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Data Centers and Water Crisis in India: Why Digital Infrastructure Could Drain Our Wells Dry by 2030

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Abstract – India faces a pivotal moment. Its ambition to establish digital sovereignty goes against the environment protection requirement. India is demonstrating its desire to control its digital backbone as expressed by large data-centre projects announced by Reliance in Jamnagar, and by Adani, a 10-billion-dollar investment in multiple states. However, these centers consume vast quantities of water, which may exacerbate the water scarcity in India that is already severe. An example 100-megawatt data centre requires approximately $2m^3$ of water daily to cool it, which is equivalent to approximately 6,500 households. Currently, India operates 270 data centers whereas it generates 20 or more percentage of the global data, thus, expansion will occur. This paper examines the water consumption of data centers, lessons learned by cities in the United States that have established data centers and gone through water wars and evaluates the potential risks of India because of the water shortages in the largest metropolitan areas. It has seven viable plans namely require alternative water supply, site selection, promote renewable energy, support innovative technology, mandate transparency, establish community benefits agreements, and implement the project in phases. The main idea is that creating a sustainable digital infrastructure must not restrict the growth it must provide India with an advantage as a pioneer of environmentally sustainable digital sovereignty.

Keywords: Data center water consumption, Digital sovereignty India, Sustainable data infrastructure, Water scarcity crisis, AI cooling requirements, Environmental sustainability technology, Renewable energy integration, Community benefit agreements.

1. INTRODUCTION

1.1 When Progress Drinks the Well Dry

On January 24, 2025, Mukesh Ambani informed investors that Jamnagar was going to be a gigawatt-scale AI world hub of data-centers. The media reacted wildly. News outlets hailed the digital ambitions of India and analysts forecasted in the billions of dollars of investment, thousands of new jobs, and a dominant place in the worldwide AI wave. The timing was perfect. The UPI transaction volumes were over 100billion a year, surpassing most of the developed economies. The rural areas were getting digital payments faster than ever before and Aadhaar was simplifying services of those who were earlier locked out. In India, the rate of AI adoption was rising at a faster rate than most western countries, with start-ups and large enterprises integrating machine learning in their agriculture and health among other fields.

Gautam Adani came after a few weeks later and declared a 10 billion commitment to develop data infrastructure in Andhra Pradesh, Gujarat and Tamil Nadu that would be of global standards. These announcements along with the plans of Reliance put India in a position of transformative growth of its digital backbone.

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However, behind the excitement is a bitter reality that has not been accentuated by many comments. Such massive amounts of water consumed by the new data centers are overloaded with servers that handle billions of transactions and AI requests that would turn the severe water crisis in India into a disaster. It is not anti-developmental rhetoric, or Luddite antisemitism it is a basic inquiry of sustainable development in a nation which boasts of being the world leader in both digital innovation and water shortage.

India produces 20 percent of the global data and retains only 3 percent within the nation. That breach undermines the national security and demonstrates why data sovereignty is important. Meanwhile, 163 million Indians are still without clean water. The groundwater levels are dwindling, and NITI Aayog is also alerted that by 2030, forty percent of the Indian cities may not have drinking water. The data-centers to be expanded in the cities of Navi Mumbai, Bengaluru, Delhi NCR, Chennai, Hyderabad and Kolkata already have acute shortages of between 80 and 1,100 million liters per day.

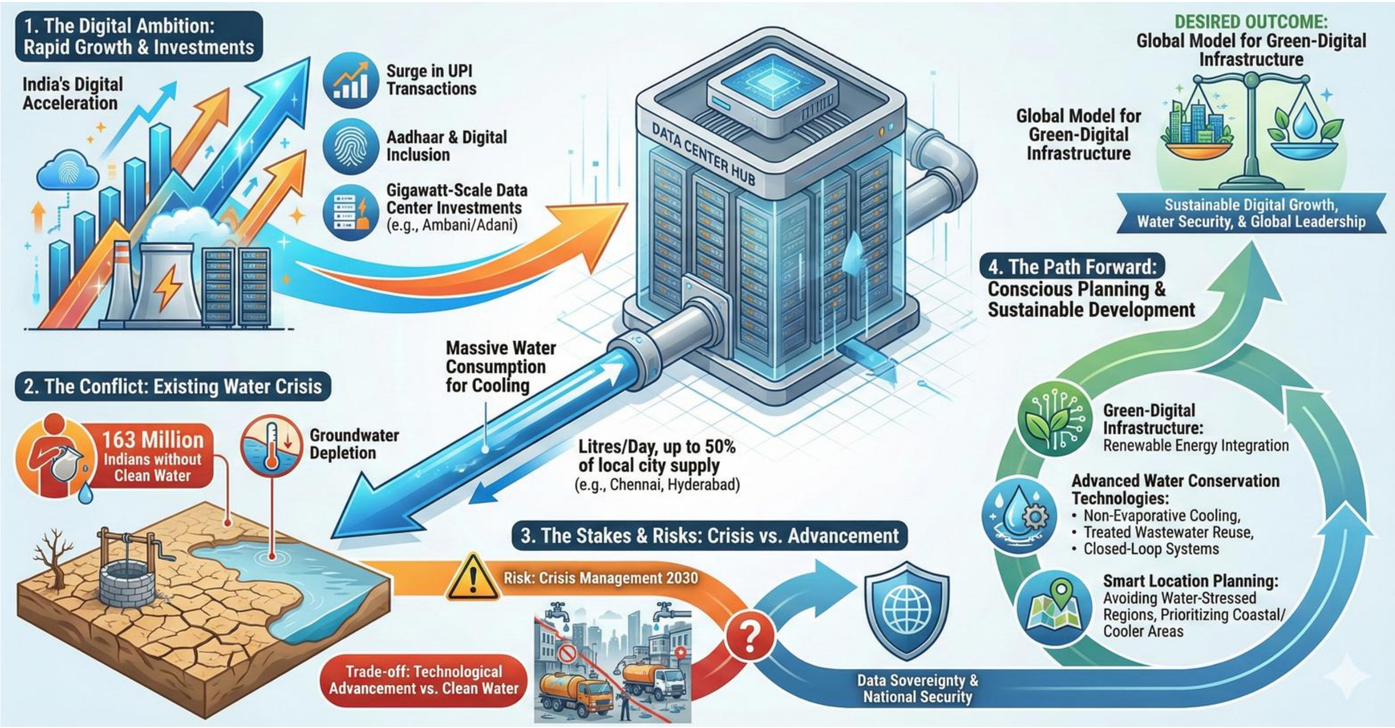

Fig -1: The Digital-Water Nexus: Balancing India's AI Ambition with Water Security

The paper discusses the functionality and necessity of data centers to consume a lot of water. It examines what has already taken place in American cities that have already adopted data-centers investments without adequate planning of the environment. It analyzes the specific weaknesses of India and reasons why merely opposing data-center development is neither possible nor prudent, in the context of the digital-sovereignty necessity. Above all, it suggests real solutions to the creation of the digital infrastructure that India should be equipped with without intruding on the water security so valued by its citizens.

Development versus sustainability is not the point it is considered planning versus crisis management. India can be a first mover of models of green-digital infrastructure envied by the world or recreate the errors of the American communities that had to resolve between technological advancement and clean water. It is not yet closed, but the time to make the decision on a conscious level is running out.

2. OBJECTIVES

The analysis defines a few interconnected objectives that combine to provide an overall overview of the data-center water issue and the paths to its environmental sustainability.

To begin with, we must have a good understanding of the operation of data centers and their water consumption. Numerous discussions on digital infrastructure remain abstract and unaware of the physical reality that the cooling of thousands of running servers 24/7 is necessary. It is necessary to know physics of computing and heat management in order to evaluate environmental impacts.

Second, we collect actual data in locations where data-centers have already triggered water wars. The effects on local communities, groundwater and environment in Georgia and Virginia are observable in cities, measurable, nothing speculative.

Third, we discuss the specific risk factors in India. There are generic warnings on the water usage in data-centers that fail to provide essential details. The combination of pre-existing water stress, proposed growth, climate susceptibility and population density in India presents one of the rare risks that require specific evaluation.

Fourth, we consider the sovereignty factor that would make it strategically hard to just block data centers. Scandals such as Edward Snowden, Microsoft in Ireland, and continued geopolitical conflict demonstrate why countries have to regulate essential digital infrastructure despite resource constraints.

Fifth, we provide effective strategies that are technically viable and are founded on available policy examples. Mere call to sustainability is not enough without certain tools to control water sourcing, site planning, energy consumption, incentives to encourage innovation, transparency, community protection and regulatory regulations.

Sixth, we dispute the common measures of development where the emphasis is on investment and GDP but environmental and social costs are not taken into account. Sustainable growth has to quantify the real things, which are water security, energy sustainability and wellbeing of communities.

Seventh, we will seek to involve all the stakeholders. People should have the means of evaluating data-centers plans within their vicinity. The policymakers require evidence based advice on the allocation of regulations. Companies require strong motivational factors to become green in their innovations. Scholars should have research gaps that they can use to pursue further research.

The giant objective is not limited to data centers. It demonstrates that properly interpreted constraints can become drivers of innovation instead of obstacles to innovation. The lack of water and energy may drive India to develop the most efficient digital infrastructure in the world, developing intellectual property, competitive advantages and models that the rest of the world would learn. This can be accomplished through altering the perception that environmental boundaries are barriers and viewing them as the drivers of excellent distinction.

3. UNDERSTANDING THE THIRST HOW DATA CENTERS ACTUALLY WORK AND WHY THEY NEED SO MUCH WATER

3.1 The Invisible Infrastructure Behind Every Click

A series of events begin when you open your phone and stream an IPL match on JioCinema. Your device transmits the request using cell networks to a data center which can be hundreds of kilometers away. There

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are thousands of servers within that center that operate in climate-controlled rooms. A load balancer receives your request and causes it to go through one of the available servers. According to that server, it verifies your subscription, locates the video file that is distributed over a set of drives, selects a quality level according to your speed of connectivity, and divides the video into data packets. The packets are sent back with fiber optics to your phone which reassembles them and then allows them to play well. All this is done within a second.

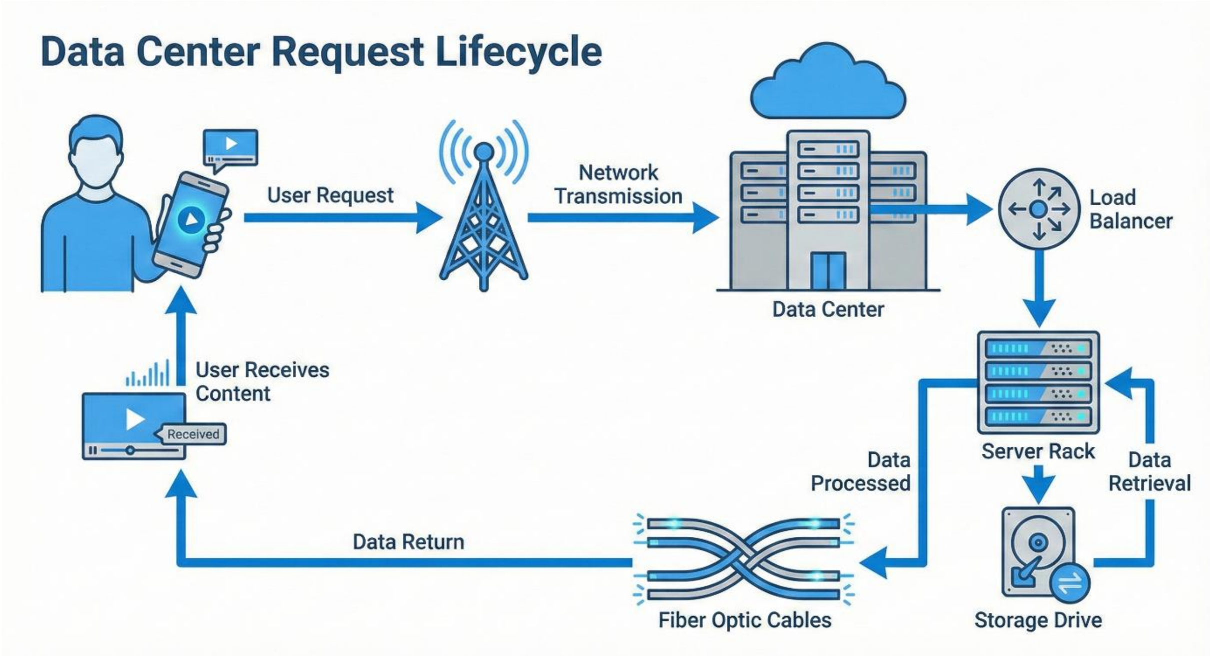

Fig -2: Data Center Request Lifecycle

All WhatsApp messages, UPI transactions, Instagram images and Google searches use the same hidden network. Data centers are giant computer warehouses, which store, compute and on-demand the delivery of digital content in real-time.

To understand the necessity of water, consider physical components of a data center:

- Servers - the computationally powerful computers.
- Storage systems- where the data including videos and databases is stored.
- Networking equipment- transmits information in and out of the servers.
- Distribution of power- power distribution provides dependable electricity.
- Backup batteries and generators - have the center running in times of unavailability.
- Security systems - safeguard the physical and electronic property.

All these parts produce heat. Servers operate around the clock, as opposed to the personal computers that do not. A single rack of servers can produce the same amount of heat as a huge home furnace being used continuously. This is on a small scale multiplied by hundreds or thousands of racks and the biggest engineering challenge is heat management.

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3.2 The Cooling Conundrum

Computation is an inevitable by-product of heat. Each arithmetic and data transfer generates heat. The heat itself is not harmful in small numbers but when it comes to the data center size, it can result in failures in servers or slower degradation of components. Failure of cooling systems results in failure of the complete system.

There are various cooling practices in the data centers, but the difference in large facilities is that water-based cooling systems are most effective as it absorbs and transfers heat much more efficiently. Air cooling is efficient when a small data center is involved but would be impractical on a large scale you would need massive fans which consume a lot of power and are not even as efficient as water.

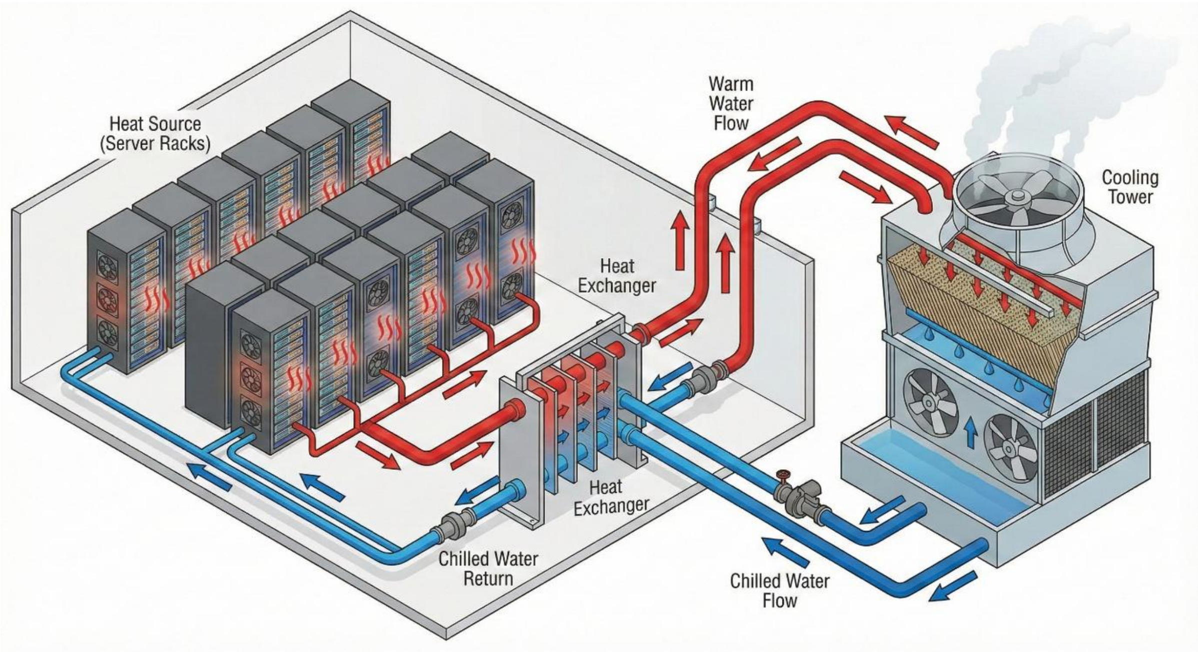

Fig -3: The Cooling Conundrum

Common water cooling takes the form of one of a number of layouts:

1. Chilled water systems - the cold water is circulated through heat exchangers around server racks and it absorbs heat and removes it.

2. Cooling towers- the warm water is then allowed to flow through towers where the heat is lost through evaporation into the air and large quantities of water are consumed.

3. Direct evaporation cooling- this is done by spraying water on the air streams in order to reduce temperature before it gets to the servers.

4. Closed-loop systems - here, the water is recycled in a loop, although, evaporation does still take place and it has to be replaced periodically.

The numbers get huge. Even a modest 100-megawatt data centre, which is small by today's standards, consumes approximately 2 million liters of water a day. That is an amount that accommodates about 6,500 American households or can fill an Olympic pool in three days. Heavy facilities in India can be planned to more than 1,000 megawatts more than 1,000 times the water requirement is multiplied.

Water consumption remains high with the computer load being low and the cooling systems are required to maintain the same temperature of the servers every time. Contrary to electricity, which flows and falls with traffic, water usage during the cooling process does not change much even as servers run all day and night.

3.3 The AI Acceleration Factor

Conventional data centers had predictable workloads email servers, web hosting, querying a database, and file storage. They had regular heat patterns that were simple to design. AI has changed everything.

The process of training massive language models such as ChatGPT takes immense amounts of data and is performed with the use of graphics processors (GPUs). During training, a GPU may consume 400 to 700 watts, whereas a CPU would consume 100-200 watts. The AI inference, the process of acting in response to user requests, even after training, consumes power. One hundred-word response of ChatGPT consumes approximately 0.14 kilowatt-hours and half a liter of cool water. Although these figures appear small, they add up in billions of questions a day, making small per-transactions a huge cumulative consumption.

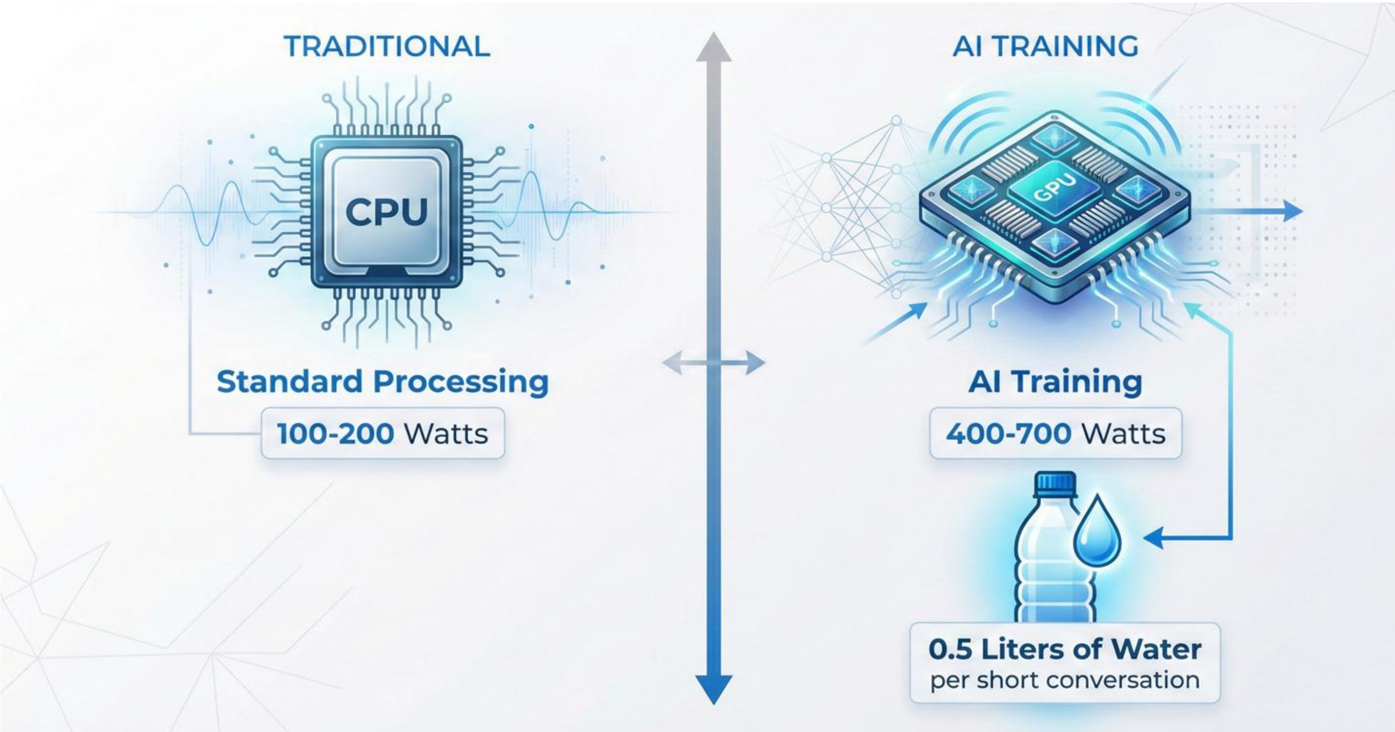

Fig -4: The Cooling Conundrum

Data has exploded with AI. The world carries approximately 2zettabytes of data in 2010. By the year 2020, that figure had increased to 64 zettabytes and it has been predicted to increase to 221 zettabytes by the year 2026. Growth has ceased to be linear it is exponential. The doubling of the annual 2010-2014 figures to 2014-2020 increased three to four times in every three to four-year period. The rapid growth began in 2020 and, as a result, recent development has significantly exceeded previous growth thanks to AI and the Internet of Things.

There is a variety of drivers behind this wave:

- AI training requires huge data.
- Self-driving cars transmit terabytes of sensor data per day.
- Video streaming transfers gigantic quantities of bytes.
- Cloud services are storage and processing consolidated.
- Cryptocurrency mining ensures round-the-clock running of rigs.
- Billions of pictures and videos are hosted on social media.

Each of these trends is a burden to systems a combination of them creates an unprecedented demand.

The actual issue is not wasting companies and unproductive designs. Heat at scale is caused by the physics of computation. Removing that heat of large scale installations can best be done with water. Since the water requirements of the computing needs are increasing exponentially, it will be impossible to break new grounds unless cooling efficiency can keep pace.

4. CURRENT TRENDS THE AMERICAN WARNING

4.1 Georgia's $40 Billion Dilemma

The state of Georgia emerged as one of the leading destinations of data centers due to a strategic approach. The state authorities provided tax breaks, eased the permitting process and enhanced power and fiber infrastructure. Technology giants monitored. The investment by Google, Amazon, Microsoft, and Meta in the state was over 40 billion dollars. Millions of square feet of new data center space were announced by Georgia alone in 2025.

The local governments rejoiced over what appeared to be an economic bonanza. There was payment of property tax to the data centers, temporary construction employment and technical staff was required in operations. Agencies of economic development emphasized the creation of jobs and generation of revenue as they addressed constituency. But the far side of the ledger had emerged. Rivers became less active in summer in Georgia. There was a reduction in the ground water levels in counties having large facilities. People living around the data centers were finding that their wells had less water or were even drying. Others poured buckets of water with sediments into toilets due to the failure of their primary sources.

The changes were documented by environmental activists. Server farms were built on beautiful pine woods. Millennia old streams were diverted to be used as cooling systems. Noise in cooling-tower was interfering with the sleep of residents. The juxtaposition was shocking the billion-dollar plants were placed right next to the struggling communities trying to make ends meet. One resident told him how contractors destroyed old trees that were more than centuries old in order to build space to place a data center and only to discover that his well could no longer sustain his household. Another one told me that he would then be able to fill storage containers in very short periods when the water pressure increased, and ration that to cooking and bathing since reliable access was no longer available.

The promised economic benefits that the communities would enjoy were not as high as anticipated. There are little permanent jobs made by data centers compared to their capital expenditure and resource utilization. Majority of the technical personnel are not regional. Although property taxes were beneficial to municipal budgets, it could not compensate environmental damage or a reduced quality of life. Georgia is experiencing a global trend. Hype is created by early announcements. Governments focus on amounts of investments and the number of jobs. Not much scrutiny on environment is conducted during approvals.

When the construction is completed and operations started, several years later, there are conflicts over the limited resources. Once that has happened it becomes legally, economically and politically difficult to undo the decision.

4.2 Northern Virginia's Loudoun County: A Cautionary Blueprint

Northern Virginia (Loudoun County), it had become the richest market of data centers in the world, having over 200 facilities. The power used by these sites is 4.14GW per day and requires 19 million liters of water every day to cool. The regional utility, Dominion Energy has publicly warned that by 2028 it needs to increase capacity by a factor of two and this raises very important questions about the infrastructure constraints.

The disjune between formal excitement and the life of the resident was sharp. The officials in the counties emphasized on tax revenues, which were allocated to schools and services. Loudoun was promoted as Data Center Alley by economic development agencies and as a result of this investment increased. But the inhabitants suffered water rationing during dry seasons, strain on power systems that worsened the quality of electricity, and environmental destruction that changed the previously rural nature of their neighborhoods. The decrease of water-tables was a great worry. Wells that had been a dependable source of water to homes and farms started to yield lesser water. The owners were forced to drill further at a high cost. The wells of others did not do so and they were forced to either use the municipal supply where one is available or truck the water in.

There is water consumption that is associated with electricity generation. Plants based on coal and natural-gas require significant cooling water those based on nuclear require even more. In this way data centers result in a twofold water load. The direct consumption of the facilities is in millions of liters. The power plants making them cost them more millions indirectly. Societies are affected by them simultaneously. Another problem was noise caused by cooling towers. These are operating systems around the clock and emit low-frequency sound continuously which disturbs the sleep of those living around the running system as well as reduces the quality of life of those living close to it. The data centers do not close down unlike the industrial sites that have fixed hours. The noise continues 24/7. The example of Loudoun County demonstrates that local governments can afford to rely on data-centers tax revenues, and yet the residents experience worse environmental quality. Authorities are under pressure to license additional facilities to ensure staffing to keep the cash coming yet current locations put pressure on resources and erupt in wrangles. This generates an uncomfortable situation where the rush money wins over sustained survival.

4.3 The Global Pattern Emerges

This happens in data-centers hubs worldwide. In Australia, water stressed facilities consume resources that are utilized in agriculture and residential purposes. The installations in Brazilian communities have the potential of growing, but they create strains on the environment. In Africa, countries aiming to invest in technology discover that data centers amass resources, exacerbating the disparities they have.

This has not been confined to America and not just because of regulatory failures in some regions. It is a foreseeable trend that arises when the data-centre development surpasses the planning and accounting of resources in the environment. Initial economic benefits in the form of real and small are a cover of the sustainability costs in the long run until the harm is difficult to reverse. The moral of the story is evident to India. Other countries have already experimented with fast data-center growth with lack of thorough sustainability systems. Findings are recorded rivers ran dry, aquifers were exhausted, and people were in conflict with what used to be a welcome addition. Governments find it difficult to reconcile economic gains and environmental expenditure and effects of the same. Foresight is an advantage to India. It is able to learn and make new strategies out of the mistakes that happened in the past. The sustainable data infrastructure technology is available. Elsewhere policy frameworks have been formulated. It is up to India to make the decision whether to use these lessons as an offensive or whether to make the expensive mistakes again and clean up afterward.

5. INDIA'S PERFECT STORM WHY WE'RE UNIQUELY VULNERABLE

5.1 The Numbers Don't Lie

The water crisis in India does not depend on data centers. The figures depict a country that is approaching an extreme level of resources. Navi Mumbai geographically experiences 80 million liter per day of water shortage. The deficit of Delhi NCR is 1,100 million liters per day. Chennai fights with 713million liters. Hyderabad is deficient in 300, 000,000 liters per day. They are not estimates or worst-case scenarios they are actual existing shortages that impact tens of millions of individuals.

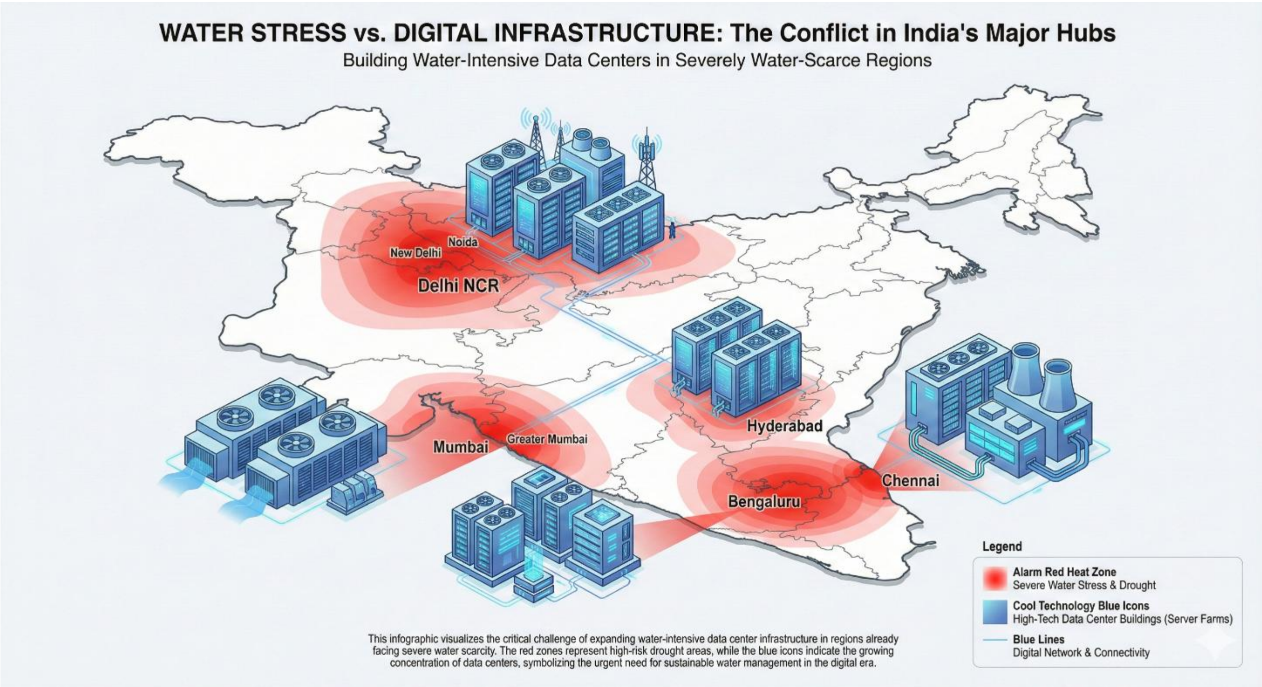

Fig -5: Water Stress Vs Digital Infrastructure

When the data-center expansion map is overlaid with it is seen that major facilities are targeted at Navi Mumbai, Bengaluru, Delhi NCR, Chennai, Hyderabad as well as Kolkata, already water stressed. It is self-contradictory India intends to build infrastructure that needs a lot of water precisely at the point of shortages. All the data centers will be competing with the residents, agriculture, and industry over already insufficient resources.

The larger picture makes it more worrisome. According to NITI Aayog research, 163 million Indians do not have clean water today, not tomorrow. Tables of groundwater decrease annually because of the surpassing of recharge over extraction. The same report cautions that in the following year, 2030, 40 per cent of Indian cities would be without drinking water unless the situation is drastically addressed.

These challenges are aggravated by climate change with erratic monsoons. Every weather pattern that has been in operation since agriculture was practiced centuries ago, and recharged aquifers, is now unpredictable. There are parts that are flooded with others facing chronic droughts, even in the same year. Gaining temperatures cause higher rates of evaporation which reduces surface water amounts when cooling is at its highest need.

5.2 The Scale of Planned Growth

The number of data centers in India is approximately 270. As opposed to this, the U.S. has more than 5,300, U.K. 514, China 449, and Australia 307. India generates 20 per cent of the world data yet retains only 3 per cent of the same locally making colossal growth unavoidable. It is this gap that introduces national-security vulnerabilities which digital-sovereignty initiatives target.

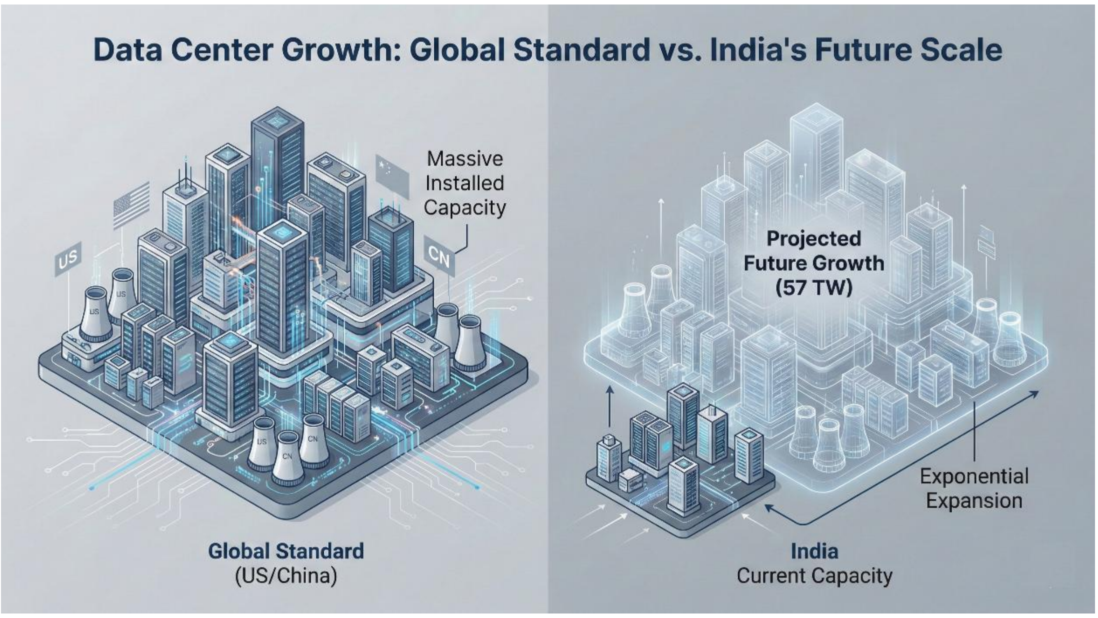

Fig -6: The Scale of Planned Growth

It is estimated that the Indian data centers will consume 57 TW of electricity in the coming 2030- almost three times of the amount that Indian Railways consumes in one year. Every terawatt-hour of generation needs cooling water, typically of freshwater, which poses an indirect demand outside that of the direct use of the data centers.

Prospective facilities are huge compared to present ones. Jamnagar hub of Reliance is aimed at gigawatt capacity. The 10 billion dollars Adani has invested in various states will create plants that are 30 times greater as compared to a normal 100-MW plant. Assuming that a small plant supplies 2m liters per day, these giants will require 60mliters per day and beyond. Such plants in water stressed cities will generate aggregate demand equal to large city water systems.

5.3 Climate Vulnerability Multiplier

These problems are aggravated by the climate trend in India. There is an increase in average temperatures at a higher rate than the global averages. The heat waves become more common and even extreme, the monsoon pattern becomes spontaneous as it becomes hard to predict, and the Himalayan glacial melt becomes accelerated, thus offering temporary plenty at the expense of long-term scarcity as ice deposits declines.

During the times of water stress, when the supply is most strained e.g. the summer months when water tempos rise to their highest and water levels sink to lowest water centers will compete over water. The data centers do not have the ability to postpone irrigation, as it can be done in agriculture, or diminish their operations, as is the case with industries, but to ensure availability of constant cooling.

The combination of this triad of troublesome trends, which is the increasing data demand, worsening water security, and climate instability, has become disastrous. Each of these is a critical planning and investment concerning the management of any of them when dealing with all three together, we need wide-ranging structures that are still lacking in the majority of development discourses.

The paradigm of conceptualizing the vulnerability of India acknowledges that the problem is not the fact that data centers are using water. It entails multifaceted relationships between technology infrastructure, availability of natural resources, climate dynamics, population density, economic growth and governance capacity. Remedies should be aimed at these links and not solutions in isolation.

6. THE SOVEREIGNTY ARGUMENT WHY WE CAN'T JUST SAY NO

6.1 The Edward Snowden Lesson

Edward Snowden revealed the U.S. surveillance programs that tapped data of tech giants, which include Google, Facebook, Microsoft, Yahoo, and Apple, in programs such as PRISM in June 2013. The user data of these companies were stored in U.S. servers, which were subject to the U.S. legal regulations, including the Patriot Act and the F.I.S.A. orders.

Fig -7: Digital Sovereignty

The disclosures revealed that foreign states could obtain data that was stored in their jurisdiction servers. Brazilian authorities came to know that there were surveillance of communications by President Dilma Rousseff by the United States agencies. The German Chancellor Angela Merkel found out that her phone was targeted. Even close allies were appalled by the size of the surveillance.

The implication of this to India is far reaching. When the payment information is stored on foreign servers, foreign intelligence agencies can gain access to it by legal procedures within the jurisdictions. In case there was a healthcare record overseas then patient privacy will depend on the overseas laws that may not be consistent with the Indian standards. In case defense communications are passing through foreign data centers, there would be vulnerability to espionage in regard to operational security.

Sovereignty dilemma is greater than privacy issues. It poses basic issues of countries being independent in the digital world. Does a country with international aspirations permit vital information infrastructure to exist on the jurisdiction and authority of overseas law.

6.2 The Microsoft Ireland Case

The United States law enforcement requested a warrant to access emails held in Ireland by Microsoft servers in 2013. Microsoft which is an American company declined to comply claiming that the information in Ireland was under the jurisdiction of Irish and EU privacy laws. The U.S. legislation could not force the creation of information that was geographically situated in another country and was subjected to the jurisdiction of the law.

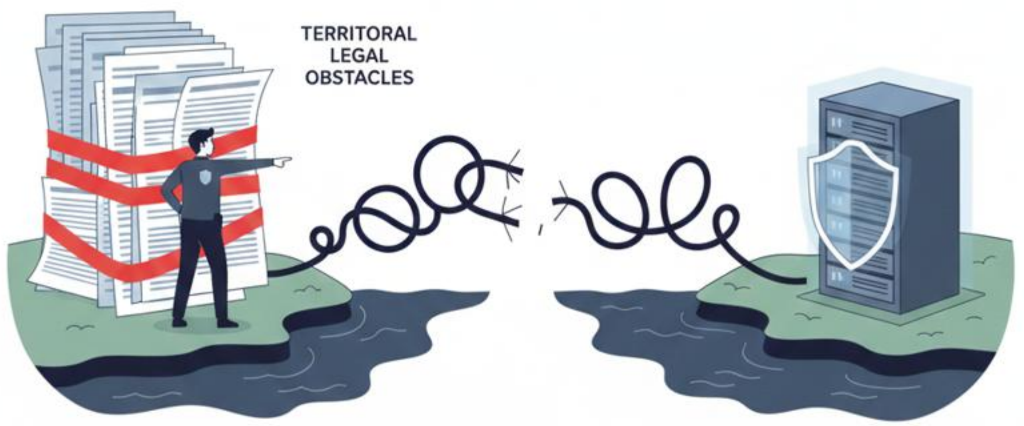

Fig -8: Territorial Legal Obstacles

This case took years to pass through the courts before it was declared moot by changes in the law. However, it set a central rule Countries without control over their data infrastructure cannot secure the information of citizens comprehensively and implement their own laws in the course of investigations. When the Indian law enforcement requires the data in case of criminal investigations, yet the data is located in another country, cooperation is the process of diplomatic negotiation instead of the legal guarantee.

The alternative is also problematic. The data of the foreign governments may be accessed in their territory without regard to the citizenship of the data subject or the nationality of the company in question. This creates an unequal advantage to countries lacking domestic data infrastructure.

6.3 Digital Sovereignty as National Security

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Data sovereignty is urgent in India due to the country-specific vulnerabilities. Aadhaar is a program that has biometric and demographic records of more than one billion individuals. UPI handles hundreds of billions of transactions with trillions of rupees every year. The systems of defense logistics, intelligence gathering and critical infrastructures are becoming more dependent on digital platforms. When these systems rely on foreign servers then they are leverage points in geopolitical fights.

Take a reasonable situation the situation escalates with a neighboring country. The host country of the Indian data infrastructure is well acquainted with that country in terms of diplomatic relations. An effort of pressure, either covert or open, is put to limit access or face closure. Foreign policy makes India a hostage to the operations of the critical services, which interfere with sovereignty and security.

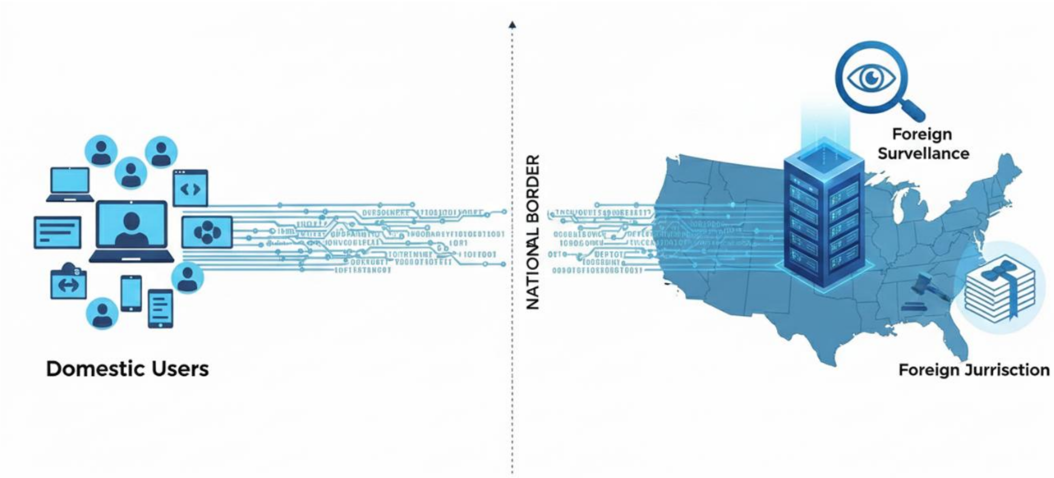

Fig -9: Cross Border Data Vulnerability

Reserve Bank of India has already identified these risks by making sure that information of the payment systems stay in India. This was a contentious requirement at the time it was implemented because it was seen that the integrity of the financial systems is based on the physical control of the infrastructure on which the transactions are being processed. The same is true of payments as of other critical areas.

Data sovereignty is not a paranoia or tech nationalism. This is elementary strategic planning of a country having international aspirations. Whether India is in need of domestic data infrastructure or not is not the issue- the need has been proven. The question is how to create that infrastructure in a sustainable way that would not provoke environmental crises that data centers are supposed to make possible.

7. THE PATH FORWARD TO SEVEN STRATEGIES FOR SUSTAINABLE DIGITAL INFRASTRUCTURE

7.1 Strategy 1: Mandate Alternative Water Sources from Day One

Amazon Web Services declared that it starts to utilize recycled water to cool down and cool the data centers which are going to be over 120 in the United States by the year 2030. This promise will conserve more than 530 million gallons, about 2 billion liters, of freshwater every year. The technology has been tested, the economics are feasible and the environmental impacts are significant.

India must require newer data centers to prepare elaborate water sustainability policies before being allowed to be constructed. Such plans have to give more focus to non-drinkable water sources such as treated wastewater of municipal systems, industrial processes water, and seawater in coastal places with desalination facilities and those systems which are closed to prevent the use of fresh water through recycle.

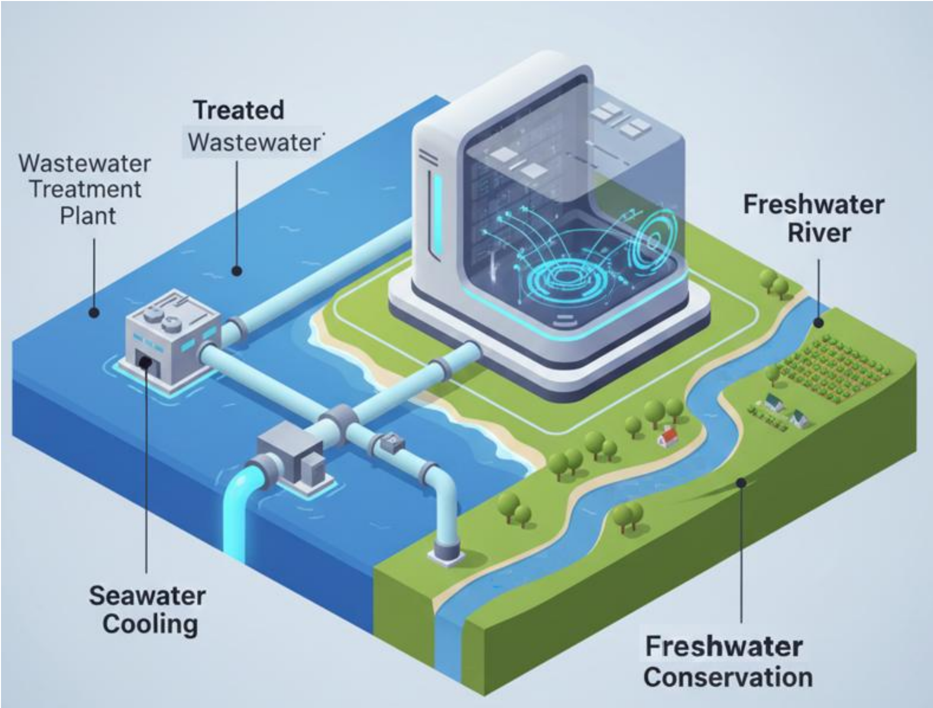

Fig -10: Mandate Alternative Water Sources

The treated wastewater is a vast unexploited resource. In most cities of India, sewage is partially treated or not treated, and discharged into rivers and the coasts. The purpose of treatment infrastructure upgrade to generate industrial cooling-fit water has several purposes it lowers pollution, provides the alternative source of data centers, and liberates freshwater to house and agricultural needs.

Seawater cooling is not available everywhere, and the costly seawater is available exclusively in seaports, such as Jamnagar. Seawater has an almost inexhaustible cooling capacity with proper intake design to safeguard marine ecosystems and proper discharge treatment to avoid thermal pollution without using freshwater resources. Seawater costs are higher than freshwater options, although the sustainability of the investment is reaped in the long run.

In closed-loop cooling systems, the water is recycled, and relatively small amounts of water are lost to evaporation, but only periodical replacement is necessary. Although these systems do not stop the use of water completely, they do cut down the consumption by 90 percent or more than the once-through or conventional cooling tower designs. Laws ought to encourage closed-loop designs by allowing permitting or tax breaks.

The system should clearly ban or highly limit the use of fresh water, which is drinkable, in cooling the data centers in regions where there is a shortage of water. Businesses ought to have a responsibility of demonstrating that no alternative is technically or economically practical instead of falling to fresh water due to it being cheapest or most convenient. Sustainability must not be an addition that can be promoted later when the problems arise.

7.2 Strategy 2: Strategic Geographic Planning

It is not found in every location that supports water-thirsty data infrastructure. India requires a country-wide site selection system that considers the location in terms of water supply and stress rates, availability of renewable energy, weather conditions that support natural cooling, geological stability and proximity to already water intensive urban areas.

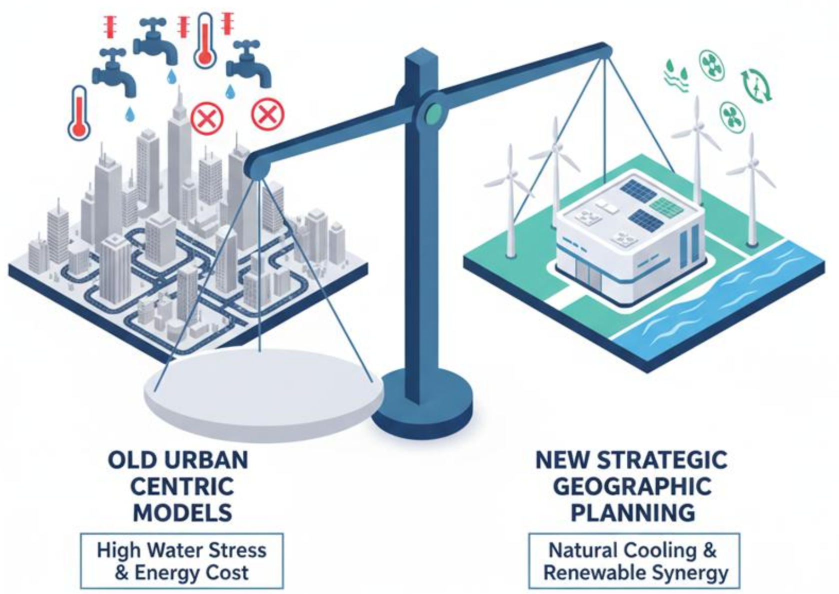

Fig -11: Strategic Geographic Planning

Data center development should be given incentives on water rich areas. Locations that experience consistent rainfall, good recharge of aquifers and those that have access to surface water can be used to have facilities that have reduced environmental stress. On the contrary, the areas that are already deficit-prone are to be limited or even banned in the use of water-consuming installations.

Jamnagar is strategically positioned at the coastline and this fact gives it natural advantages that cities at the interior are not able to enjoy. Cooling of seawater eliminates the use of freshwater. Temperatures that are moderated by the ocean decrease cooling needs in comparison to interiors of continents. Equipment delivery is promoted by the closeness to large ports. The expansion plans should be informed by these factors with development mostly focused in areas where there is an environment carrying capacity.

Data centers are drawn to countries such as Iceland due to the low cooling costs since the cold climate in the area makes the cooling cost incredibly low. The natural outdoor cooling is free and much of the year, it eliminates the need to use water and less energy. The geographic diversity of India has areas with climate benefits Himalayan foothills, high-altitude plateaus, as well as coastal areas having stable sea breezes these provide natural cooling benefits which lowers the impact of the environment.

Renewable energy availability should also be considered in the strategic planning. Areas that receive good sun or wind power can be used to serve data infrastructure with little use of water to generate electricity. Placing data center location in coordination with renewable energy development will form synergies to handle the issue of power and water at the same time.

The framework must not encourage or even allow development in Delhi NCR, Chennai, Hyderabad or other cities with a high level of existing shortages unless the facilities can show that they can source water with no reliance on stressed municipal or aquifer supplies. This limitation is a simple resource accounting. Constructing water-thirsty structures in areas that do not have water is inherently unsustainable, when it comes to the economic factors.

7.3 Strategy 3: Aggressive Renewable Energy Integration

Renewable energy is of importance to data centers even on top of reducing carbon emissions. Thermal power plants require a lot of water as opposed to solar panels and wind turbines. The amount of coal facilities use in cooling is enormous. Plants that use natural gas require large quantities although less than coal. Water is the most needed in any power production sources that are nuclear. A doubled water burden is created by the fact that data centers that obtain electricity by fossil fuel or nuclear generation cause it.

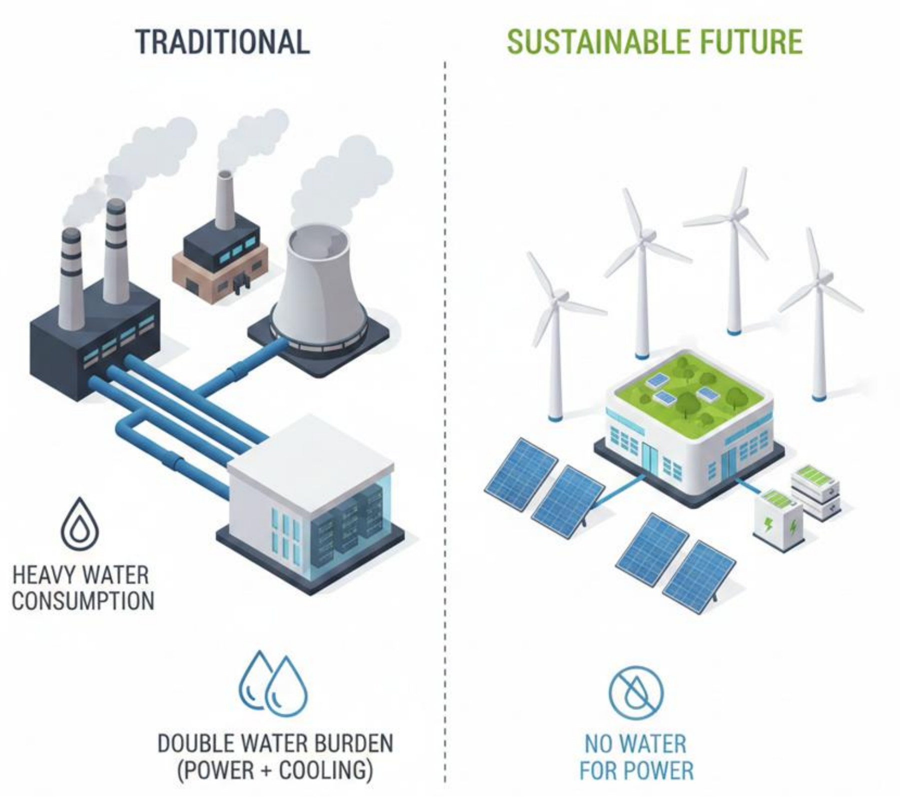

Fig -12: Aggressive Renewable Energy Integration

This relationship has been realized by technology companies around the world. In some mixes of solar, wind, battery storage, and complex grid management, Google became 24/7 carbon free in some of its facilities. Microsoft is also investing in the next-generation small modular nuclear reactors that will be used in the data center with enhanced water efficiency. Apple runs its data centers on a 100 percent renewable energy. India ought to speed up solar capacity development and wind capacity development with a specific designation in data infrastructure. Develop special renewable energy areas with simple permitting and transmission systems set up to house data centers. Provide substantial rewards to facilities that attain high percentages of renewable energy, and maybe provide an exception to some percentage requirements on water consumption provided fossil fuel production is eliminated.

It is not limited to the sustainability of individual facilities. When India establishes itself as a destination of environmentally responsible data infrastructure, it will also appeal to companies that will be under pressure on their part by the investors, customers and regulators to enhance their sustainability measures. This ends up as a competitive distinction as opposed to a compliance cost. India does not only provide cost benefits, but also provide leadership in environmental fields that further improve the corporate reputations and fulfill the expectations of the stakeholders.

The conversion of solar energy to power especially works well with data center processes. The time of maximum solar generation during midday is associated with the maximum cooling loads on hot days. Although the ideal fit cannot be achieved without storage, the solar-heavy generation profiles are more aligned with data center consumption patterns than a number of industrial uses. A combination of solar generation and battery storage during nights and the grid connections in the cases of a backup forms some of the most sustainable setups.

7.4 Strategy 4: Technology Innovation Incentives

The cooling technology is in a continuous development. The Immersion cooling immerses servers in non-conductive liquids which are better cold sinks than air or water. The liquid is further cooled and recycled in closed circulation loops which save on the amount of water being used. The immersion cooling at scale has proven to be viable by Microsoft and other companies. Though capital costs are more as compared to conventional methods, the investment can be justified by the savings on energy and water usage.

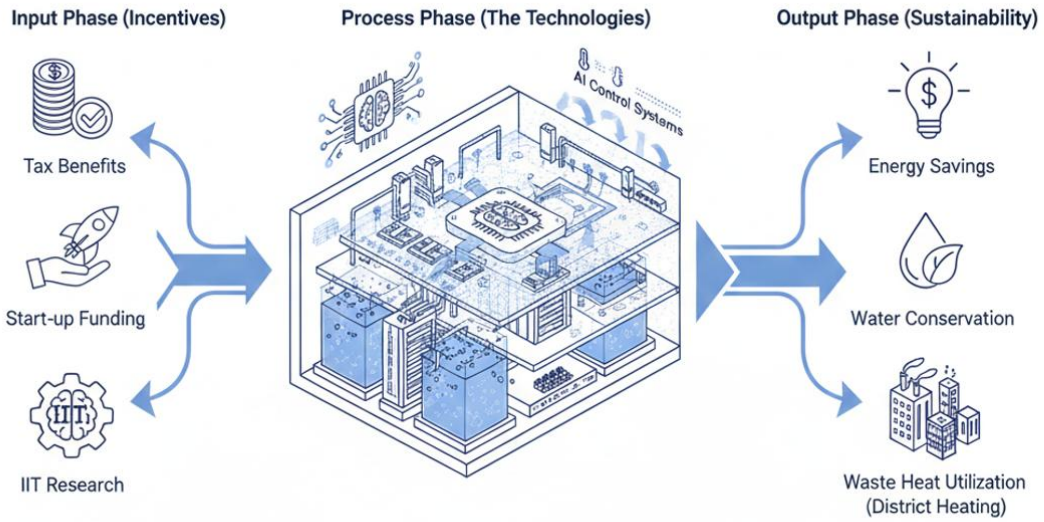

Fig -13: Integrated Framework for Data Center Efficiency

Optimized airflow, use of hot and cold aisle containment and high level of controlling of temperatures are some of the advanced air cooling measures to ensure maximum efficiency. During colder seasons, outside air can be used to offer a significant amount of free cooling in the appropriate climate. Technologies in evaporative cooling are still being developed, using less water to achieve the same thermal management.

Machine learning itself proposes its solutions to its problems. AI systems are capable of forecasting thermal loads using computational scheduling, weather forecasts as well as past trends. This predictive nature also allows proactive cooling changes to be used that helps save on water and energy use than reactive systems that react to changes in temperature once it happens. Waste heat can be recovered through heat recovery systems and put into productive use. Data centers generate very huge amounts of thermal energy that is currently being released to the environment. Such heat would be able to warm up buildings, assist industrial processes that necessitate moderate temperatures, or power absorption chillers that will provide more cooling. Though heat recovery is more complex and expensive, it turns waste into resource.

India ought to provide tax exemption, expedited license, and direct grants to plants deploying state-of-the-art efficiency initiatives. Develop competitions wherein Indian startups are challenged to come up with new cooling solutions that suit the local conditions. Fund studies at IITs and other organizations that pay emphasis on water efficient thermal management. Develop local skills and intellectual property in sustainability technologies and not bring in solutions that have been developed in different settings. This is aimed at ensuring that sustainability becomes economically viable as opposed to imposing it through regulations alone. The efficiency investments by the companies should be clearly seen with the reduction in the operating costs, a tax benefit, quicker approvals and receive the credit of the investors that are environmentally conscious.

7.5 Strategy 5: Transparent Water Accounting

Power Usage Effectiveness (PUE) is a common metric that has been adopted in the operations of data centers. It is a ratio of total facility energy utilization to energy utilized by computing equipment alone. The PUE of 2.0 implies that the facility is utilizing twice the power of the servers themselves, and the rest is being used on cooling, lighting, and other overheads. The leaders of the industry industry attain PUEs that are lower than 1.2 by means of optimization of efficiency.

India must have a similar level of water consumption standardization. Water Usage Effectiveness (WUE) is a measure of liters that are used per kilowatt-hour of IT equipment energy. The measure allows cross-facility comparison, the identification of best practice, and the active improvement on the same. There are several purposes of transparent public reporting of WUE data.

When consumption can be observed, accountability is enhanced. Plants that are aware that their water consumption will be publicly published and compared to others which will provide them with an incentive to maximize efficiency. When the data on the consumption is solid and not made by the promotion efforts, communities can make informed choices regarding suggested installations instead of basing their choices on the promotion texts.

The competitive forces lead to increment of efficiency in situations where firms are able to show better sustainability performance. Other data center operators that are selling to clients who care about the environment will invest in water reduction where it can be determined and proven. Transparency converts sustainability as a commitment to achievement.

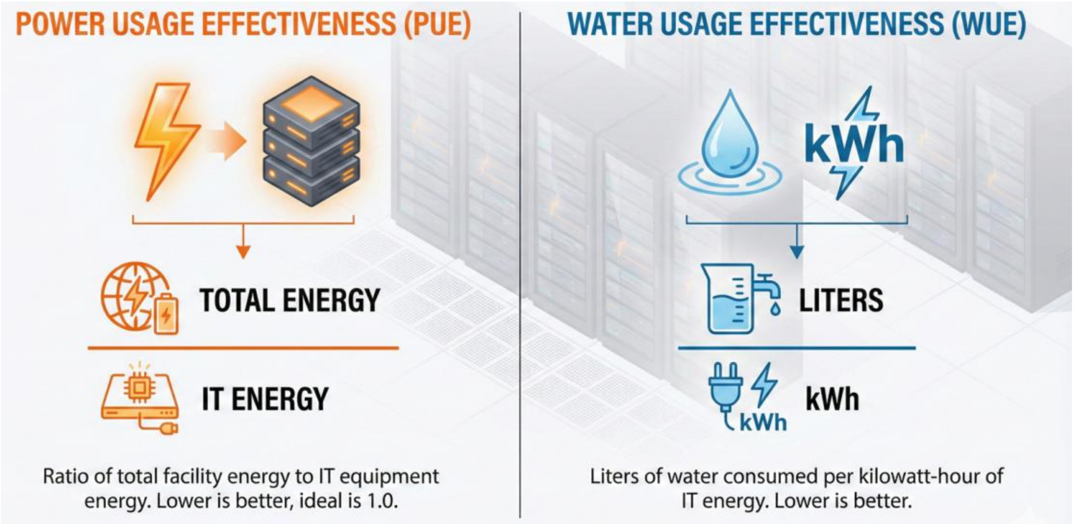

Fig -14: Transparent Water Accounting

To develop effective regulations and assess their effects, policymakers should have available good information. In the absence of standardized measurement and reporting, the design of policy will be based on an estimate and projection that might have little connection to reality. Evidence-based governance is made possible through transparency.

The policy framework must include the reporting of the water usage on a quarterly basis, by source, measures of efficiency, and percentage of recycling. The information must be made publicly available in the form of searchable databases where the community and researchers can analyze the information. Those facilities not reporting or giving inaccurate data ought to be punished heavily including possibly being denied the right to operate.

7.6 Strategy 6: Community Benefit Agreements

Community Benefit Agreements (CBAs) are used in mining projects in different jurisdictions to hold developers accountable to certain promises to protect the local population. Such agreements normally address the employment assurances, infrastructure investments, environmental surveillance, and conflict resolution procedures. The same structures must be used on data centers.

Data infrastructure CBAs must specify water availability to residents at a certain level irrespective of the data center usage, investments in local water supply infrastructure such as treatment plants and distribution networks, noise control through set go requirements or acoustic barriers as well as emergency plans that the data centers should use less water during times of severe shortage.

The contracts should be enforceable and legally binding by means of the regulatory measures, as well as by initiating a legal injunction by the affected parties. Financial penalties in case of violation must be high enough to bring in adherence and not to recognize fines as an option in business expenditure.

It is important to have community representation in the bargaining agreement. Developers should not offer take-it-or-leave-it terms to the residents and the local authorities. The imbalance of power between international business and the native population necessitates procedural safeguards against unfair bargaining.

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Fig -15: Community Benefit Agreements (CBAs)

Georgia has shown what will occur in the absence of such protections. Data centers were embraced by communities on the basis of promises that turned out not to be as valuable as promised and incurred costs that were misestimated or not provided at all. The facilities were in operation and reversing decisions was not easy and legally difficult by the time the conflicts came up. Prior to construction, CBAs negotiated set up enforceable obligations to avoid such a scenario.

7.7 Strategy 7: Phased Implementation with Trigger Mechanisms

Instead of granting huge size facilities at the first instance, India must introduce the phased approval systems of which the first-level construction can only be implemented once they show water sourcing through non-portable sources, their ability to have a renewable energy percentage, and evidence of community water security. Further growth at advanced stages demands that sustainability standards and environmental impact evaluation be addressed in which the real impacts of the project are checked against forecasts.

There should be automatic review activations in case the local water tables have fallen below the set levels, the community wells malfunction at the rate that is stipulated at the baseline, or the pollution caused by the operation of data centres is identified. These triggers need not be an absolute invoking shutdowns, the triggers need to be investigated and contained before further expansion is done.

This new model of governance is adaptive to real effects, as opposed to hypothetical ones. Projections are uncertain, models are assumptions. The actual practical results of some things are not always as predicted. Regulatory frameworks must be aware of this uncertainty by providing monitoring and adjustment systems.

The gradual rollout also diffuses the infrastructure investment over time, and the water systems can adjust to it and the communities can decide on the benefits and costs based on the real experience and not the promises. When initial stages show a positive sustainability incorporation, further growth continues. In case of issues, it is possible to implement solutions before the harm is caused.

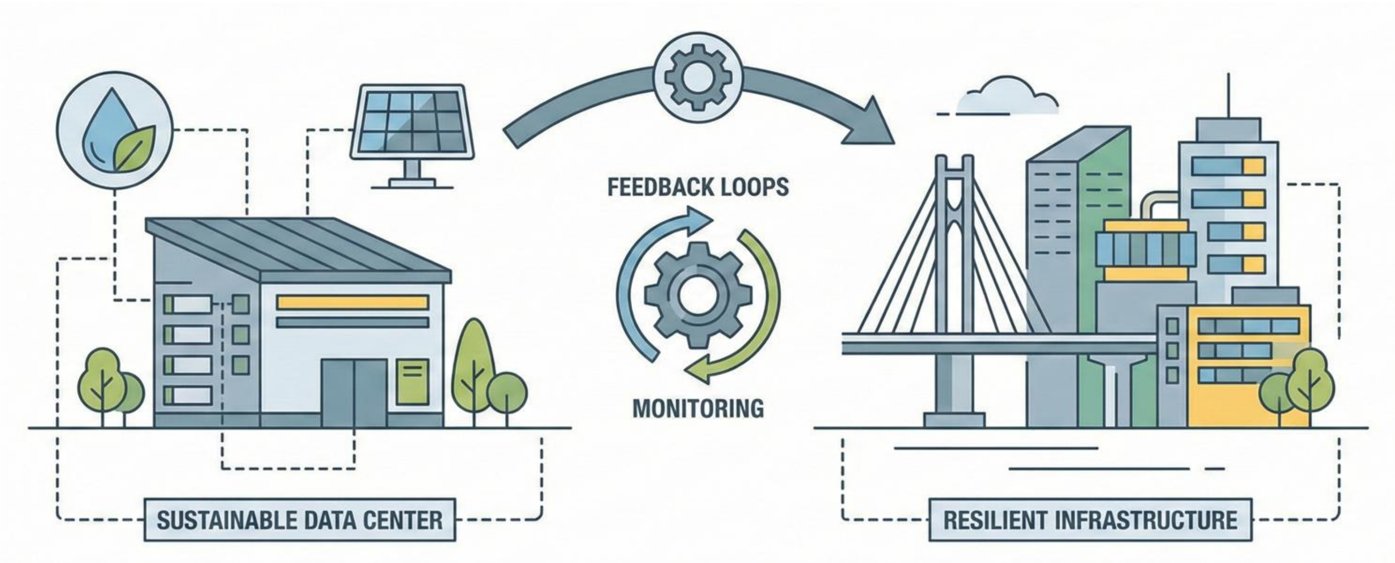

Fig -16: Adaptive Governance in Infrastructure

The system of governance acknowledges the fact that it is not possible to have perfect foresight. Instead of putting all your eggs in the initial analysis and hoping that it is right, construct feedback loops in such a way that there is correction in the course depending on the results that are being monitored. That is the way, complex systems are managed in a responsible way in uncertain contexts.

8. THE LARGER VISION REDEFINING DEVELOPMENT FOR THE 21ST CENTURY

8.1 Beyond GDP: Measuring What Matters

Conventional development indicators that are used are investment and GDP growth that do not take into consideration the environment and social costs. A data-center initiative can cost billions of dollars, become a major boost to the state GDP, and provide numerous jobs. These numbers usually dictate grants and political support.

They omit things such as depletion of water-table, which does not enter into GDP. Inaccessibility of the wells to the residents cannot be recorded in job statistics. The losses suffered to the environment are only reflected on the books of accounts when recovery has to be carried out. In this way social cost of resource usage is really paid by communities and the future generations.

India must embrace macro-indicators of water-security such as access, reliability, and quality energy-sustainability ratios such as comparing renewables to fossil fuels community-level wellbeing polls that can capture quality-of-life beyond employment and income and intergenerational environmental models that take into account climate change, resource depletion, and ecosystem health.

These measures should be given equal weight as the conventional economic indicators when making approval decisions. A project which generates employment but jeopardizes the security of water will not pass the overall test. Equally, the long term environmental sustainability could be compromised by development that increases the GDP in the present but undermines prosperity in the future.

This does not oppose development. It only requires that development must be put to its fundamental purpose improved human life. When basic needs like clean water are no longer available due to infrastructure reduction, then it is a failure of that objective, no matter how much money has been invested or how many people have gotten jobs.

8.2 Conscious Capitalism in Action

Conscious capitalism makes a distinction between opposition to progress and the demand of responsible progress. India can demonstrate to the world that it is possible to have digital infrastructure and environmental sustainability. This makes sustainability a competitive advantage rather than a liability.

Customers and companies now value those businesses who have strong sustainability history. Stakeholders encourage investors to consider ESG in their investments. Consumers of younger age tend to favor companies that are environmentally responsible. Governments are also faced with pressure by the electorate and the global community to address climate change and the preservation of resources.

The promise of India to become the worldwide greenest data infrastructure attracts the high-quality investment by companies that should demonstrate their sustainability. It puts India in a unique competition in the tight race of data-centers locations in the world. It also birches IP in efficiency technologies which can be disseminated to other nations with the same adversity.

The skeptics see sustainability as a burden imposed by activists which increases costs and reduces competitiveness. Strategists perceive it as a chance to develop distinctive capabilities unavailable to the competitors and hence India is a solution-giver rather than a problem-giver.

8.3 Learning from History

The industrial pollution in the developed nations during the 20 th century catalyzed massive cleanup expenses and health issues that in most cases overshadowed the financial benefits. Deforestation of the land in agriculture drained the soils, disrupted water cycles and produced permanent loss of productivity. The development of slums, poor infrastructure and intergenerational social issues were a side-effect of unplanned urbanization. Development always surpassed environmental planning and the outcome was much more expensive to rectify than prevent. It is many times more costly to add sustainability to the system that was not designed to have it, than to make it sustainable at the beginning.

India can take lessons out of its errors but not repeat them. Knowledge is available. Technology exists. Best tested policy frameworks have been tried in numerous locations. Political goodwill and long-term determination are the only way that success can be achieved, yet the road is understood. Development must be viewed as a means to human flourishing not as an end to itself. Infrastructure is supposed to enhance living. Data centers fail their function in case they reduce the basic needs like water. Money is just relevant to the degree that it enhances the lives of people. Any business that undermines primordial security and wellbeing has failed in the development regardless of the input of GDP.

9. CURRENT ACTIONS AND INDUSTRY RESPONSE

The story about India sleepwalking into a water crisis overlooks one significant fact policymakers, industry leaders, and researchers are already taking steps to address the issue. The difficulties are enormous, and the speed of reaction should increase, yet the ecosystem of governmental programs, business pledges, and creative pilots is growing all over the nation. This chapter looks into what is already being done as well as what such initiatives say about Indias ability to establish sustainable digital infrastructure.

9.1 Government Initiatives Already Underway

The regulatory environment of sustainable data centers in India is rapidly developing, as the importance of environmental considerations cannot be an out-of-the-box measurement in the digital transformation of the country.

9.1 .1 The Green Data Center Policy Framework

In 2023, the Ministry of Electronics and Information Technology (MeitY) published an extensive set of guidelines on the development of green data centers, and it is a big step that can change the approach towards digital infrastructure in India. The policy provides minimum energy efficiency, water use, environmental impact standards that every new facility will comprise.

The guidelines propose a level-based certification model that mirror the LEED (Leadership in Energy and Environmental Design) standards but modified to suit the Indian conditions. Depending on their performance in several indicators of sustainability, data centers can obtain Bronze, Silver, Gold, or Platinum ratings. In order to become Gold certified, such as a facility, one must have a Power Usage Effectiveness (PUE) ratio that is less than 1.4, obtain at least half of its energy through renewable sources, and use closed-loop water cooling systems that consume 80 percent less freshwater than conventional systems.

The policy is not just the voluntary compliance, but it renders green certification to facilities who are interested in receiving government contracts or partnerships. Any government data center that wants to bid on cloud services to the central government must now be at least Silver certified and the sustainable design is now under market pressure. Initial statistics indicate that this need is effective. Out of the 47 data center projects which submitted environmental clearance applications within the first six months of the policy implementation, 38 of the projects had comprehensive water recycling systems as compared to only 12 out of 52 projects which had been submitted within the six months prior to the policy implementation.

The interesting aspect about the approach to India is that it recognizes the variation in the region. The guidelines do not put generic requirements but rather set various standards between water stressed and water rich areas. In Chennai, where groundwater depletion is high, water usage limits are tighter as compared to Kerala, where rainfall is higher. This geographic subtlety indicates the advanced knowledge of the Indian varied hydrological setting.

The policy also provides financial incentives in terms of accelerated benefits of depreciation. Data centres that surpass the minimum sustainability standards have been allowed to enjoy up to 40 per cent. depreciation in the first year of operation unlike the 15 per cent. of the conventional data centres. Such a taxation system is economically appealing to sustainable design rather than green.

9.1.2 State-Level Environmental Clearance Requirements

Although national policy is establishing the baseline, certain states are going even more quickly and even further. The Maharashtra state which hosts some of the largest concentrations of the data centers within the nation would now need water impact assessments to any IT loads of the center with more than 5 megawatts. These tests should model the water consumption of the facility under a 20 years period of facility functioning and prove that local aquifers are able to meet the demand without deteriorating the use of the water by adjacent populations.

Three data center plans in Maharashtra alone have been rejected by the Maharashtra Pollution Control Board in the last one year particularly over water issues, which clearly indicates that environment clearance is not a routine. In one instance where a 15-megawatt plant was to be established near Pune, the regulators refused to sanction the plant after hydrological tests indicated that the proposed location was over an already overstressed aquifer which had been serving 40,000 people in the surrounding villages. The developer has been given a chance to be approved in a different site with more water supply and they accepted it.

Karnataka has also followed a different line where they have emphasized on the water recycling requirements as opposed to the location requirements. New data centers in the state must recycle at least 60 percent of their water consumption during the first year of operation, which will require 80 percent at least in the third year. The facilities are required to have real-time systems of monitoring that will report on the water consumption data to the state regulators after every month. The failure to do so will allow graduated penalties, which will begin with fines and could become operational restrictions.

Karnataka model is giving quantifiable outcomes. The first 12-megawatt plant in Whitefield, which became operational at the end of 2024, is already recycling 72 percent of its water in its initial months of operation, far earlier than required. Its cooling systems wastewater is treated to meet landscape irrigation and toilet flushing standards and save about 1.8 million liters each month of freshwater.

Tamil Nadu has done the most in terms of factoring in water in the process of approval. Now the state compels the data center operator to acquire water credits equal to its estimated consumption during the first five years of operation. Through these credits, watershed restoration initiatives, rainwater harvesting systems, and enhanced community access to water in the same district as the facility is in operation are financed. It is a variant of carbon offsetting to water, which organizes a system where the development of digital infrastructure makes direct investments in enhancing water security.

9.1.3 Tax Incentives Driving Sustainable Infrastructure

In addition to regulation, tax policy is also being employed by India to hasten sustainable data center development. In 2024, the Union Budget came to the rescue with a range of incentives aimed at green digital infrastructure.

Data centres using 75 percent or greater percentages of renewable energy now receive a reduced rate of construction material of 12 percent under the Goods and Services Tax (GST) in place of the usual rate of 18 percent. In the case of large facilities the difference may be as much as 50-100 crore (around 6-12 million) and hence solar panels, superior cooling systems and water recycling equipment would be much cheaper.

Some states have added more incentives to federal benefits. The state of Gujarat provides a full exemption of electricity duty on data center which attains 100 percent of renewable energy in three years of operation. Data centers that subscribe to water neutrality (i.e. returning the same volume of water to the local systems through the recycling of water and rainwater harvesting) are offered land by Telangana at subsidized rates.

These motivators are transforming the calculations of investments. In the case of CTRL's Datacenters, which is one of the largest operators in India, the financial models of the business indicated that the tax savings achieved through establishing a sustainable facility would be used to counterbalance the increased cost of building a sustainable facility in four years. The company chose to incorporate a design that involved the use of rain water harvesting, solar panels that are a quarter of the roof size, and an advanced cooling system that involves the use of indirect evaporative cooling which promotes 40 percent usage of water as compared to the conventional methods.

The outcomes can be observed in the patterns of investment. Out of the 45,000 crore [($5.4 billion) new data center investments announced in India in 2024-25], water neutrality or water near-neutrality has been promised under first five years of operation in about 68% of announced projects, compared with only 23% of announced projects in 2021-22.

9.2 Industry Commitments

Although government policy establishes guidelines and incentives, the technology and telecommunications firms operating in India are volunteering and committing a lot more than is required by the regulations.

9.2.1 Reliance Jio's Renewable Energy Transformation

Reliance Jio, one of the fastest-growing telecommunication networks in India, which also offers one of the largest data centres, has pledged to reach net-zero carbon emissions by the year 2035. This is a very ambitious goal that demands a radical change in the way the company supplies its digital infrastructure.

The strategy of Jio data centers is based on the integration of renewable energy and the preservation of water. The company has spent 15,000 crore ($1.8 billion) on solar and wind power generation with the purpose of powering its data center and network. Jio plans to use renewable energy sources to supply 60 percent of its energy by 2025, and it will reach 100 percent by 2030.

In water management, Jio is adopting what it terms as zero liquid discharge in its large facilities. These systems recycle and treat all the resulting wastewater produced by the cooling operations and any leftover concentrate is taken to solid waste instead of being released into the local water systems. In the flagship data center that Jio has in Navi Mumbai, this methodology has saved the municipality water by 85 percent of the amount of water that was initially estimated.

The use of air-cooling technology under Indian conditions is also a first in the company. In a new plant in Pune, Jio set up an indirect evaporative cooling system, together with a temperature optimization using AI. There are sensors around the entire facility that look at the conditions and change cooling output in real time to eliminate the wastes that take place when cooling systems are at full capacity even when they are not actually required. Initial findings indicate that the strategy cuts down on energy use (23 percent) and water usage (31 percent) than the assets generated by the company in past.

Probably most importantly, Jio is opening its sustainability playbook to open-source. The company has made available technical specifications in detail of its water recycling systems and renewable energy integration strategies and cooling optimization algorithms. Such transparency enables the smaller operators to follow in the same footsteps without having to invest in proprietary research, which may hasten sustainable practices throughout the industry of data centers in India in general.

9.2.2 Tata Communications' Path to Water Neutrality

Tata communications, the company that runs data centers and undersea cable facilities in the world, has made a target of becoming a water neutral company in all of its Indian plants by the year 2027. In the meaning Tata gives to it, water neutrality implies restoring to local watersheds an equivalent of water or more than the net usage of the facility in terms of recycling, rain water harvesting, and community water access.

This is an undertaking that has led to innovative engineering at Tata in Chennai at its data center. It has one of the largest commercial rainwater harvesting systems installed in the facility which opened in 2023. The 8,000 square meter roof collects about 12 million liters of water per year and this is filtered, treated and

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utilized in cooling processes. The facility is a net source of local aquifer recharge during the monsoon season at Chennai and rain water beyond capacity is channeled to percolation wells which assist in recharging ground water.

The use of municipal wastewater, which is treated, in cooling, was also pioneered in the Chennai facility. Tata collaborated with the Chennai Metropolitan Water Supply and Sewerage Board to develop a connection to wastewater treatment facility of the city. Tata further uses the tertiary treatment after the secondary treatment by the municipality to make the water fit the standards of cooling systems. This arrangement gives the city a customer to treated wastewater and Tata access to a non-competitive water source with the drinking water sources.

The economics model is educative. The project cost of the plant was increased by 8 per cent with the investment of Tata in rainwater harvesting systems and wastewater treatment. Nevertheless, the company anticipates that it will save 2.3 crore in terms of municipal water purchases and wastewater discharge fees amounting to 275,000.00, and that this will result in a payback period of approximately 7 years. More importantly, the water neutrality strategy cushions the facility against the uncertainties and volatility of water supplies and prices that have been experienced in Chennai over the last years.

This is the model that Tata is currently replicating in its Indian portfolio. The company is also installing such rainwater harvesting and recycling systems at their facilities in Mumbai, Bangalore, and Hyderabad. Another effort that the firm has made is to perform an annual water stress analysis of every place it operates in and to publish the findings publicly, establishing a level of transparency on how the activities of the firm relates with the water systems of the local places.

9.2.3 International Operators' India-Specific Sustainability Plans

Operators of data centers globally that are venturing into India are modifying their sustainability strategies to suit the local environment, and in many cases, their goals tend to be more aggressive than those that they have established in other markets.

The activities of Microsoft in India have investments that extend beyond, the global water stewardship of the company. To achieve its intended hyperscale campuses in Hyderabad and Pune, Microsoft has made the promise to be water positive, i.e. the company will be in a position to replenish more water than consuming it by the year 2027. Microsoft is doing that by cutting-edge effectiveness of its plant and investing in watershed repair undertakings in the identical river basins in which its information centers are situated.

Microsoft has collaborated with local NGOs in Hyderabad to rehabilitate traditional water harvesting systems in the rural Telangana areas. These rebuilt tanks and check dams will potentially add to the aquifer recharge about 45 million liters every year, which is more than compensating to the 32 million liters that Microsoft estimates that its facility will use. The company is also investing in water access enhancements of underserved communities, such as borewell rehabilitation and pipeline infrastructure that supplies water to 15,000 households.

Amazon Web Services (AWS) is going in a new direction, as it is implementing the latest cooling technology with the aim of reducing the amount of water at its source point. The company is installing immersion cooling high-density compute servers in the planned facility in Mumbai at AWS. With this system, servers are immersed in non-conductive fluid which is far more effective at heat transfer than air and thus the cooling of servers does not require water at all to cool a large percentage of IT load in the facility.

The Mumbai plant will also operate on free cooling when it is possible to in the atmosphere i.e. when the outside air is brought into the data center instead of running mechanical cooling systems. The geographic positioning of Mumbai and the sea winds make it possible to utilize free cooling as much as 40 percent of the yearly period and thus the energy and water consumption levels are reduced significantly at such periods.

Google is concentrating on scale efficiency. The company has ensured that the Indian data centers that it has will have a PUE of 1.15 or more which is one of the most efficient in the world. To do so, Google is rolling out its machine learning-based cooling optimization system that has lowered the amount of energy used in the global plants by an average of 30 percent. The system will consume less energy and hence less water is used since less cooling is needed.

9.2.4 Industry Consortium Formation

It has realized that, although efforts by individual companies have a value, they will not resolve the systemic issues, and it is starting to form collective action in the data center industry in India.

At the beginning of 2024, the Indian Data Center Industry Association (IDCIA) created a Water Stewardship Working Group consisting of operators that control about 70% of the commercial Indian data center capacity. The mandate of the group is to come up with best practices in the industry, establish common standards of measuring the use of water and promote the adoption of policies aimed at sustainable development.

The working group has already created the first significant output, a Water Usage Effectiveness (WUE) measuring protocol modified to meet Indian conditions. A well-known metric is WUE, the number of liters of water used per kilowatt-hour of energy used by IT equipment, and this is used worldwide, but India has a highly variable climate, and sometimes existing standards did not generate any meaningful comparison. The IDCIA protocol sets the factors of seasonal adjustment and regional standards where apples-to-apples comparison of crops could be made between various geographies and climate zones.

This standard measurement allows a meaningful transparency. Beginning in 2025, members of IDCIA have already agreed to publicly disclose their WUE indicators on a quarterly basis and this will provide an unprecedented degree of visibility into industry water consumption. The resulting openness, in its turn, causes competition pressure that drives improved performance since customers and investors are capable of directly juxtaposing sustainability measures among operators.

The consortium also shares resources in terms of technology development. The five large operators have contributed to a research fund, which is shared among the operators, with an aim to come up with cooling solutions that are optimized towards the Indian conditions. The initial project is aimed to adapt the evaporative cooling technology to function efficiently in monsoon season when it is commonly considered that the evaporation technique will be inefficient due to the high humidity. First prototypes demonstrate a potential of keeping the cooling efficiency intact, consuming 35 times less water than the best practices today.

9.3 Technology Pilots in India

In addition to the promises and policies, real innovation is underway in the data centers throughout India, and technology experiments are being made on solutions which can redefine the water footprint of the industry.

9.3.1 Liquid Cooling Deployments

Liquid cooling which has been a popular technology in high performance computing is being converted to commercial use in data centres in India. The technology demonstrates radical energy and water savings but historically it has been thought to be too costly and complex to be used on a general basis.

Such a calculation is evolving. The company has placed the first large-scale implementation direct-to-chip liquid cooling in a commercial data center system at a Yotta Infrastructure work center in Bangalore. The liquid coolant in this system does not necessitate air conditioning to cool out rooms but instead circulates direct in the liquid form to the processors utilizing the heat energy at the processor but not in the entire room.

The outcomes are beyond expectation. The high-density AI and machine learning workload that is handled by the liquid-cooled part of the facility has a PUE of 1.08, in contrast to the air-cooled parts that have a PUE of 1.35. More importantly to the conservation of water, the liquid cooling system consumes 90 percent less water compared to what would be consumed by air conditioning devices that were same-sized cooling loads.

It is operated through circulating a dielectric fluid (non-conducting) via a closed circuit. Processors emit heat through a heat exchanger which is transferred to the air through radiators like those found in car engines. Since the heat is confined in a small amount of fluid instead of being dispersed in voluminous amounts of air, heat rejection is achieved in an immensely more efficient way and uses minimal water.

The economics are coming to pass. Although liquid cooling infrastructure is about 30 per cent more expensive to install than conventional air conditioning, the energy savings (around 80 lakhs monthly to implement in Yotta) is generating a four-year payback period. Liquid cooling can replace niche usage to a matter of standard practice as the AI workloads that create exceptionally high heat density become standard in Indian data centers.

9.3.2 Rainwater Harvesting at Scale

This is not the first time a rainwater is being harvested in the residential and institutional scale, but the engineering issues in the scale of a data center are unique. These challenges can be overcome and this is being proven in several facilities.

The data center of Web Werks in Mumbai has put in place the most advanced commercial rainwater harvesting system in India. The 12,000 square meter roof of the facility along with the collection of surface water by the paved space around it is capable of retrieving about 18 million liters of water during the four months period of the monsoon season in Mumbai.

A multi stage treatment procedure is performed on the water obtained. First-flush diverters will divert the initial rainfall, which carries the pollutants off the surface, off storage. The water is then filtered by means of screens to realize rubbish and then sand filtration and UV treatment in order to eliminate the biological pollutants. Lastly, the water is contained in a 4-million-lit underground tank which is lined with food grade material to discourage pollution.

This collected rainwater supplies about 45 percent of the annual cooling water needs of the facility, which is a huge saving on the municipal water demand. The period of peak monsoon seasons sees the facility run entirely off of harvested rainwater, and excess on recharge wells that are used to replenish aquifers in the surrounding area.

The success of Mumbai has spawned imitation. Even bigger systems of rainwater harvesting are being included in new plants being developed by ADC India in Pune and Hyderabad. The facility currently being constructed in Pune will comprise 7 million liters of storage and will be geared towards fulfilling 60 percent of its water demand by way of harvesting.

The environmental benefit of these systems goes beyond the environmental benefits. Launching harvested rainwater in cities such as Chennai and Bangalore where the water distribution may be intermittent in case of dry seasons, offers operational resilience. With a high rainwater storage, the facilities are able to remain in operation when there are disruptions in supplies which can compel the less prepared competitors to reduce their operations or cause them to truck in costly tanker water.

9.3.3 Wastewater Recycling Innovation

The data centers in India have been at the forefront of developing methods of wastewater recycling that transcend beyond the traditional mode of operation and treats water to levels that can be reused a number of times.

In the plant of STT GDC India in Chennai, all the wastewater of cooling towers is recycled in a multi-stage process which allows reusing the water within the cooling tower itself, which forms a near-closed loop. It is done by means of membrane filtration to eliminate dissolved solids after which reverse osmosis is performed to bring the water to levels of purity equal to the original municipal supply of the facility.

This high-pressure recycling enables the facility to utilize less makeup water (fresh water introduced to offset losses) by 85 percent to the customary once-through cooling strategy. All water that exits the system is the one that evaporates during cooling, which is an inevitable loss in evaporative cooling systems, and a little stream of the reverse osmosis process which is still treated and used as landscape irrigation.

The energy required to carry out the treatment process is also very energy consuming and it goes to the tune of 12 percent of the saved power by efficient cooling design. The overall outcome is however heavily positive in terms of the environmental and economic aspects. Water bill at the facility has reduced by 70% and this will save the facility about 1.8 crore (215,000) every year to pay the operation costs of the treatment system and generate profits out of the initial investment of 6 crore.

CTRL's is also experimenting with an even more sophisticated method in Noida. The firm has implemented a system that recycles cooling tower blowdown (water released by the system to keep mineral levels at bay) to an elevated level at which it can be utilized to flush toilets and irrigate landscapes in the whole business park in which the data center is situated. This provision allows the business park to have a different source of water and CtrlS an effective use of water that would go to waste.

The Noida pilot illustrates a valuable point the water problems and solutions of data centers are found within the wider urban ecologies. Facilities will be able to generate efficiencies that they cannot generate by themselves because they have to think beyond their own fences and become part of the surrounding water systems.

9.3.4 Solar Integration and Energy-Water Nexus

Water and energy use cannot be separated in the operations of a data center because both are used in cooling. The solar resources available in India are facilitating the ability of the facilities to lower the two at the same time.

The facility of Netmagic at Gujarat has a 5-megawatt solar array on a piece of land measured at around 50,000 square meters near the data center. This installation will produce about 40 percent of the power needs of the facility, and it will not need as much as coal-powered grid electricity. The water indirect but notable benefit of the grid power reduction is that thermal power plants in India are very significant water guzzlers, with 3-4 liters of water typically consumed per kilowatt-hour of power production. The solar array of Netmagic avoids the use of about 6 million liters of water every year by operating power plants by using grid electricity.

Another system that the facility is utilizing is its solar array used to drive a new cooling method. When electricity is high and the sun is shining during peak hours, the facility utilizes its cooling systems in its "ice storage mode" production whereby ice in large volumes is produced in insulated tanks. This accumulated cooling capacity is subsequently used in the evening and night time whereby the cooling systems do not have to operate only to be forced to pull out the grid. This amount of load shifting decreases the cost of energy and the amount the facility contributes to a peak on-peak grid demand, during the times of year when the most water-intensive power plants (so-called peakers) are usually in operation.

The Adani Enterprises is also experimenting with an even more direct energy-water integration in its proposed site in Rajasthan. The targeted facility will not rely on the usual method of utilizing electricity to drive the absorption chillers but utilize a concentrated solar thermal technology to directly energize the chillers to produce cooling without reliance on electricity-powered air conditioning. During absorption cooling, heat is used to cool through the chemical process that creates cooling which is basically the heat of the sun to create cold.

A successful implementation of this strategy may be ground-breaking to the data centers in dry and sunny areas. Cooling directly would be produced based on the solar thermal energy which could save both electricity and water be used in large proportions. The pilot of the Rajasthan will offer important information on whether or not this method has the capacity to be utilized in a dependable manner to meet the needs of the data centers.

9.4 Academic and Research Contributions

The technical universities and research institutions in India are also bringing the much-needed knowledge and innovation in the area of developing sustainable data centers.

9.4.1 IIT Research on Tropical Climate Optimization

Indian Institutes of Technology in different parts of the country have developed special research areas on efficiency in data centers in tropical conditions having realized that solutions that work well in temperate climate may fail when the temperature and humidity are always high.

A group at the IIT Madras has come up with a computational model that forecasts optimal data center cooling settings using local weather information. The model takes into account the factors that are mostly overlooked in the traditional data center design, such as seasonal changes in humidity, dominant winds, and the relationship between the temperature and electricity grid overload. The model will be able to advise the use of certain cooling technologies and operational strategies that are the most efficient at a specific location based on decades of climate records.

Surprising findings have been produced in the research. In the case of the coastal city, such as Mumbai and Chennai, the model indicates that hybrid systems with evaporative cooling in the dry months and air-side economization (using outside air) in the monsoon season can help save 40% of water that would be used when evaporative cooling is applied throughout the year (evaporative cooling is the current industry standard). This is against common wisdom that consistency in cooling method is required to make it dependable.

A number of operators are also putting into practice the IIT Madras recommendations. One facility, implemented in Mumbai in 2024, which uses the hybrid method is already performing exactly as predicted by the model, saving 38 percent of the water that would be used by conventional cooling and still achieving the high temperature regulation data center equipment demands.

IIT Bombay is working on data center airflow. The trends of air movement within the server halls are identified and more specific cooling can be achieved using computational fluid dynamics and machine learning. It does not cool entire rooms evenly, but instead builds microclimates by providing intensive cooling at the locations of high-heat-density equipment and permitting lower-need areas to use more temperature.

This is a selective cooling method which is being tested at an Equinix site in Mumbai. Through the strategic cooling of the facility instead of cooling it evenly, the facility has saved 22 percent of its cooling energy usage with an equivalent saving of water. The research team is currently working on AI algorithms that could automatically modify cooling patterns during real-time when the workload is redistributed within the facility.

9.4.2 Indian Institute of Science Water Efficiency Studies

Indian Institute of Science (IISc) in Bangalore has also looked at data center water efficiency in systems perspective and analyzed not only individual facilities but also how data centers relate to water systems in the area.

In 2024, an IISc study team under Professor Sharachchandra Lele carried out an unprecedented study investigating the cumulative effect of developing data centers in Bangalore on the groundwater of the area. The research applied the model of hydrogeological to forecast the expected changes in the aquifer levels in 10 years to come because of various growth conditions.

The results were depressing yet practical. In a business-as-usual scenario, where data centers would carry on with the current patterns of water use, the model estimated that groundwater in major parts of Bangalore will reduce to 8-15 meters at the year 2030, posing a severe strain on the technology industry and the home dwellers. Nonetheless, the model demonstrated that offensive implementation of water recycling and rainwater harvesting throughout the data center industry can constrain the decrease to 3-5 meters which is significant in terms of aquifer sustainability.

The IISc study made the study especially useful when it mapped specific intervention effectiveness. The study found out that rainwater harvesting could be disproportionately beneficial in some geological areas where natural aquifer recharge rates are high whereas water recycling is most urgent in geological areas where the aquifers are already stressed. This geographic particularity gives operators and regulators a chance to intervene where they would be most effective.

The research has had a direct effect on policy. The water recycling requirement of data centers in Karnataka, which is mentioned above, was adjusted, according to the findings of this model by the IISc, of how much recycling would be required to prevent critical stress on aquifers. The research offers the scientific basis of what would otherwise be arbitrary regulatory demands.

IISc has now taken this research to other cities. Chennai, Hyderabad, Pune studies are being conducted, with each of them analyzing local hydrogeological conditions and the trends of development of data centers. Such a city-based study will facilitate more advanced, place-based policy solutions as opposed to national norms.

9.4.3 Public-Private Research Partnerships

These lines of demarcation between scholarly study and commercial application are becoming thin with the world of collaborative alliances that are speeding up the process of translation of innovations.

Smart Cities Mission has set up a Data Center Sustainability Lab in Pune, which was a joint venture between IIT Bombay and a group of six data center operators. The lab is a test bed whereby new technologies are tested before they are implemented on large scale. In the laboratory environment, companies can make cooling systems, recycling technologies, or monitoring equipment fly, collect performance data and not risk disrupting working facilities.

The latest laboratory projects involve testing the new coolants to use in the liquid cooling systems, testing on the use of membrane technologies in water purification and comparison between various rain filtration methods. In a single project, the lab evaluated eight various coolant formulations to determine the one that offered the best heat transfer within the temperature range in India as well as that which was safe to the environment in case it was spilled. These findings have informed technology selection of liquid cooling deployment by a few operators.

Microsoft has also created a highly innovative collaboration with IIT Hyderabad that aims at water optimization with the help of AI. The cooperation provides the IIT researchers with real-time data regarding the functioning of Microsoft plants, such as temperatures, flowing of water, and equipment operation of thousands of sensors. With such richness of data, normally proprietary, researchers are able to create machine learning models that cannot be created with small datasets.

The study has provided some useful findings. IIT Hyderabad has come up with an algorithm that forecasts the water demand in cooling systems 24 hours ahead depending on the weather forecast, anticipated workload trends, and prior performance history. This forecast enables operators to optimize the operation of the water systems by pre-treating water and staging it at low period in time and also regulating the operation of the recycling system to the expected demand. According to Microsoft, the implementation of this algorithm in their Hyderabad plant has seen a 7 percent decrease in water usage and an increase in reliability in that they are able to detect possible system problems before they occur and create issues.

Vitally, Microsoft has opened up this algorithm as open source, which means that other operators have been able to reap the benefits of the research without necessarily developing systems of a similar nature. Public-private partnerships help in the sharing of this type of knowledge and this increases the rapidity of adoption of sustainable practices in the industry.

9.4.4 Workforce Development and Knowledge Transfer

Colleges and universities are also dealing with the human capital aspect of the sustainable online data center operation by providing specialized training programs.

IIT Delhi has introduced a postgraduate certificate in Sustainable Data Center Management that it has become the first in India. The six-month program includes engineering coursework regarding cooling systems, water treatment, and renewable energy as well as management training regarding sustainability reporting, stakeholder engagement, and compliance. The first group of 45 students (primarily working professionals in data center businesses) graduated in mid-2024.

In this program and other similar programs by different companies, employees are being sponsored by various companies. CtrlS has also made an investment of training at least one employee in each of the facilities it operates on the best water management practices to establish inner capabilities that can create a continuous improvement.

This human capital investment can be vital as physical infrastructure investment. The operation of data centers sustainably presupposes the advanced knowledge of complex systems and permanent optimization. The development of workforce with such capabilities would mean that India is able to sustain and enhance performance in the long run as opposed to merely installing a system which is advanced but the knowledge is not available to run such a system effectively.

10. CONCLUSION

The data center aspirations in India pose a stark choice to the country. The country requires the digital infrastructure to be sovereign, secure and economically developed. Simultaneously it is facing the water stress that hundreds of millions of citizens are already exposed to, and predictions are not that this situation is not going to get better. These imperatives might not appear to be very consistent until we observe that development and sustainability is not a choice but rather intelligent planning and crisis control. A number of momentous insights come out of this analysis. To begin with, one should know about scale. One data center with 100 megawatts of power uses as much water as a thousand households. The aggregate demand of dozens of planned facilities will become a challenge to big cities. Understanding these magnitudes eliminates the possibility of underestimating the challenge.

Second, it is not possible to learn without making mistakes that others make. Georgia and Virginia demonstrate what can occur when economic excitement goes over the environmental planning. These are the results that India can witness rather than learn them through the bad experience. A good understanding is a headache beforehand to avoid foreseeable calamities.

Third, the idea of data sovereignty as a strategic requirement, rather than a strategic convenience, must be understood as the appropriate way of thinking on this issue. In an information age, the control of the information infrastructure poses power to the countries that do not have control over their information infrastructure, undermining security, privacy, and autonomy. The issue is not that India requires data centers, but how to be accountable about the construction.

Fourth, limitations lead to innovation when tackled in a positive manner. The lack of water and other energy constraints can drive India to create the most efficient data infrastructure in the world. This results in intellectual property, competitive advantages and models that will be studied by other countries. Sustainability is not differentiation but a burden.

Fifth, transparency and accountability safeguards citizens and facilitates growth. Development should be in the service of the people and not exploitative by imposing water consumption on a population, community benefit agreements with the implementation of enforcing mechanisms, and a staged implementation with trigger mechanism are all that is needed.

Sixth, there should be systems thinking in terms of water, energy, climate, employment, and geopolitics. All these domains are influenced by data centers at the same time. The solutions cannot be used to optimize a single variable by ignoring the relationship between variables.

Seventh, all decisions are made based on purpose. Cash flow can improve lives. Infrastructure that undermines the basic needs is lost. The growth of human being should facilitate human prosperity, rather than impair the assets of human prosperity.

India is at the crossroad where one can either succeed and have Jamnagar and other hubs become world envied examples of sustainable digital infrastructure. The alternative route is resulting in the struggle of the limited water, the destruction of the environment and communities that need to decide between technological advancement and the essential needs. This technology is available to pursue the former. The issue is, can we be wise and willing to utilize it. The citizens are to raise questions about the data center proposals within their areas, review the water sourcing plans, and insist on community protection. The policymakers ought to develop elaborate regulations ahead of reactive measures that are necessitated by crises. Businesses must also compete in environmental sustainability innovation as opposed to competing in a zero-ground-based environmental standard.

By 2025, it will not be responsible to construct data infrastructure without water planning. It means a decision of short-term profit at the long-term disaster. India deserves better. The Indian citizens are entitled to better. Through effective planning India can show the world that the AI revolution and being environmentally responsible do not go against each other, rather can co-exist. The data boom is unavoidable owing to the digital path and the sovereignty interests of India. The question is whether we create it through conscious creation by carefully planning it or we have to clean the disastrous errors afterward. History is clear that conscious planning is somewhat more difficult in the short term, but much less expensive in terms of economics, the environment, social stability, and wellbeing of people.

Water is life. Data is power. The dilemma that India faces is how to make sure that the quest to achieve power does not come at the cost of life. This balance can be attained based on the strategies presented in this analysis. Their implementation as a proactive measure is open to date, but it will not be open forever. The decisions of the coming years will be what will make the goals of India in the field of data centers a silicon mirage that disappears when people open the tap and can find them empty, or a digitally sustainable base that other countries will be imitating. The decision is ours to make.

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