Climate Vulnerability Insights Across Gujarat

District by District, Sector by Sector

Objective

Develop district-level and sector-specific vulnerability profiles and integrate the insights into the Gujarat Climate Action Tracker to support evidence-based decision-making and enable targeted actions to reduce sensitivities and strengthen adaptive capacity across the state.

Sectors

Gujarat's economy and livelihoods are deeply intertwined with climate-sensitive sectors, making a focused vulnerability analysis essential. Agriculture, Micro, Small, and Medium Enterprises (MSMEs), and water resources form the backbone of the state's economic activity, employment base, and resource security, yet all three face growing risks from recurring droughts, heatwaves, floods, cyclones, and saline intrusion. These shocks increasingly disrupt productivity, supply chains, and livelihoods across rural and urban areas.

Agriculture employs nearly half of Gujarat's workforce and remains highly dependent on monsoon patterns, temperature thresholds, and groundwater availability. Variability in any of these directly affects crop yields, farmer incomes, and food security.

Water resources cut across all sectors, underpinning agriculture, industry, and domestic needs. Uneven rainfall distribution, over-extraction of groundwater, and coastal salinity intrusion pose escalating risks that compromise both water supply and ecosystem health.

MSMEs, especially in Gujarat's major clusters such as textiles, dairy, salt, and food processing, are particularly vulnerable to heat stress, water scarcity, and climate-related disruptions in inputs and logistics. These risks threaten not only economic productivity but also employment for millions.

Given their economic importance and high climate exposure, focusing on these three sectors enables a comprehensive and actionable understanding of Gujarat's climate vulnerability, one that captures interdependencies, identifies priority risks, and supports targeted resilient strategies.

Target audience

Primary audiences include state and district level departments (such as Climate Change Department; Agriculture, Farmers Welfare and Cooperation Department; Forests and Environment Department; Narmada, Water Resources, Water Supply and Kalpsar Department; Health & Family Welfare Department; Industries and Mines Department).

Secondary audiences include CSOs, NGOs, practitioners and academia for leveraging insights to design local adaptation and resilience interventions.

Intended use of the analysis

The study identifies sectors and districts that are vulnerable to climate impacts. By analyzing both sensitivity and existing adaptive capacity, it highlights key gaps and areas that need strengthening. The insights can guide targeted actions, prioritization, and resource allocation to enhance climate resilience across districts.

Climate data

The study incorporates additional datasets on past climate events and climate risk assessments to provide a context and complement sectoral analysis on climate vulnerablity. The data has been extracted from reports and databases from Government institutions and think tanks. The following definitions and data constructs have been adopted in this study -

Past events are historically documented occurrences over specific time periods to show severity and frequency of extreme climate events. These include droughts, floods, heatwaves and cyclonic events. The data has been sourced from the climate vulnerability section of IMD website.

District level Climate Risk for flood and drought have been sourced from the District-level climate risk assessment report by the Department of Science and Technology (DST), cyclone proneness from the IMD website, while for heat risk, information was sourced from, "How extreme heat is impacting India" (CEEW).

Definitions

Hazard: Hazard refers to a natural or human-induced event (such as droughts, floods and cyclones) that can cause harm to people, infrastructure, livelihoods, ecosystems, or the environment.

Vulnerability: Vulnerability is the predisposition to be adversely affected, encompassing sensitivity to harm and lack of capacity to cope and adapt.

Sensitivity: The degree to which climate change affects a system or species, either adversely or beneficially, through direct pathways (e.g., temperature-driven yield changes) or indirect pathways (e.g., flood damages associated with sea-level rise).

Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.

Risk: Risk describes the potential for consequences when exposed to climate change. It is commonly expressed as the probability of a hazardous event and the magnitude of its impacts, and results from the interaction between hazard, exposure, and vulnerability.

List of indicators

AGRICULTURE				
Indicators		Relationship to vulnerability	Rationale for the indicator	Indicator construction and data source
Proportion of marginal and small landholdings	Sensitivity	+ve	Marginal and smallholder farmers are particularly vulnerable to climatic shocks, facing immediate livelihood disruptions. With limited access to information, credit, and resources, they struggle to make timely decisions about sowing, crop selection, and input management. Their low adaptive capacity also makes it harder for them to cope with yield losses and price fluctuations, increasing their overall climate sensitivity.[1]	(Marginal and small land holdings ÷ Total landholdings) Data extracted as hectares from the Statistical Abstract of Gujarat State 2024 which captures details from the agriculture Census 2015–16. Marginal landholdings = 0.5–0.99 sq.km Small landholdings = 1.0–1.99 sq.km
Multidimensional Poverty Index	Sensitivity	+ve	The Multidimensional Poverty Index (MPI) measures deprivation across key areas such as health, education, and living standards, offering a more holistic picture of poverty than income alone. Higher MPI levels indicate that households lack essential services, information, and resources	The data is extracted from *NITI Aayog's MPI* which is based on India's National MPI framework and utilizes data from the National Family Health Survey (NFHS-5) for the 2019–21 period.

[1] Indian Himalayas Climate Adaptation Programme (IHCAP). (2019). Climate vulnerability assessment for the Indian Himalayan region using a common framework. New Delhi: Government of India and the Swiss Agency for development and cooperation

			needed to cope with climate impacts. For agricultural communities, these socio-economic deprivations reduce their ability to adjust farming practices, access credit or technology, recover from losses, and plan for future risks. [2]	
Rainfed net sown area	Sensitivity	+ve	Rainfed agricultural systems are highly sensitive to climate variability because they depend almost entirely on rainfall for crop production. Without irrigation, farmers have limited ability to buffer against droughts, delayed monsoons, or erratic rainfall. This increases the likelihood of crop losses and leads to greater income instability for households relying on rainfed agriculture. [3]	Net irrigated area ÷ Net sown area Data taken as sq.km for 2023-24 from the *Provisional District Wise Land utilisation, Area under crops and Area irrigated by source of Gujarat State for 2023-24*
Yield variability of cereals	Sensitivity	+ve	High variability in crop yields reflects fluctuating agro-climatic conditions. Since agriculture is highly sensitive to shifts in rainfall (such as delayed monsoons, dry spells, droughts, extreme rainfall, and floods), yield variability serves as a direct indicator of this sensitivity. [4]	Coefficient of Variation (i.e., standard deviation ÷ arithmetic mean) Cereal and millets yield data (2018-2023) taken from *Directorate of Economics and Statistics*
Proportion of net sown horticulture area	Adaptive Capacity	-ve	Horticultural tree crops tend to be more resilient to climate variability than traditional agricultural crops. Once established, they are less dependent	Net sown horticulture area ÷ Net sown area

[2] O'Brien, G., O'keefe, P., Meena, H., Rose, J., & Wilson, L. (2008). Climate adaptation from a poverty perspective. Climate Policy, 194-201.
[3] Rani, C. R., Vanaja, M., & Bali, S. K. (2011). Climate change and rainfed agriculture: Rural development perspectives. Journal of rural development, 30(4), 411-419.
[4] Davis, K. F., Chhatre, A., Rao, N. D., Singh, D., & Defries, R. (2019). Sensitivity of grain yields to historical climate variability in India. Environmental Research Letters.

			on rainfall and can better withstand dry spells and temperature fluctuations. They also provide a more stable and diversified income source for farmers, reducing overall livelihood sensitivity to climate shocks. [5]	Data taken as sq.km for 2023-24 from the *Provisional District Wise Land utilisation, Area under crops and Area irrigated by source of Gujarat State for 2023-24 and Agricultural statistics 2024*
Livestock to rural population ratio	Adaptive Capacity	-ve	Livestock provides an important alternative income source for farming households. Earnings from milk, meat, or animal products can help offset agricultural losses during climate-related shocks, and animals can be sold in times of distress. This financial buffer reduces household vulnerability and supports overall livelihood resilience. [6]	Total livestock count ÷ Projected rural population Data for 2019 livestock extracted from *Agricultural Statistics 2024*, and for population projection refer methodology.
Health infrastructure (per 1000 persons)	Adaptive Capacity	-ve	Public and Community Health Centers (PHCs/CHCs) are often the first point of medical support during extreme climate events. Their availability and accessibility play a crucial role in protecting vulnerable farming communities from heat stress, disease outbreaks, and other climate-related health impacts. [7]	(Total number of public health facilities ÷ Projected population) X 1000 Data extracted from the *Health Statistics Gujarat 2015-2016* and for population projection refer methodology.

[5] Indian Himalayas Climate Adaptation Programme (IHCAP). (2019). Climate vulnerability assessment for the Indian Himalayan region using a common framework. New Delhi: Government of India and the Swiss Agency for development and cooperation

[6] Indian Himalayas Climate Adaptation Programme (IHCAP). (2019). Climate vulnerability assessment for the Indian Himalayan region using a common framework. New Delhi: Government of India and the Swiss Agency for development and cooperation

[7] Indian Himalayas Climate Adaptation Programme (IHCAP). (2019). Climate vulnerability assessment for the Indian Himalayan region using a common framework. New Delhi: Government of India and the Swiss Agency for development and cooperation

Number of person days per 1000 people in MGNREGA	Adaptive Capacity	-ve	MGNREGA provides an alternate livelihood support and income stabilization through guaranteed wage employment to rural households. This offers a safety net during climate shocks such as droughts, floods, or crop failures. [8]	(Number of persondays ÷ Projected rural population) X 1000 Data for 2024-25 taken from MGNREGA website and for population projection refer methodology.
Rural women's participation in work force	Adaptive Capacity	-ve	Women are often more sensitive to climate risks because persistent gender inequalities limit their access to resources, information, and decision-making power. Women's participation in the labour market is therefore an important indicator of gender equality. Regions with higher female employment typically reflect greater financial independence, improved purchasing power, and better social standing for women, resulting in stronger coping capacity and lower vulnerability to climate impacts. [9]	Data taken from Census 2011

[8] Adam, H. N. (2014). Mainstreaming adaptation in India – the Mahatma Gandhi National Rural Employment Guarantee Act and climate change. Climate and Development, 7(2), 142-152.

[9] Human Development Report. (2019). Beyond income, beyond averages, beyond today: Inequalities in human development in the 21st century. New York: United Nations Development Programme.

WATER RESOURCES

Indicators		Relationship to vulnerability	Rationale for the indicator	Indicator construction and data source
Ground water extraction	Sensitivity	+ve	Groundwater dependency shows how much a city or region relies on groundwater for its water needs. High dependence makes the water system more sensitive to climate changes, overuse, and depletion risks. [10]	The annual ground water extraction is calculated as an annual average between 2017 and 2024 Data extracted as hectare-metre (ham) from National Compilation on Dynamic Ground Water Resources of India
Interannual variability	Sensitivity	+ve	Interannual variability captures the changes in freshwater availability from year to year. Regions with high year-to-year fluctuations in water availability face greater risks from droughts and floods and may need strategies to manage both surplus and shortage. [11]	Data extracted from Aqueduct 4.0 managed by WRI's data lab
Loss of forest area	Sensitivity	+ve	Forest cover dynamics strongly influence local climate conditions and water availability. Changes in forest cover affect groundwater recharge, runoff, and soil moisture, making this	Forest area in 2014-15 – forest area in 2024-25 Forest area includes reserved forest, protected forest and unclassed forest.

[10] N.H & N. Y. P. 2023. Mapping Climate Change Vulnerability: An assessment of water resources sector across different districts of Karnataka. Environmental Management & Policy Research Institute.

[11] N.H & N. Y. P. 2023. Mapping Climate Change Vulnerability: An assessment of water resources sector across different districts of Karnataka. Environmental Management & Policy Research Institute.

			an important indicator for understanding climate impacts on water resources. [12]	Data taken as Sq.kms from *Gujarat Forest Statistics.*
MSMEs with high water use	Sensitivity	+ve	MSMEs with high water use reflect the degree of pressure that local economic activities place on available water resources, indicating sensitivity to fluctuations in water availability and quality. [13]	(Number of water-intensive MSMEs ÷ Total number of MSMEs in the district) X 100 *Data extracted from the Industries Commissionerate for 2015. For the list of MSMEs with high water use, refer annexure 1.*
Multidimensional Poverty Index	Sensitivity	+ve	The Multidimensional Poverty Index (MPI) measures deprivation across key areas such as health, education, and living standards, offering a more holistic picture of poverty than income alone. Higher MPI levels indicate that households lack essential services, information, and resources needed to cope with climate impacts. For agricultural communities, these socio-economic deprivations reduce their ability to adjust farming practices, access credit or technology, recover from losses, and plan for future risks. [14]	The data is extracted from *NITI Aayog's MPI* which is based on India's National MPI framework and utilizes data from the National Family Health Survey (NFHS-5) for the 2019–21 period.
Water gap	Sensitivity	+ve	The water gap represents the difference between total demand and available water. It captures how well existing water resources can meet current and projected needs. Higher gap	Water demand - Water available

[12] Sahin, V. and Hall, M.J., 1996. The effects of afforestation and deforestation on water yields. J. Hydrol., 178: 293309. doi: 10.1016/0022-1694(95)02825-0
[13] GIZ. NA. Facing the Impacts of Climate Change: Indian MSMEs and Adaptation. Available @ https://www.sidbi.in/uploads/publicationreport/Facing-the-Impacts-of-Climate-Change-Indian-MSMEs-and-Adaption_(2).pdf
[14] O'Brien, G., O'keefe, P., Meena, H., Rose, J., & Wilson, L. (2008). Climate adaptation from a poverty perspective. Climate Policy, 194-201.

			signals increased vulnerability to water resources. [15]	Data extracted as Million Cubic Metres (MCM) from *District irrigation plans (2016-2020)*
HHs having adequate water supply	Adaptive Capacity	-ve	Piped water supply can improve reliability and access to drinking water security. [16] Considering Gujarat has 100% pipe connections, the indicator on supply of water on an annual basis is considered.	*Data extracted from NSS 2018 – Report on Drinking Water, Sanitation, Hygiene and Housing Condition In Gujarat*

[15] N.H & N. Y. P. 2023. Mapping Climate Change Vulnerability: An assessment of water resources sector across different districts of Karnataka. Environmental Management & Policy Research Institute.

[16] Lalthanpuia, H. Laldinpuii, S. Lalmalsawma, & J. L. Hrahsel. (2022). Assessment of district level climate vulnerability of Mizoram, India: Water resources approach. *Journal of Climate Change*, *8*(3), 21–29. https://doi.org/10.3233/JCC220018 (and) N.H & N. Y. P. 2023. Mapping Climate Change Vulnerability: An assessment of water resources sector across different districts of Karnataka. Environmental Management & Policy Research Institute.

Net irrigated area	Adaptive capacity	-ve	Access to irrigation is an adaptation strategy to climate change as it reduces water stress and improves crop productivity [17]	The percentage of net sown area irrigated by surface water (tanks and canals) is extracted from *Irrigation in Gujarat 2023-24*

MSMEs

Indicators		Relationship to vulnerability	Rationale for the indicator	Indicator construction and data source
MSME employment per 1 lakh population	Sensitivity	+ve	A higher employment share, particularly in climate-sensitive sectors, implies greater potential for income loss, productivity disruption, and socio-economic vulnerability under climate extremes. [18]	(MSME employment in district ÷ district population) X 1 lakh *Data extracted from the Industries Commissionerate for 2015* and for population projection refer to methodology.
MSMEs with high water use	Sensitivity	+ve	MSMEs with high water use reflect the degree of pressure that local economic activities place on available water resources, indicating sensitivity to	(Number of water-intensive MSMEs ÷ Total number of MSMEs in the district) X 100 *Data extracted from the Industries Commissionerate for 2015. For the list of*

[17] Rosa L, Chiarelli D D, Sangiorgio M, Beltran-Peña A A, Rulli M C, D'Odorico P and Fung I 2020 Potential for sustainable irrigation expansion in a 3 °C warmer climate *Proc. Natl Acad. Sci.* **117** 29526–34 (and) N.H & N. Y. P. 2023. Mapping Climate Change Vulnerability: An assessment of water resources sector across different districts of Karnataka. Environmental Management & Policy Research Institute.

[18] Parmar, H., & Gawde, N. (2023). Heat Stress Vulnerability Among Small-Scale Factory Workers and Adaptive Strategies in Ahmedabad: a Cross Sectional Study. International Journal of Occupational Safety and Health, 13(3), 321–330. https://doi.org/10.3126/ijosh.v13i3.44241

			fluctuations in water availability and quality. [19]	*MSMEs with high water use, refer annexure 1.*
MSMEs with high energy use	Sensitivity	+ve	MSMEs with high energy use reflect the extent to which enterprises rely on continuous and affordable energy for production. High dependence on energy, especially fossil fuels or unreliable power supply makes these enterprises highly sensitive to fluctuations in energy availability, cost, and climate-related disruptions. [20]	(Number of energy-intensive MSMEs ÷ Total number of MSMEs in the district) X 100 *Data extracted from the Industries Commissionerate for 2015. For the list on MSMEs with high water use, refer annexure 1.*
Health infrastructure (per 1000 persons)	Adaptive Capacity	-ve	Public and Community Health Centers (PHCs/CHCs) are often the first point of medical support during extreme climate events. Their availability and accessibility play a crucial role in protecting vulnerable farming communities from heat stress, disease outbreaks, and other climate-related health impacts. [21]	(Total number of public health facilities ÷ Projected population) X 1000 Data extracted from the *Health Statistics Gujarat 2015-2016* and for population projection refer methodology.
Women participation in work force	Adaptive Capacity	-ve	Women are often more sensitive to climate risks because persistent gender inequalities limit their access to resources, information, and decision-making power. Women's participation in the labour	Data taken from Census 2011

[19] GIZ. NA. Facing the Impacts of Climate Change: Indian MSMEs and Adaptation. Available @ https://www.sidbi.in/uploads/publicationreport/Facing-the-Impacts-of-Climate-Change-Indian-MSMEs-and-Adaption_(2).pdf

[20] GIZ. NA. Facing the Impacts of Climate Change: Indian MSMEs and Adaptation. Available @ https://www.sidbi.in/uploads/publicationreport/Facing-the-Impacts-of-Climate-Change-Indian-MSMEs-and-Adaption_(2).pdf

[21] Indian Himalayas Climate Adaptation Programme (IHCAP). (2019). Climate vulnerability assessment for the Indian Himalayan region using a common framework. New Delhi: Government of India and the Swiss Agency for development and cooperation

			market is therefore an important indicator of gender equality. Regions with higher female employment typically reflect greater financial independence, improved purchasing power, and better social standing for women, resulting in stronger coping capacity and lower vulnerability to climate impacts. [22]	

Methodology

The methodology is designed to develop robust, district-level, and sector-specific vulnerability profiles for Gujarat. It aligns with the, 'Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework,' by the Department of Science and Technology's (2024).

Step 1: Indicator Selection and Data Collection

The assessment focuses on three climate-sensitive sectors: Agriculture, Water resources, and Micro, Small, and Medium Enterprises (MSMEs). A total of 18 biophysical and socio-economic indicators were selected as per the definition of 'sensitivity' and 'adaptive capacity' as defined in the IPCC AR6. The primary criterion for indicator selection was the consistent availability of uniform data across all districts of Gujarat, which ensures a valid basis for comparison.

Note: District-level urban population was estimated by applying the 2011 district-wise urban population share as a weighted average to the projected urban population of Gujarat (as per Census projections). Rural population was derived by subtracting the estimated urban population from the total district population reported by IIPS.

[22] Human Development Report. (2019). Beyond income, beyond averages, beyond today: Inequalities in human development in the 21st century. New York: United Nations Development Programme.

Step 2: Data Normalization

To enable a comparable analysis, all indicators were normalized. This process transforms the data, which have different units and scales, into a common dimensionless range. The Min-Max Normalization technique was used, which rescales indicator values to a range between 0 and 1. For indicators that represent sensitivity, the formula is:

Normalized Value = $X - X_{MIN} / X_{MAX} - X_{MIN}$

Conversely, for indicators that represent adaptive capacity, an inverted formula was used to ensure all indicators point in the same direction of vulnerability:

Normalized Value = $X_{MAX} - X / X_{MAX} - X_{MIN}$

X represents the original data point, while X_{MIN} and X_{MAX} are the minimum and maximum values for that indicator across all districts.

Step 3: Vulnerability Index Calculation

All 19 indicators were given equal importance in the calculation. The composite vulnerability index for each district was calculated as the arithmetic mean of the normalized values of all indicators. This approach creates a comprehensive score reflecting a district's overall vulnerability by aggregating the impacts of various sensitivity and adaptive capacity factors.

Step 4: Vulnerability Classification

The final vulnerability index for each district was categorized using the Natural Breaks classification method. Through this method, districts were grouped into three distinct categories of vulnerability: **Low, Moderate, and High**. This helps to identify priority districts and sectors where urgent and targeted measures are required.

Annexure 1: Classification of MSMEs based on high water and energy use

Legend
High water use
High energy use
High energy and water use

NIC Code (Division)	**Industry type**	**Rationale**
2	Forestry Products	Forestry plantations (timber, pulpwood, bamboo) have long rotations and high transpiration rates. Pre-processing of timber (seasoning, steaming, preservation) requires large volumes of water. [23]
10 & 11 (2008)	Manufacture of food products and beverages	Bottled beverages and many dairy operations have modest product mass but require several litres of water per litre of product. Estimates for rice, wheat, maize (among other crops) in India: water footprints (m^3/kg) showing high volumes of irrigation - they depend on raw material involving water use. [24]
12 (2008)	Manufacture of tobacco products	The manufacturing stage of tobacco products, including onsite cigarette production, is energy intensive due to the need for processing, curing, and packaging operations. Tobacco curing within manufacturing is particularly energy demanding, for example through flue-curing processes that require artificial heat over days to weeks using wood, coal, or other fuels. [25]

[23] Indian Council of Forestry Research and Education. (2019). Productivity enhancement in forestry plantations. Dehradun, India: ICFR

[24] Xu, Y., M., Li, J., & Zhang, W. (2022). Carbon and water footprints of major crop production in India. Journal of Cleaner Production, 455, 130554. https://doi.org/10.1016/j.jclepro.2022.300515 (and) Ministry of Food Processing Industries. (n.d.). Sector profile: Beverages (Sector Profile). https://mofpi.gov.in/sites/default/files/KnowledgeCentre/Sector_Profile_Beverages%20(1).pdf

[25] World Health Organization. (2016). Progress on sanitation and drinking-water: 2015 update and MDG assessment. World Health Organization.

13 (2008)	Manufacture of textiles	In textile wet processing, water is used mainly for three purposes: as a solvent for dyes and chemicals, as a medium for transferring dyes and chemicals to fabric, and as a washing and rinsing medium. Apart from the above processes, ion exchange, boiler, cooling water, steam drying, and the cleaning part of the process also consume a considerable amount of water. [26]
14 (2008)	Manufacture of wearing apparel; dressing and dyeing of fur	Colouring, bleaching, scouring, and rinsing of materials require multiple wash/ rinse cycles, making dyeing one of the most water-consuming stages in textile/fur processing. [27]
15 (2008)	Tanning and processing of leather	Tanning agents are applied in aqueous baths (usually with floats or drums). Many operations use multiple baths (pre-tanning, tanning, re-tanning, dyeing, fat-liquoring) — each needs fresh or partially fresh water and rinses to control chemistry. [28]
17 (2008)	Manufacture of paper and paper products	Processing of pulp from wood, bamboo, and agricultural residues requires a large amount of water. To achieve white paper, pulp is bleached requiring dilution and washing cycles consuming water. [29]
20 (2008)	Manufacture of chemicals and chemical products	Chemical industries (fertilizers, petrochemicals, pharmaceuticals, dyes) require intense heat and pressure for reactions like cracking, reforming, and synthesis indicating heavy fuel use. [30]

[26] Raja, A. S. M., Arputharaj, A., & Patil, P. G. (2019). Water requirement and sustainability of textile processing industries. In Water in Textiles and Fashion (pp. –). Elsevier. https://doi.org/10.1016/B978-0-08-102633-5.00009-9

[27] Central Pollution Control Board. (n.d.). Effluent/emission. Government of India. Retrieved from https://cpcb.nic.in/effluent-emission/

[28] CSIR-Central Leather Research Institute. (2023). Technology compendium – English version (Technology Contr. No. CLRI/TechComp/2023). CSIR-CLRI.

[29] Central Pollution Control Board. (2020). Charter on pollution control for the pulp & paper industry (Version 3.0). Government of India (and) Schyns, J. F., Booij, M. J., & Hoekstra, A. Y. (2017). The water footprint of wood for lumber, pulp, paper, fuel and firewood. Advances in Water Resources, 000, 1-12. https://doi.org/10.1016/j.advwatres.201

[30] Ministry of Statistics and Programme Implementation. (2024). Energy Statistics India 2023 (247th ed.). Government of India.

24 (2008)	Manufacture of basic metals	Converting ores to metals (iron from iron ore, aluminium from bauxite) requires very high-temperature furnaces (blast furnaces, electric arc furnaces, smelters). Aluminium production, in particular, uses large amounts of electricity for electrolysis. Processes like refining, steel-making (basic oxygen furnace, electric arc), and alloy addition involve continuous heating and melting, all energy heavy. [31]
30 (2008)	Manufacture of other transport equipment (Railways, Airways, Ships & Road Surface Transport)	Production of motors, transformers, cables, and heavy equipment requires metal casting, forging, machining, insulation, and testing, all of which are electricity-intensive. [32]
37 (2008)	Sewage and refuse disposal, sanitation and similar activities	huge volumes of sewage generated (≈72,000 MLD) and the need for large-scale conveyance and treatment capacity demonstrating that the sector is fundamentally driven by water handling and treatment. [33]
20 (1987)	Agro-based industries	Agro-based industries comprise of both energy and water intensive industries including textiles, food processing, paper and pulp, beverages, sugar and edible oils. Industries such as textiles, food processing, paper and pulp require substantive water use while sugar and dairy are highly energy intensive. Textiles, food processing, paper and pulp's core production processes depend heavily on water as a processing medium. Sugar and

[31] Ministry of Statistics and Programme Implementation. (2024). Energy Statistics India 2023 (247th ed.). Government of India (and) Ministry of Environment, Forest & Climate Change. (2019). Draft National Resource Efficiency Policy (Version 2019). Government of India

[32] Ministry of Statistics and Programme Implementation. (2024). Energy Statistics India 2023 (247th ed.). Government of India (and) Climate Analytics. (2024). India: Transport sector – 1.5 °C national pathway explorer. Retrieved from https://1p5ndc-pathways.climateanalytics.org/countries/india/v6/sectors/transport/

[33] Central Pollution Control Board. (n.d.). Status of Sewage Treatment Plants (STPs). Government of India.

		dairy require high steam and power demand for production and refrigeration. [34]
22 (1987)	Soda Water	Typically requires multiple litres of water for washing, cooling, carbonation, and cleaning processes—far beyond the water in the final product. Packaging, CO_2 production, and wastewater treatment add further water demand. Groundwater withdrawal in water-stressed regions magnifies its impact. [35]
25 (1987)	Jute and jute based	The jute industry is water-intensive because of retting and washing processes; its energy use is moderate and mainly mechanical. [36]
26 (1987)	Ready-made garments & embroidery	Sewing, embroidery machines & finishing equipment (ironing, pressing, dryers) run on electricity. Garment factories require strong illumination and climate control. Automation & embroidery machines are increasingly digital/electrical, making electricity demand significant. [37]
27 (1987)	Wood/wooden based furniture	Wood is treated with water-based preservatives (borates, chromated copper arsenate, etc.) to protect against termites, fungi, and borers. Timber is soaked or steamed in water to reduce moisture and prevent cracking.[38]
31 (1987)	Rubber, Plastic & Petro products	1. Rubber: Natural rubber processing (coagulation, washing, leaching, drying) uses large volumes of water and generates effluents with high organic loads requiring treatment. Rubber manufacturing (mixing, extrusion,

[34] Bureau of Energy Efficiency. (2021). SEEAP Whitepaper – Uttar Pradesh. Government of India; Shelar, M. N., Matsagar, V. K., Patil, V. S., & Barahate, S. D. (2023). Net energy analysis of sugarcane-based ethanol production. Cleaner Energy Systems, 4, Article; United Nations Industrial Development Organization. (n.d.). Technology compendium – Gujarat dairy cluster [PDF]; Nayak, A. K., Li, J., & Zhang, W. (2023). Carbon and water footprints of major crop production in India. Journal of Cleaner Production, 455, Article 130554 (and) Raja, A. S. M., Arputharaj, A., & Patil, P. G. (2019). Water requirement and sustainability of textile processing industries. In Water in Textiles and Fashion (pp. 159–172). Elsevier. https://doi.org/10.1016/B978-0-08-102633-5.00009-9

[35] Beverage Industry Environmental Roundtable. (2024). 2023 BIER benchmarking executive summary report [PDF]. https://www.bieroundtable.com/wp-content/uploads/2023-BIER-Benchmarking-Executive-Summary-Report.pdf

[36] National Food Security Mission. (n.d.). Brief note on jute. Government of India.

[37] Çay, A. (2018). Energy consumption and energy saving potential in clothing industry. Energy, 159, 74–85. https://doi.org/10.1016/j.energy.2018.06.128

[38] Indian Council of Forestry Research and Education. (n.d.). Seasoning of wood & bamboo and wood preservation. Indian Council of Forestry Research and Education.

		vulcanisation/drying) needs continuous heat/steam and mechanical energy for heavy machinery. 2. Plastic: plastics production and forming use large volumes of process and cooling water (polymerisation reactors, condenser cooling, extrusion/mould cooling) and water for cleaning and washing resins and moulds. Producing monomers and polymers (steam cracking, polymerisation) and downstream moulding (melting, extrusion, heating) require high thermal and electrical energy. 3. Petrochemicals: refineries and petrochemical plants require very large cooling-water circuits, desalting and steam generation, and produce oily effluents needing extensive wastewater treatment. crude distillation, catalytic cracking, reforming, hydrogen production and steam-driven unit operations operate at high temperatures and pressures — refineries and petrochemical complexes are among the country's heaviest continuous energy users. [39]
32 (1987)	Minerals based	Mineral-based industries like cement, glass, and ceramics are energy intensive because they need very high heat in kilns and furnaces (often above 1,400–1,700 °C) to process raw minerals. Producing this heat takes huge amounts of coal, gas, or electricity, which makes these industries heavy energy users. [40]
35 (1987)	Engineering Units	Engineering units are energy-intensive because machining, casting and heat-treatment require heavy electricity/thermal power; they are water-

[39] Central Pollution Control Board. (2018, May). Life cycle assessment report: Plastic packaging and films in India. Government of India; NITI Aayog. (2022). Plastics alternative study – final report [PDF]. Government of India; Dey, S., & Dhar, S. (2024). Critical review on water footprints of industrial sectors: Towards sustainability-driven water-energy-material nexus. Journal of Environmental Management, 334, Article 120645. https://doi.org/10.1016/S0926-6690(24)23276-6 (and) TERI. (2017). Assessment of water footprints of India's long term energy scenarios (Report for NITI Aayog).

[40] Aramendia, E., Brockway, P. E., Taylor, P. G., & Norman, J. (2023). Global energy consumption of the mineral mining industry: Exploring the historical perspective and future pathways to 2060. Global Environmental Change, 83, 102745. https://doi.org/10.1016/j.gloenvcha.2023.102745

		intensive because cooling, washing, plating and metal finishing processes require large water use and generate significant effluent. [41]
36-37 (1987)	Electrical Machinery & Transport Equipment	Production of motors, transformers, cables, and heavy equipment requires metal casting, forging, machining, insulation, and testing, all of which are electricity-intensive. [42]

[41] Beverage Industry Environmental Roundtable. (2024). 2023 BIER benchmarking executive summary report [PDF]. https://www.bieroundtable.com/wp-content/uploads/2023-BIER-Benchmarking-Executive-Summary-Report.pdf (and) Joseph, N., Azad, A. K. D., & Bhattacharya, A. (2019). Estimation of industrial water demand in India using 50-year trends and industrial census data. Resources, Conservation and Recycling, 149, 85-94. https://doi.org/10.1016/j.resconrec.2019.06.008

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