pressure on the dependability and the strength of the current water systems. Due to ever-growing cities and limited resources, it is strongly necessary to innovate urban water management [1,2].

Major changes presented by such issues have led to the advent of smart water grids, which have come to rescue the contemporary systems of water distribution in urban areas. A smart water grid is an interconnected network of cutting-edge technologies like the Internet of Things [IoT], Artificial Intelligence [AI], big data analytics and automation to develop a highly efficient, responsive and sustainable water network. Smart water grids allow the utilities to be aware of the water distribution in real time, identify inefficiencies, control consumption, anticipate problems, and make informed decisions on the basis of data that enhance the overall functioning of the system. These developments will bring a revolution in the way water is handled since more proactive, as opposed to reactive, approaches will be offered to a diversity of water-related issues [3,4].

A smart water grid is not similar to the common water distribution networks in any way. Unlike traditional systems that require periodical examination and repairs, smart grids make use of digital technologies to ensure constant testing of major indicators, including water pressure, the quality of the liquid, and the rate of water flow. By performance of the Internet of Things sensors, utilities can obtain real-time data on the whole of the water distribution network, locate the leakages, detect pollution, and better regulate the supply and demand. Also, the developed metering infrastructure (AMI) on the basis of smart meters allows measuring the consumption of individual water consumers, thus giving consumers and utilities information concerning the consumption of water in detail. Such transparency helps in not only creating awareness of water conservation but also enables the utilities to base the model of pricing according to the real consumption [5].

AI and machine learning also significantly boost the potential of smart water grids, as they allow the application of predictive analytics. Relying on huge volumes of information compiled by various sources such as weather forecasts, patterns of water, and historical records, AI algorithms can deduce how the demand can increase or decrease, anticipate failure of the infrastructure, and optimise the distribution process. These technologies can make the utilities minimize their operational expenses, avoid water loss, and increase the robustness of a water network against natural disasters or unexpected situations. Like, predictive maintenance model through AI can predict equipment which can fail, thus enabling utilities to do targeted repairs before failures, thus reducing the costs of maintenance by minimizing downtimes [6].

One of the other major achievements in smart water grids is the use of big data analytics, which enhances efficiency in operations and decision making. As a result of collecting large amounts of data through sensors, meters, and outside sources, cloud computing platforms and data analytics platforms, as well as trends and patterns, can be analyzed, and real-time decisions can use cloud computing and data analytics platforms to optimize water distribution. The approach allows predicting water demand more accurately, managing water resources more efficiently, and addressing the needs of the urban population more closely to their actual needs [7].

Although the smart water grid promises massive potential use, its use does not come without its challenges. The implementation of new technologies in the cities will mean that cities need to marry new technologies with previously established, and in many cases, outdated infrastructure, which is a tricky and demanding task. The complexities of implementing various technologies involve a stable communication system, a standardised data protocol, and the participation of different stakeholders in the process, i.e. the water utilities, the technology providers and the policymakers. Also, data security and privacy should be ensured, since the more the water systems undergo connectivity, the greater the threat of cyberattacks. The barrier is even further by the huge initial investment cost that is required in installing IoT devices, smart meters and AI-driven systems, which is beyond the capacity of some municipalities, especially those with small budgets [8].

Still, there is no doubt about the advantages of smart water grids. They offer cities the means of more sustainable management of water resources, less waste of water, better reliability of service and customer satisfaction. Additionally, smart water grids can significantly contribute to the situation with climate change and make cities more adaptive and resistant to unpredictable weather conditions and water shortages.

With the ongoing process of the urbanization of the world, the water need will only grow, and the city will be imperative to implement the latest technologies, which add efficiency and sustainability to its water distribution network. The smart water grid offers the next frontier in urban water management and is likely to not only transform the distribution and use of water but also water management as a whole in the setting of modern and sustainable cities. With the adoption of these emerging technologies in the urban water system, it will be made more intelligent, efficient, and resilient to give a guaranteed flow of water that will be sustainable for future generations [9-11].

2. Key Technologies in Smart Water Grids

Smart water grids make use of the aggregation of sophisticated technologies to streamline the management of water distribution systems in cities. The technologies cooperate to ensure greater efficiency, resilience, and sustainability in the process of water supply, minimizing wastage, operating expenses, and real-time data on how the system is performing. Among the technologies that define the development of smart water grids, the following can be mentioned:

2.1 IoT in water distribution

The Internet of Things (IoT) is one of the fundamental technologies in the implementation of smart water grids. IoT is a collection of machines and gadgets used to collect and share information through the internet. To give an example in the context of distributing water, IoT makes real-time coordination and management of several parameters, including water pressure, water flow rates, water quality, and water temperature, through the entire water system.

IoT Sensors: IoT Sensors are attached to many locations in the water distribution system and are tiny and cheap sensors operating wirelessly. They are also constantly gathering information on how the system is and its pressure, flow of water, leakage and contamination. An example is that pressure sensors are able to pick up anomalies in the system, which can be a sign that there is either a break in the pipe or perhaps the blocking of a pipe, whereas water quality sensors prevent the presence of things like chlorine or pH levels.

Data Transmission: Transmission of data that is recorded using these sensors is conducted in real-time into a central platform where it is analyzed. The IoT device network allows the utility to keep track of the system all the time and be able to address any malfunctions immediately, including leaks and contamination, before they grow into more serious, complicated problems.

Tangible value: IoT will add value to the decision-making process by making decisions quickly and based on data, so the work of water utilities will be reduced to decades of no downtime in the system, no water pollution or damage loss, and minimal costs to maintain [12,13].

2.2 Artificial intelligence (AI) and Machine learning

Machine Learning (ML) and Artificial Intelligence (AI) are quickly revolutionizing how utilities utilise and derive insights about the large quantities of data produced by smart water grids. Such technologies allow automation of the higher-order decisions and increase efficiency, as well as give an opportunity to utilities to optimise water distribution according to the predictive models [14].

Predictive Maintenance: The predictive models based on AI, using data collected by the sensors of IoT, as well as historical data, predict possible failures of the water system. ML algorithms can be used to determine patterns based on which it is possible to determine the approximate time of failure of pipes, pumps, or other important infrastructure, at which point utilities can conduct maintenance work before a failure. This saves idle time, prevents interference and ensures that the repair expenses are reduced.

Demand Forecasting: Demand Forecasting is also the method by which AI can forecast future demands of water using historical data of water usage, weather data, etc. This enables the utilities to better manage their water resource, thus raising or lowering the supply according to the demand and reducing waste.

Leak Detection: Machine learning can learn to detect abnormalities in the patterns of water flow that will indicate the possibility of a leak. The issue of a decrease in pressure or an unusual flow rate could be identified and reported to the utilities on the fly as well, which can enable them to find and fix the leak more productively.

Advantages: AI and ML can offer a wiser, data-informed decision-making system to make the way the water is handled better, decrease the expenses, and boost the reliability of the systems by warning about probable problems before they have a chance to turn threatening [15].

2.3 Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure is also known as AMI, which is the combination of smart meters with their communication system to gather very specific, real-time water consumption data. A smart water grid cannot be complete without AMI systems because water usage could be monitored continuously at the household or business level.

Smart Meters: These are digital meters that directly record water use and relay information to the utility on a real-time basis. In its operation, the smart meters do not need physical visits to take manual readings, as it would be the case with traditional water meters.

- **Real-time data access:** AMI allows the water supplier and customer to obtain real-time data on consumption. This openness enables utilities to improve the prediction of the demand and dynamically optimise the delivery of water, in addition to providing customers with visibility about their individual use of water, thereby encouraging the use of conservation.

Benefits: The use of smart meters increases the accuracy of billing, as estimated readings are no longer used, lowers operational expenses, causing the costs of reading the meter to be automated and helps with water conservation by making the customer more aware of their consumption patterns. Also, utilities will be able to identify anomalies in the consumption, e.g. leakages and wastage, and eliminate them in time [16].

2.4 Big Data and Cloud Computing

The amount of data produced by IoT devices, smart meters, sensors and other objects of a smart water grid is huge. It is this large body of data which is processed, stored, and analysed on big data analytics platforms to help utilities interpret actionable information that helps in improving how water is managed.

- **Data Integration:** Smart water grids need to accumulate data from various together, which is available through IoT sensors, weather prediction, or client use patterns. Cloud computing systems can allow utilities to receive all of this data in real time and analyze it, giving everyone an overview of the whole water system.
- **Real-time Analytics:** Big data platforms, which are on the cloud, allow utilities to manipulate massive data within a short time and find some trends or abnormalities that might not be realized based on their conventional analysis. To give an example, utilities can use a combination of past usage records and weather predictions to estimate water demand during a heatwave or drought, and pre-meter it in the corresponding amounts of water.
- **Benefits:** With big data analytics, utilities can make better decisions, optimise the distribution of water, anticipate their future water demand, and also be able to detect potential issues in the future. It also allows working and sharing of data across different stakeholders (e.g., municipalities, water utilities, and researchers) that leads to a more coordinated process of managing water [17].

2.5 Data Security Blockchain

Blockchain technology may become an effective solution to the problem of assuring the security and transparent nature of the information in smart water grids. Blockchain is a ledger system where the data and transactions are kept securely and in a decentralized, immutable manner.

- **Data Integrity and Transparency:** Blockchain enables water utilities to safely store and share data about water usage, system treatment, and transact (water trades, or water bills). Blockchain will guarantee that the data cannot be modified or manipulated, which will help to inspire the stakeholders with trust and minimize the risk of fraud.
- **Water Trading and Resource Allocation:** Blockchain has potential applications in smart water grids to trade water, such that water whose supply exceeds its demand can be traded with water with excess water demand. This may especially come in handy in regions where there is a shortage of water, and this will enable proper distribution of resources.
- **Advantages:** Blockchain creates an additional layer of safety and transparency of data, which allows tracing the water usage and management decisions, which it more convenient. It also inculcates trust among utilities and consumers since they know that the data is true, accurate and cannot be tampered with.

All these technologies, i.e., IoT, AI and AMI, big data analytics, and blockchain, are so important in the operation and optimization of smart water grids. Collectively, they can ensure that water utilities transform water distribution systems management modalities to proactive ones. The implementation of the technologies in urban water systems increases not only efficiency but also makes the old systems more sustainable, customer-satisfying, and increases the overall robustness of the water infrastructure [18,19].

3. Benefits and Applications

A lot of advantages can be realized with the integration of smart water grids into the local water distribution system of its urban area, and could largely contribute to the efficiency, sustainability, and resilience of the water resources management process. Smart water grids allow utilities to control their water networks in a much proactive way and increasingly provide a good service at reduced operating expenses and thereby encouraging better conservation. This part examines the major advantages and uses of smart water grids within a city [20].

3.1 Efficiency of operation would be better.

The dramatic increase in the operational efficiency of water distribution systems by the use of smart water grids is one of the main benefits of smart water grids. The conventional water system follows the approach of periodic inspections and manual controls to keep the infrastructure intact and track the performance. Conversely, smart water grids allow real-time monitoring of the water network that will result in more efficient operations in the following ways:

Water Leak Detection and Reduction: A modern water system uses high-tech panels and embedded systems that analyse data and can identify where leaks have occurred or the pipes have collapsed; this situation is known in conventional systems as the non-revenue water / NRW. By leveraging IoT sensors and more complex analytics, smart water grids can detect even the slightest of pressure changes or anomalies in flow, which could imply a leak. Leak detection in the early stages averts major failures, as well as ensuring utilities detect problems before they result in a substantial loss of water. Consequently, the utilities can increase the efficiency of the system by minimising NRW, as well as decreasing the expenditures spent in water waste.

Real-time optimisation of water flow: Sensor-based real-time data allows for maximising water flow within the network. Due to the dynamic control of pressure levels, water will be distributed most efficiently, decreasing the energy usage and wear and tear on the infrastructure. As an example, utilities can use controlled pressure in pipes to ensure that bursting of pipes due to pressure over demand is avoided, which increases the system reliability as well as extends the infrastructure's life.

Predictive Maintenance: Utilities can use machine learning algorithm techniques in predictive maintenance to help them know the approximate time that equipment (pumps, valves, and pipes) will fail based on historical records. This type of predictive maintenance gives utilities a chance to do maintenance plans at a planned time and not in response to emergencies. It decreases unproductive hours and minimises operation shutdowns and increases the serviceable life of essential infrastructure [21,22].

3.2 Proper Decision-Making Using Data-Based Insights

Smart water grids produce tons of data through sensors, meters and other monitoring equipment. Such information can be processed and used to make more informed and timely decisions, which eventually translates to good management of water resources. Improved decision-making includes some of the following aspects:

- **Demand Forecasting:** This is one of the most useful big data analytics in smart water grids since it allows predicting water demand. Looking at past consumption advances, climate conditions, and others (the development of the population or weather effects), utilities can determine the intensity of the variations. This allows the utility to vary its water distribution and maximize resources across the board. Another example is that when the consumption is high (e.g. in summer months), the utilities can ensure that they have enough water to serve those needs so that there will be no shortages and other incidents that interfere with the supply.
- **Efficient Water Supply:** Utilities can operate with an efficient water supply using smart water grids because they will be able to manage water resources with proper demand estimation. This degree of accuracy can prevent the unnecessary excessive production of water and will guarantee the proper supply of all the regions in the system. The utilities are also able to reduce operations through maximization of the flow of water and minimised the usage of energy.

- **Real-Time Performance Monitoring:** Real-time monitoring of water systems will allow the utility to detect and solve any problems that occur during the normal running of systems. A real-time monitoring of the performance enables the decision-makers to monitor the efficiency of the pumps, pipes, reservoirs and other parts of the water distribution system with ease and, therefore, identify the inefficiencies easily in order to make the necessary corrections. Such a proactive strategy results in the improvement of resource management and the increased reliability of the system [23].

3.3 Improved Customer Satisfaction and Commitment

Smart water grids not only positively affect utilities but also add many benefits to the customers. These systems result in enhanced client satisfaction and interaction due to the increased transparency, reliability in the provision of services, and improved communication:

- **Proper Billing and Visibility of Consumption:** The traditional water meters are based on a manual dial, and there is always an estimated charge billing, which may cause conflicts between the customers and the utilities. Smart meters, one of the most important parts of AMI, give accurate readings of water consumption in real time. These smart meters will also make sure that the customer is charged only according to what they consume, and the bill alignment is removed to give customers more credibility with the utility and the customer. Also, customers will be able to get in-depth information on their consumption patterns that prompts them to develop water-saving habits.
- **Consumer Empowerment:** Smart water networks place more power in the hands of consumers as to how they use water. The customers will be able to track their daily usage through the mobile applications or by using online portals, receive notifications on their possible leakage or other anomalies in usage, and address them. Such openness promotes the saving of water and guides consumers to be more conscious of their water resources usage, particularly in regions that experience low water supply.
- **More responsive and proactive customer service:** Utilities have the potential to give better and more responsive customer service since they can monitor consumption in real time. As an example, should a customer receive an unusual rate of water consumption (e.g. sudden erratic rise of water consumption due to a leak), the utility can alert the customer and suggest a solution to that problem in real time. This initiative of communication assists in a decrease of customer complaints and a better service satisfaction [24].

3.4 Conservation and Environmental Sustainability

Environmental sustainability and water conservation are the key issues when it comes to climate change, water scarcity, and the increased population in cities. By:

- Efficient Management, efficient use of resources through the optimisation of water supply according to the actual demand and the minimum water loss by detecting the leakages: The smart water grids can ensure that the use of resources (water) is more rational. This minimizes needless water losses and makes sure that the supply of water that is available is utilised to full capacity.

- **Energy Efficiency:** The water distribution systems have great energy consumption, especially when it comes to moving and pumping water. Energy is saved with the help of smart water grids due to optimization of pressure and water flow. Moreover, the predictive maintenance makes the downtime minimal, and the system operates effectively, and efficiency is maintained in terms of energy consumption. This, in turn, lowers the carbon footprint of water utilities.
- **Supporting Sustainable Practices:** Smart grids can support the conservation of water by ensuring real-time information on consumption, which can be used to guide policy and support sustainable practice. In one example, utilities can use smart meter data to discover a locale with abnormal use of water use and where special programs could be instituted to promote using less water. Special programs may include tiered water prices or water efficiency programs [25].

3.5 Cost effectiveness and financial gains

Although in the short-term perspective, smart water grid technology can be expensive to apply, financially, the payoff will be high in the long run:

- **Operational Cost:** Smart water grids lower down costs of operation since much less water is lost, the system is more efficient and manual work is reduced. Automatic meter reading, leak detection and monitoring of the systems ensure that fewer staff are required to carry out manual operations; therefore, labour cost is minimized and efficiency is enhanced.
- **Preventative Maintenance:** The possibility of predictive maintenance through the application of AI enables any infrastructure of this type to be predicted in terms of its failure, thus avoiding costly repairs and periods of system immobilisation. It also increases the life of infrastructure, and the utilities are not condemned to early replacement of costly equipment.
- **Better Financial Administration:** Real-time information allows the utility companies to allocate their resources and price them correctly using precise predictions of demand. This has the effect of improving financial control, enhancing prediction and fairer pricing to customers.

The advantages of smart water grids are vast and are expected to change the urban water distribution system. These technologies are defining a new level of efficiency in operating water systems, decision making, customer interaction, sustainability, cost savings and setting a new paradigm on how the 21st century will operate, manage and treat water. With increasing populations living in cities where rising pressure poses a challenge to the concept of water scarcity and climate change, the adoption of smart water grid will be instrumental towards providing a future-proof supply of water that is more sustainable, efficient and reliable to deal with the population increase in cities in the future [26].

4. Challenges and Limitations

Although smart water grids can change things in urban water distribution in a transformative way, such an undertaking comes with inherent challenges that cannot be lightly overlooked. These issues cut across technical, financial, regulatory and social aspects. It is important to comprehend these constraints to help stakeholders (utilities, governments, technologists and communities) form realistic expectations, and thus integrate strategies to help realise the sustained and equitable roll-out [27].

4.1 Legacy infrastructure integration

Most urban water systems, particularly in older cities, are constructed on infrastructure decades in the making that was never envisioned to include the introduction of digital technologies.

- **Incompatibility:** Old pipelines and pumps, and valves do not have the interfaces required to integrate sensors and communication gadgets. Modernization of such systems with new components may be technically sophisticated and labour-intensive.
- Disruption on Upgrade: The installation of smart meters, sensors and automated valves may need temporary closure or disruption of service, which needs to be properly handled to curb backlash among the people.
- **Interoperability Problems:** The different vendors can sell their new technology, but they might not be able to readily communicate with others since they lack universal norms. This has the potential to create divided systems and less efficiency.

Solution Direction: Implementation phased approach (E.g. phasing in), creating interoperable and modular technologies, and interoperable technologies are aimed toward cutting costs and disruption [28].

4.2 Heavy Initial Capital Investment

The adoption of smart water grids requires a huge initial outlay of hardware, software and investments on infrastructure renewal.

It includes:

- Purchase and fixation of IoT sensors and smart meters.
- Developing a data communication network (e.g., fibre, 5G, LPWAN) within a secure network.
- Modernisation of backend systems (reach cloud storage, platforms doing analytics).
- Development of staff and coping with organizational change.

Return on Investment (ROI): In terms of long-term cost savings and efficiency palpability, the cost of implementing it is still high, particularly to the municipalities with limited funds or other priorities.

Equity Issues: The poorer communities shall be disadvantaged in case of prioritising installations in places with higher returns or a lower rate of risk.

Directions to the Solution: Governments can use stimulus incentives, public-based partnerships and gradual releases to make sure that the financing load is not a strain and that adoption becomes evenly distributed [29].

4.3 Privacy of Information and Online Threats

The digitization of water systems poses a chance of cyber threat and an issue of data privacy.

The Defects in Cybersecurity:

Hacker attacks on innovative water systems may let hackers interfere with the working process of the water supply, change pressure regulation, or make it contaminated.

Hackers may also access billing systems or sensitive information on operations.

- **Data Privacy:**
  - Smart meters record detailed data on the usage of water by households, and this may lead to the disclosure of personal patterns and routines.
  - Without effective data governance policies, utilities will have a legal or ethical predicament regarding data handling practices and have rights over their consumers.

Direction of the solution: a security approach needs to be built in by design, to utilise global standards of communications, system auditing, high-powered encryption, and stringent enrollment protocols. The approval structure should also determine specific rules on data usage, storage and consent [30].

4.4 Barriers to regulation and institutions

The implementation of smart water technologies usually not only demands institutional and regulatory changes but also might fall behind technological advancement.

- **The Absence of Clear Standards:** In most cases, there is no clear protocol over data formats, gadget incompatibility, and cybersecurity in the sphere of water utilities, defining the absence of efficiency.
- **Tardy Water Policy Dynamics:** Water regulations and procurement methods have the tendency to move at a snail's pace. The old standards might fail to support innovation, such as the blockchain-based water trade or predictive maintenance using AI.
- **Stakeholder Fragmentation:** The water utilities, municipal governments and environmental agencies, and may have differing priorities and/or may be operating in silos, and may require difficult coordination in order to implement.

Direction of the solution: Government agencies need to collaborate with technologists and city planners to update the regulations as well as establish guidelines that will allow progress through innovation, protecting the common good [31].

4.5 Challenges of Workers and Technical Skills Gap

Smart water grids have new technical skills that several old but good workers in water utilities are unlikely to have.

- **Skills Shortage:** Digital systems need someone to have a command of data analytics, cybersecurity, management of IoT devices, and AI, which is currently lacking in the water utilities today.
- **Resistance to Change:** Current employees can resist the use of the new technologies because they have not been trained, they fear being fired, or they are not conversant with digital tools.
- **Training and Retention:** Everything needs to be trained, but training is costly and may take time. Besides, capable employees can transfer to better-paid positions in the commercial technological field.

The solution direction should be to invest in upskilling efforts, University-Industry ties, as well as the motivation of tech-savvy professionals to join the workforce in the field of public utility, as this is the key to closing the skills gap [32].

4.6 Management problem of data overload

Smart water grid sends in a huge amount of data, which the utility can easily drown in unless it handles such data well.

- **Data Storage and Processing:** To deal with data volume, velocity and variety, the utilities would have to invest in efficient cloud infrastructure and data analysis tools.
- **Relevant Insights:** Harvesting data is one thing; the real problem lies in the important insights to be taken out. The value of smart grid investments may be constrained by poor quality of data, the absence of integration, or limited analytical capabilities.
- **Operational Overload:** In the case of too frequent or frequent false smart system alerts, operators may end up being desensitized and missing critical problems [33].
- **Solution Direction:** To make sure that the data being amassed is effectively utilised, it is possible to execute AI-enabled analytics, data dashboards that have a user-friendly user interface, and data governance strategies that are well structured.

Although the potential of smart water grids is high, the implementation process is constrained by a complicated set of impediments. Either the technical problems of new system implementation to an old infrastructure framework, the matter of cybersecurity, financial and budgetary issues and the regulatory barriers, utilities have to work through a complex environment. A comprehensive way of addressing such limitations is through innovation, policy reform, capacity building and inclusive planning. Cities can begin unleashing the full potential of smart water grids by recognising and proactively addressing these challenges and making sure that cities continue to enjoy equitable, efficient, and resilient urban water systems into our futures [34-37].

5. Conclusion and Future Outlook.

Due to the increasing urban population and insufficiency of scarcity of a reliable supply of water, traditional water supply systems are becoming quite insufficient to deal with the contemporary challenges of ageing infrastructure, water loss, climate change and inefficiency in the utilization and management of resources. In this regard, smart water grids became an exceptional innovation in the future of city water management.

Smart water grids take advantage of modern technologies, e.g., the Internet of Things (IoT), Artificial Intelligence (AI), Advanced Metering Infrastructure (AMI), big data analytics, and, to an increasing degree, blockchain to allow monitoring and troubleshooting in real-time, predictive maintenance, automated control, and decision-making fuelled by information. Other than making the operations more efficient in terms of water loss reduction and improved operational efficiency, such innovations are improving sustainability, customer engagement, and creating water loss options that are associated with improved transparency in terms of service delivery. But the use of smart water grids does not lack major obstacles. The high initial cost, the threat of cyberattacks, the compatibility of the legacy systems with the infrastructure, regulatory inertia, and the shortage of personnel with the skills required are all obstacles that have to be eliminated by careful planning, policy amendments, and cooperation between the stakeholders. The government agencies, utilities, technology providers, researchers, and local communities will need to work collectively to successfully implement the same.

In the future, smart water grids are likely to be part of functional smart cities, which are more resilient and sustainable. As the digital infrastructure is developing further, we may expect the water systems to be more autonomous, incorporated with other services within the urban area (including energy systems and waste systems), and adaptive to the real-time changes within the environment and society. The interrelation between digital innovation and water management is a new stepping-stone towards more innovative, safe and sustainable urban life.

To realise the full potential of smart water grids, we need to go beyond investing in technology to focus on governance as well as capacity building and inclusive policymaking, which can guarantee equal access to clean and affordable water. Wise implementation and long-term innovation of smart water grids can become a frontier in ensuring the security of water for future generations and improving the quality of living in the global city.

Conflicts of Interest

The authors declare no conflict of interest.

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