The Global Water Crisis: Six Steps for Survival

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Sustainable Development And Water: A Global Challenge For Local Actions
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Two Road Blocks on the Path to Sustainability

Thomas Robert Malthus, (1766-1834)

David Ricardo. (1772-1823)

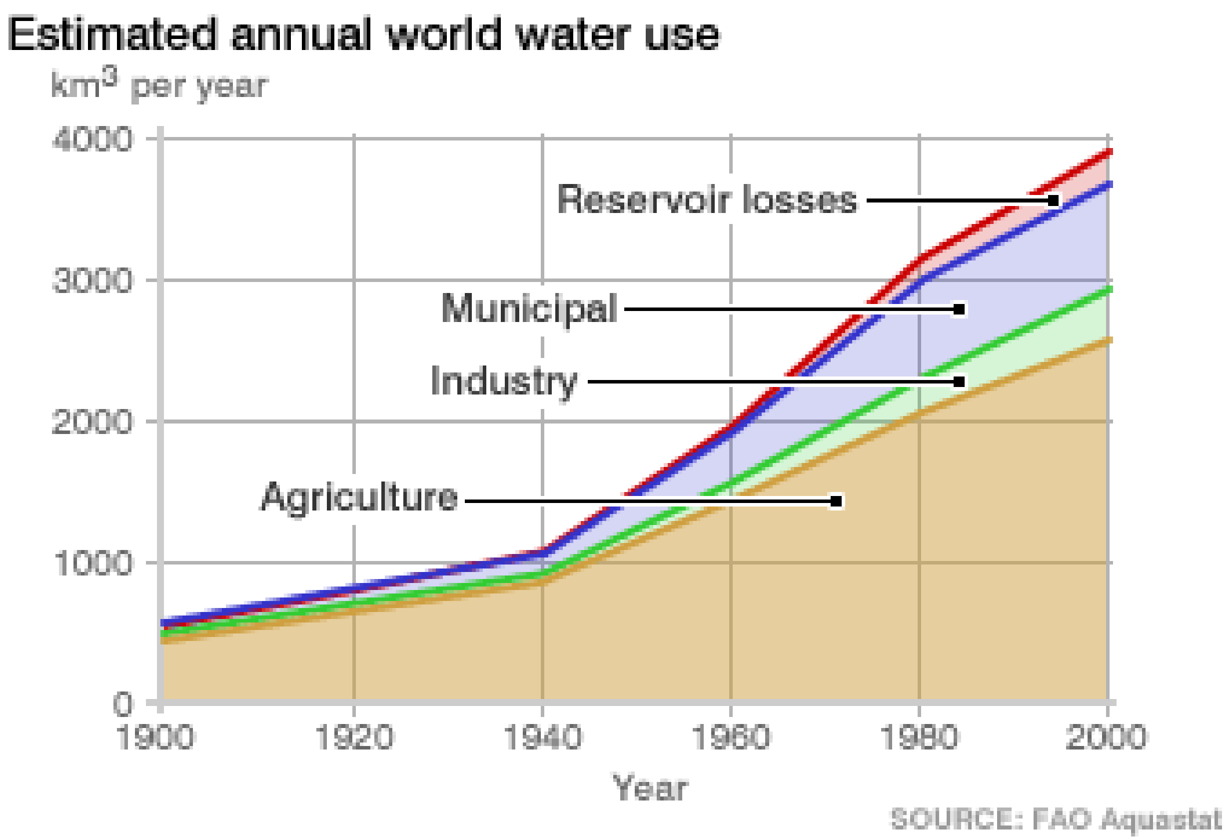
Malthus postulated a geometric rate of growth of population and an arithmetic growth of land being brought under cultivation and, hence, an arithmetic rate of growth of food production. Malthus predicted widespread famine or violent conflicts to bring food and population into alignment with each other by “misery, war, pestilence, and vice.”

Ricardo articulated “declining returns” on investments in resources (coal and iron ore in his time, water, oil, and gas in our time) whereby the best (least-cost) resources are used first, followed by the next best, and so on. Increasing demand for the resource leads to price increases that will continue to rise until the resource becomes too expensive to use.

These two nineteenth century concepts are at the root of our concern for Sustainable Development.

Conventional View of Increasing Demand Meeting Fixed Supply

- Since 1900 global population has tripled
- Water use has increased more than six-fold



Outline of talk

- What is the Global Water Challenge?
- Some Comments on Climate
- Where does Water for Food fit in?
- Water, Sanitation, and Health
- Urban Water Infrastructure
- Some Technical Fixes
- A Six-Point Plan for the Future

Water Wars

At the World Economic Forum, in Davos (24 January 2008) Mr.Ban Ki-moon, the UN Secretary-General, implicated drought as a cause of the conflict in Dafur and cautioned that a shortage of water resources could spell increased conflicts in the future. He pledged UN action on water resources. He also noted;

"Our experiences tell us that environmental stress, due to lack of water, may lead to conflict, and would be greater in poor nations,"

"Population growth will make the problem worse. So will climate change. As the global economy grows, so will its thirst. Many more conflicts lie just over the horizon,"

"This is not an issue of rich or poor, north or south," he said, pointing to examples of water problems in China, the United States, Spain, India, Pakistan, Bangladesh and the Republic of Korea. All regions are experiencing the problem."

Water Crisis Issues

flooding due to increased or changed rainfall patterns, coastal flooding due to sea level rise, storm damages due to intensification of cyclones and hurricanes,

droughts due to reduced precipitation, melting of glaciers, reduced snow pack, diversion of streams,

reduction in quality due to pollution from households, cities, industries and agriculture,

severe damage to the aquatic ecosystem due to these quantity and quality changes,

and finally economic conflict among countries, cities, industries, and agriculture over shrinking water supplies,

While these issues are often presented as problems for the future, they do need to be assessed under the current global situation of widespread asymmetries in the amount of available water resources across countries and regions within them, but also the widespread disparities in the ability of groups

What are the big ideas about the water crisis?

First, there is an incomplete understanding of the science and technology of water management which essentially implies that we cannot physically run out of water.

Second, the allocation of water among competing uses is what determines its scarcity.

Third, the allocation decisions depend most importantly on social and political choices.

And fourth, there are already technologies currently available that will enable us to avoid major crises if the social and political frameworks are in accordance with them.

Maybe the one big idea is that social and political conditions determine water use and development conditioned by the physical availability of water.

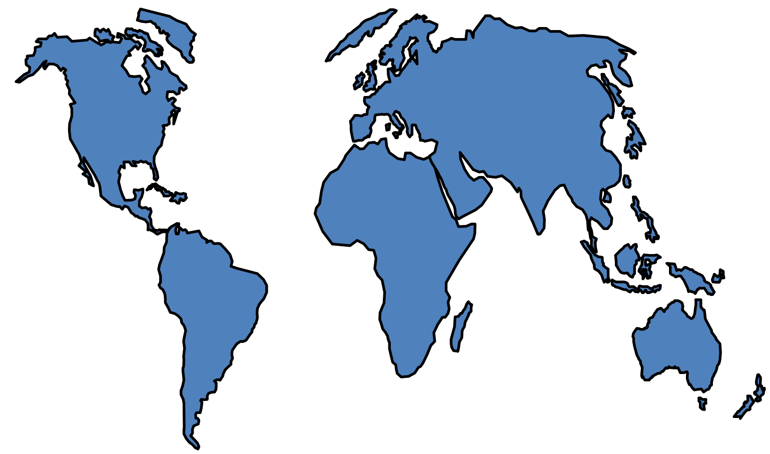
Huge needs

- over 1 billion people without safe water, 2 w/o sanitation, 4 w/o sewage treatment
- existing systems are run-down
- Sanitation for 1.2 millions and water for 600,000 additional persons each week over 15 years to meet MDG

No money

- ➔ fiscal constraints
- ➔ official aid stagnant (< $3bn/yr, WB $1bn)
- ➔ public utilities unable to self-finance or to carry debt
- ➔ private investment: a relative trickle so far

An old story

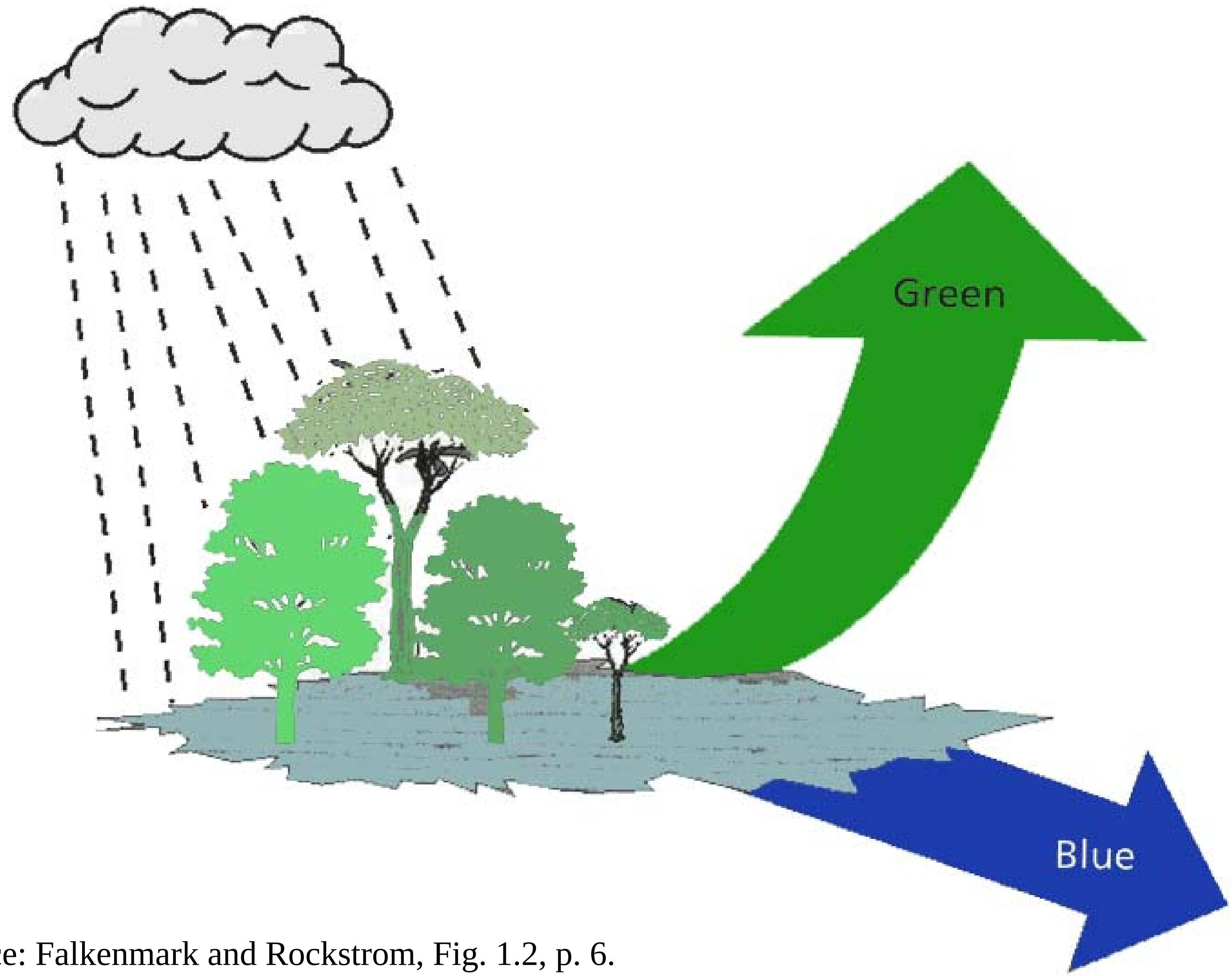


what can we do?

Janssens, J., (2003)

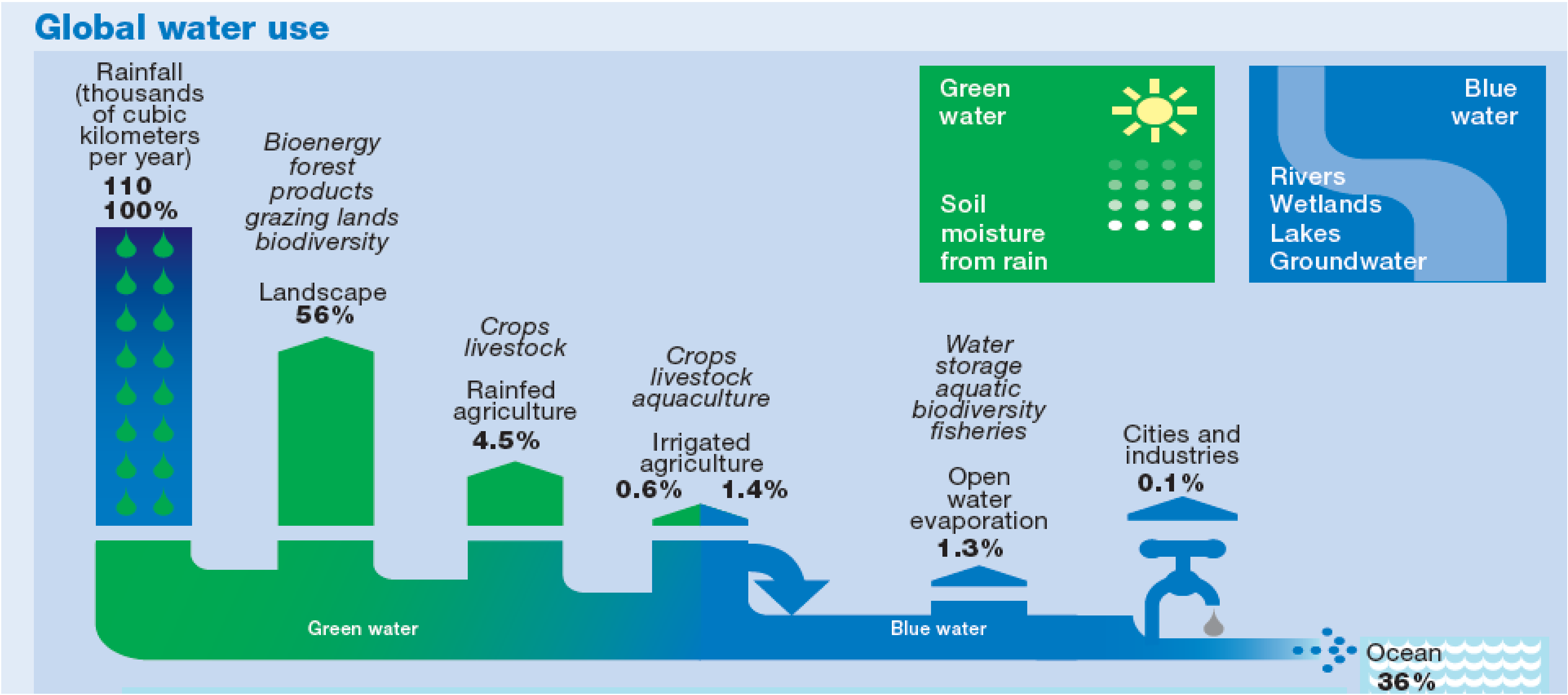
What is the
Global Water Challenge?

The Colors of Water: Green and Blue



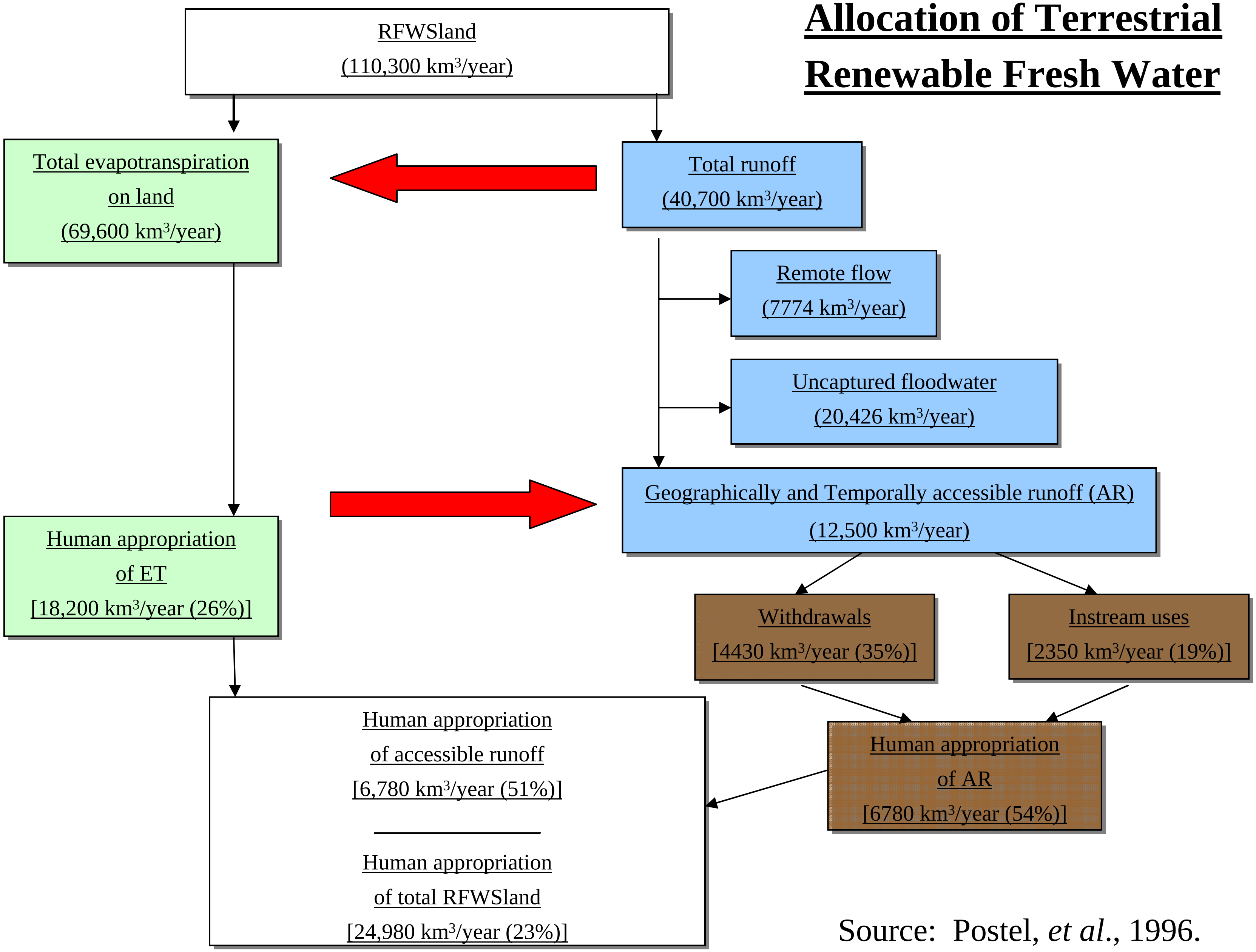
Source: Falkenmark and Rockstrom, Fig. 1.2, p. 6.

Where the Green and Blue Water Go?



Source: Comprehensive Assessment, 2007, p. 6.

Allocation of Terrestrial Renewable Fresh Water



Source: Postel, *et al.*, 1996.

Five Numbers to Remember

- 1.0 Km^3 of water is 1.0 billion m^3 or 1.0 billion tons of water (264 billion gallons).
- Total evapo-transpiration (ET) of green water 60,000 km^3/year.
- Total amount of easily accessible blue water is 12,500 km^3/year.
- Current diversion of blue water for agriculture is 2,500 km^3/year.
- Current total agricultural use of blue and green water is 7,000 km^3/year.

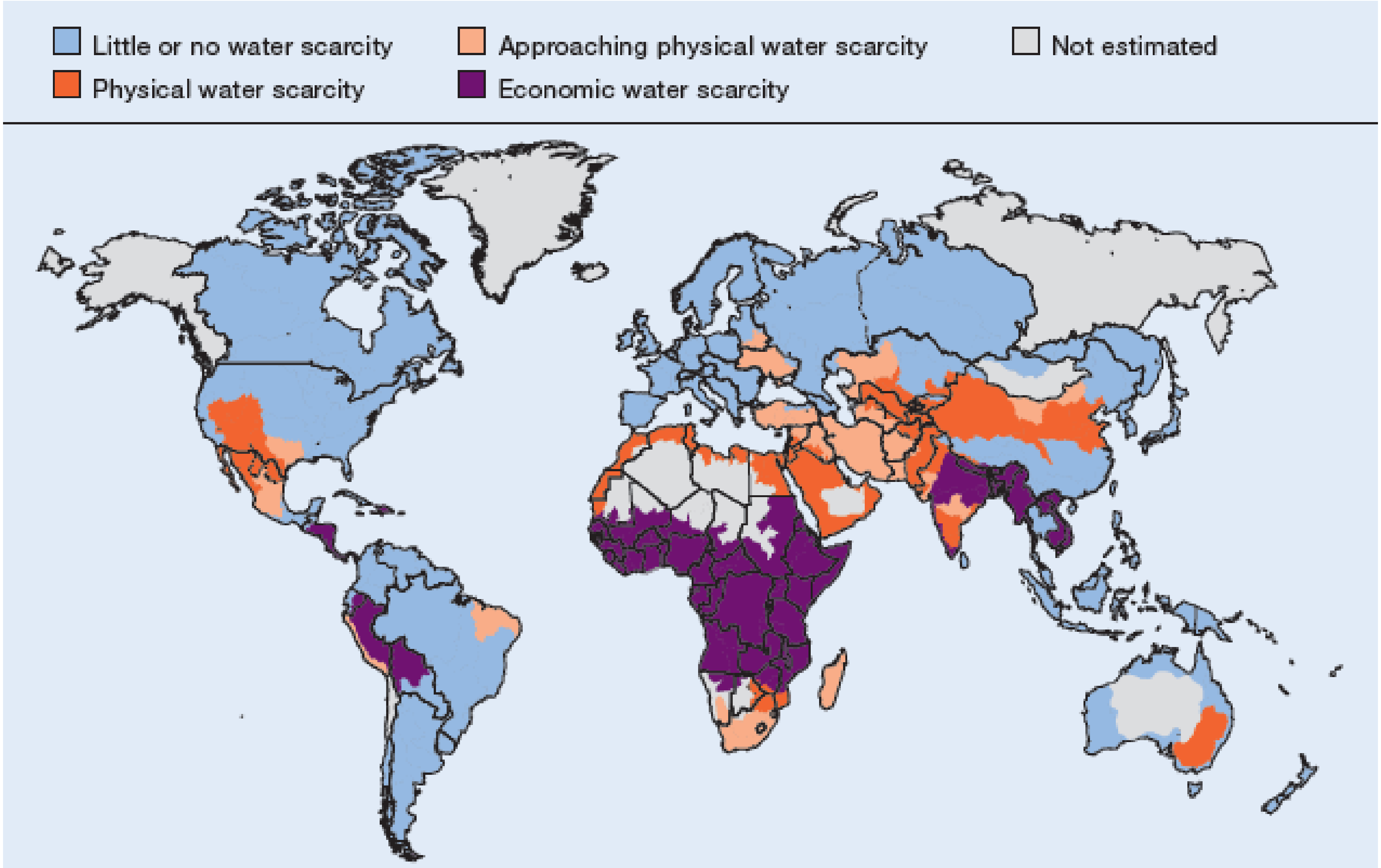
Getting Hydrologists and Economists to agree on the Concept of Scarcity

Results in a Hybrid defining it two ways: Water Scarcity Based upon Physical Resource Availability and upon Economical Resource Availability

Four types of water scarcity: Difference between having the resource and being able to use it

1. Little or no scarcity (less than 25% of blue water used)
2. Approaching physical scarcity
3. Physical scarcity (more than 75% of blue water used)
4. Economic scarcity (less than 25% withdrawn)

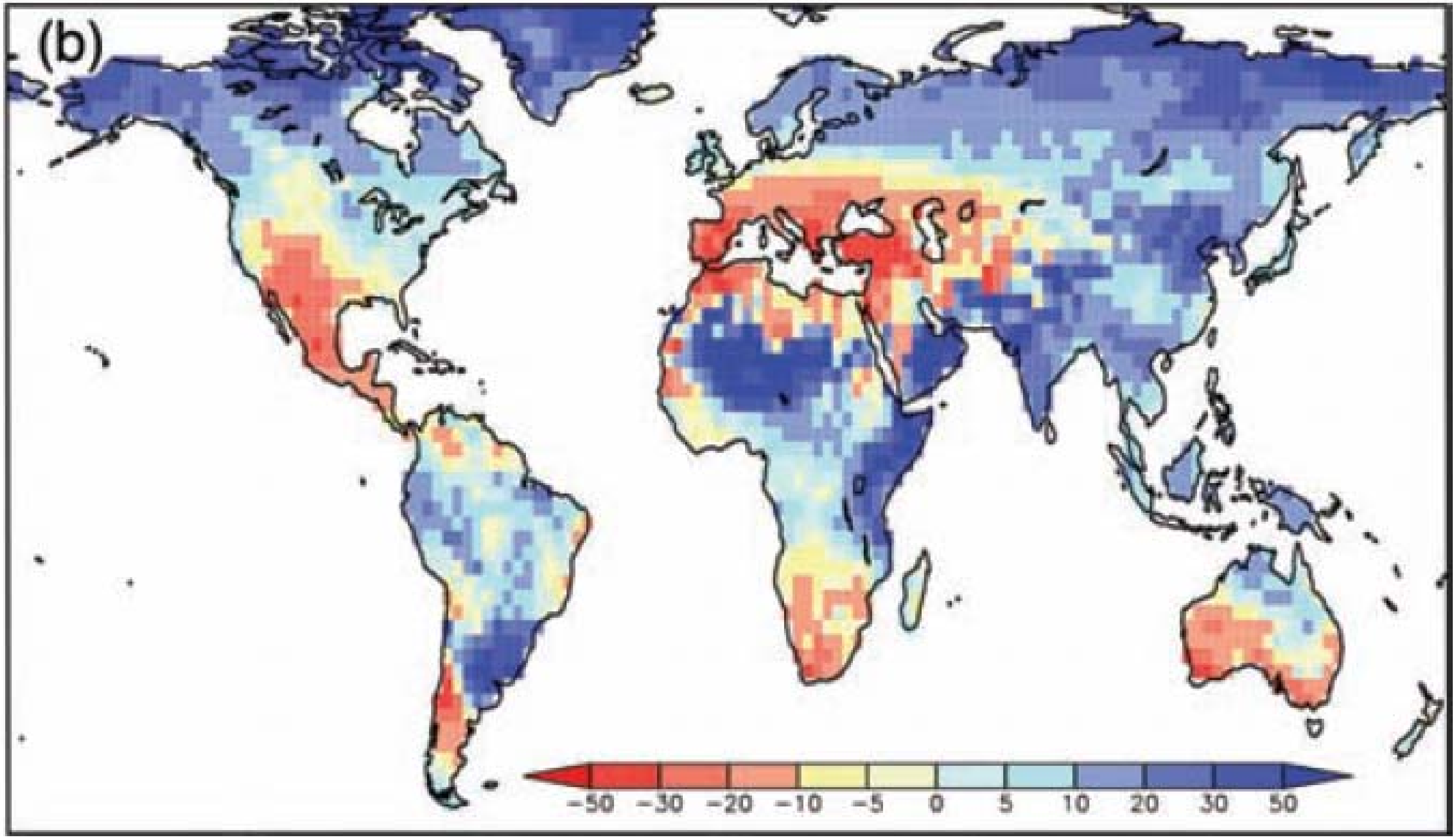
The Present Physical and Economic Scarcity



CA, p.11

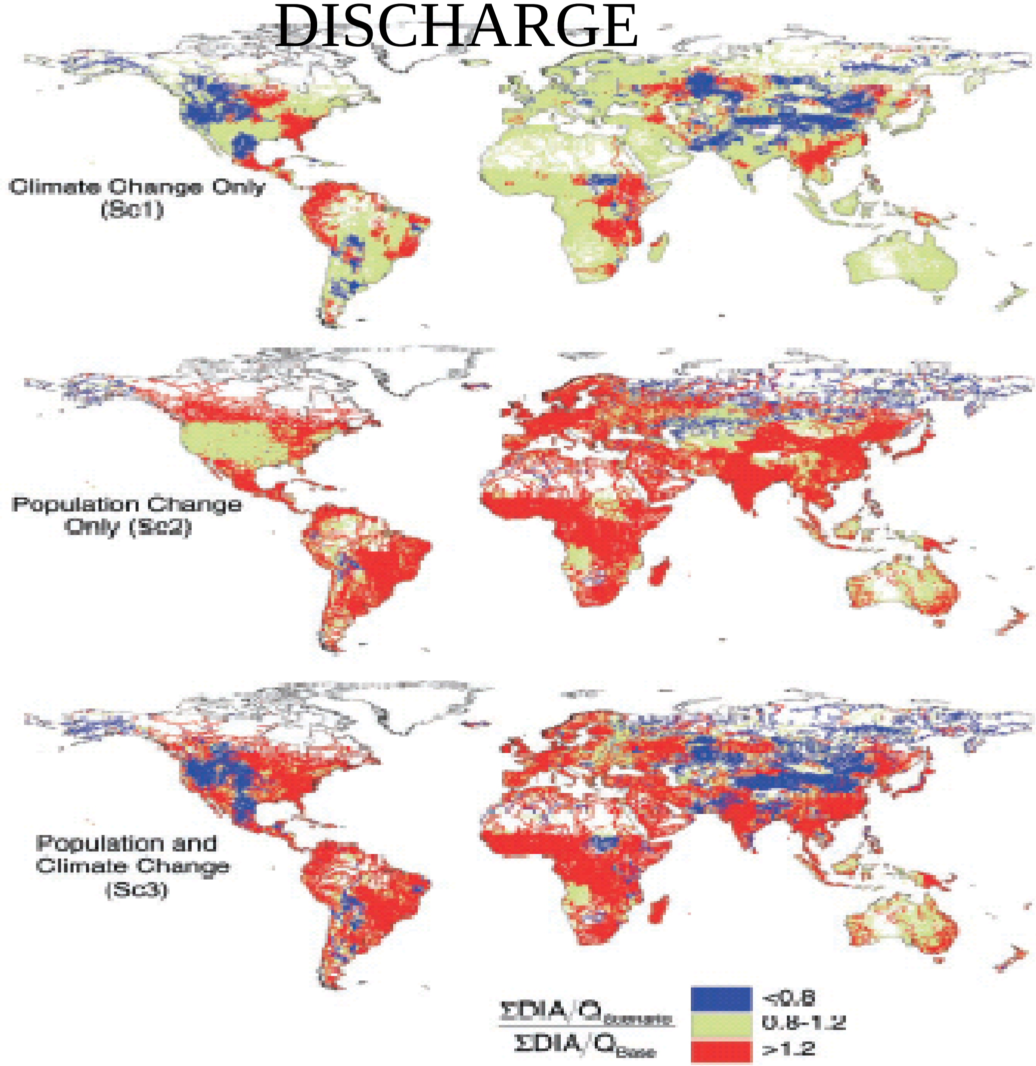
WHICH WILL HAVE THE GREATER IMPACT:

CLIMATE CHANGE OR SOCIO-ECONOMIC DEVELOPMENT?



Ensemble mean % change in mean runoff, 2000-2100. FAR WGII, p. 280.

RELATIVE CHANGE IN DEMAND PER DISCHARGE



Vorosmarty et al, **Science**, Vol. 289, 14 July, 2000.

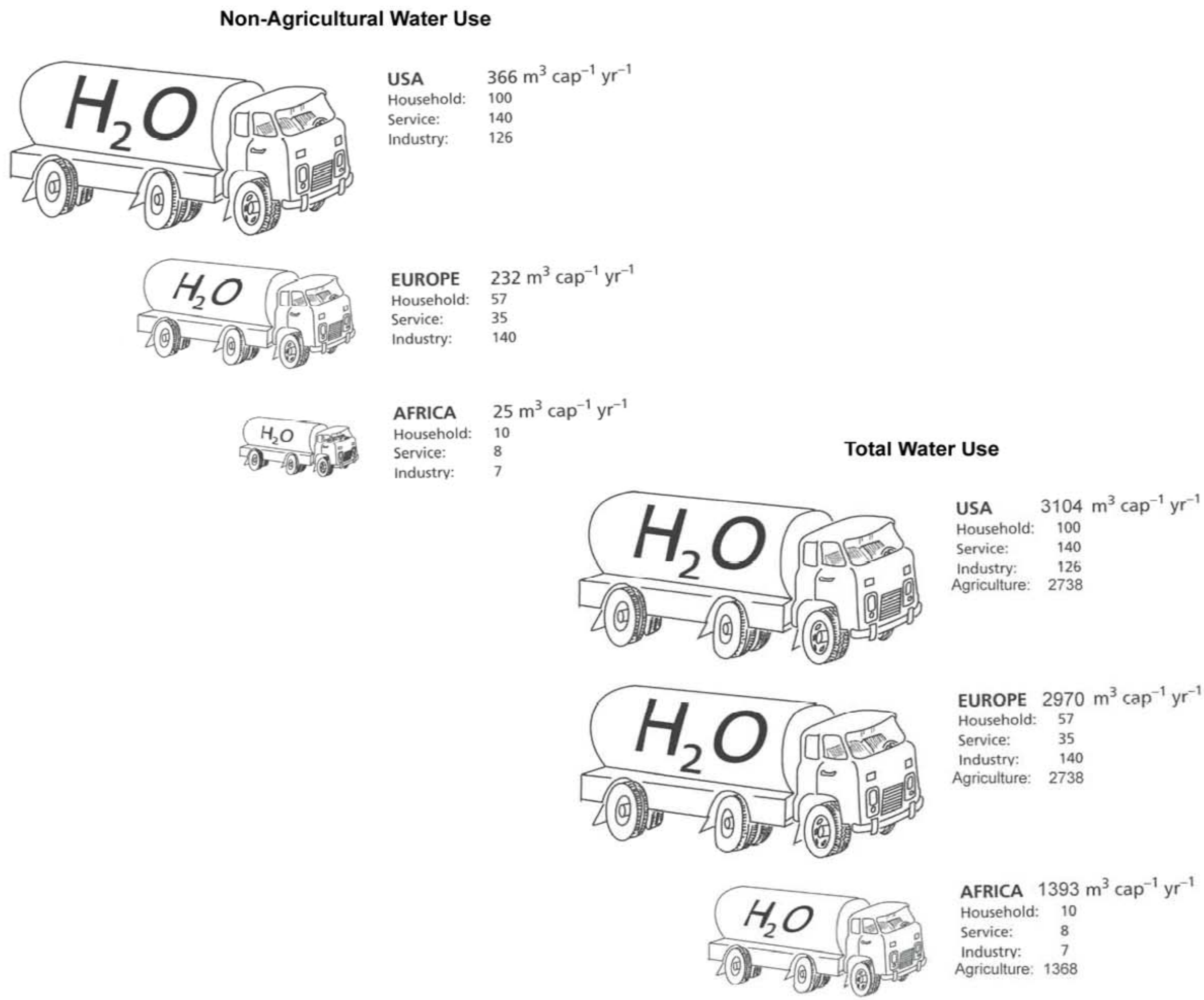
Per capita water uses

US households use 333 lpcd, or 88 gpcd for domestic uses, which is what Clemens Herschel estimated for ancient Rome!

The conventional view is that water amounts used by populations are widely different. However, when the water needed per capita to produce food is included, then there is a remarkable closing of the gap.

As incomes rise and diets change in Asia and Africa, the gap will disappear.

TOTAL WITHDRAWAL USES OF WATER



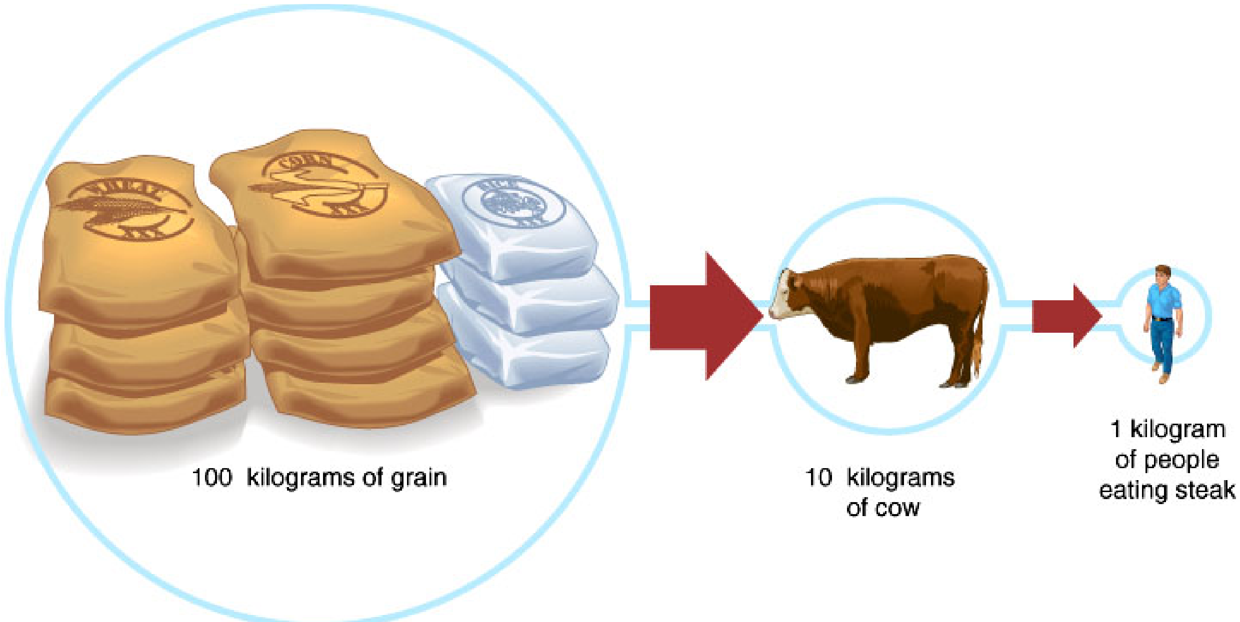
Adapted from Falkenmark and Rockstrom, Fig. 3.2, p. 47.

Agriculture is the big user

Under best conditions, approximately 2,000 tons of water are needed for 1 ton of grain.

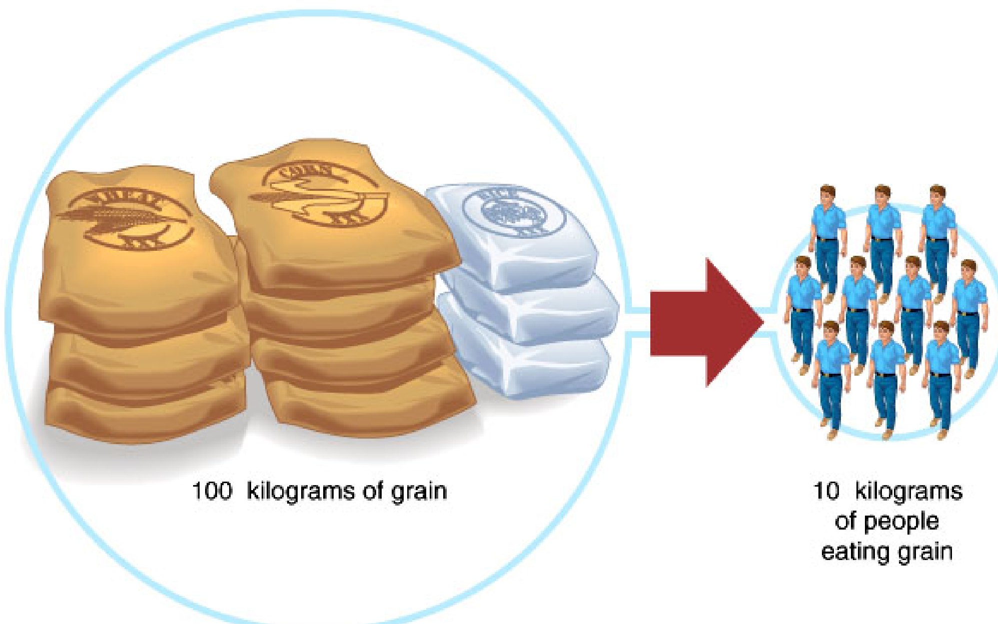
WATER ?

200,000 kg of water



WATER ?

200,000 kg of water



Source: The McGraw-Hill Companies,Inc

Some factoids about water and agriculture

- There are two types of water:
  Blue water is the rain that enters into streams, lakes, and groundwater. Green water is the remainder of the total rain.
- Note the huge asymmetry between Blue and Green water.
- 40% (5.2 billion ha.) of Earth’s land surface is currently managed for cropland and pasture.
- 30% (3.9 billion ha.) is under natural forests.
- 450 million of the world’s poorest people are entirely dependent on managed ecosystem services.
- 2.6 billion people rely on fish for more than 20% of their animal protein intake.

Water, Climate, Food: The Issues

- Food production is, by far, the largest water user on the planet.
- There is no substitute for water in crop production.
- There are currently large quantities of fresh water available on the earth, but they are poorly distributed with regard to space, and seasonal timing (more than 40,000 Km^3).
- Demand for fresh water for cities and industries has doubled over the past 20 years, and is predicted to increase by a factor of 2.2 from 900 Km^3 in the year 2000 to 1,963 Km^3 by 2050.
- The global climate is changing which will cause changes in magnitude, location, and timing of the primary sources of freshwater: rainfall and snow melt.
- Unfortunately, the state of the science is currently unable to predict these changes in magnitude, location, timing, and even whether the magnitudes will increase or decrease in particular locations.
- Used as a substitute for fossil fuels, biofuel demand from 2000-2007 is estimated to have accounted for a 30% increase in average cereal prices over the period. However, the subsequent high prices for food and feedstock are already causing shifts back into food crops in the US. (World Bank, 2008).

Future Agricultural Water Needs

IPCC Fourth Assessment Report Food and Nutrition Impacts

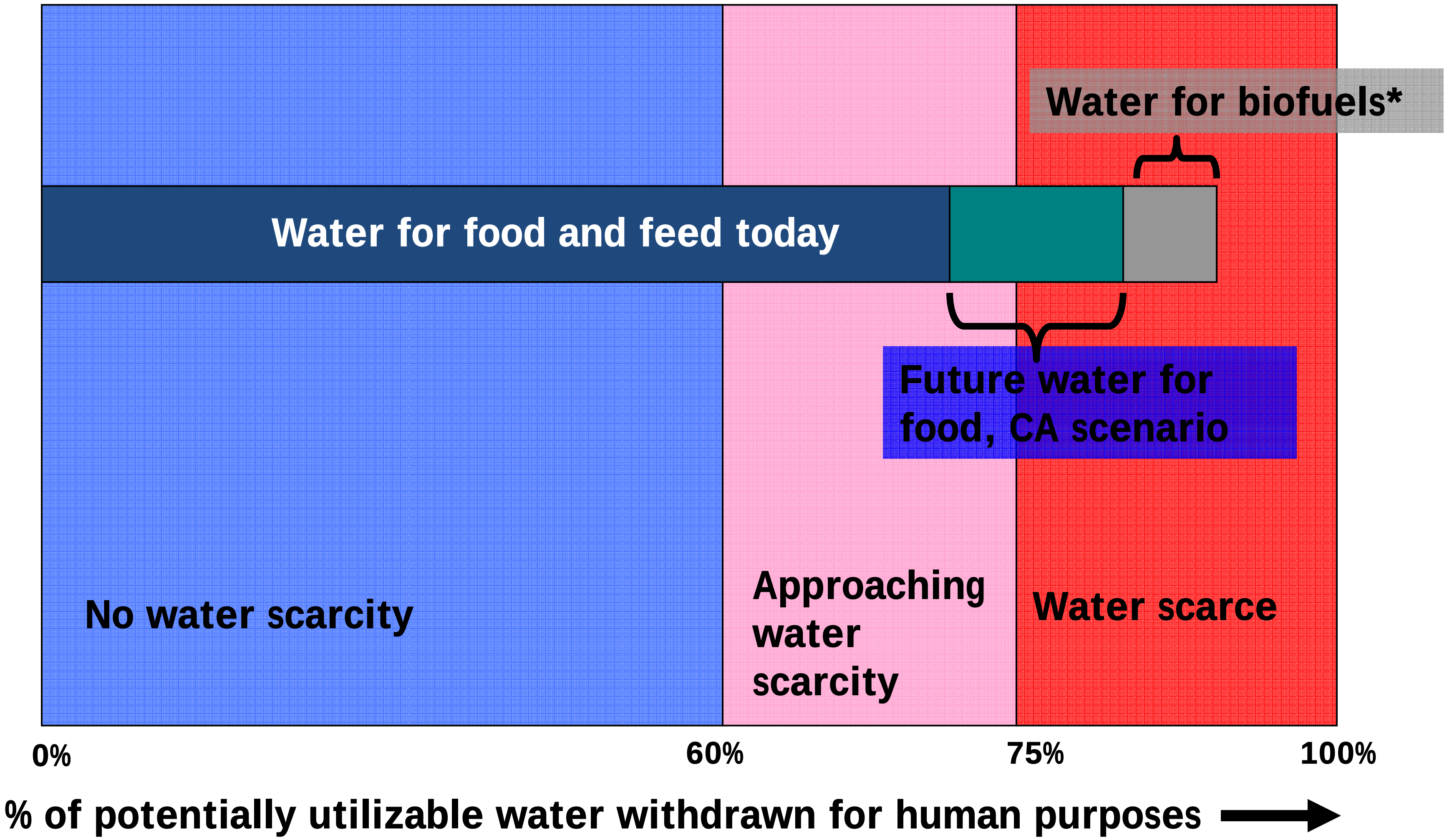
- Moderate warming (to 3°C) in mid- to high-latitudes benefits crop and pasture yields, but decreases yields in seasonally dry and low-latitude regions. An increase of 1 to 3°C increases global food production.
- 820 million undernourished today could decline to between 100-380 millions without climate change, but rise to 740-1,300 million with climate change.
- Changes in the frequency and severity of extreme events could have significant consequences for food and forestry production and risks of fires and pest and pathogen outbreaks.
- Local extinctions of fish species impact nutrition.
- At 550 ppm CO_2, under unstressed conditions, average crop yield increases by 15%.

Needs for Global Agriculture

- Global agricultural production growth rate will decline from the historical rate of 2.2% per year to 0.8% per year by 2050 (these rates still imply an 80% increase in production compared to 2000).
- By 2050 need another 185 million ha. (+19%) of rain-fed crop land, and another 60 million ha. (+30%) of irrigated land.
- To meet these goals for improved irrigation, the total capital investment needs from 2000 to 2050 were estimated to be $304 billion to rehabilitate 222 million ha. and construct additional storage of 766 Km^3 of water.

Source: Comprehensive Assessment, 2007

Global Water For Agriculture Until 2050

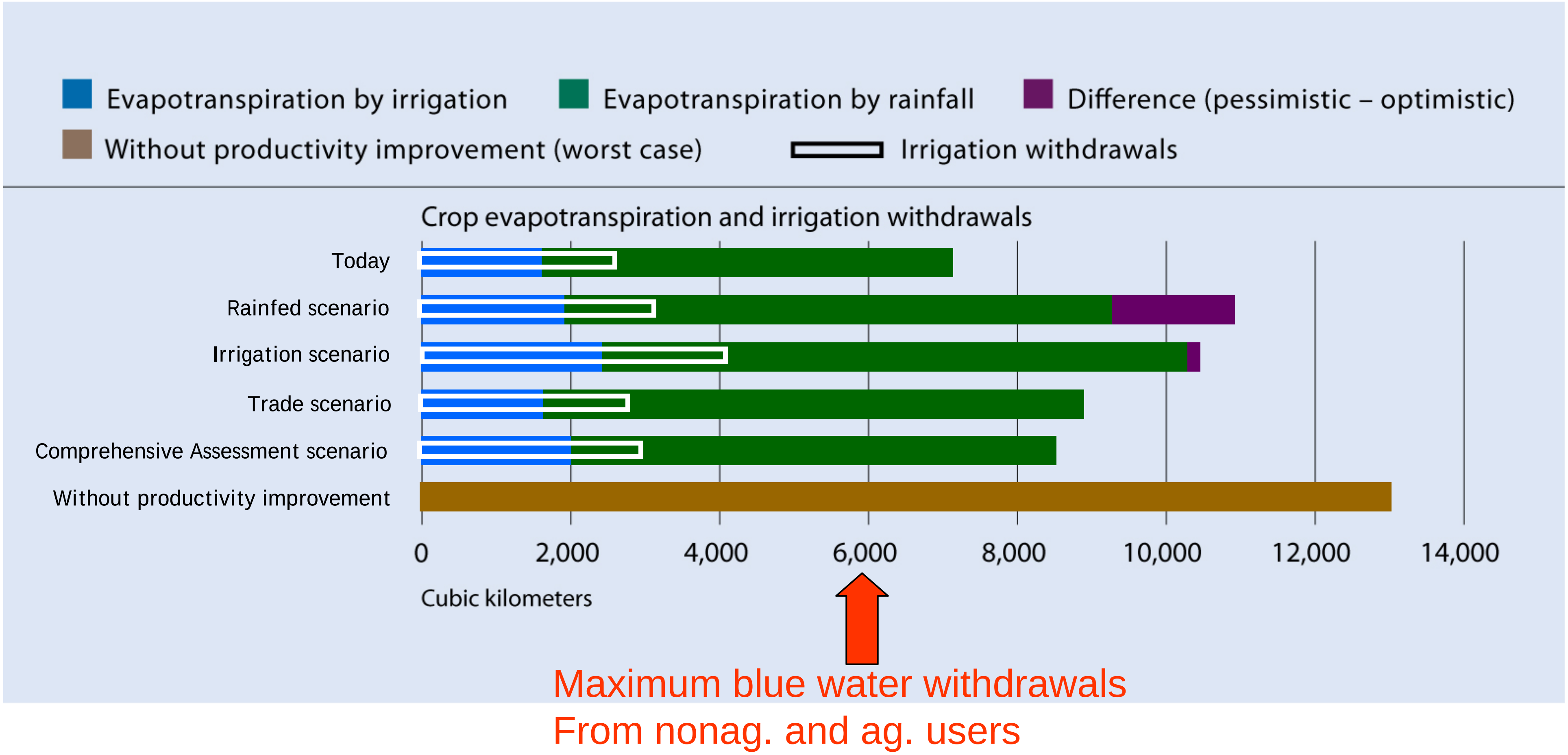


Source: Comprehensive Assessment, 2007

Comprehensive Assessment Scenarios

- Rainfed scenarios
  - High yield
    - Emphasizes investments in rainfed areas, water harvesting, and supplemental irrigation
  - Low yield
    - Pessimistic case where rainfed is not a successful strategy
- Irrigation scenarios
  - Area expansion
    - Emphasizes food self-sufficiency thru area expansion
  - Yield improvement
    - Increasing performance of existing irrigated areas
- Trade scenario
  - Increased agricultural trade from water-rich to water-scarce countries
- Comprehensive management
  - Optimal strategies that vary among regions

Scenarios to 2050



Based on WaterSim analysis for the CA.

Comprehensive Assessment of Water Management in Agriculture

- *Globally there are sufficient land and water resources to produce food for a growing population over the next 50 years.*
- *But it is probable that today's food production and environmental trends, if continued, will lead to crises in many parts of the world.*
- *Only if we act to improve water use in agriculture will we meet the acute freshwater challenge facing humankind over the coming 50 years.*

Water and Energy

- We usually think of energy from water as in hydropower
- However, gathering, treating, and transporting water have huge energy demands
- In 2005 in California, 19% of the state's electricity, 30% of its natural gas, and 88 billion gallons of diesel fuel were used for various water uses

Some Technical Fixes

Virtual water

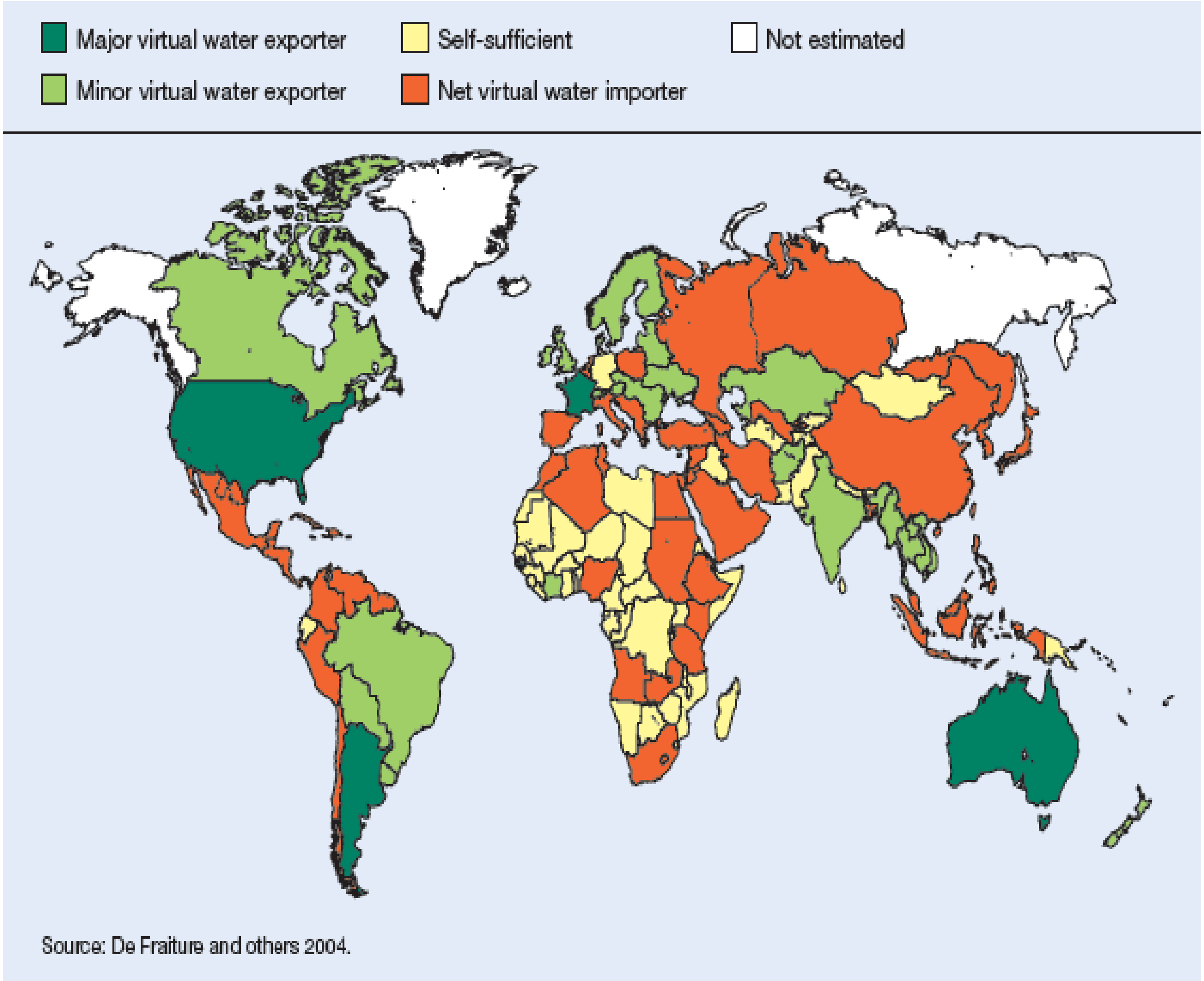
Desalination

Improving Irrigation Efficiency

Recycling Urban Wastewater

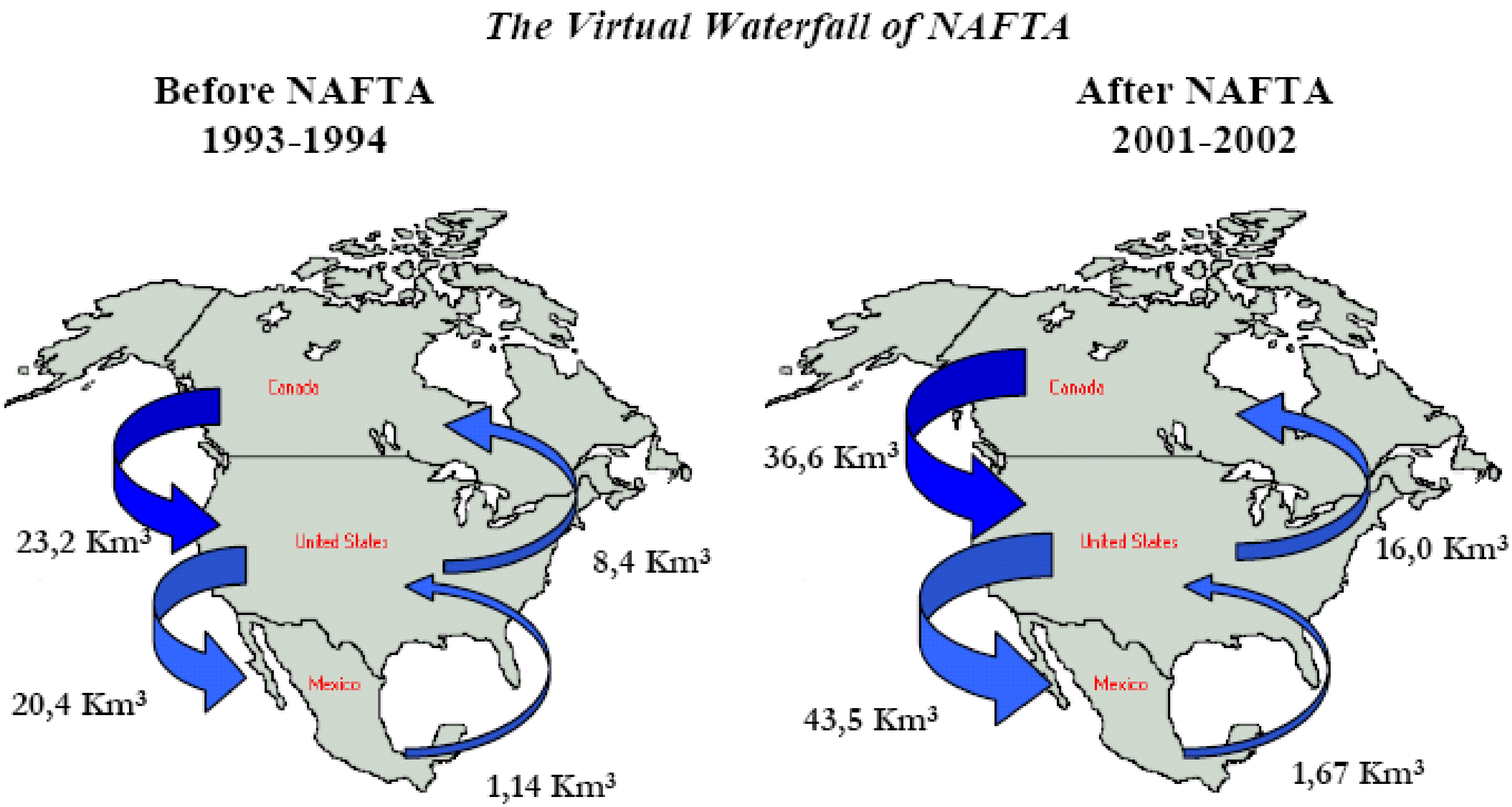
Infrastructure investments

Economic and regulatory controls



Source: De Fraiture and others 2004.

In 2003 total “Virtual Water” trade amounted to 700-900 km^3. US was net exporter of 100 km^3



Source: J. Ramirez-Vallejo and P. Rogers, 2006.

Can we afford to irrigate using desalination?

Is Desalination Economical?

Field research on the crystalline properties of desalinated water

Dubai, UEA, July 8, 2008.

TABLE 3.1

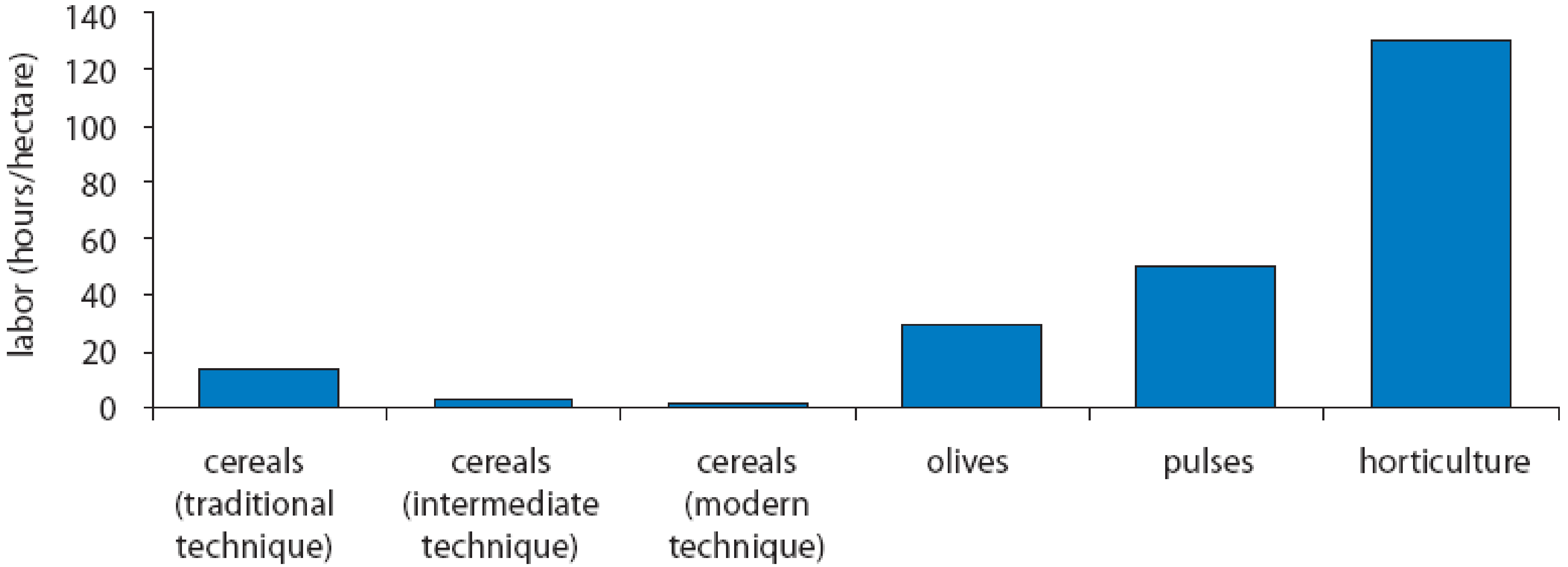
Returns to Water Use in the MENA Region, by Crop

Product	Water (m^3/ton)	Revenue (US$/ton)	Return to water use (US$/$m^3$ water)
Vegetables	1,000	500	0.50
Wheat	1,450	120	0.08
Beef	42,500	2,150	0.05

Source: World Bank 2003d.

FIGURE 3.2

Labor Requirements of Moroccan Agriculture

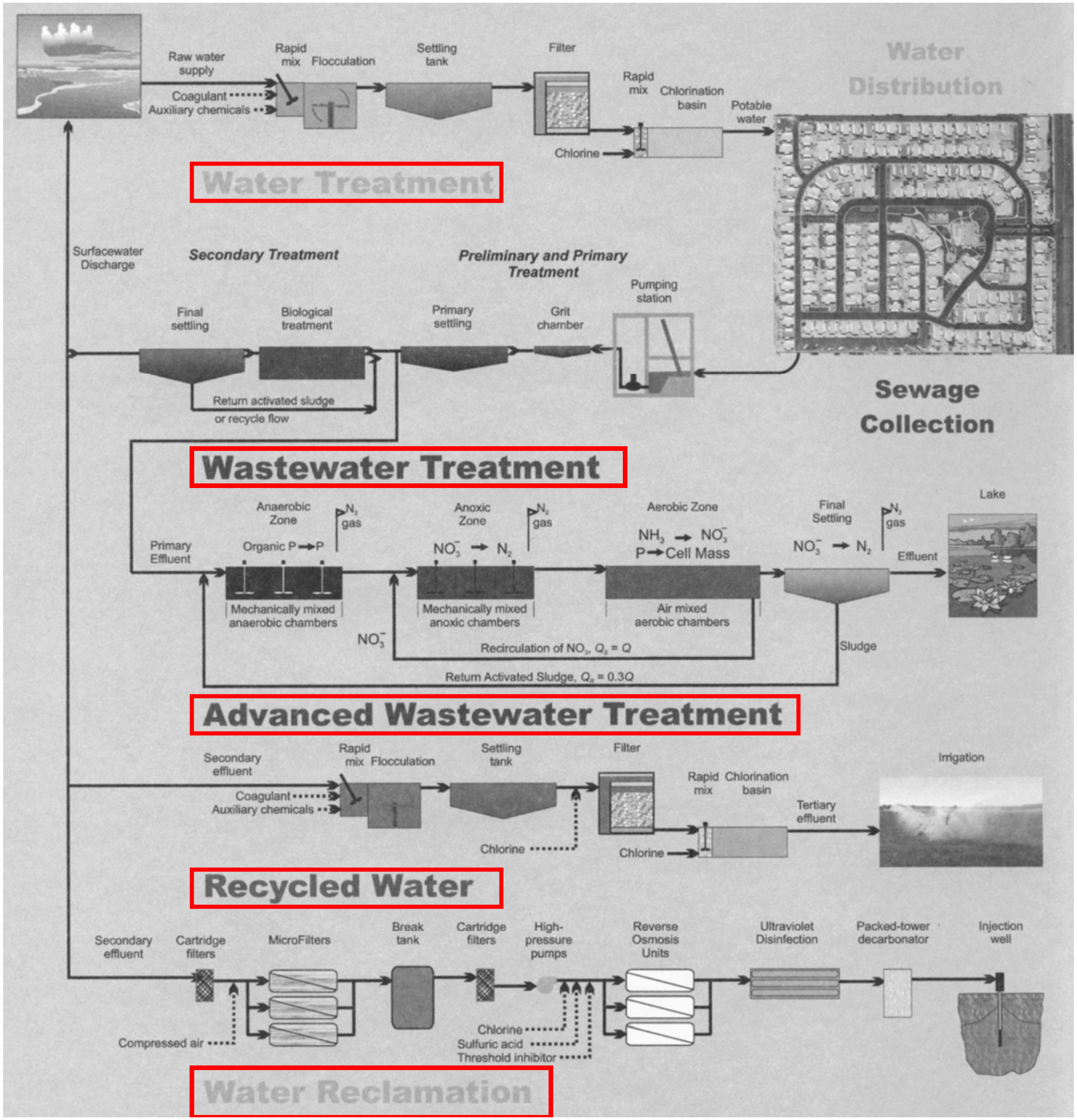


Source: Ministry of Agriculture, Rural Development and Fisheries.

Toilet-to-Tap: Recycling Urban Wastewater

- Singapore NEWater. Classic water security
- Orange County, California (unfortunately provides water for another 500,000 people in the LA area!)
- Many other US urban areas following suit
- Option being taken-up because of competition for additional supplies and increased water quality standards

WATER AND WASTEWATER TECHNOLOGY, Hammer and Hammer, 6th ed.



The Infrastructure Challenge: How Large Is It Really?

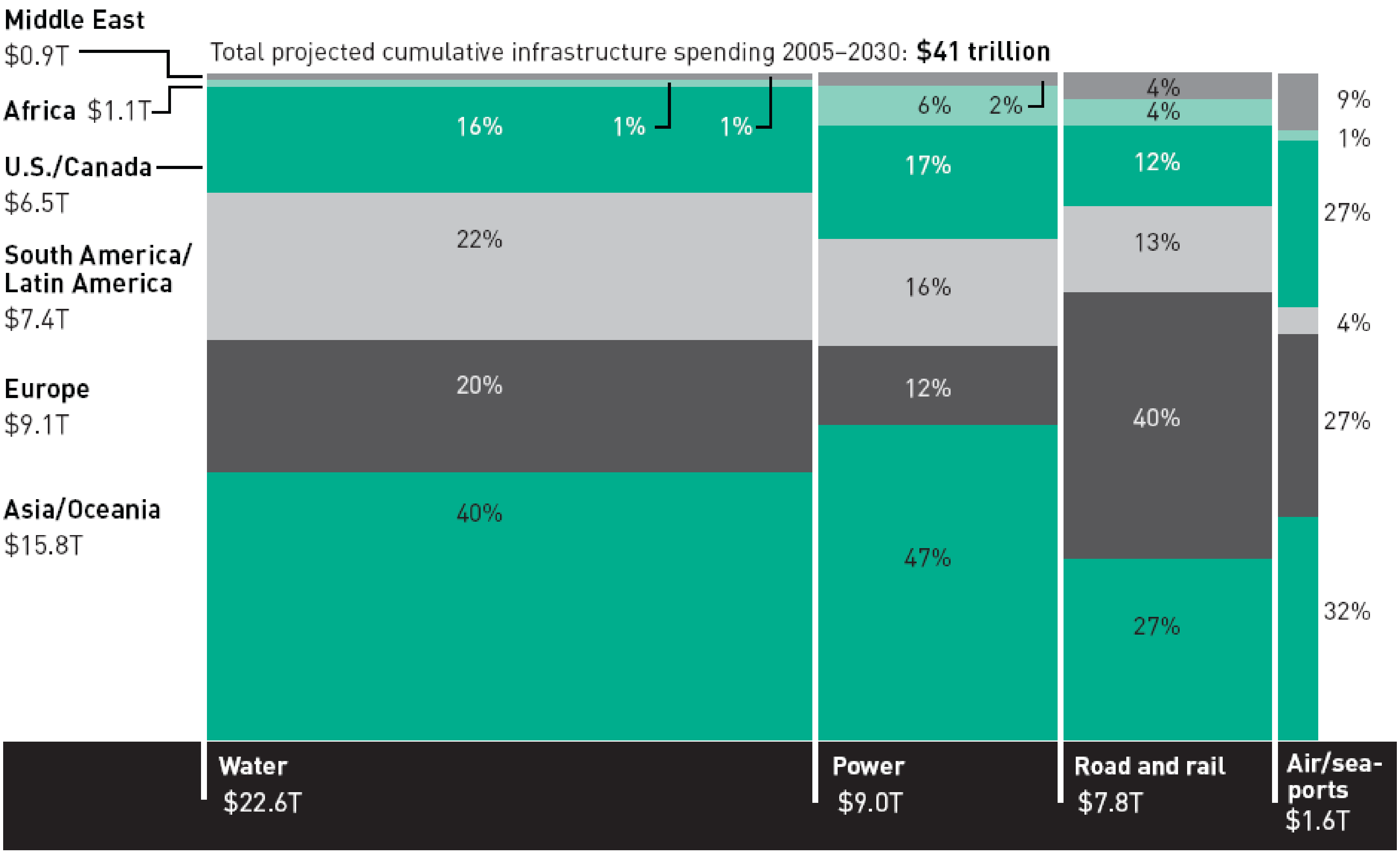
Gaping Reminders of Aging and Crumbling Pipes

Robert Stolarik for The New York Times

Deferred Maintenance?

Exhibit 1: **The Infrastructure Challenge**

Percentages of total projected cumulative infrastructure investment needed during the next 25 years to modernize obsolescent systems and meet expanding demand, broken down by region (rows) and sector (columns).



Source: Booz Allen Hamilton, Global Infrastructure Partners, World Energy Outlook, Organisation for Economic Co-operation and Development (OECD), Boeing, Drewry Shipping Consultants, U.S. Department of Transportation

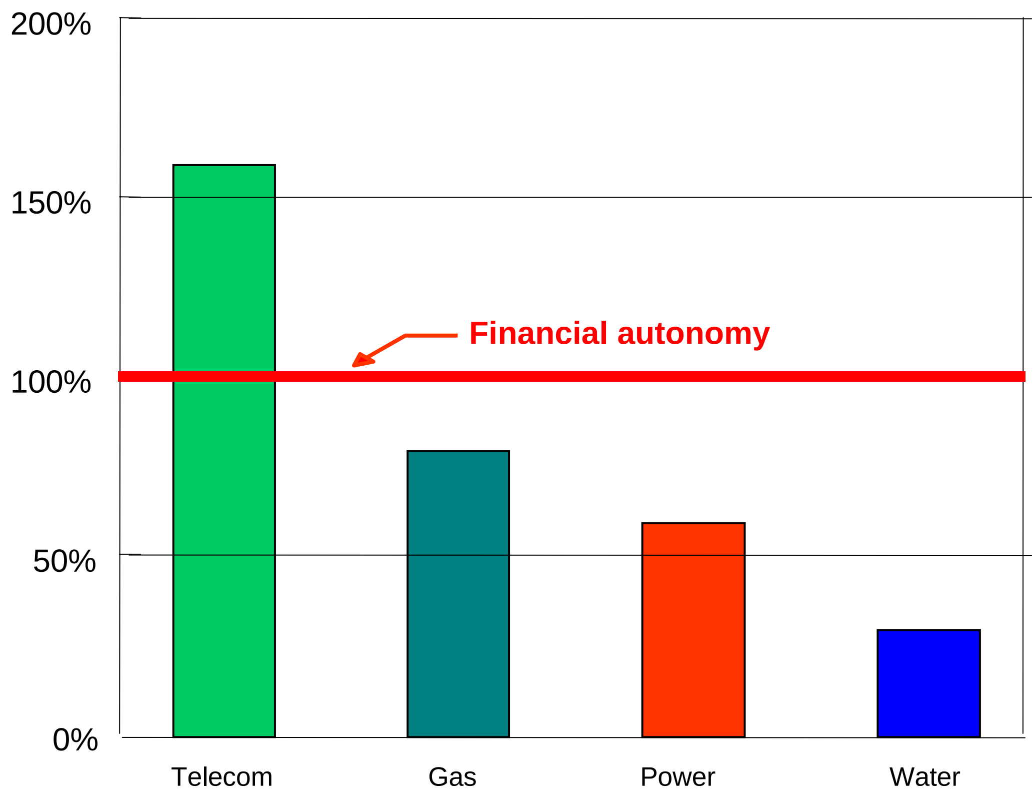
The Infrastructure Challenge: How Large Is It Really?

- The $22.6 trillion global need for all types of water infrastructure from 2005 until 2030 seems like a daunting number, but really how large is it compared with the global GDP and expenditures in other social sectors?

- It turns out to be about 1.5% of annual global GDP, or about $120 per capita.

- Global spending on health amounted to 4.3% of GDP in 2005.

Reasons NOT TO INVEST in the Water Business…



Degree of cost recovery

Source: World Bank, ca 2003.

Is Water Demand Price Elastic?

- Water demand is often assumed to be inelastic since its price elasticity is less than 1.
- However, for the Boston Metropolitan Water Resources Agency (MWRA), demand dropped from 325 mgd (which exceeded the safe yield of 300 mgd) in 1986 to less than 200 mgd in 2008
- This happened when the average annual water bill for households rose from $113 per year before 1986 to $1,132 in 2008, because Boston was forced to construct of a new secondary sewage treatment plant without major subsidies

Where is Harry Houdini when we need him?

A SIX-POINT PLAN
TO AVOID A GLOBAL CRISIS

Peter Rogers, "Facing the Freshwater Crisis," Scientific American, August 2008, pp. 28-35.

1. Water pricing: toward full socio-economic costing.
2. Conserve irrigation water: technical changes.
3. Invest in water infrastructure: maintenance issues.
4. Wastewater Recycling: cuts water demand.
5. Ship virtual water: rationalize world food trade.
6. Exploit advanced desalination technology.

Important Take Home Message

Policies based upon these six points are necessary to meet increasing population and affluence with, or without, climate change.

Conclusions

- Global water crisis; we can have one if we are not careful.
- US crisis: unlikely, we have many options and a plentiful water supply, but it will be expensive.
- Asian crisis likely to get worse, particularly in China and India
- There are, however, many mitigation options available globally and domestically.
- We should move to a closed system for urban water management; it will be easier to manage, maintain quality, be drought resistant, and be less expensive.

China's Smoky Air: The Impact on Children (page 72)

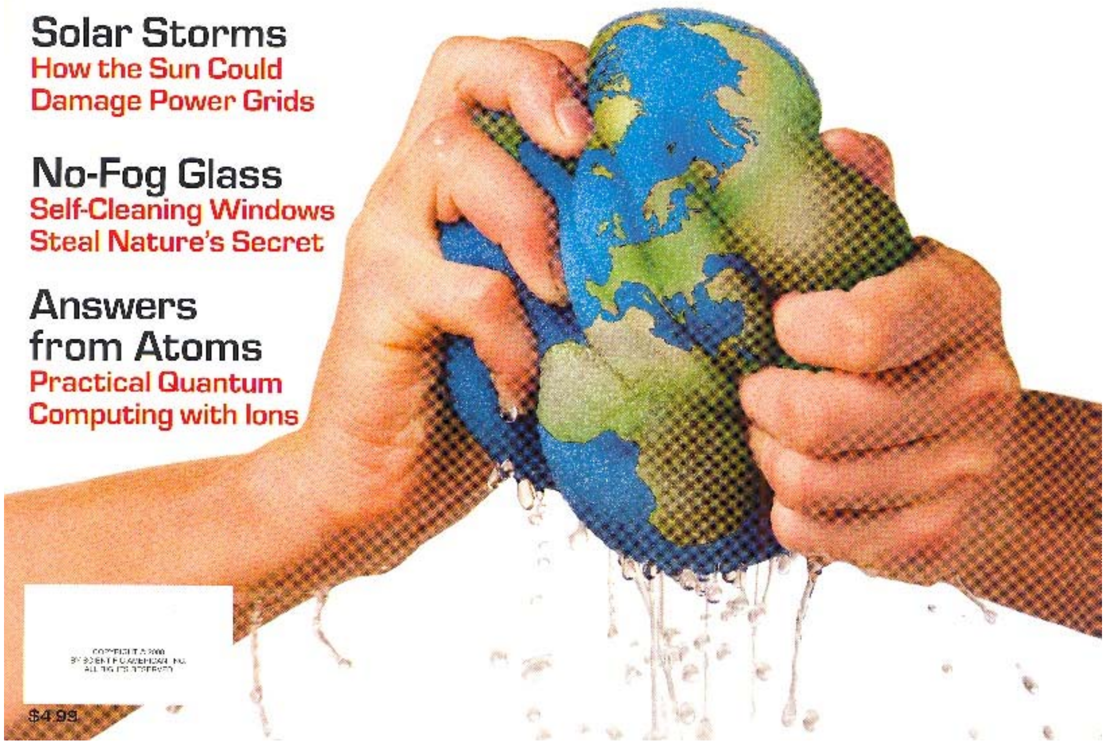
SCIENTIFIC AMERICAN

What Causes MIGRAINES page 56

August 2008 www.SciAm.com

Running Out of WATER

A six-point plan to avert a global crisis



Solar Storms
How the Sun Could Damage Power Grids

No-Fog Glass
Self-Cleaning Windows Steal Nature's Secret

Answers from Atoms
Practical Quantum Computing with Ions

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