Analyzing India’s Compute Capacity and AI Infrastructure Needs

Report submitted in completion of

Case Study Challenge

AI Blueprint For BHARAT - Case Study Challenge

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September 2024

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1. Introduction

Artificial Intelligence (AI) has rapidly transformed from a specialized research field to a cornerstone of technological innovation, driving advancements across various sectors, including healthcare, finance, agriculture, and governance. The growing integration of AI into these sectors is fundamentally reshaping the landscape of modern industries and public services. Central to this transformation is compute power—the backbone that enables the training and deployment of complex AI models. Compute power, often quantified in terms of Floating Point Operations Per Second (FLOPs), refers to the computational capacity required to perform the massive calculations essential for AI applications. For instance, the training of advanced models like OpenAI's GPT-3 required thousands of petaFLOPs*, underscoring the critical role of computational resources in AI progress.

In India, the momentum behind AI adoption is accelerating, driven by the government's initiatives and increasing investment in cutting-edge technologies. Recent announcements, such as the plan to procure 10,000 GPUs under the National AI Mission, highlight the nation's commitment to scaling its compute infrastructure. However, to sustain and further accelerate this growth, it is imperative to accurately estimate the current and future compute capacity requirements. This estimation will enable strategic planning and investment, ensuring that India's AI aspirations are not hindered by inadequate infrastructure.

The challenge lies in understanding the compute needs of a rapidly evolving AI landscape. Given the exponential growth in AI model complexity and data generation, compute requirements are expected to rise significantly. Key questions include: What are India's current compute needs, and how will they evolve over the next five years? What factors will drive this growth, and how will these factors influence projections under different scenarios? This report aims to address these questions by analyzing current infrastructure, projecting future needs, and providing recommendations for ensuring that India's AI development trajectory remains robust and sustainable.

Through this study, we will explore the factors influencing compute growth, compare India's progress with global trends, and offer strategic actions for policymakers and stakeholders. The goal is to provide a comprehensive assessment of India's compute capacity landscape, equipping decision-makers with the insights needed to support the nation's AI-driven future.

** 1 petaFLOP(PF)=one quadrillion (10^15) floating-point operations per second.

2. Current Compute Infrastructure in India

Compute is used to refer to many things—the capacity to perform complex calculations, specific hardware equipment like semiconductors, or as a unit of measurement expressed in floating-point operations per second (FLOPS) that quantifies a computer's ability to execute high-performance tasks like machine learning.[1]

A more holistic view of compute positions it as a technology stack comprising three layers—a hardware, a software, and an infrastructure layer. Collectively, this forms what has come to be known as the "compute stack," which may include:

- Advanced chips (GPUs, TPUs)
- Specialized software to run the chips (compute unified device architecture or CUDA)
- Data centers and network infrastructure (Google, AWS, Azure)
- Data storage and management software (Oracle, IBM, SAP)

A country's compute capacity can be measured by the total number of GPUs available, or in terms of FLOPS. Under the AI mission, the government intends to build compute infrastructure of 10,000 or more GPUs. According to recent data from the Department of Science and Technology, the National Supercomputing Mission (NSM) has a total compute capacity of 24.83 petaflops (1 petaflop = 10^{15} flops), at the cost of Rs. 1,218 crores. The official target for the NSM is 66 PF by 2025. These supercomputing systems are installed at several institutes across the country.

Sr. No.	Institute Name	HPC System Name	Compute Power
1	IIT (BHU), Varanasi	PARAM Shivay	838 TF
2	IISER, Pune	PARAM Brahma	1.70 PF
3	IIT, Kharagpur	PARAM Shakti	1.66 PF
4	JNCASR, Bangalore	PARAM Yukti	1.8 PF
5	IIT, Kanpur	PARAM Sanganak	1.66 PF
6	C-DAC, Pune	PARAM Siddhi-AI	5.2 PF / 210 PF (AI)
7	IIT, Hyderabad	PARAM Seva	838 TF
8	NABI, Mohali	PARAM Smriti	838 TF
9	IISc, Bangalore	PARAM Pravega	3.3 PF
10	C-DAC, Bangalore	PARAM Utkarsh	838 TF
11	IIT, Roorkee	PARAM Ganga	1.66 PF
12	IIT, Gandhinagar	PARAM Ananta	838 TF
13	NIT, Trichy	PARAM Porul	838 TF
14	IIT, Guwahati	PARAM Kamrupa	838 TF
15	IIT, Mandi	PARAM Himalaya	838 TF

Table 1: Major HPCs of India set up with the National Supercomputing Mission[2]

It is to be noted that C-DAC(Centre for Development of Advanced Computing) has implemented **AI Research Analytics and Knowledge Dissemination Platform (AIRAWAT)** of 200 AI Petaflops at C-DAC, Pune under the initiative of Ministry of Electronics and IT, Government of India in 2023.

The AIRAWAT PoC of 200 AI Petaflops integrated with PARAM Siddhi – AI of 210 AI Petaflops gives a total peak compute of 410 AI Petaflops Mixed Precision and sustained compute capacity of 8.5 Petaflops (Rmax) Double Precision. The peak compute capacity (Double Precision, Rpeak) is 13 Petaflops.[3]

Rank	System	Cores	Rmax (PFlop/s)	Rpeak (PFlop/s)	Power (kW)
110	**AIRAWAT - PSAI** - NVIDIA DGX A100, AMD EPYC 7742 64C 2.25GHz, NVIDIA A100, Infiniband HDR, Netweb Technologies Center for Development of Advanced Computing (C-DAC) India	81,344	8.50	13.17	
185	**PARAM Siddhi-AI** - NVIDIA DGX A100, AMD EPYC 7742 64C 2.25GHz, NVIDIA A100, Mellanox HDR Infiniband, EVIDEN Center for Development of Advanced Computing (C-DAC) India	41,664	4.62	5.27	
230	**Pratyush** - Cray XC40, Xeon E5-2695v4 18C 2.1GHz, Aries interconnect , HPE Indian Institute of Tropical Meteorology India	119,232	3.76	4.01	1,353
388	**Mihir** - Cray XC40, Xeon E5-2695v4 18C 2.1GHz, Aries interconnect , HPE National Centre for Medium Range Weather Forecasting India	83,592	2.57	2.81	955

Fig 1: Most powerful Supercomputers of India (Source:https://top500.org/)

Global cloud service providers such as Microsoft, Google, and AWS also make compute available to Indian customers through different models (public, private, hybrid) and pricing plans (pay-as-you-go, subscriptions). Hyperscalers also bundle compute with other services, such as data storage and security.[1]

AI-specific data centers often include GPU clusters or TPUs (Tensor Processing Units) tailored for AI and machine learning workloads. AWS, Google Cloud, and Microsoft Azure dominate the cloud landscape in India, with their data centers capable of providing scalable compute. The capacity in petaflops is challenging to pin down exactly, as these systems are multi-tenant and shared across many users. Also, we have no relevant data from these companies to show how much of the compute is actually allocated for AI workloads. Typically, 1 megawatt of power can support around 10-20 petaflops of AI or HPC compute capacity in modern data centers.

Generally speaking, not considering other inherent factors for calculation, approximately 3,547 NVIDIA Tesla GPUs/ 2,560 NVIDIA A100 GPUs are required to attain a compute capacity of 24.83 PF, which is India's current compute capacity.

3. AI Adoption in India and Growth Trends

Sectoral Integration of AI

AI adoption in India is witnessing rapid integration across multiple sectors:

- **Healthcare**: AI-driven diagnostics, personalized medicine, and predictive analytics are enhancing patient care and operational efficiencies.
- **Finance**: Fraud detection, algorithmic trading, and customer service automation are key areas leveraging AI technologies.
- **Agriculture**: Precision farming, crop yield prediction, and supply chain optimization are being transformed by AI applications.
- **Government Services**: Smart city initiatives, public safety, and administrative automation are critical areas for AI implementation.

Data Growth and AI Demand

The exponential growth in data generation across these sectors fuels the demand for AI compute power. As datasets become increasingly large and complex, the computational requirements for training and deploying AI models escalate. For example:

- **Large Language Models (LLMs)**: Models like GPT-4 require extensive compute resources for training, necessitating continuous scaling of HPC infrastructure.
- **Real-Time Analytics**: Applications that provide real-time insights and decision-making capabilities depend on robust computational support to process data instantaneously.

Growth Trends

- **AI Model Complexity**: The trend towards more sophisticated AI models with higher parameter counts directly correlates with increased computational needs.

- **Adoption Rate**: The accelerated adoption of AI across industries implies a corresponding rise in the demand for compute resources to support diverse and scalable AI applications.

Recent Adoptions:

- NSM has successfully installed 24.83 PF of HPC machines across the country against 15-20 PF originally envisioned.
- Our server, Rudra, built on the Intel Cascade platform, underscores our dedication to innovation and efficiency. Not only are these systems cost- effective, but they also boast superior power efficiency in operation. Together, these advancements will culminate in a substantial leap in computing power, with a total capacity of 64 PF. These groundbreaking supercomputers will comprise of the following:
    - 3 PF HPC system at IUAC New Delhi
    - 650 TF HPC system at SN Bose Kolkata
    - 650TF HPC system at IIT Patna
    - 1 PF HPC system at GMRT-TIFR Pune
    - 3 PF HPC system at IIT Bombay
    - 3 PF HPC system at IIT Madras
    - 650TF HPC system at IIT Jammu
    - 20 PF HPC system at C-DAC Bangalore
    - 200TF HPC system at C-DAC Delhi
    - 1 PF HPC system at C-DAC Pune
    - 250 AI PF System at IIT Delhi
- The overall utilization of the NSM systems stands at over 80%* with the recent installations gaining utilization by users. In the upcoming year, ten more supercomputers based on Rudra servers will be deployed. These supercomputers include a 3 PF HPC system at IUAC New Delhi, a 650 TF HPC system at SN Bose Kolkata, another 650 TF HPC system at IIT Patna, a 1 PF HPC system at GMRT-TIFR Pune, a 3 PF HPC system at IIT Bombay, a 3 PF HPC system at IIT Madras, a 650 TF HPC system at IIT Jammu, a 20 PF HPC system at C-DAC Bangalore, a 200 TF HPC system at C-DAC Delhi, and a 1 PF HPC system at C-DAC Pune. Additionally, there is a plan for a 250 AI PF System at IIT Delhi.
- It may be noted that MeitY has already envisioned a roadmap for scaling AIRAWAT to 1,000 AI Petaflops Mixed Precision compute capacity to cater to the current AI computational needs.

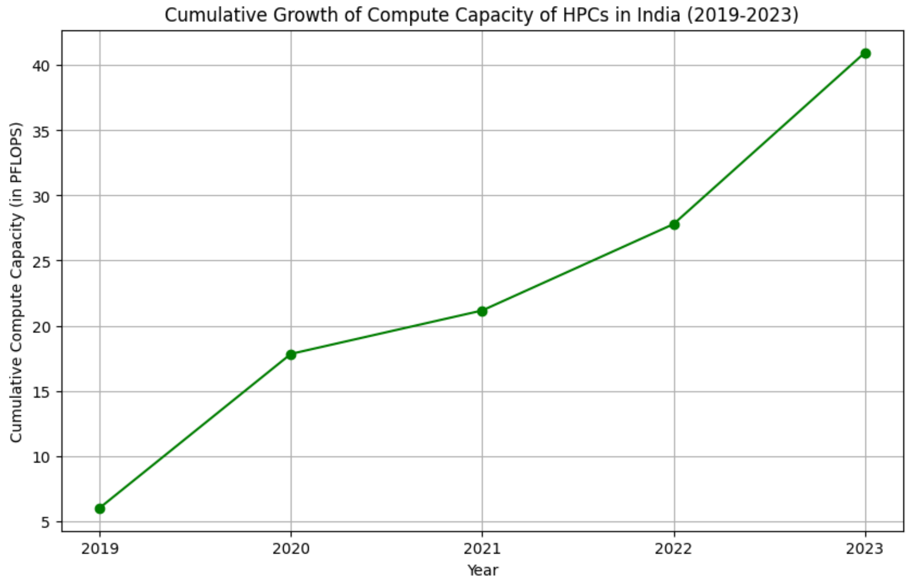
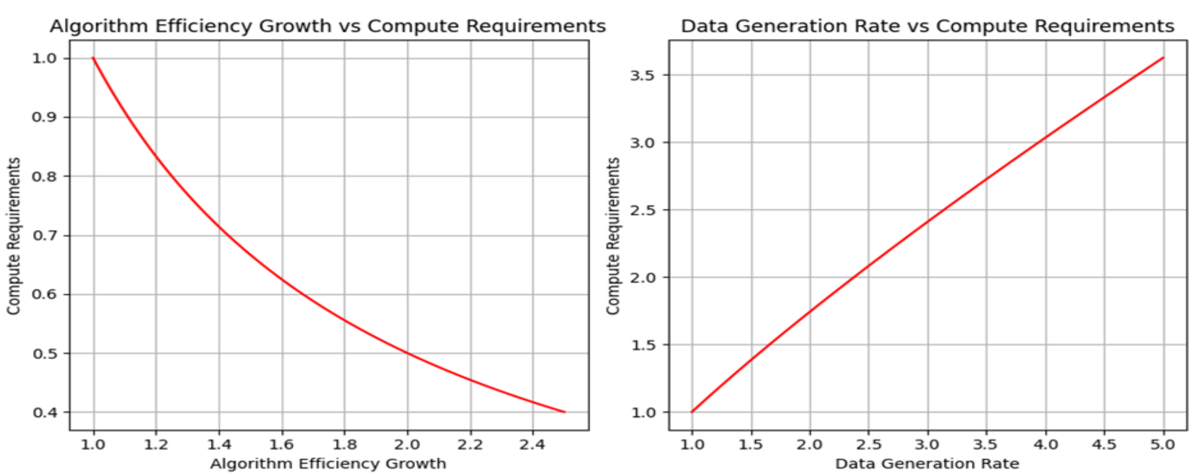


Fig 2: Cumulative Compute Capacity vs Year (2019 to 2023)

4. Factors Influencing Compute Growth

The main factors influencing the growth rate of compute requirements are as follows:

1. **Algorithmic Efficiency**: As AI algorithms become more efficient, they require fewer computational resources to achieve the same or even better performance. Efficient algorithms optimize resource use, reduce training times, and cut down on energy consumption, thus potentially lowering the compute requirements.
2. **Data Generation and Usage**: The rapid increase in data generated by industries adopting AI leads to a greater demand for computational power. More data means models need more resources for training, storage, and processing, thereby increasing the need for compute capacity.



3. **Technological Innovations**: Advances in technology can either increase or decrease compute requirements. For example:
    - **Quantum Computing**: Quantum computing has the potential to significantly reduce the time needed to train complex AI models, impacting the compute requirements by making computations exponentially faster.
    - **Edge Computing**: By processing data closer to the source (e.g., on devices rather than centralized data centers), edge computing can reduce the need for large-scale compute resources and lower latency.
    - **Specialized Hardware**: The development of AI-specific hardware like GPUs, TPUs, and other accelerators optimizes computations, reducing the compute time needed for AI workloads.
4. **Model Complexity and Size**: Increasingly complex AI models, such as large language models, require exponentially more computational resources to train and deploy. As models grow in size and complexity, the demand for compute resources grows correspondingly.
5. **Scalability of Compute Infrastructure**: Advances in cloud computing and the availability of scalable infrastructure (e.g., distributed computing, serverless architectures) allow for handling larger computational loads, driving further growth in compute requirements.
6. **Energy Efficiency Concerns**: As compute demands grow, the energy consumption of data centers and computational hardware also increases. Innovations focused on energy efficiency can influence compute growth by balancing the need for computational power with sustainability considerations.
7. **Regulatory and Environmental Considerations**: Policies aimed at reducing carbon footprints and promoting green computing may influence how compute resources are allocated and developed, impacting growth in specific ways.
8. **Economic Factors**: The cost of compute resources, including hardware, electricity, and data center maintenance, can directly influence the rate at which compute capacities grow. Economic incentives, subsidies, or penalties related to energy usage can also play a role.

These factors interplay to shape the trajectory of compute growth, balancing advances in efficiency and technology against the ever-increasing demand for computational power in AI and other data-intensive fields.

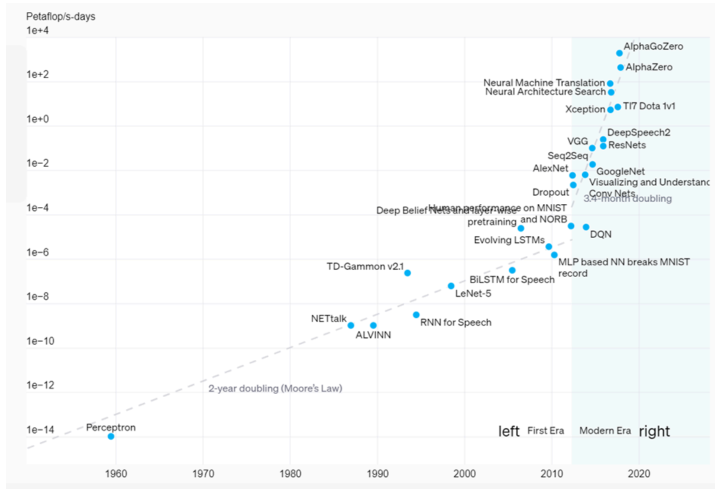


Fig 3: Growth of Compute Capacity (**Source:**"AI and Compute" by OpenAI (2018))

Figure 3 examines how increased model complexity and scale impact compute growth.

5. Projections of Future Compute Requirements

To estimate the Future compute requirements we shall analyze the growth in compute capacity from 2019 to 2024, for that we'll consider two approaches: **Exponential Growth** and **Compound Annual Growth Rate (CAGR)**. Additionally, we'll use the doubling period of 3.4 months for new AI models, as referenced in the scenario.

1. Exponential Growth Calculation

Exponential growth can be expressed by the equation:

$$\text{Future Value} = \text{Present Value} \times (1 + r)^t$$

Where:

- **Present Value (C_0)** is the initial compute capacity in 2019,
- **r** is the growth rate per period,
- **t** is the number of periods (years in this case).

Given Data:

- **Doubling period**: 3.4 months (or 0.283 years).
- This means that the compute capacity doubles approximately 3.53 times per year (12 months / 3.4 months ≈ 3.53).

To calculate the annual exponential growth rate, we use:

$$r_{\text{annual}} = 2^{3.53} - 1$$

The final compute capacity in 2024 after 5 years of growth is:

$$\text{Future Value} = \text{Present Value} \times (1 + r_{\text{annual}})^5$$

2. Compound Annual Growth Rate (CAGR) Calculation

CAGR provides a smoothed annual growth rate over the period of interest. It is calculated as:

$$\text{CAGR} = \left(\frac{\text{Final Value}}{\text{Initial Value}}\right)^{\frac{1}{t}} - 1$$

For the CAGR calculation, we need the final value of compute capacity in 2024, which will be calculated using the exponential growth formula.

Step-by-Step Calculations

1. **Exponential Growth Rate Calculation**:
   - Calculate r_{annual}ased on the doubling every 3.4 months.
   - Determine the compute capacity in 2024 using exponential growth.
2. **CAGR Calculation**:
   - Use the final compute capacity from the exponential growth calculation to determine the CAGR over the 5-year period.

Calculated Results assuming the initial compute capacity $C_0 = 1$ unit in 2019 for simplicity:

1. **Exponential Growth Rate (Annual Growth Rate)**: The annual exponential growth rate, considering that compute demand doubles every 3.4 months, is **1054.67% per year**. This implies that the compute capacity increases more than tenfold every year.
2. **Future Compute Capacity by 2024**: Assuming an initial compute capacity of 1 unit in 2019, the compute capacity is projected to increase to **205,255.14 units** by 2024, reflecting the exponential nature of growth.
3. **Compound Annual Growth Rate (CAGR)**: The CAGR over the 5-year period (from 2019 to 2024) is also **1054.67%** per year. This indicates an average annual increase that aligns with the exponential growth trend, given the rapid doubling every 3.4 months.

★ **Key Insights:**

- **Exponential Growth**: The extremely high annual growth rate suggests a massive increase in AI compute capacity over the period. If India matches this growth, it will stay on track with global trends in AI compute needs.
- **CAGR**: The CAGR value confirms that the overall annual growth remains consistent with the exponential doubling pattern.

Both methods indicate a rapid escalation in compute demands, and India's ability to keep pace with such trends will be crucial in maintaining competitiveness in AI development.

Assumptions for Projections

- **Doubling Time**: Compute demand is assumed to double every **3.4 months**, translating to approximately **3 doublings per year**.
- **Current Capacity**: **66 PetaFLOPS (PF)** by the end of upcoming NSM installations.

Exponential Growth Projection

Using the exponential growth formula:

$$\text{Future Compute Capacity} = \text{Current Capacity} \times 2^{\frac{n}{3.4}}$$

Where n is the number of months. Over **5 years (60 months)**:

$$\text{Future Compute Capacity} = 66 \times 2^{\frac{60}{3.4}} \approx 66 \times 2^{17.65} \approx 66 \times 216,000 \approx 14,256,000 \,\text{PF} \,(\approx 14.26 \,\text{ExaFLOPS})$$

Conservative CAGR-Based Projection

Alternatively, using a **Compound Annual Growth Rate (CAGR)** of **70%** (midpoint between 60-80%):

$$\text{Future Compute Capacity} = \text{Current Capacity} \times (1 + \text{CAGR})^t$$

Where $t = 5$ years:

$$\text{Future Compute Capacity} = 66 \times (1 + 0.70)^5 \approx 66 \times 7.836 \approx 517.76 \,\text{PF}$$

Projected Requirements by 2029

- **Exponential Growth Estimate**: **8,644,800 PetaFLOPS (~8.64 ExaFLOPS)** by 2029.

- **CAGR-Based Estimate**: **500-1,000 PF** by 2029.

Given the impracticality of reaching exaflop-scale within five years, a more realistic target aligns with the **CAGR-based projection**, emphasizing the need for strategic and scalable growth in compute infrastructure.

6. Comparing India's Growth with Global Trends

Global Supercomputing Landscape:

Leading countries in supercomputing, such as the United States, China, and members of the European Union, have surpassed the exaflop threshold (1,000 petaflops) in computational capacity. These nations allocate significant resources to high-performance computing (HPC) systems to maintain leadership in AI research, quantum computing, climate modeling, and other advanced fields. For instance, the U.S. is home to Frontier, the world's first exascale supercomputer, capable of over 1.1 exaflops, and China boasts several top-ranked machines, such as Sunway TaihuLight.

India's Position:

Current Capacity: **66 PF** (projected by 2025) positions India as a significant player but still behind global leaders. India's compute capacity is expected to reach 66 PetaFLOPS (PF) by 2025 under the National Supercomputing Mission (NSM). While this marks significant progress, it still lags behind global leaders who have already achieved exascale computing. PARAM Siddhi-AI and other supercomputers place India on the path to competitiveness but further investments are necessary to bridge the gap.

Growth Trajectory: To remain competitive, India must align its growth trajectory with global trends, aiming for **500-1,000 PF** by 2029. This projection aligns with the rapid increase in AI complexity, sectoral integration, and data demands.

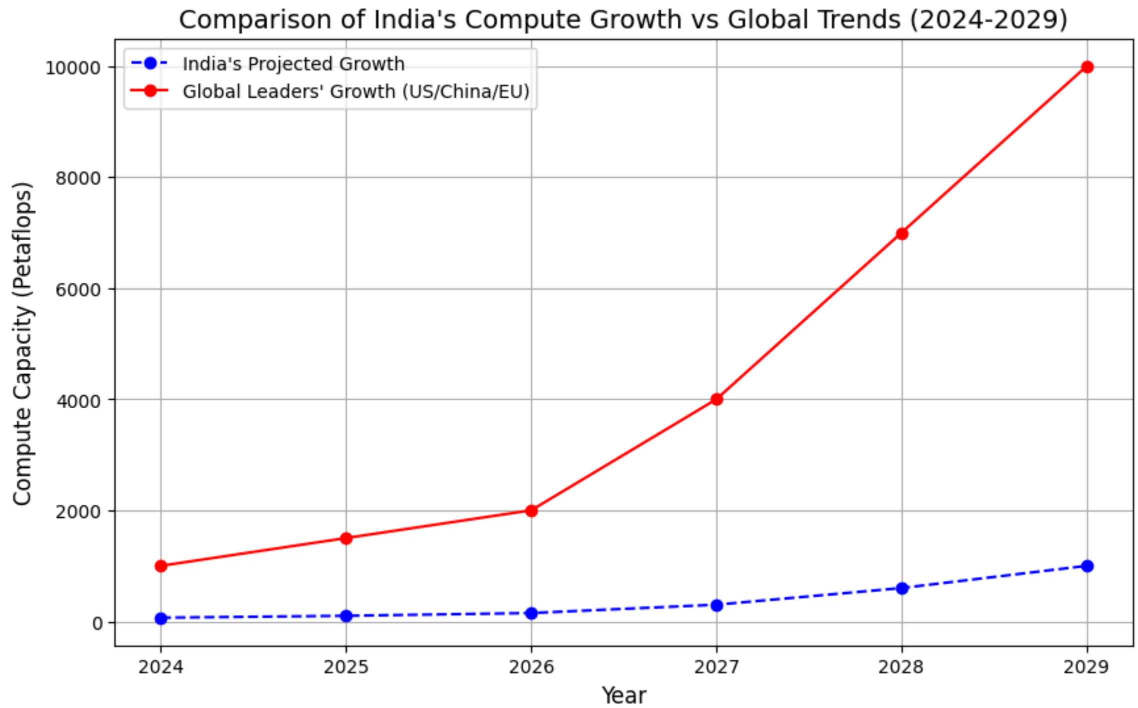


Fig 4: India's Compute Growth vs Global Trends (projected in 2024 to 2029)

Competitive Analysis:

India's current investments in HPC and AI infrastructure fall short of those in global leaders, who invest tens of billions of dollars annually. The United States has committed to significant annual funding, particularly in AI R&D and HPC, through agencies like the National Science Foundation (NSF) and Department of Energy (DOE). Similarly, China and the EU are rapidly expanding their compute capacities, with China housing some of the most advanced AI-focused machines.

Technological Advancements:

For India to remain competitive, continuous investments in cutting-edge technologies such as quantum computing, GPU advancements, and AI-specific hardware are critical. Emerging technologies like quantum computers have the potential to revolutionize AI model training, drastically reducing compute times. Additionally, focusing on algorithmic efficiency (developing models with fewer parameters but higher performance) can help India optimize its current infrastructure and achieve global competitiveness.

Strategic Implications:

India risks lagging in the global AI and HPC race without substantial infrastructure scale-up. Falling behind in AI development may lead to missed opportunities in strategic sectors such as defense, healthcare, and climate science, where AI is becoming increasingly pivotal. Moreover, economic growth driven by AI innovations could slow, affecting India's competitiveness in the global market.

Insights:

To close the gap with global supercomputing leaders, India must expand its compute infrastructure, aiming for 500-1,000 PF by 2029. This requires not only increased funding and international collaboration but also leveraging innovations in hardware and software to boost performance without excessive resource consumption. Without these strategic steps, India could miss out on the significant economic and societal benefits that AI advancements bring.

7. Possible Policy Initiatives

Here are some possible policy initiatives to support AI and compute infrastructure growth in India:

1. Enhance Compute Capacity and Infrastructure

- Increase Investment in HPC Systems: Accelerate investments to increase India's high-performance computing (HPC) capacity beyond the current target of 66 PetaFLOPS (PF) to closer to global standards, aiming for 500-1,000 PF by 2029.
- Develop Indigenous Compute Hardware: Encourage domestic production of advanced compute hardware, such as GPUs and TPUs, by providing incentives to local manufacturers. This would reduce dependency on imports and enhance the self-reliance of India's AI infrastructure.
- Expand Data Centers: Promote the establishment of more AI-specific data centers with adequate GPU and TPU clusters to support machine learning workloads, offering subsidies or tax incentives for private sector investment in AI compute infrastructure.

2. Promote AI Research and Development

- Fund AI-Specific Research: Establish dedicated funds to support research in areas like quantum computing, edge computing, and AI-specific hardware (such as TPUs) that could dramatically increase computational efficiency and lower costs.

- Create AI Research Hubs: Develop regional AI research hubs linked with academic institutions, startups, and industries to foster innovation and collaboration, accelerating the development and deployment of new AI technologies.

3. Focus on Energy-Efficient Computing

- Green Computing Initiatives: Promote energy-efficient computing practices by incentivizing the use of renewable energy sources in data centers and funding research on low-energy AI models and technologies.
- Set Sustainability Standards: Develop policies that mandate sustainability standards for compute infrastructure, focusing on reducing carbon footprints and promoting green computing practices.

4. Support for Algorithmic Efficiency

- Encourage Development of Efficient AI Algorithms: Provide grants or incentives for projects focused on creating more efficient AI algorithms that require less computational power while maintaining or improving performance. This could also involve collaborations with international research organizations.
- Leverage Quantum Computing: Invest in quantum computing research to develop capabilities that can drastically reduce training times for AI models and optimize compute requirements.

5. Strengthen Data Privacy and Security Frameworks

- Establish AI Data Regulations: Formulate data privacy and security regulations specific to AI, ensuring safe storage, transfer, and usage of data across sectors, particularly in sensitive areas like healthcare and finance.
- Enhance Cybersecurity Measures: Implement stringent cybersecurity measures to protect AI infrastructure and data from potential cyber threats, ensuring the secure operation of AI applications.

6. Foster Public-Private Partnerships

- Public-Private Collaboration Models: Encourage partnerships between government bodies, private companies, and academia to co-develop AI compute infrastructure and drive innovation. This could include joint research initiatives, shared infrastructure, and open data platforms.
- Leverage Global Expertise: Collaborate with leading global AI and tech companies to bring advanced computing technologies and best practices to India, enhancing the overall AI ecosystem.

7. Develop Workforce and Skills for AI

- AI Skill Development Programs: Implement nationwide training programs focused on AI and compute skills to build a workforce ready to support the growing AI ecosystem. This could include specialized courses in AI, machine learning, data science, and advanced computing.
- Incentivize AI Education: Offer scholarships, grants, and other incentives for students and professionals to pursue AI-related studies and research, focusing on underrepresented regions and communities.

8. Monitor and Project Future Compute Needs

- Establish a National AI Compute Council: Create a dedicated body to regularly assess and project India's compute requirements, ensuring policies are responsive to the rapidly evolving AI landscape and aligned with global trends.
- Conduct Regular Audits: Implement a framework for regular audits of compute infrastructure to identify gaps, ensure optimal utilization, and guide future investments.

These initiatives can help India keep pace with global AI advancements and fully leverage the economic and societal benefits of AI technologies.

8. Conclusion

India stands at a critical juncture in its journey towards becoming a global leader in artificial intelligence (AI) and high-performance computing (HPC). With significant strides made under the National Supercomputing Mission and the establishment of platforms like AIRAWAT, the country has laid a solid foundation. However, to keep pace with the rapidly evolving global AI landscape, India must accelerate its investment in compute capacity and infrastructure, aiming for 500-1,000 PetaFLOPS by 2029.

Strategic policy initiatives focused on expanding compute resources, fostering research and innovation, enhancing energy efficiency, and strengthening public-private partnerships are vital. Additionally, prioritizing the development of efficient AI algorithms, sustainable computing practices, and robust data privacy frameworks will ensure a resilient AI ecosystem. By aligning with global trends and leveraging domestic capabilities, India can not only meet its AI ambitions but also drive significant economic and societal advancements, positioning itself at the forefront of the global AI revolution.

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