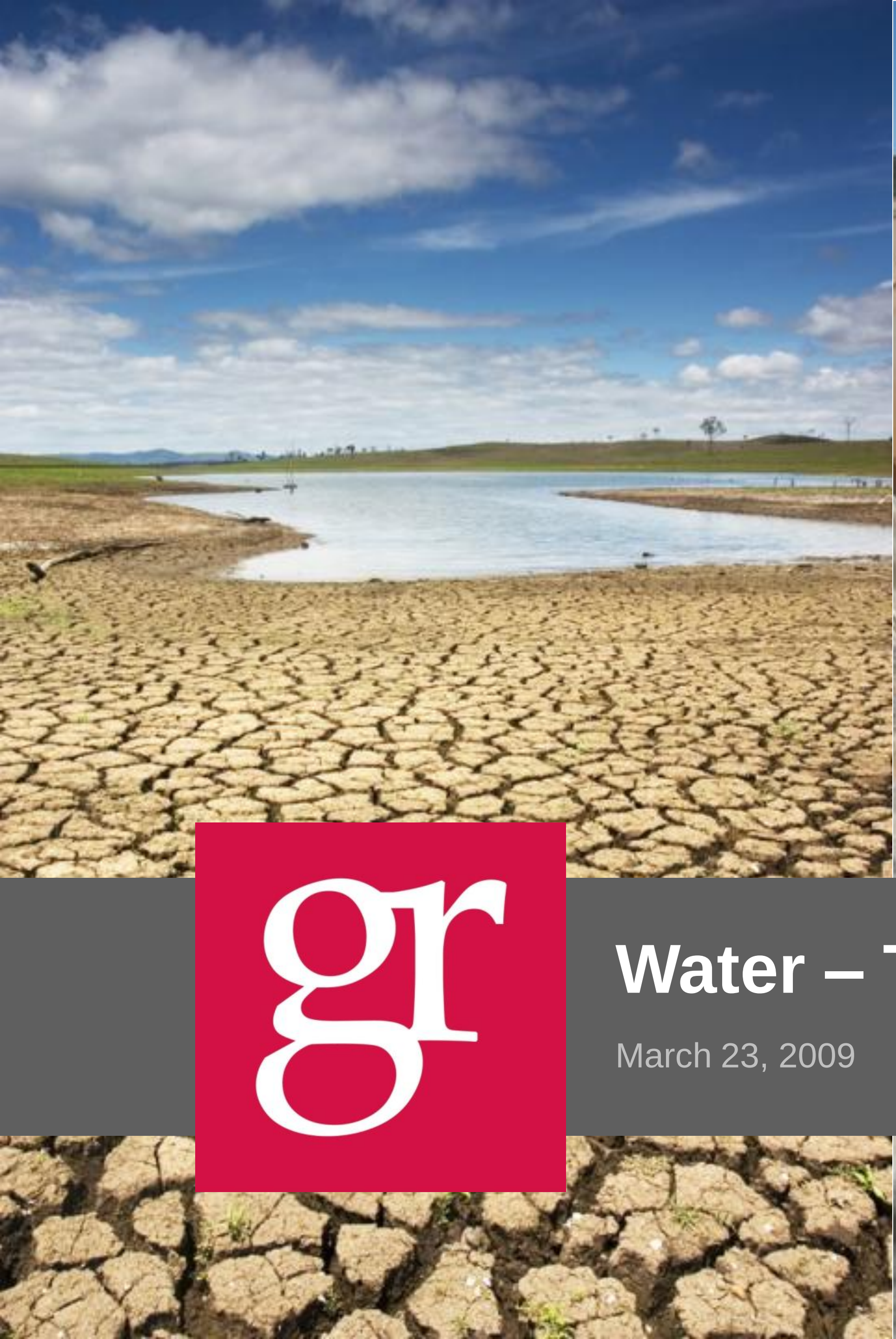


Water – The India Story

March 23, 2009

Table of Contents

Freshwater rich regions across the globe are projected to face water scarcity if current reserves are not managed effectively

Global Freshwater Scenario

- Global Freshwater reserves are rapidly depleting and this is expected to significantly impact many densely populated areas of the world
- Low to middle income developing regions as well as highly developed countries will face water stress in the future, unless existing water reserves are managed effectively
  - Although low and middle income developing countries currently have low per capita water consumption, rapid growth in population and inefficient use of water across sectors is expected to lead to a water shortage in the future
  - Developed countries traditionally have high per capita water consumption and need to focus on reducing their consumption through improved water management techniques and practices
- By 2025, India, China and select countries in Europe and Africa will face water scarcity if adequate and sustainable water management initiatives are not implemented

Freshwater Situation in India

- Traditionally, India has been well endowed with large Freshwater reserves, but the increasing population and overexploitation of surface and groundwater over the past few decades has resulted in water scarcity in some regions
- Growth of the Indian economy is driving increased water usage across sectors. Wastewater is increasing significantly and in the absence of proper measures for treatment and management, the existing Freshwater reserves are being polluted
- Increased urbanization is driving an increase in per capita water consumption in towns and cities. Urbanization is also driving a change in consumption patterns and increased demand for water-intensive agricultural crops and industrial products

India can prevent an impending water stress situation by integrating its regional water management programs at the national level

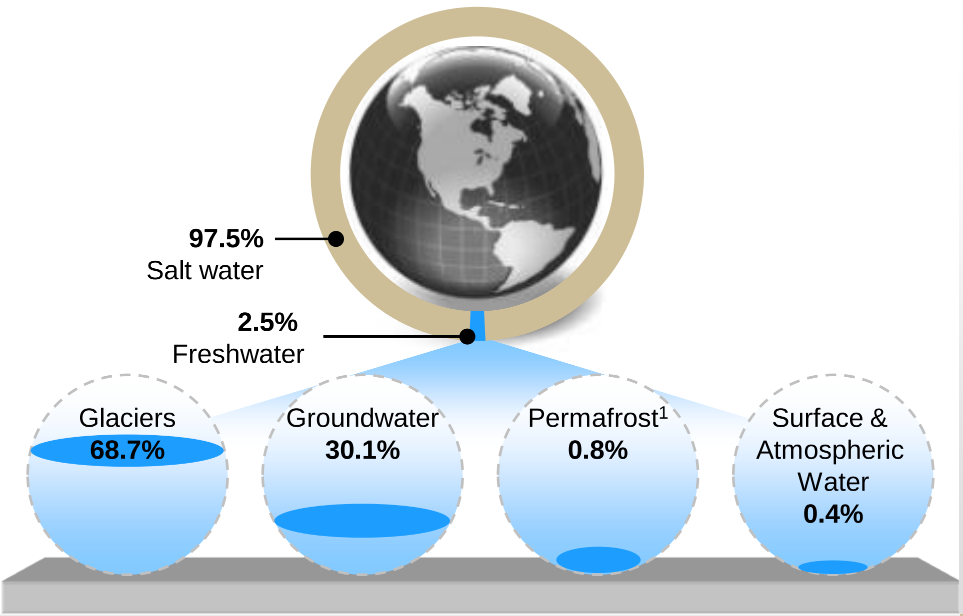
Is India prepared to face the impending water scarcity?

- India recently recognized the need to manage existing water reserves in order to avoid future water strain; however, for a country of such vast geographical expanse the initiatives taken so far are too few and too spread out
- India would benefit from establishing an independent central regulatory agency to design, control and coordinate national programs for water conservation
- Government policy changes (such as those mentioned) below would also ensure that water management techniques and initiatives are executed at a national level across sectors
  - Agricultural Sector
    - Improve water usage efficiency in the production of water-intensive crops such as rice, wheat and sugarcane; encourage adoption of techniques such as rain-water harvesting and watershed management in agriculture
    - Reduce subsidies on power and implement customized pricing models to counter groundwater exploitation through excessive withdrawal
  - Industrial Sector
    - Encourage investment in recycling and treatment of industrial wastewater through regulations and subsidies for water treatment plants
  - Domestic Sector
    - Implement policies to make rain-water harvesting mandatory in cities with new construction projects
    - Propagate efficient water usage practices through community based education programs
- Prioritizing the implementation of the National River Link Project (that connects 30 big rivers and canals and generates 175 Tr liters of water by the interlinking of rivers) is also an important step for the government to take because it will reduce regional disparities in water availability

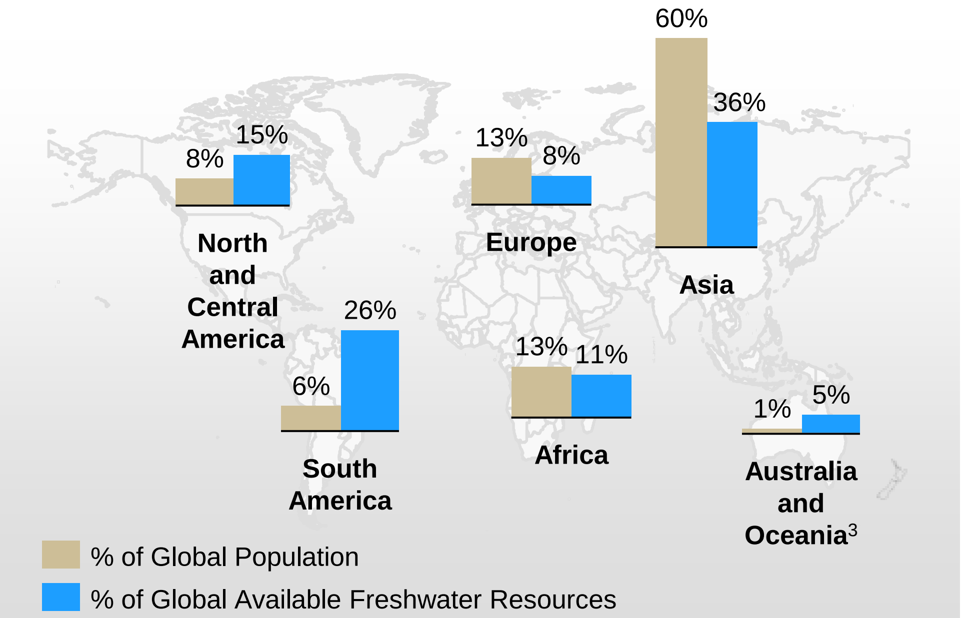
Table of Contents

Freshwater constitutes 2.5% of the total water on the planet. Half of the Freshwater reserves supports 86% of the population

Breakdown of Global Freshwater Reserves



Global Population Distribution vs. Freshwater Reserves[2]



- Total global water reserves is ~1400 MM Tr liters, of which Freshwater consists of only about 35 MM Tr liters
- Groundwater and surface water, which together constitute 30.5% of the Freshwater reserves (~0.76% of the total water on the planet), are the most easily accessible and used sources of water
- Every year, 0.11 MM Tr liters of precipitation falls on land
  - 92% of this is lost due to surface runoff, evaporation, etc.

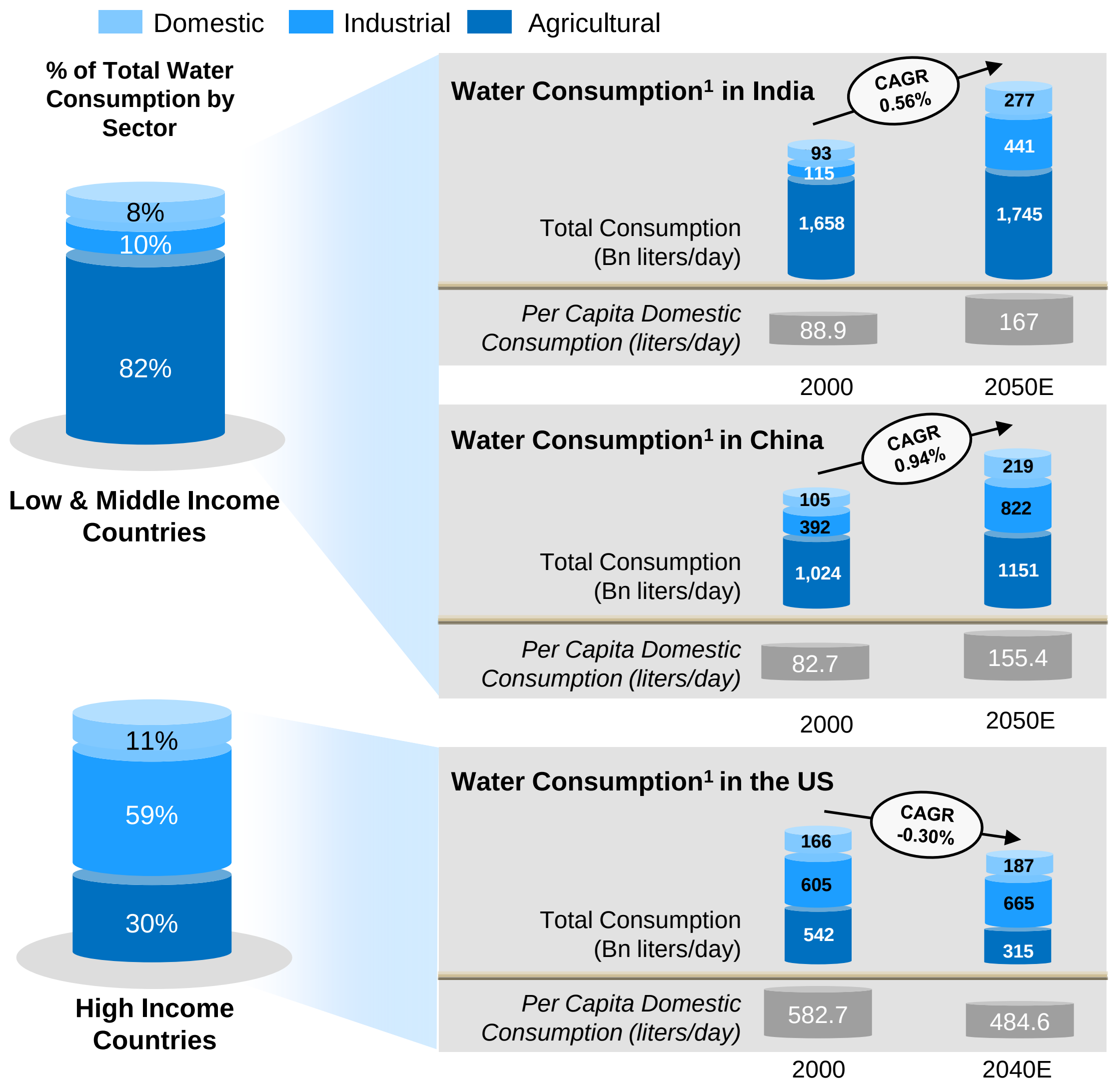
- By 2025, an estimated 3 Bn people will be living below the water stress threshold[4]
  - Between 1995–2025, global population and per capita water consumption are projected to grow at a CAGR[5] of 1.16% and 0.67% respectively
  - Densely populated and developing regions of the world, such as Asia and Africa are expected to face the maximum water stress

Note:; [1]Permafrost is defined on the basis of temperature, as soil or rock that remains below 0°C throughout the year; [2]2003 Data, % figures for population and available Freshwater resources don't add up to 100 due to rounding off; [3]Includes Australia, New Zealand and Pacific Islands (Population of Australia and Oceania is less than 1% of world population); [4]Annual per capita water availability of 1.7 MM liters; [5]Compound Annual Growth Rate;

Source: 'Water- A Shared Responsibility', United Nations World Water Development Report 2, 2006; 'The Global Water Crisis: A Question of Governance', Policy Research Division, Department of Foreign Affairs and International Trade, Canada; 'Water for People Water for Life', United Nations World Water Development Report, 2003; 'Global Water Outlook to 2025', International Food Policy Research Institute; UNEP Annual Report 2002, US Census Bureau Statistics

Per capita domestic water consumption in low and middle income developing countries is projected to increase by 2050

Global Sectoral Water Consumption



Impact on Water Stress

For **Low and Middle income countries**, the overall water usage and per capita domestic consumption of water is expected to increase due to

- Increase in population and urbanization
- Changing consumption patterns of the population towards use of more water-intensive products
- Rapid industrial growth

Developed nations and other **high income countries** are projected to reduce their overall water consumption across sectors by 2050, through

- Better water management measures
- Reduction in per capita water consumption

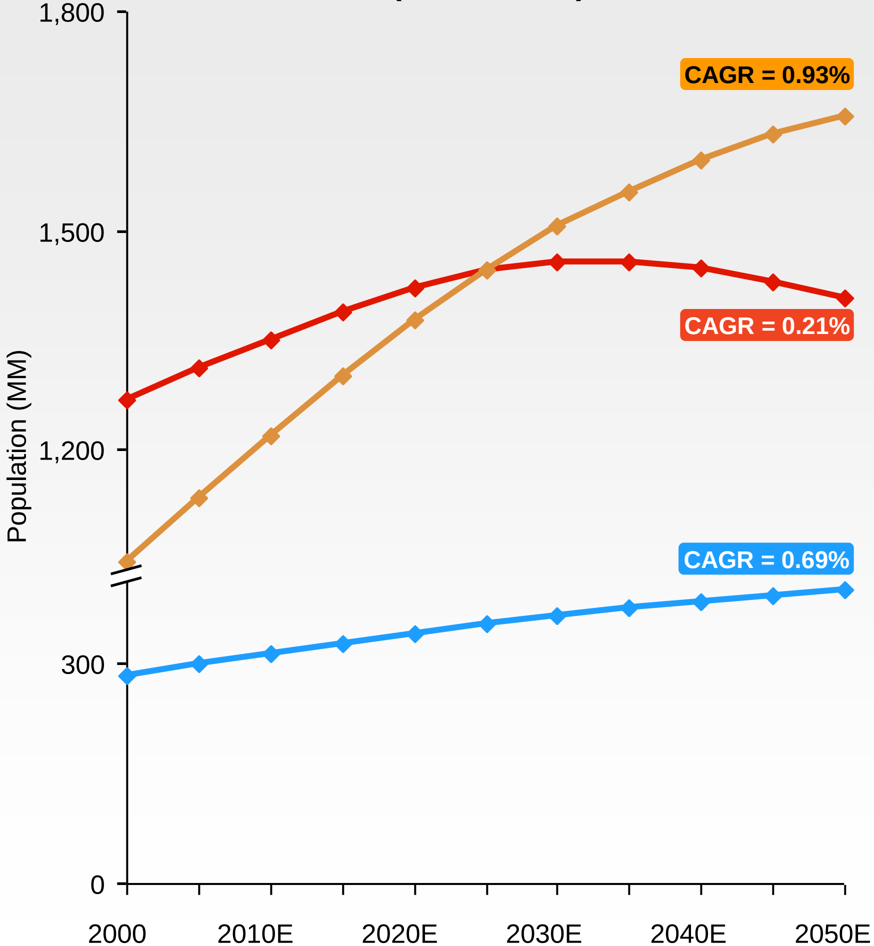
Note: [1]All projected figures indicate water demand

Source: 'Water for People Water for Life', United Nations World Water Development Report, 2003; 'The Global Water Crisis: A Question of Governance', Policy Research Division, Department of Foreign Affairs and International Trade Canada; 'Statistical Yearbook for Asia and the Pacific 2007', United Nations Economic and Social Commission for Asia and the Pacific; 'India's Water Future to 2025 – 2050: Business as Usual Scenario and Deviations', International Water Management Institute; OS-Connect Database; US Geological Survey - Water Resources; Aquastat Database

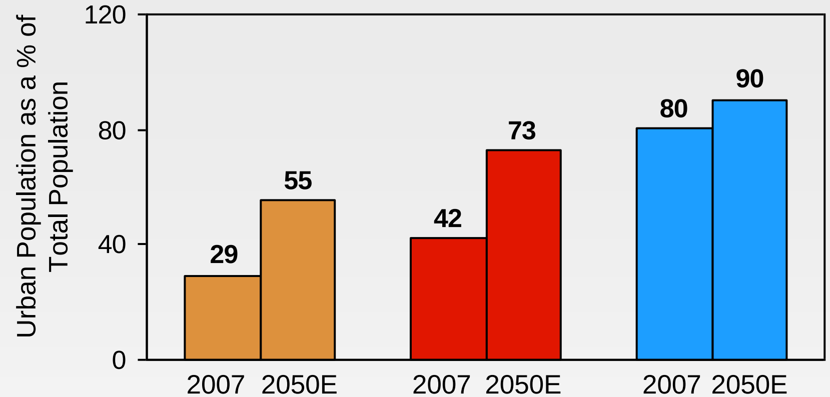
Increased population, urbanization and growth in non-agricultural activities is driving water consumption and is projected to lead to future water stress

Demographic and Economic Indicators – India, China and the US

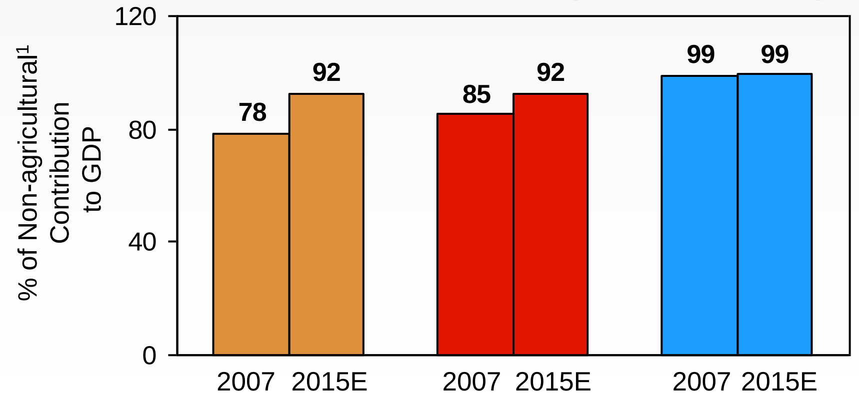
Population – India, China and the US (2000-2050E)



Urbanization – India, China and the US (2007 and 2050E)



Non-Agricultural Contribution to Total GDP – India, China and the US (2007 and 2015E)

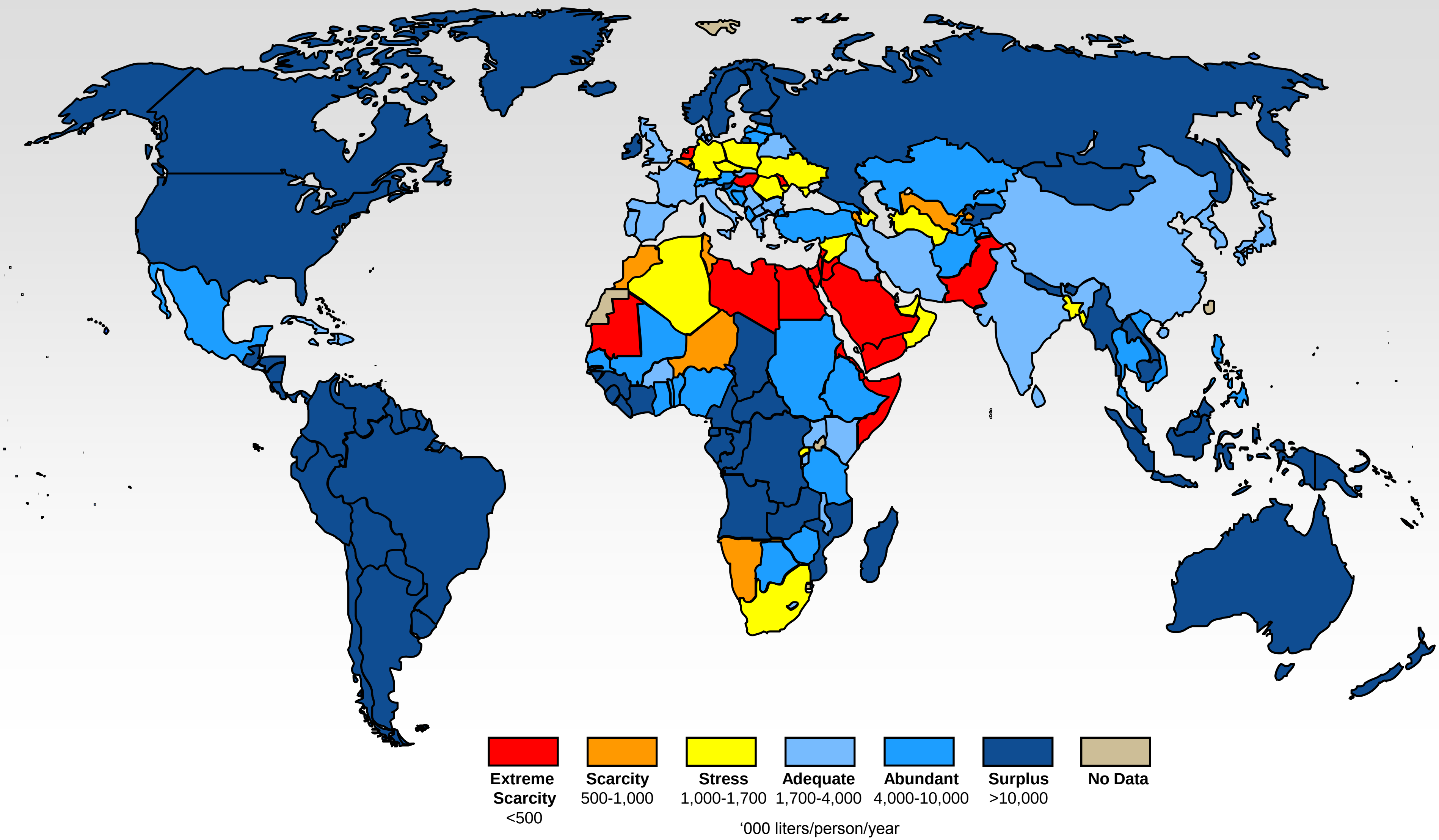


India China US

Note: [1]Non-agricultural contribution is defined as Agricultural contribution to total Gross Domestic Product (GDP) subtracted from the total GDP at current prices (in US dollars)
Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat; Datamonitor; Urban and Rural Areas 2007, UN Population Database

In 1975, water scarcity was limited to a small number of countries in North Africa, Europe and the Middle-East

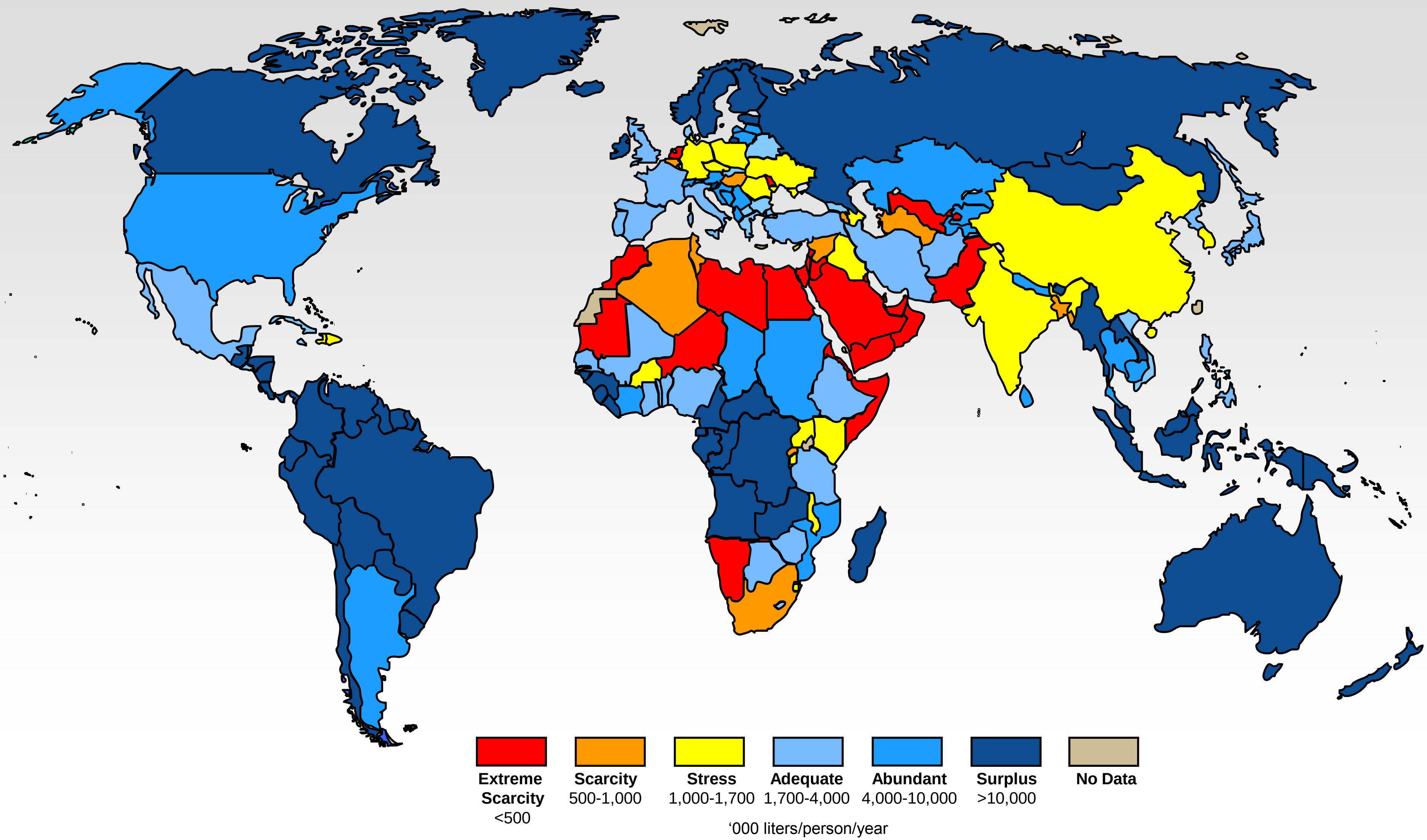
Global Per Capita Water Availability (1975)



Source: 'Global Water Initiative' (June 2005), GEF International Waters Conference, The Coca-Cola Company

By 2000, water scarcity had spread to many large and densely populated countries in Asia

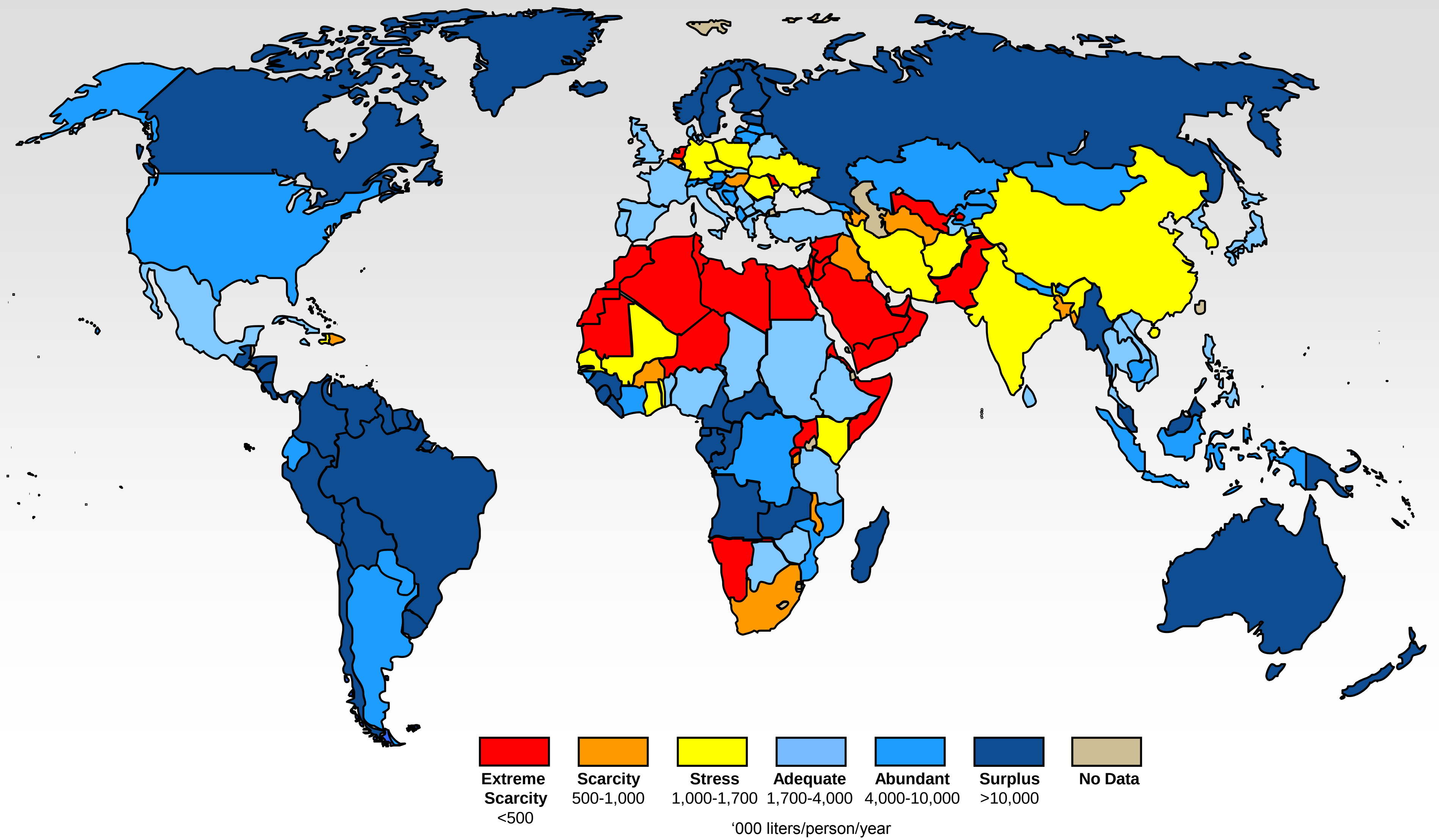
Global Per Capita Water Availability (2000)



Source: 'Global Water Initiative' (June 2005), GEF International Waters Conference, The Coca-Cola Company

By 2025, water scarcity will have spread further; India and China will continue to be the largest countries facing water stress

Global Per Capita Water Availability (2025)



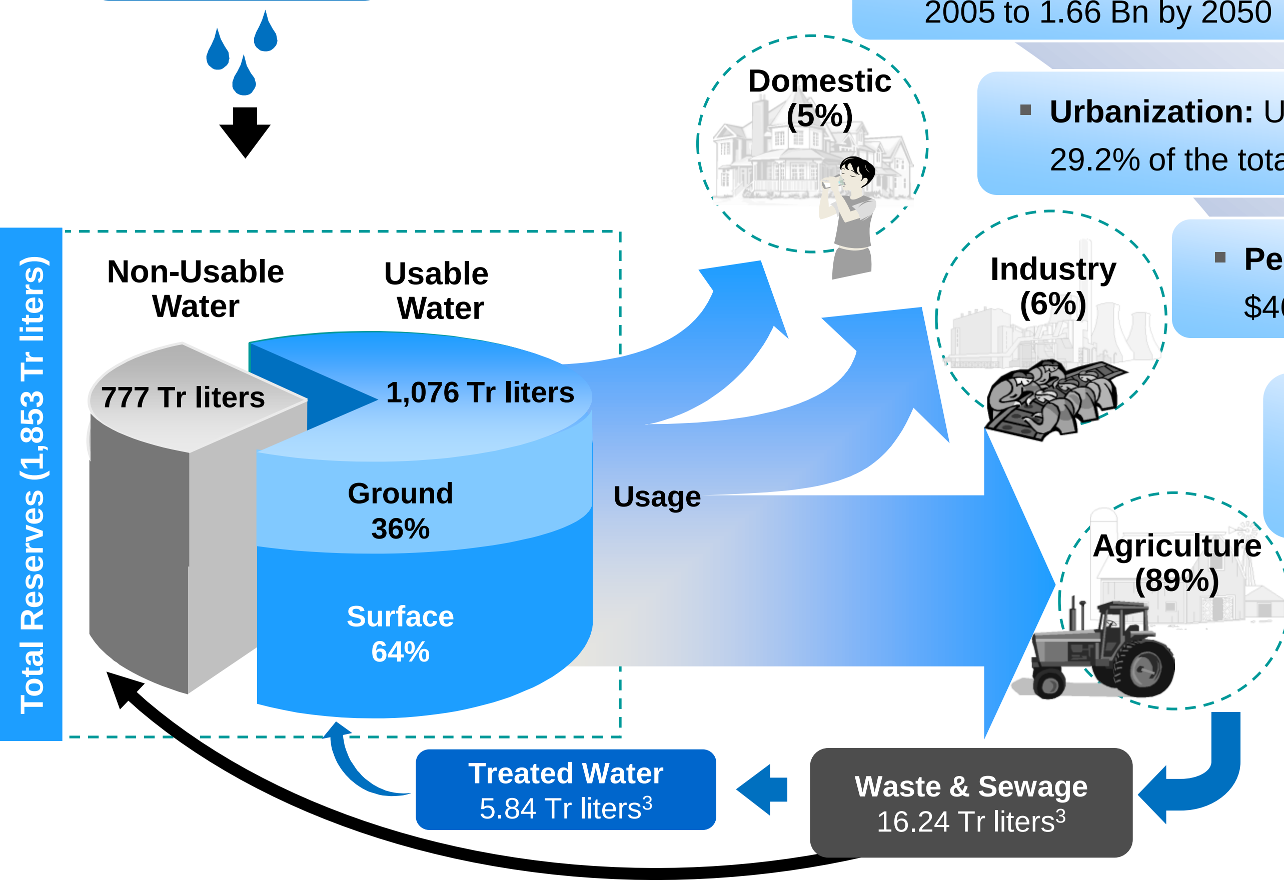
Source: 'Global Water Initiative' (June 2005), GEF International Waters Conference, The Coca-Cola Company

Table of Contents

Population growth and overall economic development are expected to lead to an increase in water usage across sectors

Water in India – Overview

Annual Precipitation: 4,000 Tr liters



Drivers of Water Usage in Future

- **Population:** Expected to increase from 1.13 Bn in 2005 to 1.66 Bn by 2050
- **Urbanization:** Urban population is expected to grow from 29.2% of the total population in 2007 to 55.2% by 2050
- **Per capita income:** Expected to increase from \$468[1] in 2007 to \$17,366[1] by 2050
- **Industrialization:** Industrial contribution to the GDP is expected to increase from ~78%[2] in 2000 to ~92%[2] by 2015
- **Agriculture:** Production of water-intensive crops is expected to grow by 80% between 2000 and 2050

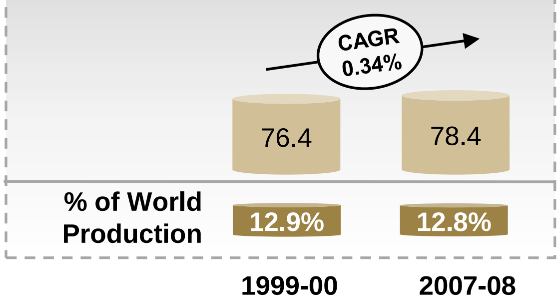
Note: Unless otherwise mentioned all data is for the year 2000; [1]GDP per capita; [2]Gross Domestic Product of Industry and Services at current prices (\$); [3]Includes only Industrial and Domestic

Source: 'India's Water Future to 2025-2050', International Water Management Institute; Datamonitor; 'Dreaming With BRICs: The Path to 2050', Goldman Sachs Global Economics Paper No: 99; Population Division, Department of Economic and Social Affairs, United Nations; 'Sustainable Technology Options for Reuse of Wastewater', Central Pollution Control Board; 'Urban and Rural Areas 2007', Population Division, Department of Economic and Social Affairs, United Nations; 'India's Water Resources, Availability, Needs and Management: 21st Century', German Coastal Engineering Research Council

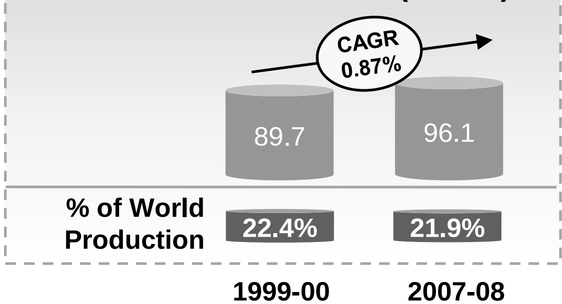
India is one of the world's leading crop producers. Over the years, this has led to an increase in water consumption in the agricultural sector

Water Consumption in Indian Agriculture (1/2)

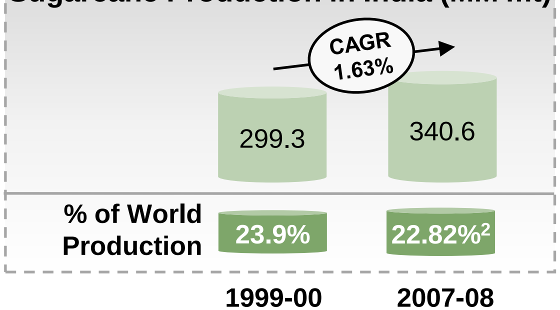
Wheat Production in India (MM mt[1])



Rice Production in India (MM mt)



Sugarcane Production in India (MM mt)



Wheat, Rice and Sugarcane together constituted 91% of India's crop production[3] in 2008

Consumption of water for irrigation is rising

The volume of water used for irrigation in India is expected to increase by 68.5 Tr liters between 2000 and 2025

Virtual Water[#] Consumption

- Another approach to assessing water consumption in agriculture is through the concept of virtual water.
- Direct (irrigation) and indirect (for production of fertilizers, machinery, consumed by farmers, etc.) use of water in agriculture constitute virtual water usage

Water Footprint[4] ('000 liters/mt)

Crop	India	Global
Wheat	1,654	1,334
Rice[5]	2,850	2,291
Sugarcane	159	175

Virtual water consumed for production of wheat, rice and sugarcane increased by 88 Tr liters over the period 2000 to 2008

- For Wheat it increased by ~4 Tr liters
- For Rice it increased by ~18 Tr liters
- For Sugarcane it increased by ~66 Tr liters

Note: [#]Virtual water consumed in one year for the production of a crop is calculated as the product of its annual production and its water footprint

Note: [1]Million Metric Tons; [2]2007 data; [3]Includes food grains and sugarcane; [4]Average value for the period 1997-2001;[5]Paddy Rice;

Source: FAO Corporate Document Repository; 'World Steel in Figures 2008:2nd Edition', 'Water Footprints of Nations: Water Use by People as a Function of their Consumption pattern', Water Footprint Network; 'Status of Virtual Water Trade from India', Indian Academy of Sciences; Reserve Bank of India publications; 'Product Gallery', Water Footprint Network; Index Mundi Historical Data Graphs Per Year; FAOSTAT; 'India's Water Future to 2025 – 2050: Business as Usual Scenario and Deviations', International Water Management Institute

Available resources are likely to be overexploited with a rise in the consumption of water for irrigation

Water Consumption in Indian Agriculture (2/2)

Demographic and economic factors are driving the use of water in agricultural production

- **Rise in domestic demand for food grains**: India's demand for food grain will grow from 178 MM mt in 2000 to 241 MM mt in 2050
- **Increase in exports**: Value of agricultural exports of India have tripled from $5.6 Bn in 2000 to $18.1 Bn in 2008
- **Change in consumption pattern of agricultural products**: Demand for agricultural products with high water footprint is projected to rise with increased disposable income and urbanization
  - Contribution of non-food grain (sugarcane, fruits and vegetables, etc.) and animal products[1] in daily food intake for an individual is expected to grow from 35%[2] in 2000 to ~50% 2050

Agricultural production growth is leading to greater water stress

- **Rise in water consumption**: Rice, wheat and sugarcane together constitute ~90% of India's crop[3] production and are the most water-consuming crops
  - India has the highest water footprints among the top rice and wheat producing countries (China, US, Indonesia, etc.)
- **Over-exploitation of groundwater**: States with the highest production of rice/wheat are expected to face groundwater depletion of up to 75%, by 2050
- **Increase in wastewater discharge**: Agriculturally based industries such as textiles, sugar and fertilizer are among the top producers of wastewater

Note: [1]Animal products includes livestock, dairy products, etc. and falls under the category of agricultural products; [2]% of total daily calorie intake; [3]Includes all food grains and Sugarcane

Source: Reserve Bank of India publications; 'India's Water Future to 2025-2050', International Water Management Institute; 'Changing Consumption Patterns: Implications on Food and Water Demand in India, International Water Management Institute; 'Water footprints of nations: Water Use by People as a Function of Their Consumption Pattern', Water Footprint Network; 'Mapping Water: Scarcity and Pollution', Center for Science and Environment

Irrigation demand in the major river basins is expected to deplete groundwater levels by 2050

Population and Irrigation in River Basins of India

Major River Basins	Major Agricultural States in the River Basin	Population Density[1]	Water Used for Irrigation as a % of Total Consumption
Ganges	Uttar Pradesh (UP)	449	91%
Krishna	Maharashtra, Karnataka	253	90%
Kaveri	Tamil Nadu, Karnataka	389	95%
Godavari	Andhra Pradesh (AP), Karnataka	189	89%

Groundwater depletion has started affecting most of the river basins which support agriculture in these states

By 2050…..

- Groundwater level in the Ganges basin (which provides water to UP) is projected to deplete by 50-75%
- Groundwater levels in the Krishna, Kaveri and Godavari basins (which provide water to Maharashtra, Tamil Nadu, Karnataka and AP) are projected to deplete by ~50%

- **The population density supported by India's river basins is higher than most other developing countries**
- **The above mentioned five states are the highest producers of rice, wheat and sugarcane (water-intensive crops) and together produce ~70%[3] of the total food crops in India**
- **Subsidies on electricity in these states has led to excessive pumping of groundwater for agriculture**

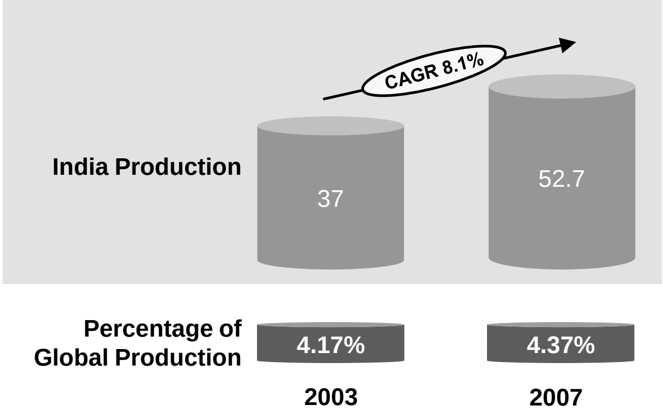
Note: [1]number of people per square kilometer

Source: 'Dynamic Groundwater Sources of India', Ministry of Water Resources, 2006; Reserve Bank of India database and publications; 'Spatial Variation in Water Supply and Demand Across the River Basins of India ', International Water Management Institute, 2003; Proposal to Introduce Direct Power Subsidy to Farmers', The Indian Express Newspaper, June 2008

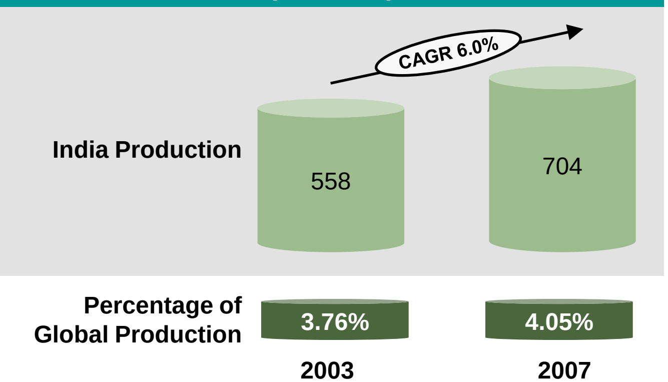
Industrialization and infrastructure growth are projected to drive water consumption and lead to increased discharge of untreated wastewater

Water Consumption by Industries

Steel[1] Production in India – 2003 and 2007 (MM mt)



Electricity Generation in India – 2003 and 2007 (Bn Kwh[3])



Growth Drivers for Water-Intensive Industries

- FDI[2] equity inflow in the industrial sector has grown from $1.93 Bn in 2004–2005 to $17.68 Bn in 2007–2008
- Steel and electricity dependent industries are expected to grow in the coming years
  - Between 2006 and 2010, investment in infrastructure development is planned to be 7.7% of India's GDP
- The manufacturing sector grew at an average of 8.6% between 2002 and 2007 and is expected to grow at 9.5% per annum in 2008-09
- Thermal power plants (the most water-intensive industrial units), constituted 64.6% of the installed power capacity in India during 2008
  - Annual per capita consumption of power is expected to grow from 704.2 Kwh in 2008 to 1,000 Kwh by 2012
  - 75% of the total planned power capacity expansion is projected to come from thermal power

Impact on Water Stress

- Industrial water consumption is expected quadruple between 2000 and 2050; by 2050 industrial water consumption will reach 18% of total annual water consumption, up from just 6% in 2000
- Industrial wastewater discharge causes pollution and reduces available Freshwater reserves
  - ~6.2 Bn liters of untreated industrial wastewater is generated every day
  - Thermal power plants and steel plants are the highest contributors to annual industrial wastewater discharge

Note: [1]Finished; [2]Foreign direct investment [3]Kilowatt Hour

Source: 'India's water future to 2025 – 2050: Business as Usual Scenario and Deviations', International Water Management Institute; 'India's Economic Survey 2007-08: Impressive Growth and a Promising Future', Institute of South Asian Studies; 'To use or to misuse', Center for Science and Environment; 'Estimation of Infrastructure Investment Needs in the South Asia Region', World Bank; 'Handbook of Statistics on Indian Economy', Reserve bank of India; 'World Steel in Figures 2008', World Steel Association; 'World - Electricity - production', Index Mundi; 'New thermal power capacity to fall short', Projects Monitor; 'Power', India Brand Equity Foundation; 'Opportunities In Indian Power Sector & role of Private Participation', Everest Power Private Limited; ''Sustainable Technology Options for Reuse of Wastewater', Central Pollution Control Board; 'Fact sheet on foreign direct investment', Ministry of Commerce and Industry, 2008; 'India's manufacturing sector to grow by 9.5 percent', Indo Asian News Service, August 2008

Industry bodies are encouraging companies by recognizing their proactive implementation of sustainable water management programs

Select Recipients of the National Award for Excellence in Water Management, 2007-08 (1/2)

Company	Water Management Techniques Applied	Initiatives
VIZAG STEEL Infrastructuring India and Beyond **Visakhapatnam Steel Plant**	▪ Rainwater harvesting ▪ Sewage water management and recycling	▪ Invested $0.47 MM for water conservation and $4.6 MM for ongoing projects in 2006-2007 ▪ Installed 9 check dams and 18 recharge wells for water harvesting
HINDALCO ADITYA BIRLA GROUP **Hindalco**	▪ Watershed management ▪ Rainwater harvesting ▪ Community programs	▪ Set up 36 lift irrigation projects, 27 small check dams and 150 tanks for rainwater harvesting at Renukoot, Uttar Pradesh between 2004-2007 ▪ Provided irrigation water for 16,000 Hectares of land, increasing agricultural production by 17,850 mt and benefiting 20,655 farmers
ACC **ACC LTD**	▪ Rainwater harvesting ▪ Water consumption monitoring	▪ Saved 1 MM liters/day at their cement plant in Chaibasa, Jharkhand during 2006-2007
WIPRO **Wipro Limited**	▪ Rainwater harvesting ▪ Recycling water from cooling towers	▪ Harvested 8.5 MM liters of rainwater through projects at 6 locations across India in 2007-2008
TATA TATA CHEMICALS LIMITED **Tata Chemicals**	▪ Sewage water management ▪ Desalination ▪ Watershed management	▪ Invested $21,000 in 2006-2007 for water conservation and recycling projects saving 50 MM liters of water per year

Source: Presentations on CII - Sohrabji Godrej Green Business Centre; Best Practice Case Studies, India Water Portal

Large Indian companies are investing in multiple water management initiatives across their operations

Select Recipients of the National Award for Excellence in Water Management, 2007-08 (2/2)

Company	Water Management Techniques Applied	Initiatives
Ashok Leyland	▪ Rainwater harvesting ▪ Optimization of cooling tower operations	▪ Built rainwater storage capacity of 70 MM liters at Hosur, Karnataka in 2007 ▪ Improved Groundwater table in Hosur (e.g. a depleted well started yielding O.1 MM liters of water per day)
Bajaj Auto	▪ Drinking water and purification systems ▪ Rainwater harvesting ▪ Watershed development	▪ Implemented PLC[1] based systems which contributed to the reduction of water usage by 16% during 2007-2008
Mahindra & Mahindra	▪ Wastewater treatment and recycling	▪ Reduced water consumption per vehicle manufactured from 6,380 liters in 2003-2004 to 4,620 liters in 2006-2007 at their plant in Nasik, Maharashtra ▪ Used water cleaning and recirculation systems in the paint section of the plant to save 3,00,000 liters per year
GlaxoSmithKline Consumer Healthcare	▪ Water conservation equipment	▪ Invested $12,600 in floor and tray cleaning machines in 2007, saving 27.3 MM liters of water per year
ITC Limited ITC	▪ Community water management ▪ Rainwater harvesting ▪ Recycling and conservation	▪ Saved 1.1 Bn liters of water in 2006-2007 at Bhadrachalam, Andhra Pradesh

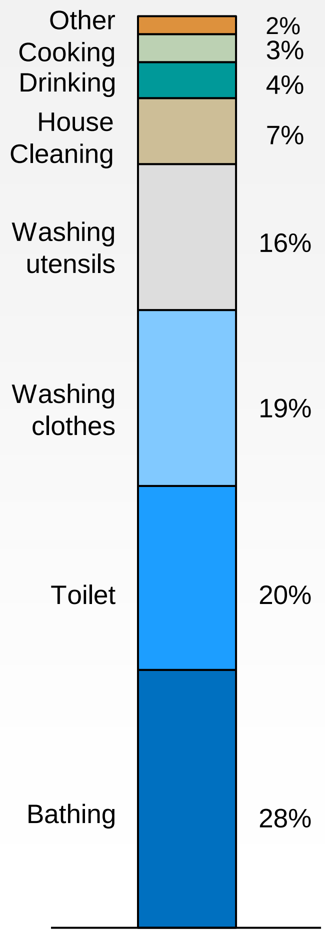
Note: [1]Programmable Logic Controllers

Source: Presentations on CII - Sohrabji Godrej Green Business Centre; Best Practice Case Studies, India Water Portal; Director's Report 2007-08, Bajaj Auto Ltd.

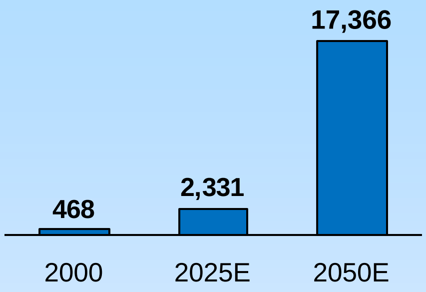
Domestic water demand is expected to rise as disposable income and urbanization increase

Domestic Water Consumption in India

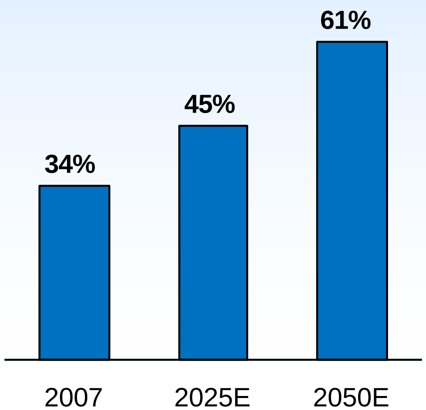
% Water Usage for Domestic Activities[1]



Per Capita Income[2], 2000-2050E ($)



Urban Population as a % of Total Population, 2007-2050E



Impact on Water Stress

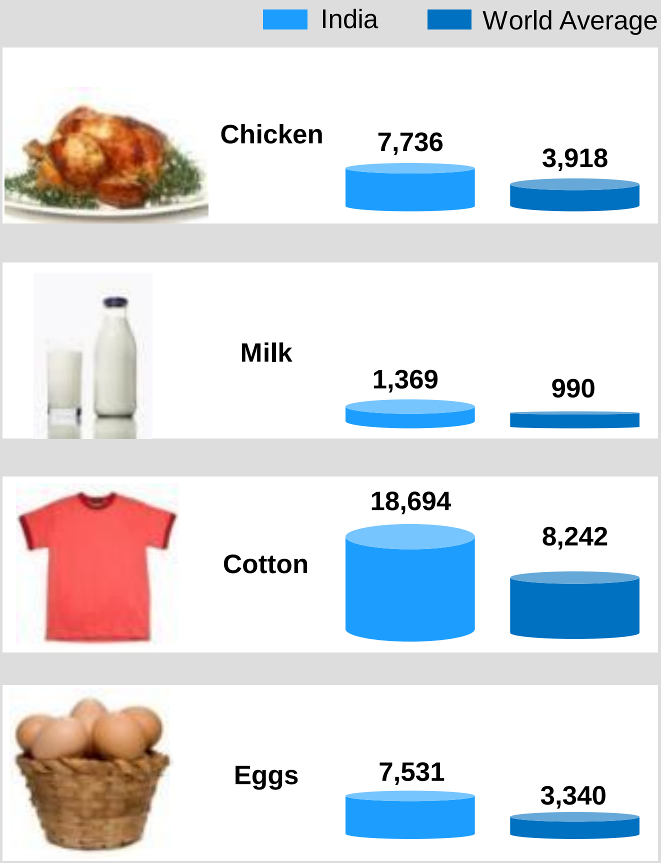
- Domestic contribution to the total water consumption is projected to increase from 5% in 2000 to 11% by 2050
  - Domestic consumption of water is expected to triple from 2000 to 2050
  - Per capita water consumption is expected to double from 89 liters/day in 2000 to 167 liters/day by 2050
- Cities are facing severe water shortage
  - In 2005, 65% of households across 7 major cities[1] face water deficiency
  - Cities are reaching out to distant water sources, e.g., Delhi and Chennai receive water from rivers that are 250 Km and 450 Km away, respectively
- Untreated sewage from cities is leading to severe water pollution
  - Only 31% of the ~9,275 MM liters per day of wastewater generated by 23 metropolitan cities is treated
  - Severely polluted stretches in 18 major rivers identified by the CPCB[3], were located in and around large urban areas

Note: [1]Data for Ahmedabad, Delhi, Hyderabad, Kanpur, Kolkata, Madurai, and Mumbai; [2]Per capita Income has been taken to be GDP per capita; [3]Central Pollution Control Board
Source: 'India's Water Future to 2025 – 2050: Business as Usual Scenario and Deviations', International Water Management Institute; India Census 2001; 'Water Poverty in Urban India: A Study of Major Cities', Jamia Millia Islamia; 'Troubled Waters', Development Alternatives; 'Dreaming With BRIC's: The Path to 2050', Goldman Sachs, 2003; 'Urban and Rural Areas 2007', United Nations; 'Water Supply – The Indian Scenario', IEA India; 'Status Of Water Treatment Plants In India', Central Pollution Control Board; Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat

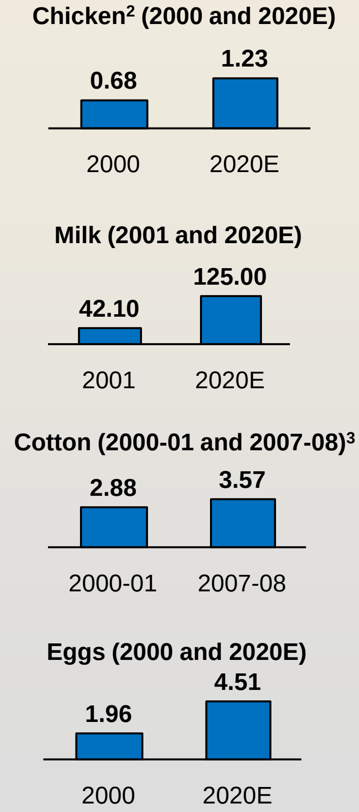
Increased disposable income and urbanization is projected to change consumption patterns towards more water-intensive products

Usage of Water-Intensive Consumer Products – Domestic

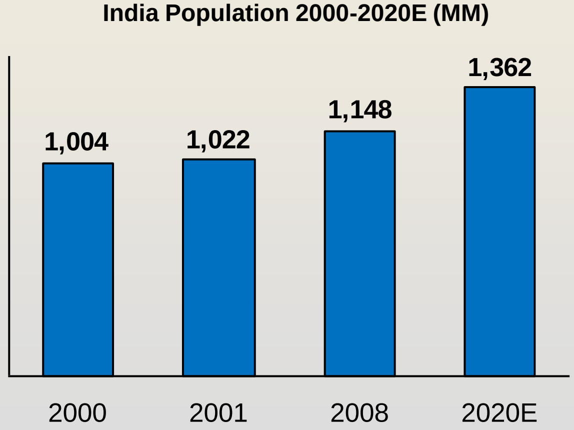
India's water footprint[1] (liters/Kg) for key domestic products is higher than the global average



India's annual domestic per capita consumption (kg) of these products is increasing



India's population is projected to continue to increase, driving further consumption increases



While some demand growth will be met through imports, domestic production is also expected to increase

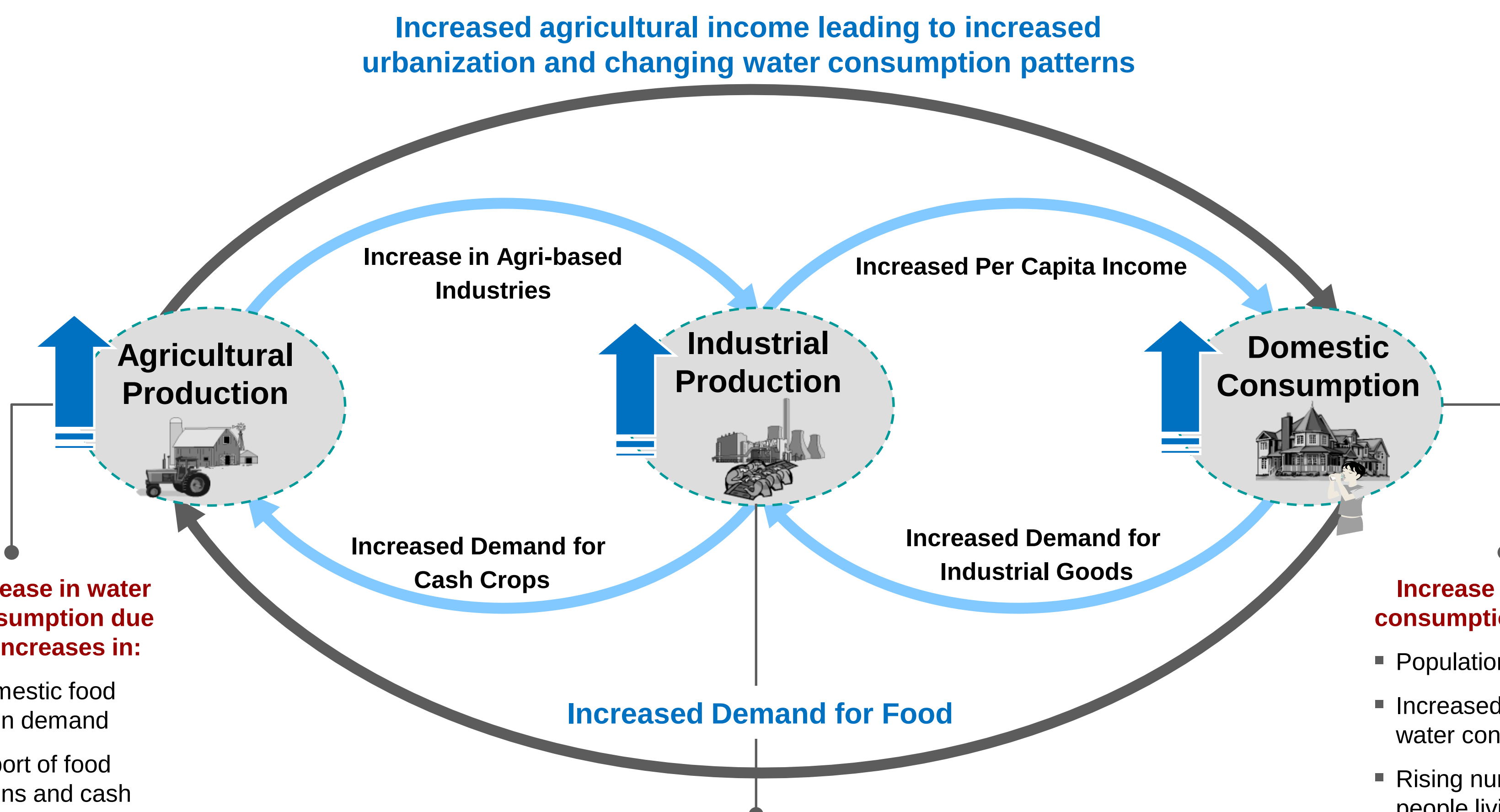
- During the period 2000-2020, chicken and milk production is projected to grow at a CAGR of 3% and 4% respectively
- Production of cotton is expected to grow at a CAGR of 1.6% during the period 2000-2025

Note: [1]Total volume of Freshwater (in liters) that is used to produce the 1 Kg of the product; [2]Poultry Meat; [3]October to September

Source: '2020 Vision for Indian Poultry Industry', International Journal of Poultry Science; 'Water Footprints of Nations: Water Use by People as a Function of Their Consumption Pattern', Water Footprint Network; 'The Coming Livestock Revolution', Background Paper, Food and Agriculture Organization; FAO Corporate Document Repository; Cotton Corporation of India Statistics; US Census Bureau Population Statistics

In a large developing country such as India, the links between water consumption across sectors complicates water management

Water Consumption Cycle in India



Increase in water consumption due to increases in:

- Domestic food grain demand
- Export of food grains and cash crops
- Demand for water-intensive crops

Increase in water consumption due to:

- FDI in industrial sector
- Increase in agri-based and other water-intensive industries
- Investment in infrastructure development

Increase in water consumption due to:

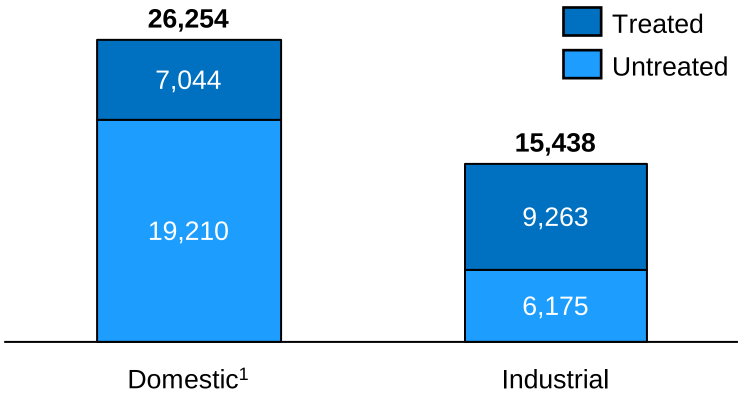
- Population growth
- Increased per capita water consumption
- Rising number of people living in cities

Source: Grail Analysis

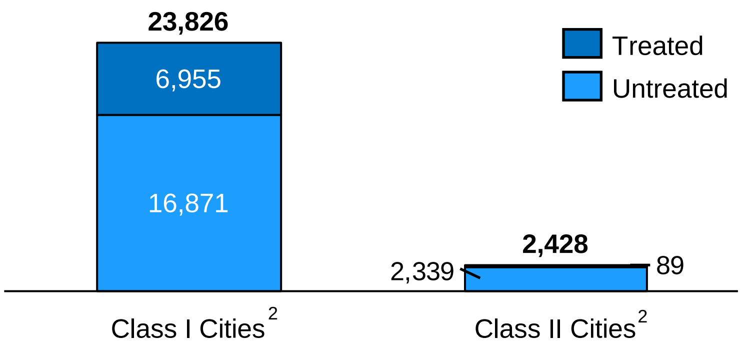
Rapid industrialization and unplanned urban growth is resulting in the generation and discharge of large quantities of wastewater into existing water bodies

Wastewater Generation and Treatment

Sectoral Wastewater Generation, 2003 (MM liters/day)



Domestic Wastewater Generation in Cities, 2003 (MM liters/day)



Wastewater Treatment – Issues

- Inadequate treatment infrastructure
  - Only 26.8% of domestic and 60% of industrial wastewater is treated in India
  - Wastewater management plants in cities have a capacity of approximately 6,000 MM liters per day
  - 423 Class I[2] cities treat just 29.2% of their wastewater. 499 Class II towns are able to treat just 3.7% of wastewater due to poor treatment infrastructure
  - Delhi, the national capital, treats less than half of the 3,267 MM liters of wastewater it generates every day
- Use of untreated wastewater for irrigation
  - Reduction in agricultural production e.g. in Hyderabad, wastewater drawn from the river Musi for irrigation has reduced rice output by 40-50%

Note: All figures on this slide are for 2003;[1]Includes only Class I and Class II cities; [2]Class I cities (population > 100,000) and Class II towns (population between 50,000 and 100,000)
Source: Sustainable Technology Options for Reuse of Wastewater', Central Pollution Control Board; 'Wastewater Management and Reuse for Agriculture and Aquaculture in India', CSE Conference on Health and Environment 2006; 'Wastewater Reuse and Recycling Systems: A Perspective into India and Australia', International Water Management Institute

Discharge of untreated wastewater is leading to increased pollution and depletion of clean water resources

Water Pollution in India

Major Contributors to Water Pollution in India

Untreated Wastewater

Untreated wastewater is responsible for polluting water resources

- Small and medium plants do not invest in effluent s e.g., over 3,000 units in Ankleshwar, Gujarat discharge ~270 MM liters of effluents each day
- Untreated domestic wastewater is reused for agriculture causing health hazards

Extensive Use of Chemicals

Runoff from agricultural fields contains pesticides & fertilizers that pollutes surface water

- Use of pesticides increased from ~1 MM tons in 1948 to 52 MM tons by 2001
  - ~47% of irrigated areas in India lie in the Ganges basin which contains chemicals such as HCH[2] DDT[3], methyl malathion etc. in excess of international standards
- Use of fertilizers in India has increased from 0.55 Kgs/hectare in 1950 to 90.12 Kgs/hectare in 2001–2002
  - High fertilizer use has led to eutrophication[4] in several water bodies, such as the Hussein Sagar in Hyderabad and Nainital in UP

Impacts

Water Quality Deterioration in India

- **Pollution is affecting the quality of Surface water across India**
  - 14% of total river length in India is severely polluted and 19% is moderately polluted (based on BOD[5] levels)
- **High levels of chemicals in soil and water have worsened the quality of groundwater**
  - 69 districts across 14 states have fluoride above acceptable levels
  - 6 districts in the Ganges river plains of West Bengal have high levels of arsenic
  - Heavy metals in groundwater have been found in 40 districts across 13 states

Notes: [1]As per 2000 data; [2]Hexachlorocyclohexanes, used as insecticide, [3]Dichloro-Diphenyl-Trichloroethane, used as pesticide; [4]Reduction in water quality due to excessive chemical nutrients in water bodies; [4]Biochemical Oxygen Demand, indicates the quality of a water source

Source: 'Water Pollution Control in India – Policies and Stragetgy'', Central Pollution Control Board; 'Case Study I - The Ganga, India', Water Pollution Control - A Guide to the Use of Water Quality Management Principles, WHO/UNEP; 'Groundwater Pollution and Contamination in India: The Emerging Challenge', India Water Portal; 'India, The Land of Holy Rivers, is Fast Becoming a Land of Highly Polluted and Even Toxic Rivers', Development Alternatives; 'Agricultural Inputs Market Trends & Potentials in India', Food and Agriculture Organization Articles;'Top 10 Worst Pollution Problems', Blacksmith Institute

In an attempt to conserve water, India has launched numerous programs, but lacks an independent regulator to control and coordinate implementation efforts

Water Governance Issues

Multiplicity of Organizations

Multiple government agencies have responsibility for water management, which hinders effective policy development and implementation

- State governments and local bodies in urban areas are mainly responsible for offering drinking water and sanitation facilities
- The Central Water Commission (CWC)[1] is responsible for regulating the use of surface water for irrigation, industry, drinking, and for mediating inter-state water allocation disputes
- There are multiple government bodies that manage water resources in India. However, there is a lack of coordination between them. E.g. the CPCB[2](which monitors pollution) and CWC conduct separate, uncoordinated water quality monitoring exercises in 507 and 300 locations respectively

Inadequacy in Generation of Revenue to Meet Costs

- Water tariffs and policies differ across states. Water is available for free or is highly subsidized in some states
  - More than 40% of India's water does not generate any revenue
  - ~13.8 MM people living in the national capital Delhi, pay for less than 50% of the water they consume

Outdated Policies

- India has inadequate legislation on the exploitation of groundwater
  - There are very few legal restrictions on who can pump groundwater, how much and for what purpose
- Historical government subsidies for the use of water for the irrigation and domestic purposes have led to the undervaluation of water as a resource
- Management and supply of water resources is perceived to be a public sector monopoly.
  - In the absence of an independent regulator, the very few pockets of water privatization have resulted in government sanctioned monopolies

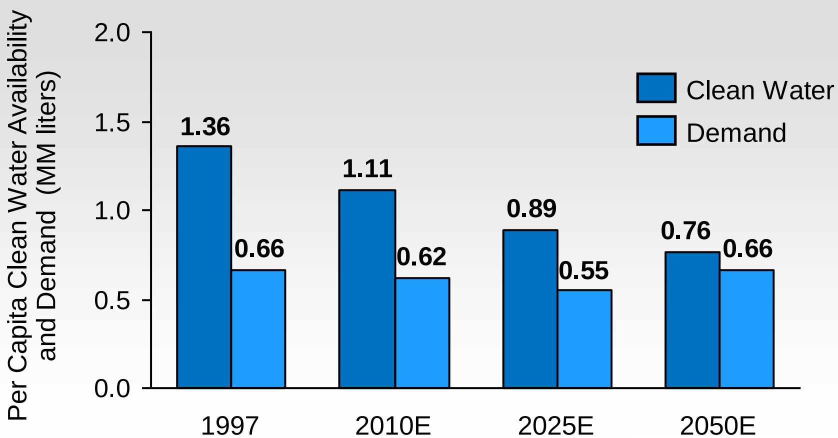
Note: [1]Central Water Commission, part of the Ministry of Water Resources, Government of India; [2]Central Pollution Control Board

Source: 'Sustaining India's Irrigation Infrastructure', Indian Council of Agricultural Research, 2001; 'Community – Led Alternatives to Water Management: India Case Study', Human Development Report India, UNDP, 2006; 'Troubled Waters: Water Issues in India', Development Alternatives, 2001; 'Water Privatization and Implications in India', Association for India's Development; Central Pollution Control Board

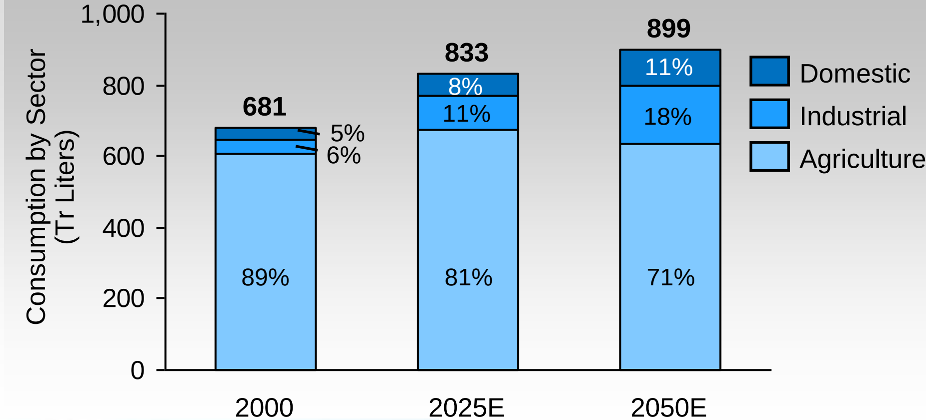
With rising consumption, deteriorating water quality and inadequate governance, India is likely to face a water shortage by 2050

Utilizable Water and Demand

Comparison of Per Capita Clean Water Availability[1] and Demand in India (1997–2050E)



Water Consumption Breakdown in India by Sector (2000–2050E)



- Between 1997 to 2050, India will move toward water scarcity due to growing demand and a drop in the supply of clean water
  - Total water demand is projected to increase by 89% due to rapid increase in population
  - Per capita water availability is projected to decrease by ~44% during the same period
- Regional disparities in reserves and replenishment are expected to intensify water scarcity

- Agriculture's share of total water consumption is expected to decrease between 2000 and 2050
  - More efficient methods of irrigation and lower reliance on agriculturally-based products are expected to lead to this reduction
- Domestic and industrial sectors are projected to constitute a growing share of the total water consumption between 2000 and 2050
  - The industrial sector demand is expected nearly quadruple due to rapid industrialization and economic growth

Note: [1]Water availability is the total utilizable water in India; [2]All projected figures indicate water demand
Source: 'India's Water Economy: Bracing for a Turbulent Future', World Bank, 2006; 'India's Water Future to 2025 – 2050: Business as Usual Scenario and Deviations', International Water Management Institute; US Census Bureau

To prevent future water scarcity, India needs to implement programs based on established water management techniques

Sustainable Water Management Techniques

Sectors: **Agriculture** | **Domestic** | **Industry**

Watershed[1] Management

Involves implementing plans to enhance management of water supply, drainage and watershed inventory across lakes and other natural and manmade reservoirs

- **Agriculture:** In 2001, the 'Karnataka Watershed Development Project' resulted in an increase of 24%[2] in total crop yield
- **Domestic:** Reliance Energy's community-based watershed management plant has resulted in an increase in the Groundwater table in Dahanu, Maharashtra
- **Industry:** Hindalco Industries' plant at Renukoot, UP, includes a watershed management project benefiting farmers across 30 villages

Rainwater Harvesting

Includes building recharge wells, roof catchments, gutters, downpipes, cascade captures, etc. to store rainwater

- **Agriculture:** Government has implemented soil and water conservation scheme in many states for rainwater harvesting through farm ponds and rejuvenation of failed or unused wells
- **Domestic:** In Chennai, rainwater is harvested in nearly 29,000 domestic households and 2,000 government buildings
- **Industry:** Coca-Cola India's Mehandiganj plant, at Varanasi, UP, used rainwater harvesting to reduce water usage ratio[3] by 23% between 2003-2007

River Interlinking

Involves construction of river linkages through dams, canals and other interventions

- **Agriculture / Domestic:** The National River Link Project of India under the supervision of the International Water Management Board, will connect 30 big rivers and canals. The capacity generated by interlinking of rivers would be 175 Tr liters

Desalination

Involves the use of thermal / membrane technology to reduce salt content in water

- **Domestic:** India is building a new sea water reverse osmosis plant in Chennai, Tamil Nadu; by early 2009, it will produce 100 MM liters of water per day for domestic consumption
- **Industry:** The Bhabha Atomic Research Centre, Mumbai has built a barge-mounted desalination plant that can produce 50,000 liters of drinking water per day

Other Techniques

Involves the reuse of water condensed from boilers though membrane filtration, side steam treatment , etc. for cooling towers

- **Industry:** Mahindra & Mahindra Ltd. reduced its per vehicle water consumption from 6,380 liters in 2003-2004 to 4,620 liters in 2006-2007, through reuse of wastewater

Note: [1]A watershed is defined as the drainage area on earth surface from which the run off (resulting from precipitation) flows at a common point of drainage; [2]In five selected districts in Karnataka, India; [3]Water usage ratio is defined as raw water used on a peak day divide by beverage generated

Source: 'Corporate Initiatives for Water Conservation and Waste Water Management' India Water Portal; 'Higher Incomes for farmers in India's Karnataka Watershed', World Bank; 'Rain Water Harvesting Catches on in Chennai', The Hindu Business Line; 'Agricultural Engineering', Government of Tamil Nadu; 'Sea Water Reverse Osmosis Plant to be Established in Chennai', Andhra News; 'BARC Builds Barge-mounted Plant to Produce Safe Drinking Water', Live Mint; 'Garland of Hope: River-linking as a Solution to Water Crisis', The Times of India

Policy makers and businesses have started preparing action plans and implementation roadmaps to ensure adequate water availability in the country

Implications for Policy Makers / Businesses	
Regulations for Rain-water Conservation	▪ Between 1999 and 2004, rainwater harvesting was made mandatory in all new buildings having a specific area in the states of Delhi, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Tamil Nadu, Haryana, Rajasthan, Maharashtra and Gujarat
Laws for Inter-State Water Sharing/Linking	▪ The National Water Development Agency has been set up to build 30 inter-basin water transfer links, which have a capacity of 175 Tr liters
Involvement of NGOs	▪ NGOs such as Arghyam, support information dissemination among communities. They have developed a Water Portal on India for increasing awareness of water issues among citizens ▪ Local clubs, local student communities and employees of Reliance Energy's Thermal Power Station in Dahanu, Maharashtra, run a community-based watershed management program
Social Responsibility Initiatives	▪ Coca-Cola along with the CII[2], invested $0.14 MM in 2005 to help farmers halt watershed erosion and grow more food in Dungarpur (Rajasthan) and Thirunelveli (Tamil Nadu) in 2006
Privatization of Water	▪ The Delhi Jal Board (DJB) has built a water treatment plant at Sonia Vihar near New Delhi at a cost of ~$42.35 MM with Degremont of France ▪ The Tirupur project in Tamil Nadu, set up in 1995, was awarded to a consortium of Mahindra & Mahindra, North West Water, Larsen and Toubro and Bechtel by the state government. Pricing for this water recovers the entire cost of operations and maintenance ▪ The Rasmada scheme, a project that helps supply water to the Chhattisgarh State Industries Development Corporation from a stretch of the Shivnath river, was awarded to Radius Water, Inc. on a 22-year lease

Note: [1]NGO (Non Government Organization); [2]Confederation of Indian Industry

Source: 'Legislation on Rain Water Harvesting', Centre for Science & Environment; 'Water and Industry', India Water Portal; Coca Cola India; 'Garland of Hope: River-linking as a Solution to Water Crisis', The Times of India; Arghyam Publications; 'ICRISAT to collaborate with CII and Coca Cola Foundation on Watershed Development', World Resource Institute; 'Water Privatization and Implications in India', University of Texas

Table of Contents

China is implementing many large scale, multi-sector projects using innovative water management techniques to reduce the impact of water stress

Water Management Techniques in China

Inter-Basin River Linkage

- Plans to build three massive north-south aqueducts to pump water from the Yangtze River. The three channels combined will pump 47.7 Tr liters of water every year
- Water pumped from the Yangtze River will reach Beijing by 2010. The entire project is expected to finish by 2050

Community-based Rainwater Harvesting

- The government provided logistical support for rainwater harvesting to families in Gansu, the country's 7th largest province
- By 2000, over 2 MM rainwater tanks were built with a total capacity of 73.1 Bn liters to supply drinking water to nearly 2 MM people and to supplement irrigation for 236,400 hectares of land

Water Treatment Technologies

- Zhumadian city implemented water treatment technologies based on techniques such as Baffled Reactors[1]
- 400,000 domestic and industrial users receive 120 MM liters of treated water every day from the project
- Similar projects serve 5 other cities[3] across China

Note: [1]Used in water treatment to allow for slow reactions to reach completion in as small a reactor volume as possible; [2]includes Yancheng, Fuzhou, Xinmin, Yanjiao and Quitaihe

Source: 'Economic Impact of Interlinking of Rivers Programme', National Council of Applied Economic Research; US Water News Reports; China Water Projects Database; Rain Water Harvesting Website Country Profiles

The US is focusing on modern techniques to improve the effectiveness of its existing water management programs

Water Management Techniques in the US

Inter-Basin River Linkage

- Colorado River Canal System[1] supplies water to over 25 MM people and helps irrigate 1.42 MM hectares of land
- More water is exported from this basin than from any other river basin in the world. Most of Southwest US receives water supplied from this canal system

Pre-Treatment Program

- In 2005, the EPA[2] launched a pre-treatment program in the Mid-Atlantic Region
- Publicly owned treatment works collect wastewater from domestic, commercial and industrial facilities and transport it to treatment plants before it is discharged
- 1,900 industries across 6 states[3] are regulated under this program

Note: [1]The Colorado River Canal System was started in 1922; [2]U.S. Environmental Protection Agency; [3]Delaware, District of Columbia, Pennsylvania, Maryland, Virginia, and West Virginia
Source: 'Economic Impact of Interlinking of Rivers Programme', National Council of Applied Economic Research; U.S. Environmental Protection Agency Programs; National Water Program, US Department of Agriculture - Cooperative State Research, Education, and Extension Service; US Water News Reports; China Water Projects Database; Rain Water Harvesting Website Country Profiles

With only a few states implementing water management techniques, India still lacks a national initiative to tackle the impending water crisis

Water Management Techniques in India

Subsidized Micro-Irrigation

- Government subsidies of up to 50% on Micro-Irrigation equipment are being utilized, but only by 8 states[1]

Community-Based Watershed Management

- Local communities are implementing several techniques of watershed development, to increase water levels and enhance productivity of crops across 5 states[3]

Mandatory Rainwater Harvesting

- Laws have been enacted for rain-water harvesting on the roofs of all new buildings, but in only 10 states[2]

System of Rice Intensification

- Between 1997 and 2007, innovative cultivation programs (e.g. spacing between plants, transplanting younger seedlings) were implemented to reduce the need for flood irrigation in water-intensive crops, but only across 6 states[4]

Note: [1]Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Uttar Pradesh, Madhya Pradesh, Rajasthan, Tamil Nadu; [2]Kerala, New Delhi, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Haryana, Rajasthan, Maharashtra, Gujarat;[3]Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Punjab; [4]Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Orissa and W Bengal
Source: '2007 A Water Year: Future Water Solutions for India', South Asia Network on Dams, Rivers & India; 'Adoption and Impacts of Microirrigation Technologies Empirical Results from Selected Localities of Maharashtra and Gujarat States of India', International Water Management Institute; 'Water Privatization and Implications in India', Association for India's Development; India Water Portal Case Studies

To prevent a water shortage, India needs to invest in large-scale initiatives for managing water resources

Examples of Water Management Solutions

Recycling

Deep Pond System

Forward Osmosis Desalination

Metal-mediated Aeration

Ostara Reactor

Conservation

EcoTech Digital

Micro-irrigation Sprinkler

The "Deep Pond System" in Hyderabad treats 37,854 liters of wastewater per day

Example I

Description

- Deep Pond System is a wastewater treatment system which consists of a digestion chamber within an anaerobic deep pond for decomposing sewage sludge and solids present in wastewater
- Methane generated and captured in the process can be used as an energy source

Key Facts

- The system treats 37,854 liters[1] of wastewater per day
- Similar systems tested in the US required no sludge removal for more than 20 years
- This project received $80,000 in funding from the US Council of State Governments and S&E Engineering (US)

Benefits

- Provides clean water and generates energy from wastewater
- Low cost of installation, operation, and maintenance due to the simplicity of design
- No chemicals are used in the process and the treated water does not require significant post-treatment
- No sludge is produced since the system's anaerobic digestion converts sludge to methane, carbon dioxide, and water
- Treatment capacity augmentation through addition of ponds provides scalability
- Can be used for other purposes such as irrigation, fish culture, and recreation

Implementation

- This system was implemented as a low-cost wastewater treatment unit in 2004 at the Jawaharlal Nehru Technology University campus in Hyderabad, India

Note: [1]The value of liters is calculated based on the conversion factor of 1 US gallon = 3.785411784 liters

Source: 'Deep Pond System (Hyderabad) Case Study', India Water Portal; 'Building Capacity To Monitor Water Quality: A First Step To Cleaner Water In Developing Countries', OECD, 2006

“Forward Osmosis Desalination” reduces the cost of desalinating water and the quantity of brine discharged

Example II

Description

- Forward Osmosis[1] (FO) is an osmotic process in which the two solutions used are salt water and a draw solution (Freshwater concentrated with Ammonia and Carbon dioxide)
  - Water flows from the salt water solution to the draw solution
  - Freshwater can be easily obtained from this draw solution

Key Facts

- Conventional desalination technology is expensive due to high energy costs
  - FO consumes about 21% and 9% of the power consumed by the two most common desalination technologies, Multi-Effect Distillation and Reverse Osmosis (RO), respectively
- FO has Freshwater recovery of 85% compared to just 35-50% in RO

Benefits

- Reduces water generation costs through lower energy requirements – the primary cost component in any desalination technology
- Recovers more Freshwater from saltwater compared to other desalination technologies
- Lowers brine[2] discharge relative to other desalination technologies

Implementation

- Menachem Elimelech (Professor, Yale University) and his graduate researchers Robert McGinnis and Jeffrey McCutcheon developed the technology
- The technology is being further developed and tested at Yale University to get detailed estimates of costs
  - The Office of Naval Research, US, provided funding for setting up a pilot plant for FO desalination

Note: [1]Forward Osmosis is an osmotic process that, like reverse osmosis, uses a semi-permeable membrane to effect separation of water from dissolved solutes; [2]Brine is defined as water that is saturated or strongly impregnated with salt

Source: ‘Desalination by Ammonia–Carbon dioxide Forward Osmosis: Influence of Draw and Feed Solution Concentrations on Process Performance', Yale University, 2005

"Metal-Mediated Aeration Process" for purification of water is more economical than existing water treatment methods

Example III

Description

- Metal-mediated aeration[1] is a method for removing organic and inorganic contaminants from water, wastewater and solid media
- This method cleans groundwater and wastewater from a wide range of pollutants by oxidizing organic contaminants and simultaneously precipitating inorganic material

Key Facts

- Patent application for the process was filed in 2007

Benefits

- Cost effective in comparison to other methods used for water and wastewater treatment
- Removes both organic and inorganic contaminants unlike some of the existing technologies[2] used for treating organic contaminants

Implementation

- James Englehardt (Professor, University of Miami) and Daniel Meeroff (Assistant Professor, Florida Atlantic University) developed this technology
- Developers are seeking interested parties to market, develop and sell the product

Note: [1]Method generates natural oxidants and coagulants in water in order to destroy organic pollutants and remove metals and metal oxides, through aeration in the presence of metallic media; [2]Such as Fenton processes UV/titanium dioxide, UV/ozone processes, Simple Ozonation, etc
Source: Miller School of Medicine, University of Miami

“Ostara reactor” increases the effective capacity of wastewater treatment plant and also initiates fertilizer production

Example IV

Description

- Ostara reactor recovers ammonia and phosphates from nutrient rich fluids, recycling them into fertilizer
  - Used in wastewater treatment plants to remove phosphorus and other nutrients from liquid sewage
- Fertilizer produced by this process is environmentally safe and releases slowly. This suits golf courses, commercial nurseries and other specialty agriculture markets

Key Facts

- Recovers over 80% of phosphorous from the influent stream; reduces phosphate and ammonia levels in the effluent stream
- Each reactor can produce up to 200 mt of fertilizer per year and it costs $2-4 MM
- The treatment plant should be linked with a city/municipality having a population of over 100,000 to ensure economic feasibility

Benefits

- Increases capacity and reduces maintenance costs of wastewater treatment plants
- Fertilizer sales add to the revenue of the plant

Implementation

- Technology was invented by University of British Colombia (UBC)
- Rights to the technology were licensed to Ostara in 2005, while UBC retained royalties and ownership rights
- Technology has been used in some plants across Canada and the US since 2005

Source: 'UBC Engineers Invent Phosphate Recovery System in Vancouver', Journal of Commerce, 2007; 'Ostara Nutrient Recovery Technologies Inc.: Edmonton Reveals World's First Industrial Scale Sewage Treatment Facility to Recycle Nutrients Into Environmentally-Safe Commercial Fertilizer', Marketwire

EcoTech provides a technology based solution to water measurement and management

Example V

Description

- EcoTech is a digital water management system to control and monitor water supplies
  - Provides information to users on factors such as water consumption, leakage, points of water waste, etc.
  - Monitors and intervenes by stopping supplies in case of leakages and notifies the monitoring agency

Key Facts

- Can be applied in a variety of places that consume water, e.g., house, building, etc.
- Allows users to measure the amount of water they use

Benefits

- Improves the reliability of water consumption statistics. Enables the water distribution office to accurately charge for water based on usage
- Reduces corruption, manpower and human error in meter reading
- Helps identify water waste points resulting in efficient use of water
- The system can also be used to measure water pollution levels

Implementation

- The technology was developed at Tecnológico de Monterrey, Mexico (a Mexican educational institution**)**
- Prototype featuring about 75% of all the features was ready in 2007
- Targeted at institutions responsible for water distribution primarily in Mexico but can be applied in other countries as well

Source: 'EchoTech: A Water Management System', IEEE Computer Society Paper 2007

"Varsha, the Rain Gun" – micro-irrigation equipment helps conserve irrigation water by up to 50%

Example VI

Description

- Varsha is a micro-irrigation[1] device that consists of a sprinkler head and was developed to improve existing sprinklers
- Varsha reduces the 40-60% of water lost in traditional irrigation methods due to seepage, evaporation, and general waste

Key Facts

- One unit costs $80 and the total installation cost per acre is $350
- Sprinkles up to 500 liters of water per minute, up to a distance of 90 feet

Benefits

- Reduces water consumption by up to 50% compared to traditional irrigation methods
- Reduces irrigation time and hence power consumed by 40-50%
- Increases crop yield by up to 10% (after continuous usage for 2-3 years) through Nitrogen-fixation[2]
- Can be used to irrigate multiple crops
- Reduces pestilence by washing off pests[3]

Implementation

- Developed by Anna Saheb, a sugarcane farmer in Karnataka, India
- Rural Innovations Network incubated the product
- AIMVCF[5] made a venture capital investment in Varsha
- Anna Saheb has licensed Servals Automation[4] to manufacture and market Varsha

Note: [1]Micro-irrigation refers to low-pressure irrigation systems that spray, mist, sprinkle or drip. Deliver water onto the soil surface very near the plant or below the soil surface directly into the plant root zone; [2]Nitrogen fixation is the process by which atmospheric nitrogen is converted to ammonia; [3]Like aphids and white flies etc; [4]Servals Automation is a Chennai, India based manufacturer of socially relevant products motivated by Rural Innovation Network – a NGO specializing in incubating and networking rural innovators;[5]Aavishkaar India Micro Venture Capital Fund
Source: Dare (Print Version), August 2008, Rural Innovations Network Publication

For More Information Contact:

- **Grail Research**
  (info@grailresearch.com)