Running Out of Water: How Serious are the Assaults on Our Most Precious Resource

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Madrid, May 21, 2012

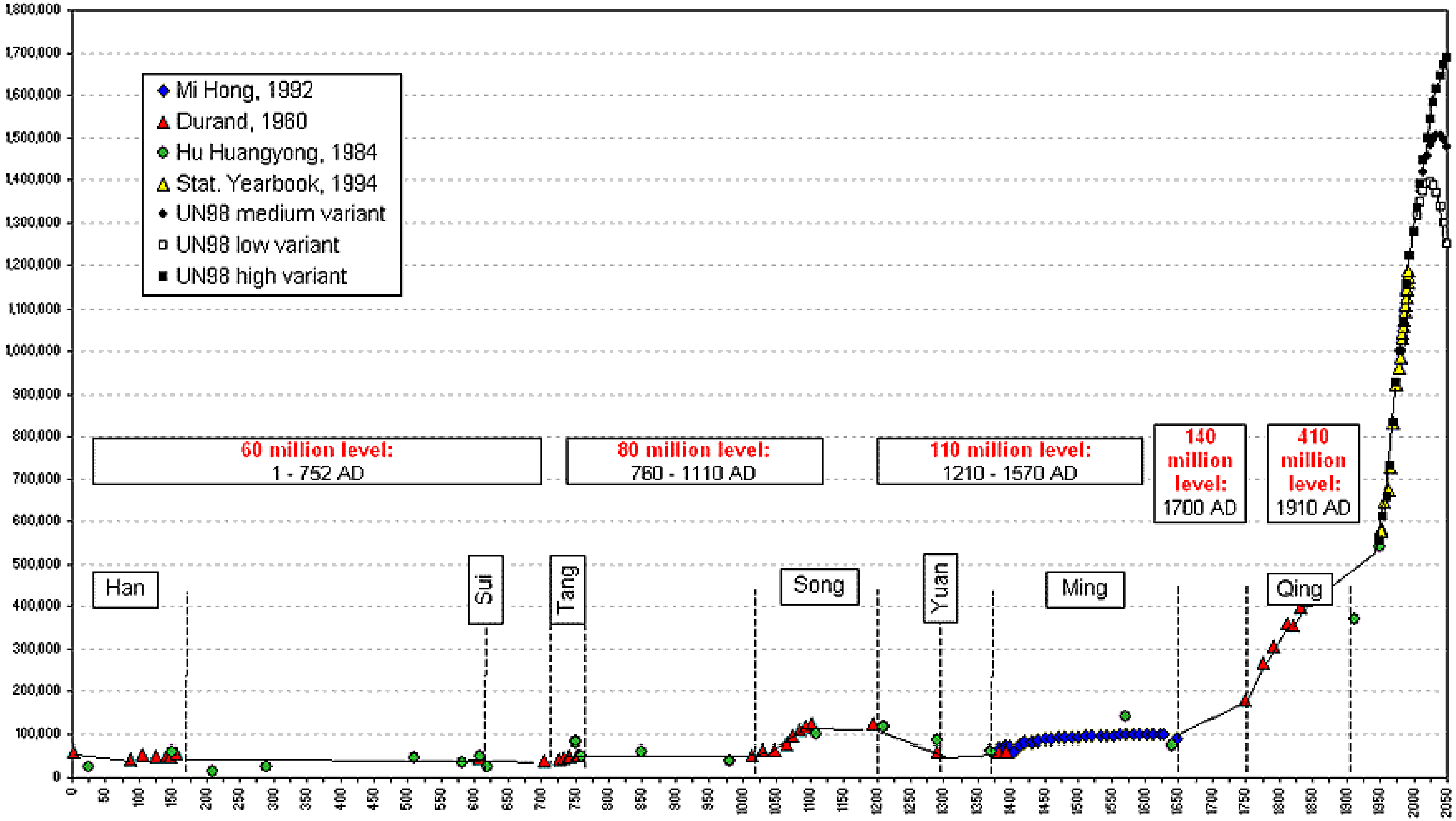
What's Driving the Overall Water Problem?

- Resources under pressure everywhere
- Many populations under severe water stress
- The water-food-energy nexus
- The health and sanitation crises
- Huge uncertainties about climate impacts
- Water governance crisis in most countries
- Financing water development a problem everywhere

What’s Different This Time?

- Since the Medieval warming period (900–1300), we have added 6 billion people.
- The majority of the Earth’s population now is far wealthier than in previous times.
- By 2050 there will be 9 billion humans seeking resources on the globe.
- Even without global warming, we would need major adaptation strategies to cope with this huge population increase.
- In the past warm periods the human population was mobile and could move into more congenial regions; now we have national boundaries.
- By 2007 the majority of the world’s population were urbanized and with less flexibility to move.
- The next 3 billion will be urban dwellers.

Why wouldn't there be a water Supply Crisis?



The Bogeymen of Sustainability

Thomas Robert Malthus, (1766-1834)

David Ricardo. (1772-1823)

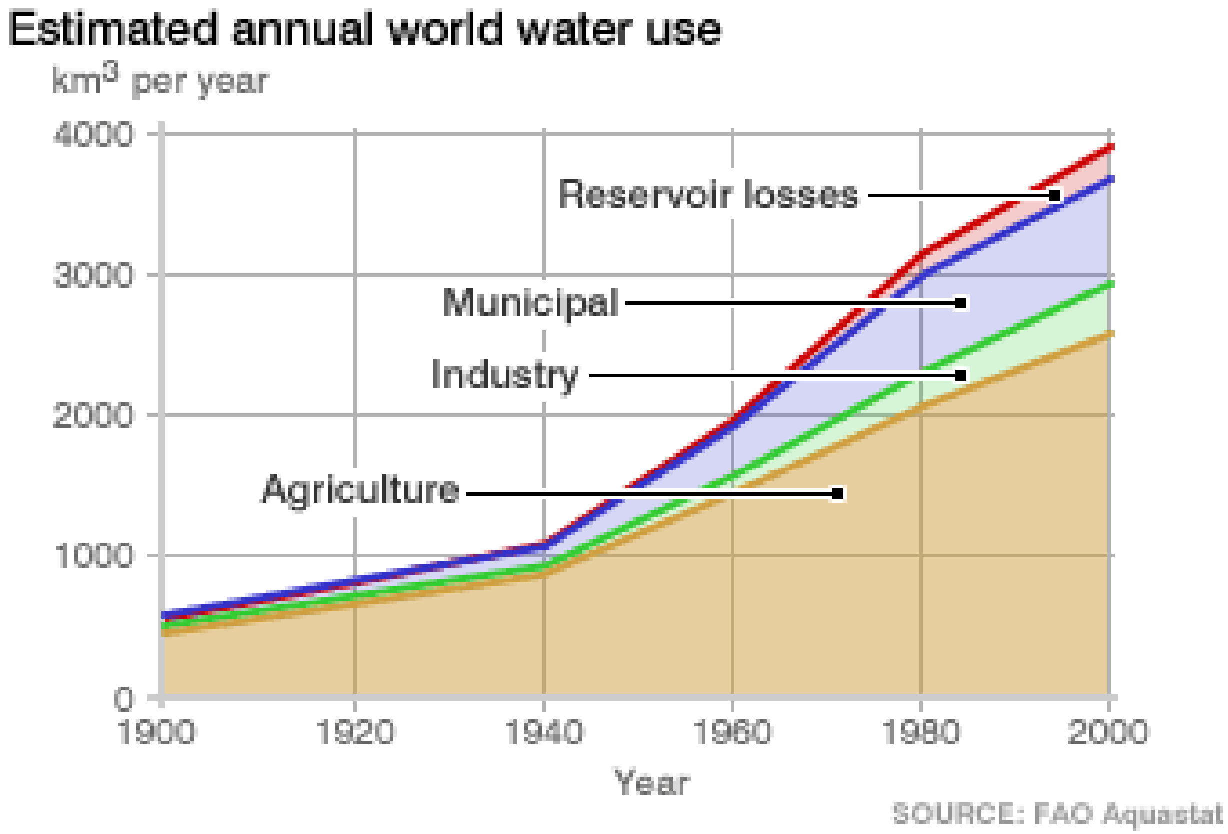
Malthus postulated a geometric rate of growth of population and an arithmetic growth of land being brought under cultivation and, hence, an arithmetic rate of growth of food production. Malthus predicted widespread famine or violent conflicts to bring food and population into alignment with each other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

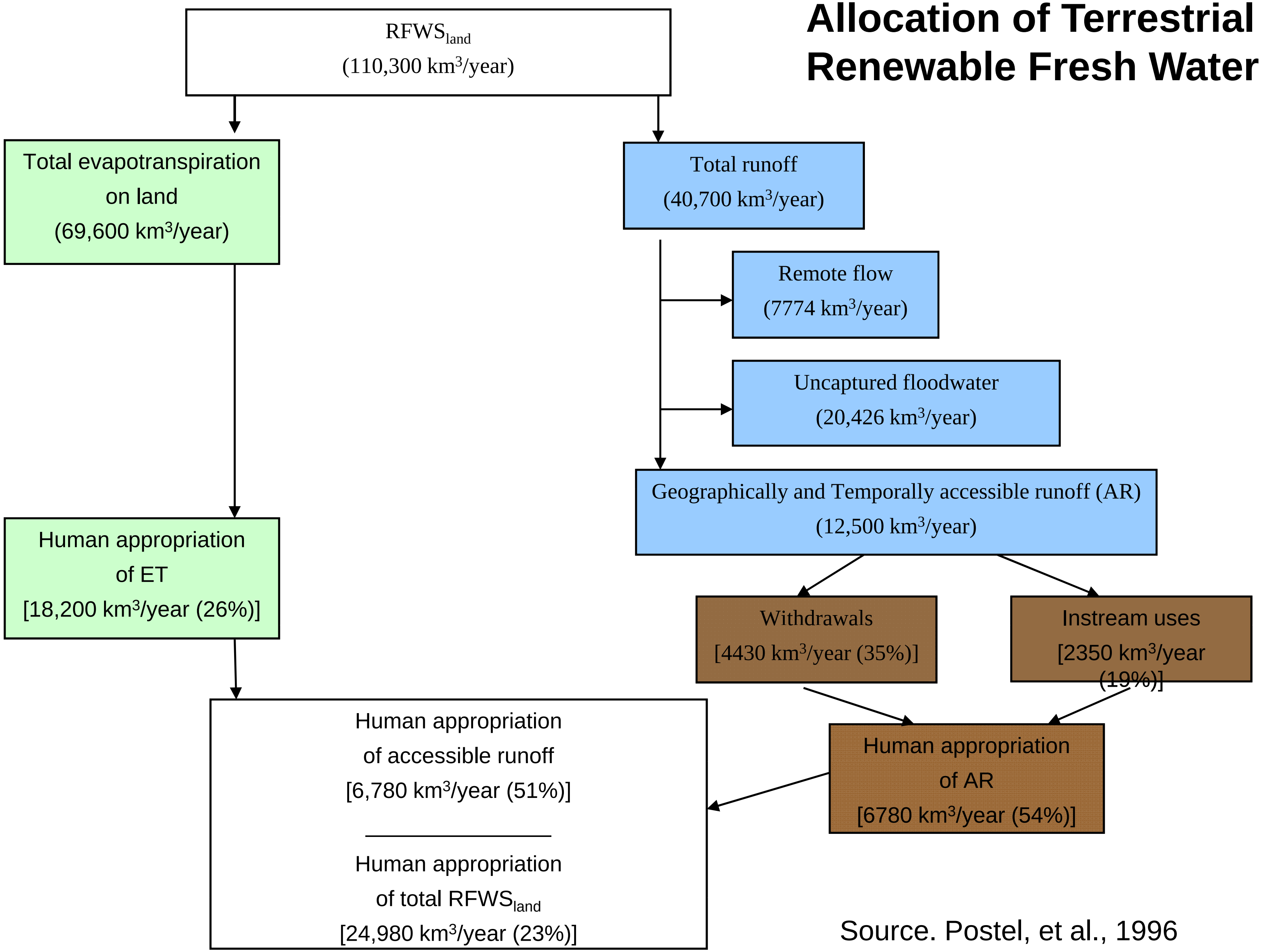
These two nineteenth century concepts are at the root of our concern for Sustainable Development.

Conventional View of Increasing Demand Meeting Fixed Supply

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

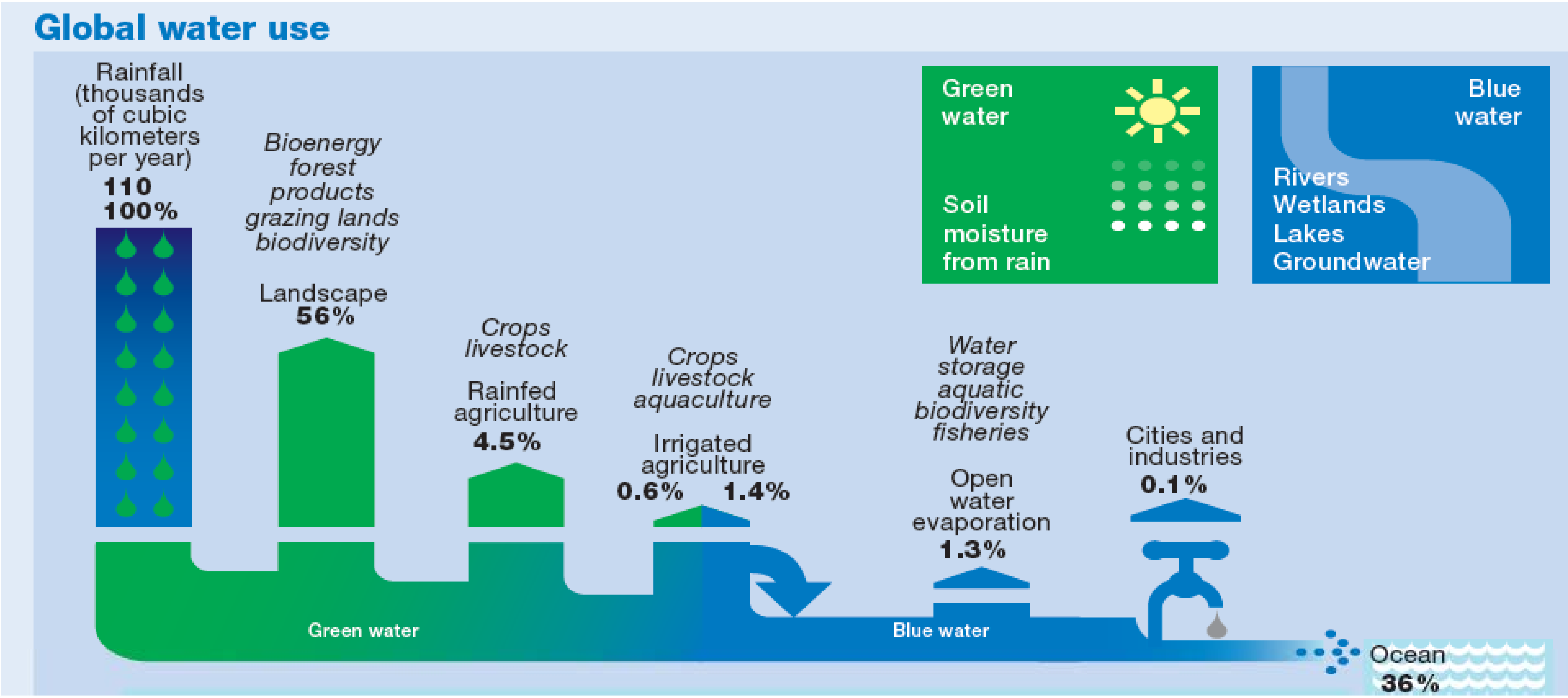


Allocation of Terrestrial Renewable Fresh Water



Source. Postel, et al., 1996

Cities and Industries use very little of total globally available water



Source. Comprehensive Assessment, 2007

Global Predictions on Water Resources

Water Security Index

Legend	
Extreme risk	
High risk	
Medium risk	
Low risk	
No Data	

Rank	Country	Rating
1	Mauritania	Extreme
2	Kuwait	Extreme
3	Jordan	Extreme
4	Egypt	Extreme
5	Israel	Extreme

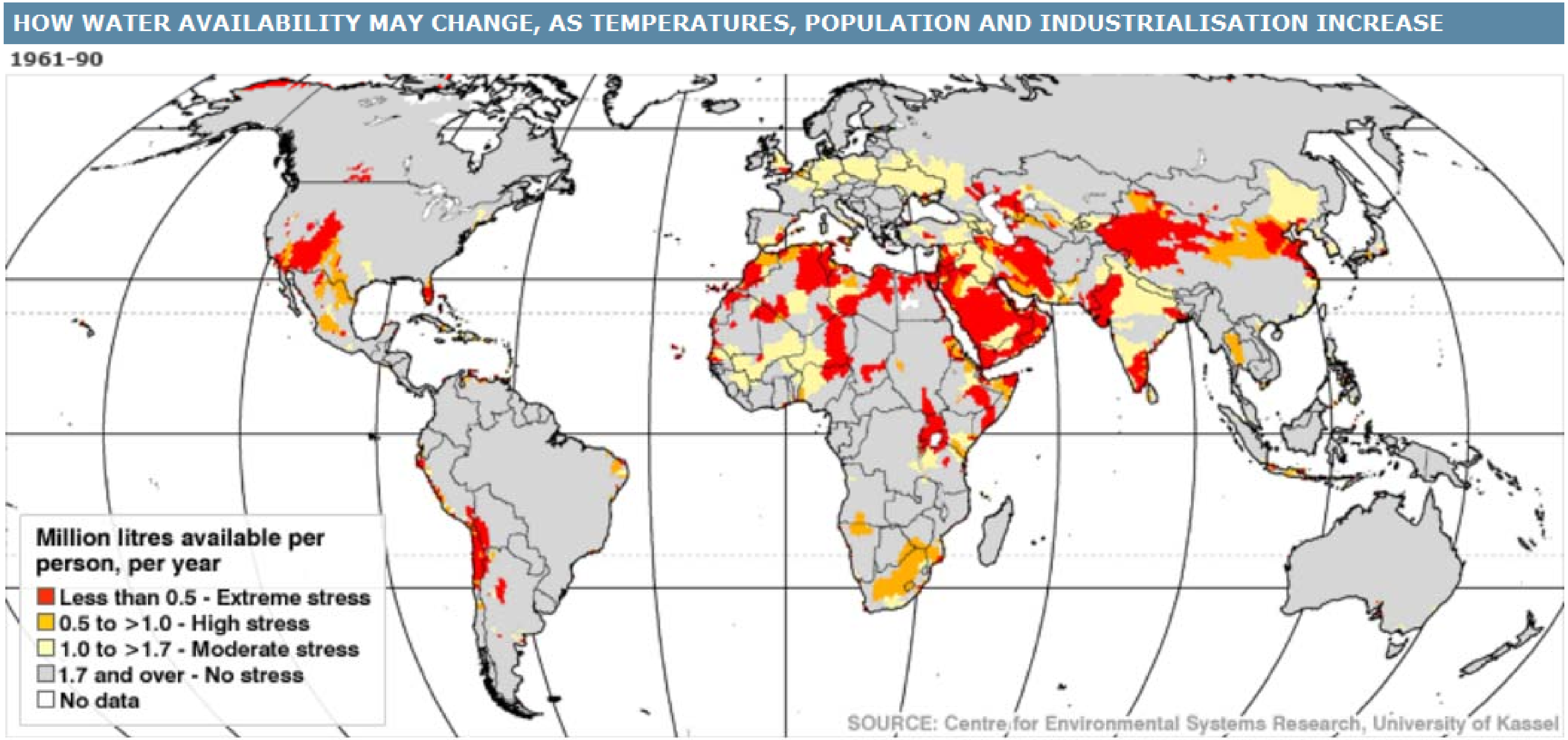
Rank	Country	Rating
6	Niger	Extreme
7	Iraq	Extreme
8	Oman	Extreme
9	U.A.E.	Extreme
10	Syria	Extreme

Index includes: access to improved drinking water and sanitation; the availability of renewable water and the reliance on external supplies; the relationship between available water and supply demands; and the water dependency of each country's economy.

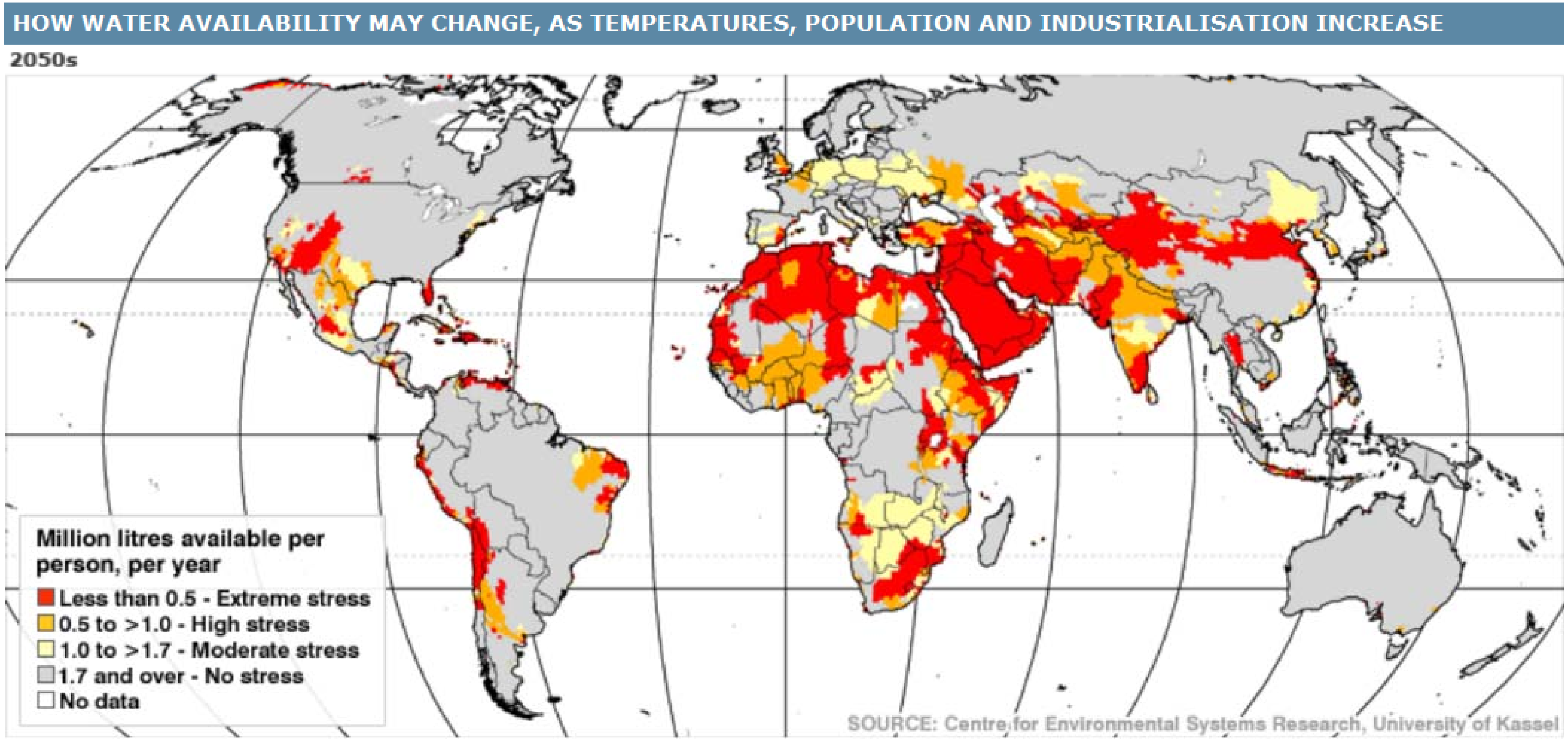
Kassel Predictions

- The projections of per-capita water availability in the maps below were made by Martina Floerke and colleagues at the University of Kassel in Germany, by combining different types of forecast.
- A computer model of climate change developed by the UK Met Office Hadley Centre generates projections of future temperature and rainfall. The Kassel team applied Hadley projections on a finer geographical scale. These projections were fed into a programme that models water flow in river basins.

Down loaded from BBC, Tuesday, 8 December, 2009.


HOW WATER AVAILABILITY MAY CHANGE, AS TEMPERATURES, POPULATION AND INDUSTRIALISATION INCREASE
1961-90
Million litres available per person, per year
Less than 0.5 - Extreme stress
0.5 to >1.0 - High stress
1.0 to >1.7 - Moderate stress
1.7 and over - No stress
No data
SOURCE: Centre for Environmental Systems Research, University of Kassel

1961-90

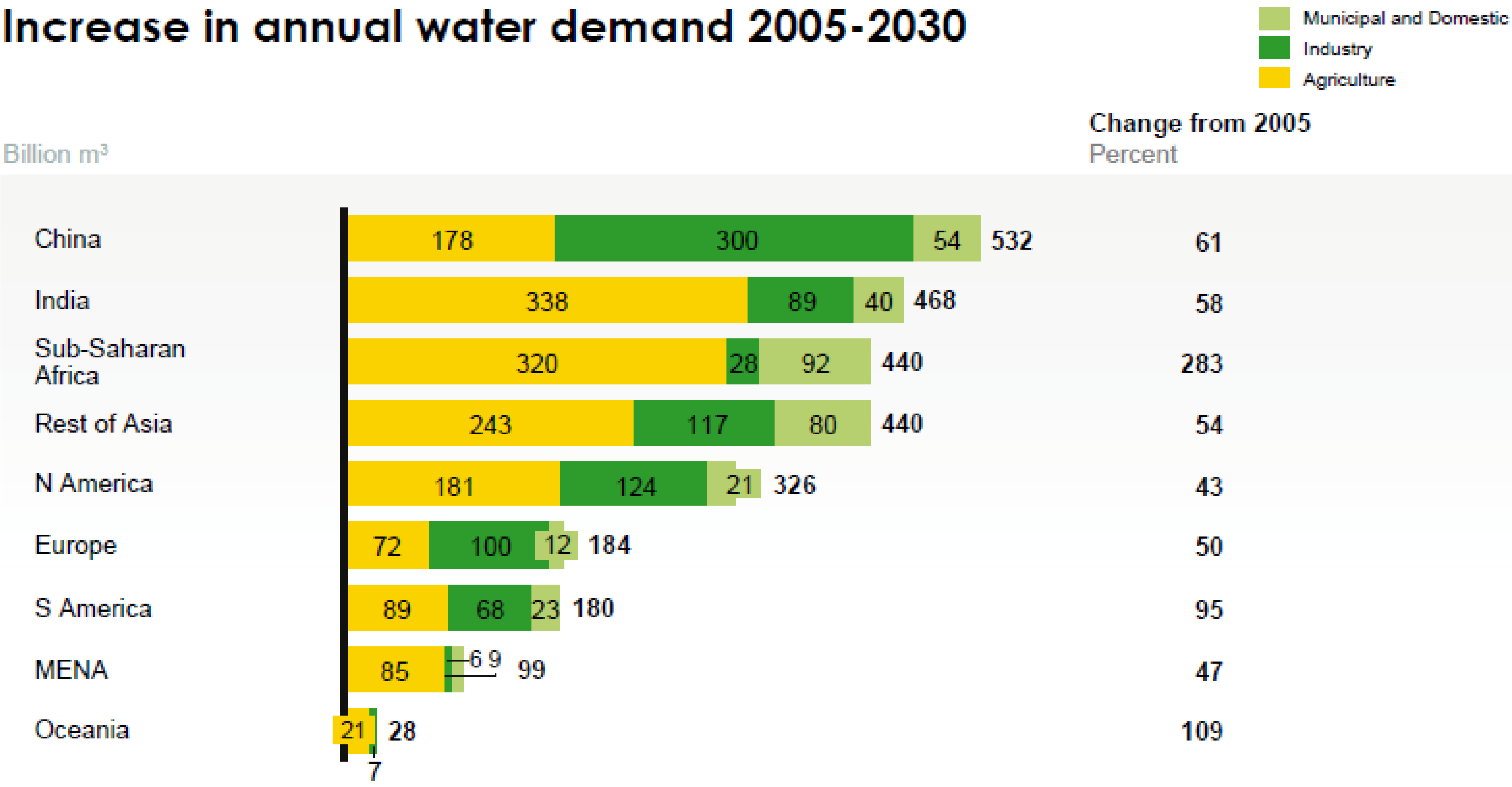


2050s

NOTE: April 13, 2036 is when the 885-ft diameter asteroid, Apophis, is predicted to pass within 18,300 miles of planet earth. MSMBC 13 Oct. 2010

Exhibit 5

Increase in annual water demand 2005-2030



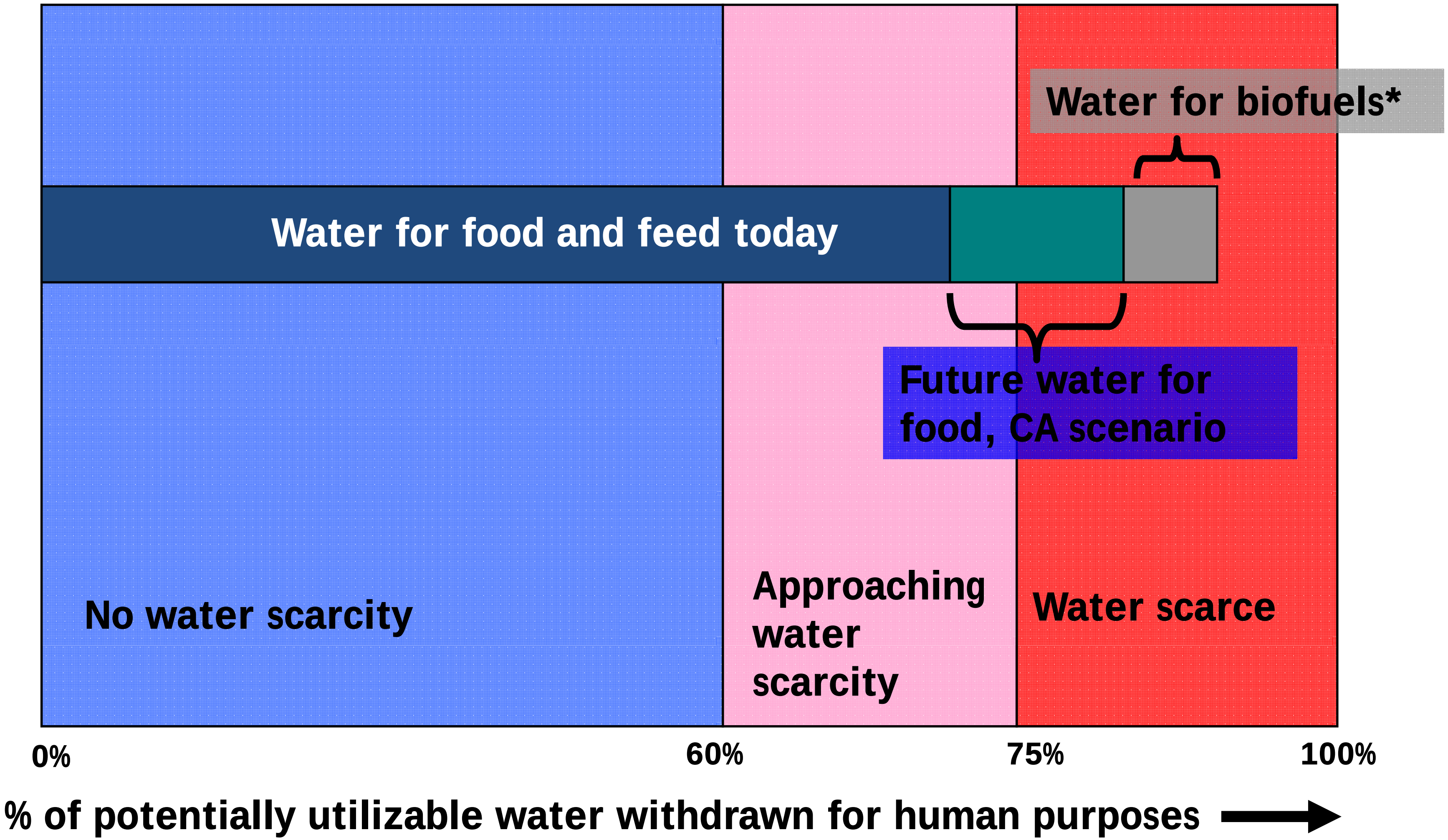
SOURCE: 2030 Water Resources Global Water Supply and Demand model; baseline agricultural production based on IFPRI IMPACT-WATER base case

Comprehensive Assessment of Water Management in Agriculture

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.*

Global Water For Agriculture Until 2050

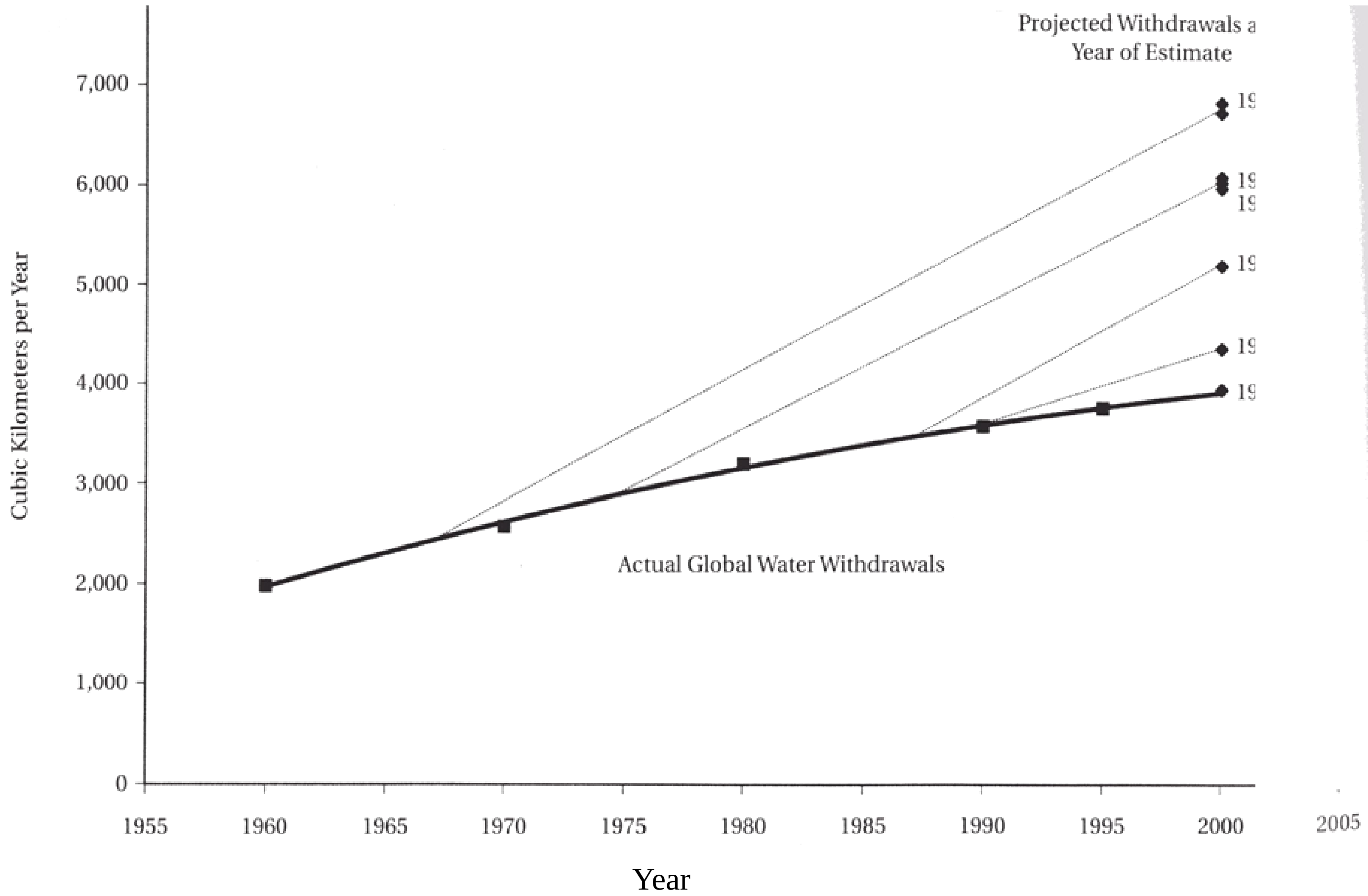


Source: Comprehensive Assessment, 2007

Problems with Forecasts: A Cautionary Tale

Over and Under predictions 1974 to 2000 as a Percentage of the year 2000 Population

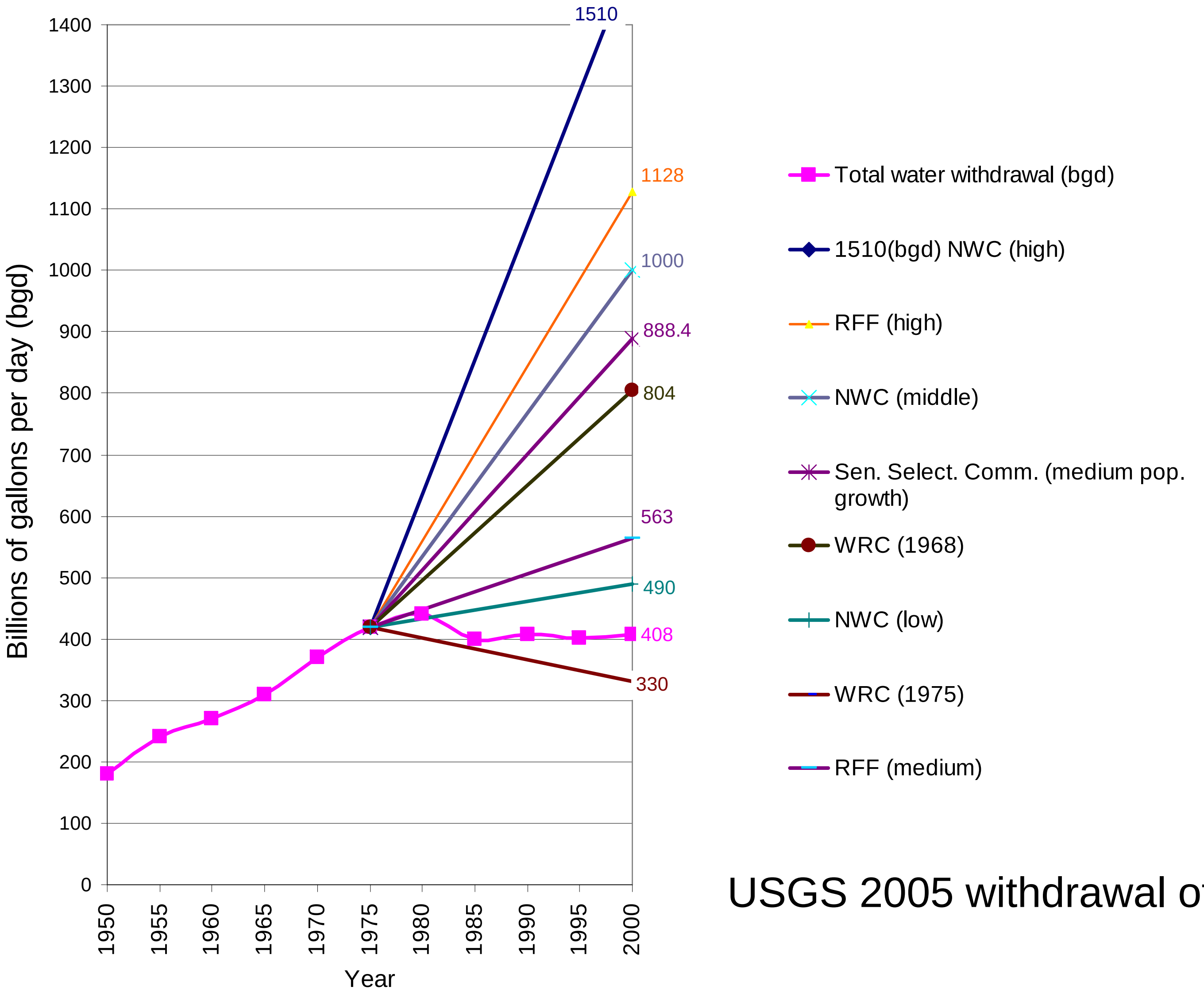
GLOBAL WATER WITHDRAWAL FORECASTS 1950-2000



Shown here are estimates of global water withdrawals from the year 2000. These eight estimates were made between 1967 and 1996. The earliest estimates predicted far greater water demands than have actually materialized.

Source. Gleick, (1998)

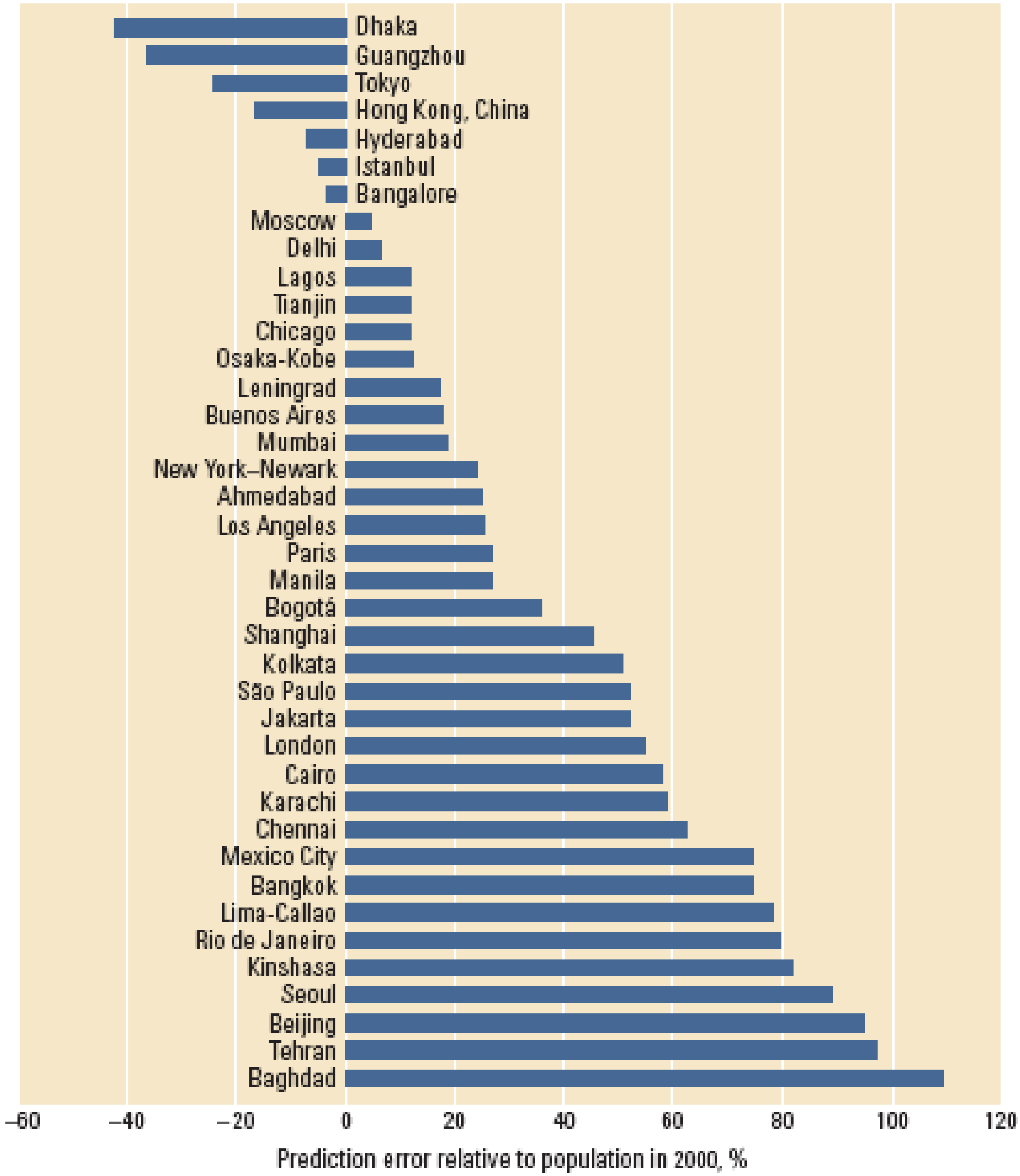
US WATER WITHDRAWAL FORECAST 1950–2000



USGS 2005 withdrawal of 410 bgd

Source. Rogers, 1993

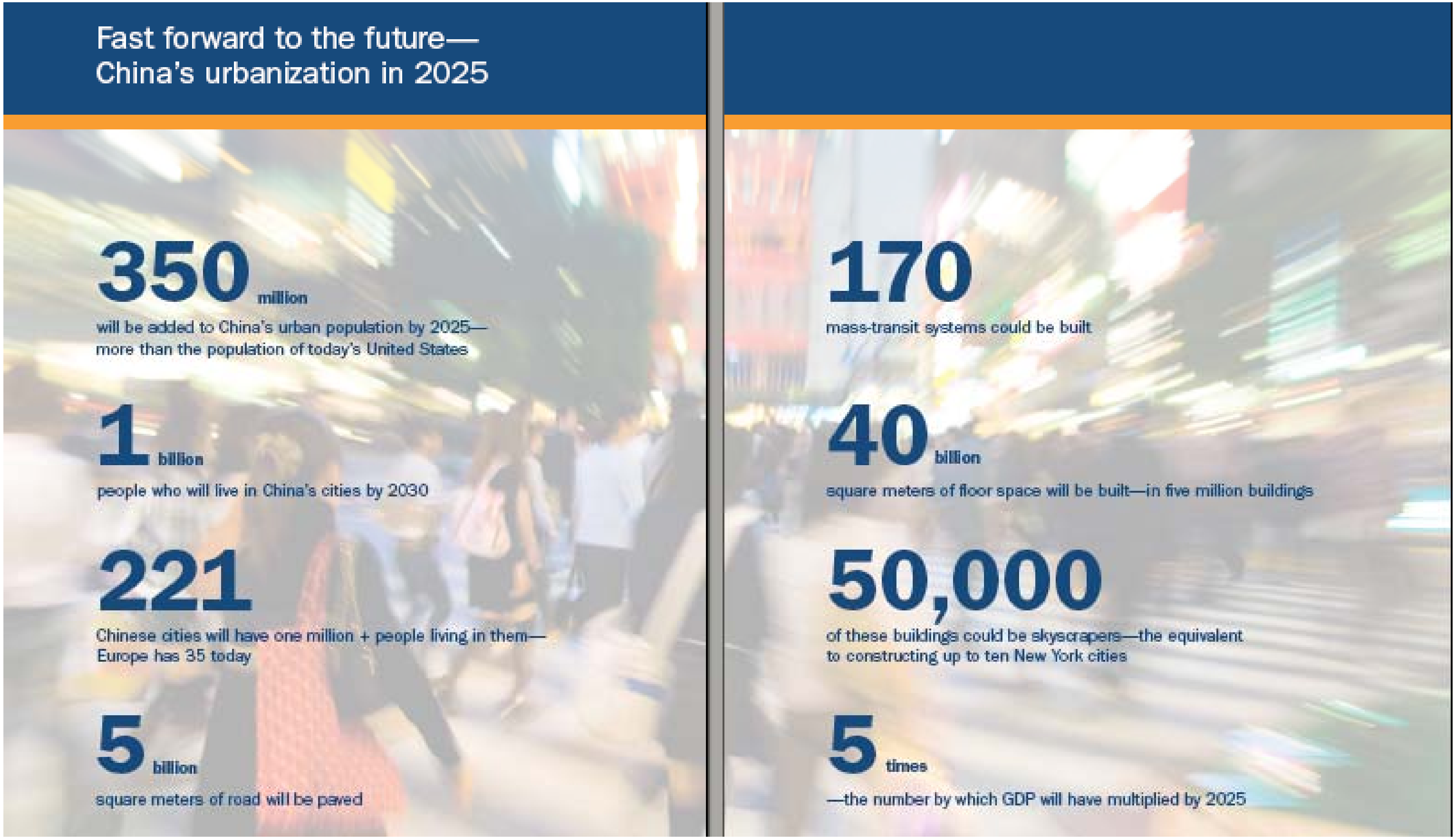
Figure 7.1 The growth of cities has been grossly overestimated



WDR 2009, p. 199

Source: Satterthwaite 2007.

Note: Comparison of predictions in 1974 with estimates of city populations in 2000. Bar indicates the extent to which the city population was overpredicted in 1974 relative to its size in 2000. A negative number indicates that a city size was greater in 2000 than predicted.

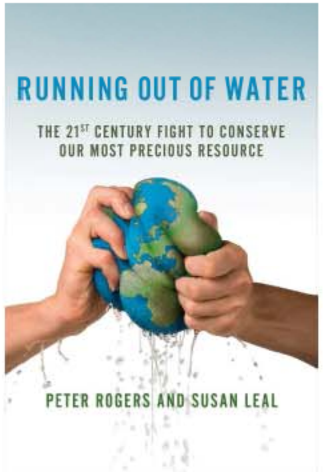


Some Predictions for Urbanization in China by 2025

Source. McKinsey, 2009

The Facts about Horse Manure in NYC

- **THE PROBLEM**
- 1860s most popular travel mode; horse drawn street cars.
- 35 million trips per year in 1860, by 1870 number had risen to over 100 million
- Standard horsecar; 20 passengers, 2 horses each working a 4 hour shift, 16 hours per day implies 8 horses per car
- There were also other major needs for horse-drawn freight transport
- By 1880 at least 150,000 horses living in NYC
- Each horse produced 22 lbs of manure each day for a total of 45,000 tons per month
- One prediction was that by 1930 horse manure would reach the level of Manhattan’s third floor windows



RUNNING OUT OF WATER

The Looming Crisis and Solutions to Conserve Our Most Precious Resource

Peter Rogers and Susan Leal

Foreword by Congressman Edward J. Markey

In this ground breaking and forward-looking book, Peter Rogers and Susan Leal give us a sobering perspective on the water crisis—why it's happening, where it's likely to strike, and what puts the worst strain on our supply. They introduce exciting new technologies that can help revolutionize our consumption of water and explain how different areas of the world have taken the helm in alleviating the burden of water shortages. Rogers and Leal also show how it takes individuals at all levels to make this happen, from grassroots organizations who monitor their community's water sources, to local officials who plan years in advance how they will appropriate water, to the national government who can invest in infrastructure for water conservation today. Informed and inspiring, this is a clarion call for action and an innovative look at how we can confront the crisis.

"A call to action as well as a celebration of the progress already under way. *Running Out of Water* offers hope and guidance for getting that crucial job done."**—from the foreword by Congressman Edward J. Markey**

"An admirably clear exposition of the lamentable state of the planet's water. I particularly liked Rogers and Leal's selection of eminently sensible, easily replicable, scalable solutions, and their sense that yes, the water world can be fixed."**—Marq de Villiers, author of Water: The Fate of Our Most Precious Resource**

Running Out of Water: Themes

- Facing a crisis in water due to population, wealth, and changing climate
- Too much Gloom and Doom
- The technologies are already available to improve the efficient use of existing water supplies by:
  - Improved irrigation efficiency
  - Trade of virtual water
  - Moving from conventional wastewater
  - Reuse of water in industry, agriculture, and domestic uses
  - Socially enforced changes in demand

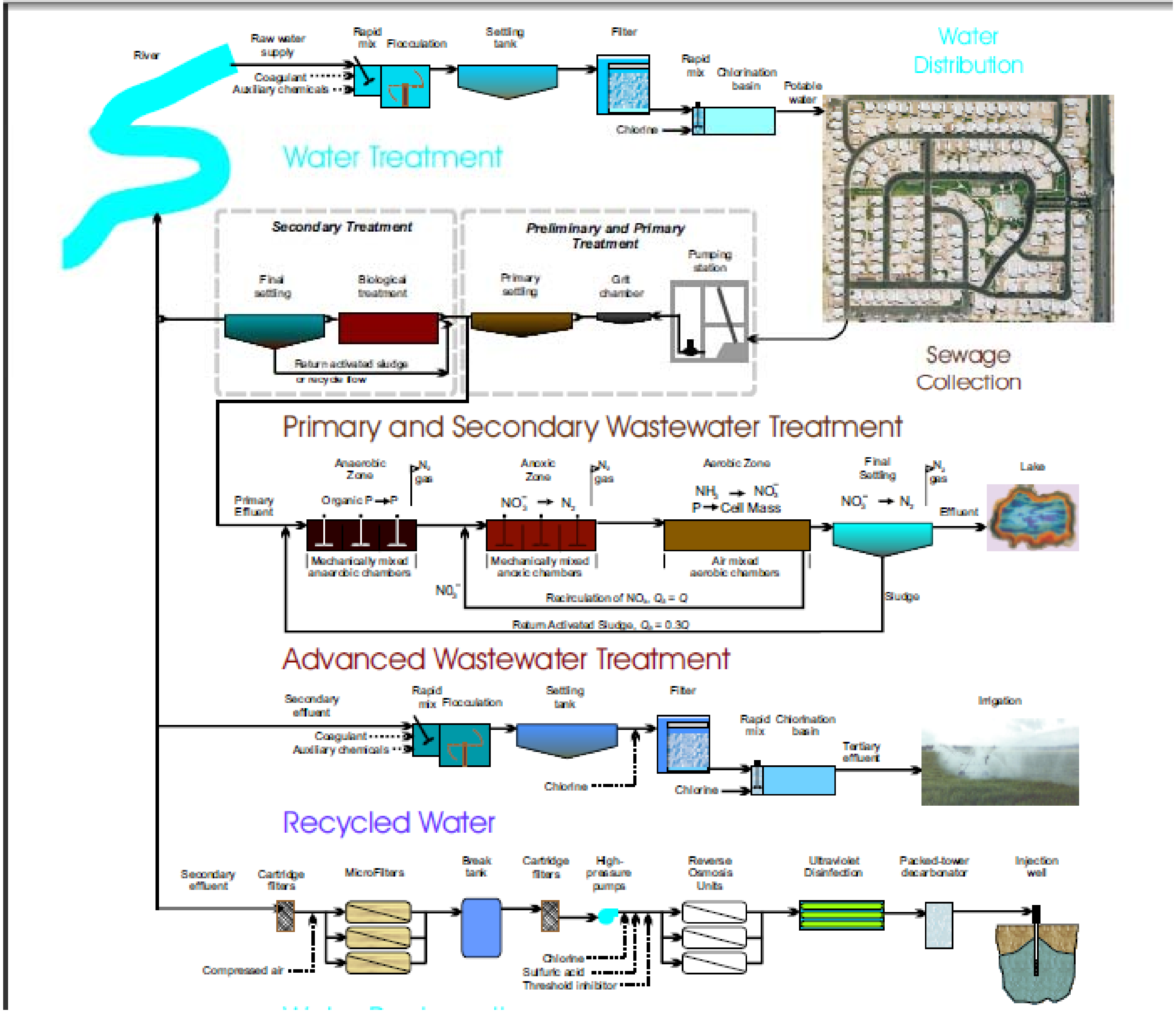
- Missing ingredient is “leadership”

Running Out of Water: Cases

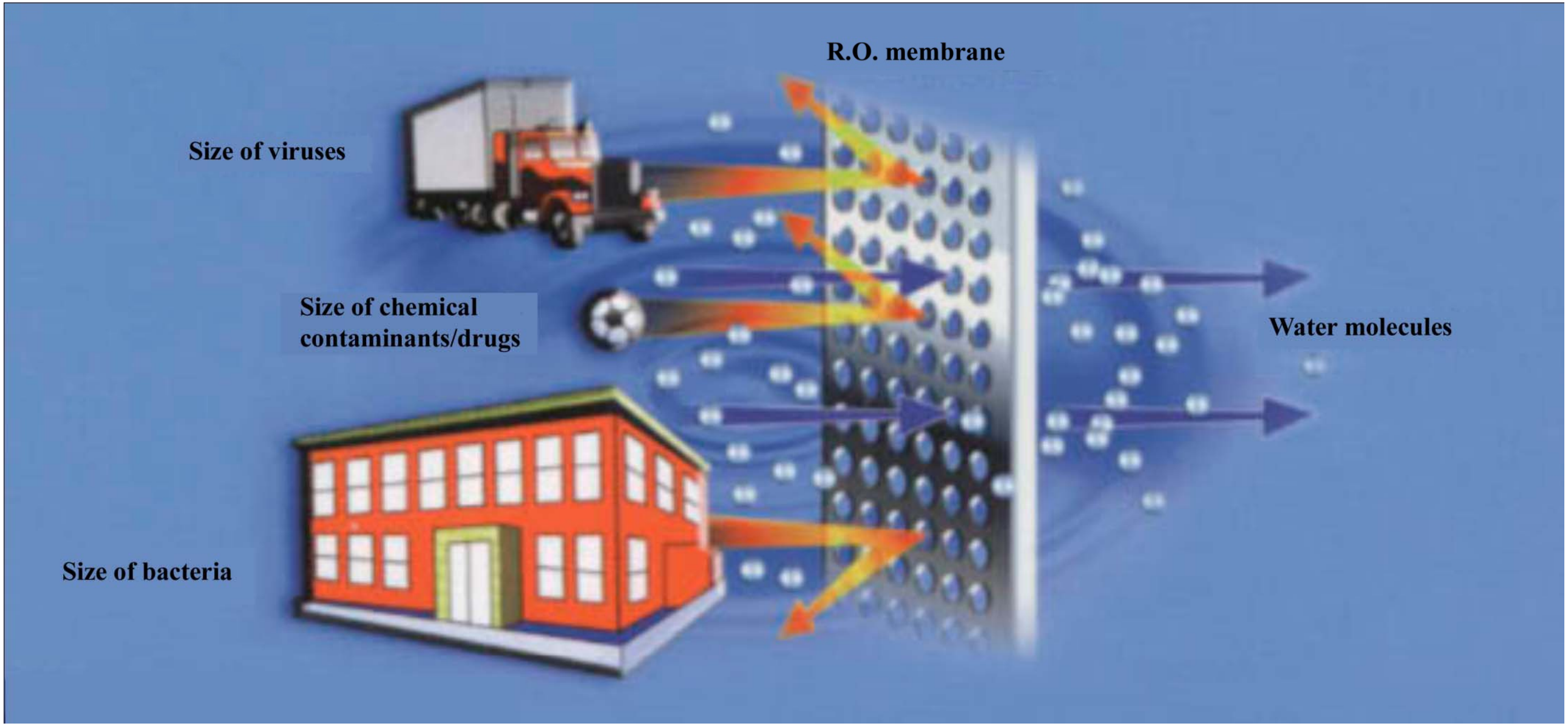
- Recycling wastewater; Orange County, Ca., Singapore, and St Petersburg, Fla
- Improving Agricultural use; Rising City, Nebraska, Imperial Valley, California, and Murray-Darling, Australia
- Public involvement in urban water issues; San Francisco, Ca., innovative urban water supply and sewers in Brazil
- Valuing water the role of economic thinking in managing water resources; the case of Boston Harbor
- Urban wastewater as a resource; San Francisco FOG, East Bay MUD and blood as a resource, Santa Rosa and the Geysers.
- Transboundary conflicts; the Indus as a success story, other major international basins in play, Nile, Ganges, Mekong.
- Bottled water working against improving maintenance and expansion of public systems

Toilet-to-Tap: Recycling Urban Wastewater

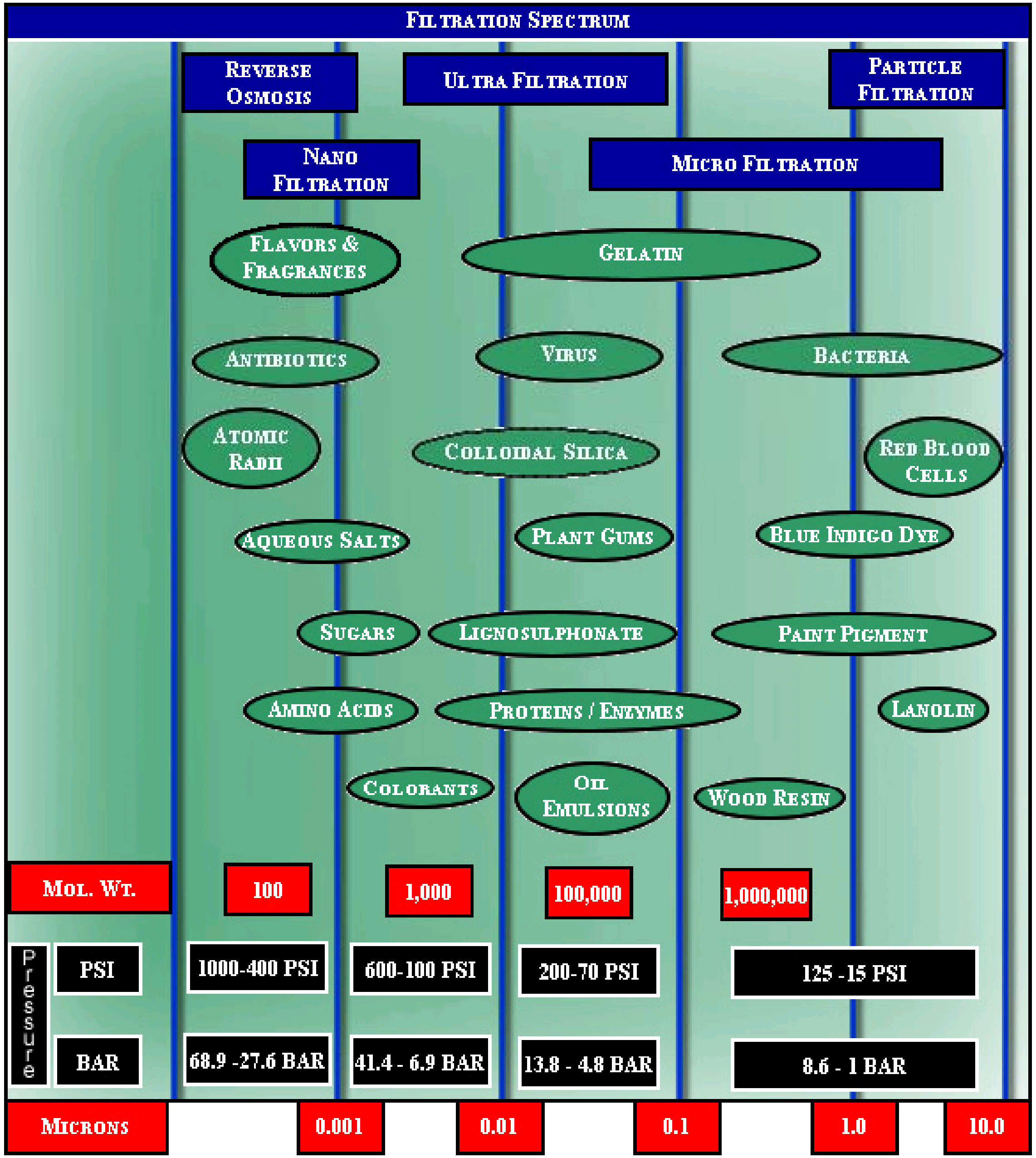
- Singapore NEWater. Classic political security
- Orange County, California (unfortunately provides water for another 500,000 people in the LA area!) Classic economic security
- Many other US urban areas following suit
- Option being taken-up because of competition for additional supplies and increased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


River
Raw water supply
Rapid mix
Flocculation
Settling tank
Filter
Coagulant
Auxiliary chemicals
Rapid mix
Chlorination basin
Potable water
Chlorine
Water Distribution
Water Treatment
Secondary Treatment
Preliminary and Primary Treatment
Final settling
Biological treatment
Primary settling
Grit chamber
Pumping station
Return activated sludge or recycle flow
Sewage Collection
Primary and Secondary Wastewater Treatment
Anaerobic Zone
Anoxic Zone
Aerobic Zone
Final Settling
Lake
Primary Effluent
Organic P → P
NO_3^- → N_2
NH_3 → NO_3^-
P → Cell Mass
N_2 gas
Effluent
Mechanically mixed anaerobic chambers
Mechanically mixed anoxic chambers
Air mixed aerobic chambers
Sludge
Recirculation of NO_3, Q_r = Q
Return Activated Sludge, Q_r = 0.3Q
Advanced Wastewater Treatment
Secondary effluent
Rapid mix
Flocculation
Settling tank
Filter
Coagulant
Auxiliary chemicals
Chlorine
Rapid mix
Chlorination basin
Tertiary effluent
Irrigation
Recycled Water
Secondary effluent
Cartridge filters
MicroFilters
Break tank
Cartridge filters
High-pressure pumps
Reverse Osmosis Units
Ultraviolet Disinfection
Packed-tower decarbonator
Injection well
Compressed air
Chlorine
Sulfuric acid
Threshold inhibitor

Reverse Osmosis in layman's terms



Source. PUB, Singapore.



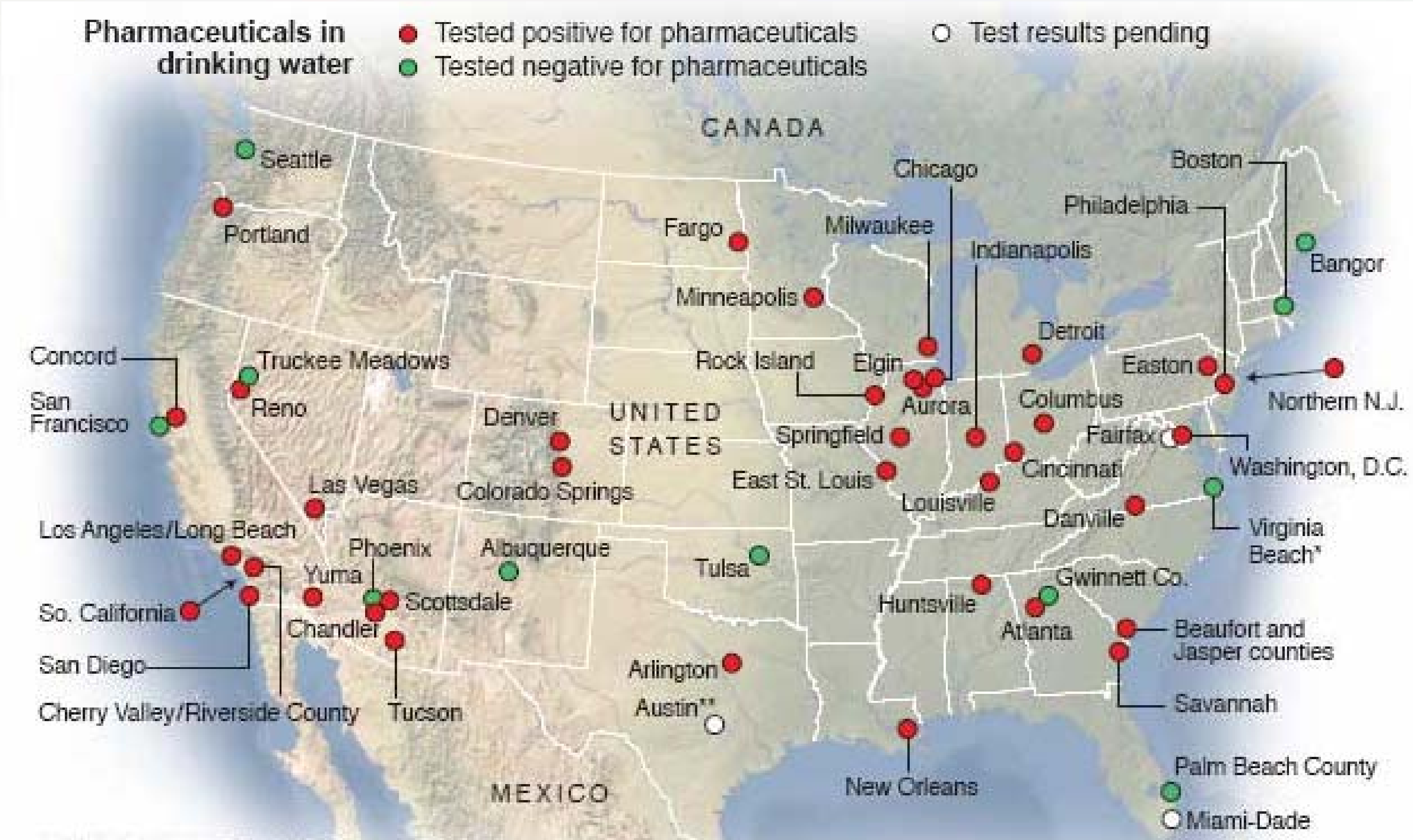
Filtration Spectrum
Reverse Osmosis
Ultra Filtration
Particle Filtration
Nano Filtration
Micro Filtration
Flavors & Fragrances
Gelatin
Antibiotics
Virus
Bacteria
Atomic Radii
Colloidal Silica
Red Blood Cells
Aqueous Salts
Plant Gums
Blue Indigo Dye
Sugars
Lignosulphonate
Paint Pigment
Amino Acids
Proteins / Enzymes
Lanolin
Colorants
Oil Emulsions
Wood Resin
Mol. Wt.
100
1,000
100,000
1,000,000
Pressure
PSI
1000-400 PSI
600-100 PSI
200-70 PSI
125 - 15 PSI
BAR
68.9 - 27.6 BAR
41.4 - 6.9 BAR
13.8 - 4.8 BAR
8.6 - 1 BAR
Microns
0.001
0.01
0.1
1.0
10.0

Recycling wastewater; Orange County, Ca.

- Increasing Demands
  - Population growth, wealth, life-style
- Decreasing Supply
  - Federal Endangered Species Act, restricted pumping out of San Jaoqin Delta
  - Reduced snow melt from N. California
- Increasing Regulation
  - Due to complaints about offshore pollution from long ocean outfall
  - EPA pushing for higher levels of treatment
- The Eureka Moment
  - Move to upgrade treatment—add on—to RO and UV disinfection
  - Produces an additional 70 mgd of potable water at lower cost than importing it from the North
  - Protects endangered species and off-shore water quality
- But there is more…
  - 46 million people in the US are exposed to unregulated chemicals
  - EPA has now promulgated for discussion its Candidate Contaminant List Number 3 (CCL3), proposing to add 116 new contaminants to its existing list of 86—includes pharmaceuticals and endocrine disruptors
  - Possibly the only way to effectively remove these from wastewater streams is by RO
  - Hence, Orange County will be ahead of the regs. others will have to use RO

46 million in U.S. have drugs in drinking water

Testing shows traces of meds in water greater than previously reported



* In Virginia Beach, pharmaceuticals were found in source water but not in treated drinking water.
** Drinking water in Austin, Texas, was tested for only one prescription drug, a synthetic birth control chemical.

NOTE: All places include some surrounding areas except: Albuquerque, N.M.; Arlington, Texas; Long Beach, Calif.; Los Angeles; New Orleans.

SOURCES: Drinking water providers' responses to Associated Press questions; AP review of scientific literature. AP

Contaminant Candidate List 3 (CCL 3) EPA site

CCL 3 is a list of contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations, that are known or anticipated to occur in public water systems, and which may require regulation under the Safe Drinking Water Act (SDWA). The list includes, among others, pesticides, disinfection byproducts, chemicals used in commerce, waterborne pathogens, pharmaceuticals, and biological toxins. The Agency considered the best available data and information on health effects and occurrence to evaluate thousands of unregulated contaminants. EPA used a multi-step process to select 116 candidates for the final CCL 3. The final CCL 3 includes 104 chemicals or chemical groups and 12 microbiological contaminants.

Is Desalination Economical?

Field research on the crystalline properties of desalinated water

Dubai, UEA, July 8, 2008.

Even the Economics Look Good: Orange County Groundwater Replenishment System

- Average cost $561 per acre-ft for 55,000 acre-ft per year production, or 45 cents/cubic meter
- Removing all subsidies, $681 per acre-ft, or 51 cents/cubic meter
- Globally many other cities including Singapore and Scottsdale, Arizona, now use similar systems
- Sommariva (2010) reports typical commercial tariffs for sea water reverse osmosis (SWRO) of between 55 and 75 cents/cubic meter

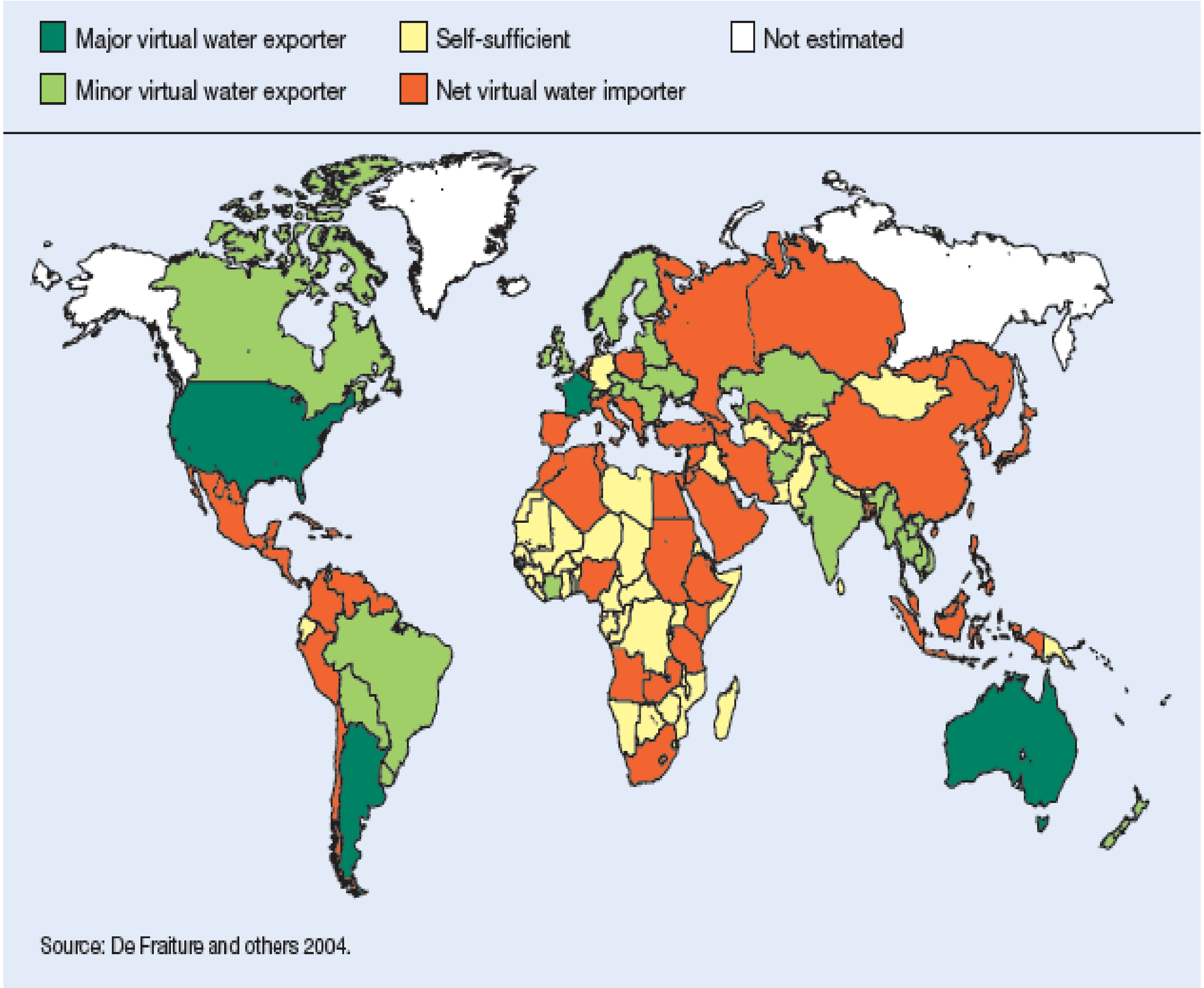
Agriculture is the Big User

Improving Agricultural use; Rising City, Nebraska

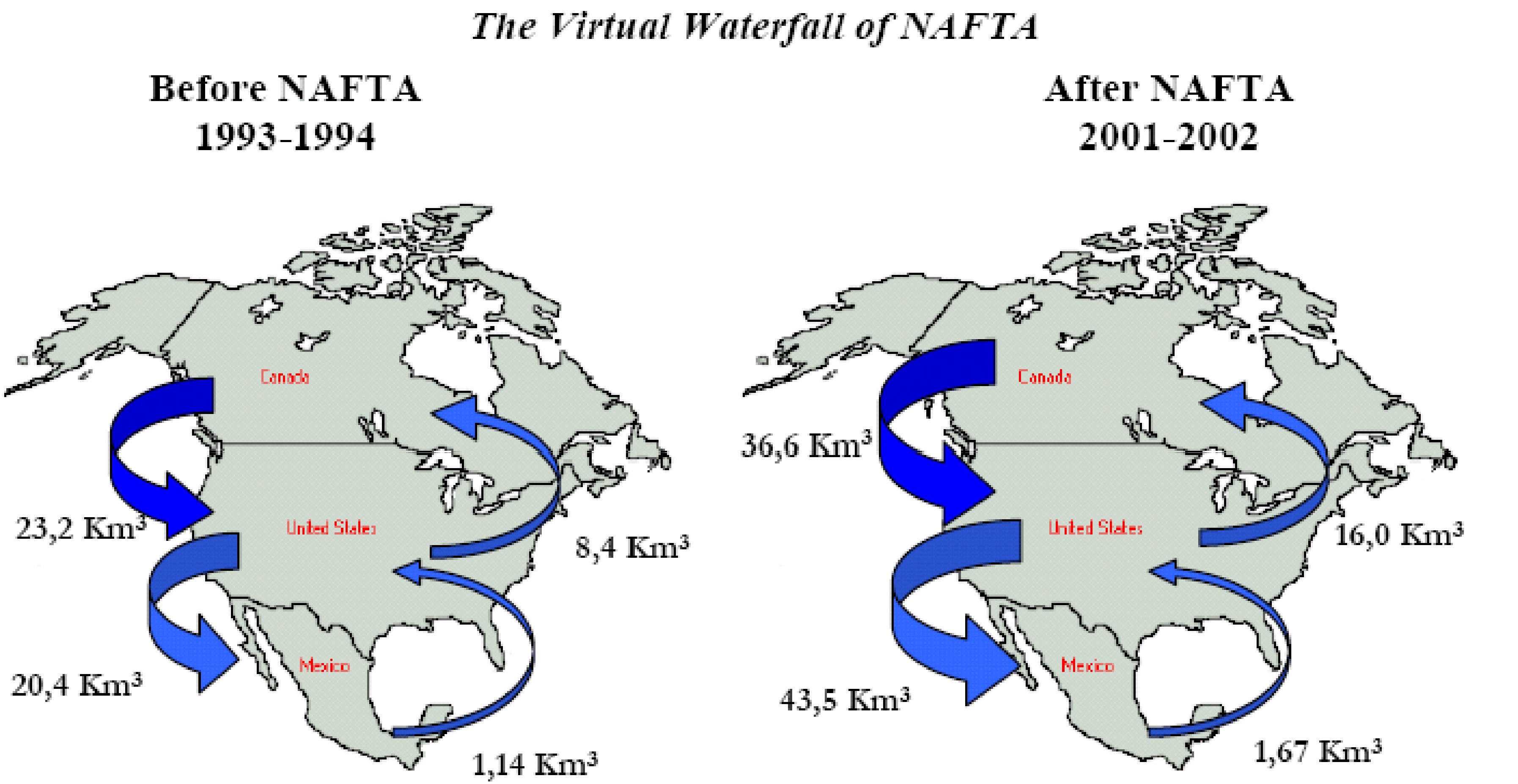
- Farmer Glock
  - 77-year old farmer and his wife farm 700 plus acres of irrigated crops
  - Moved up technology ladder from furrow, to spray, to center pivots
- Center Pivots
  - Typically irrigate quarter section (180 acres)
  - Capital costs less than US$100,000
  - Allow for multiple cropping in same field
  - Avoids costly land levelling
  - Applies fertilizer and other chemicals without clogging
  - Can be completely controlled with a lap-top computer
- Actual Performance
  - two thirds reduction in water use and a doubling of crop yield
- Global implications
  - Good example of existing technology with widespread application
  - Just one example of many water saving technologies

Center pivot in Kenya with different crops. (Naivasha)

VIRTUAL WATER



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

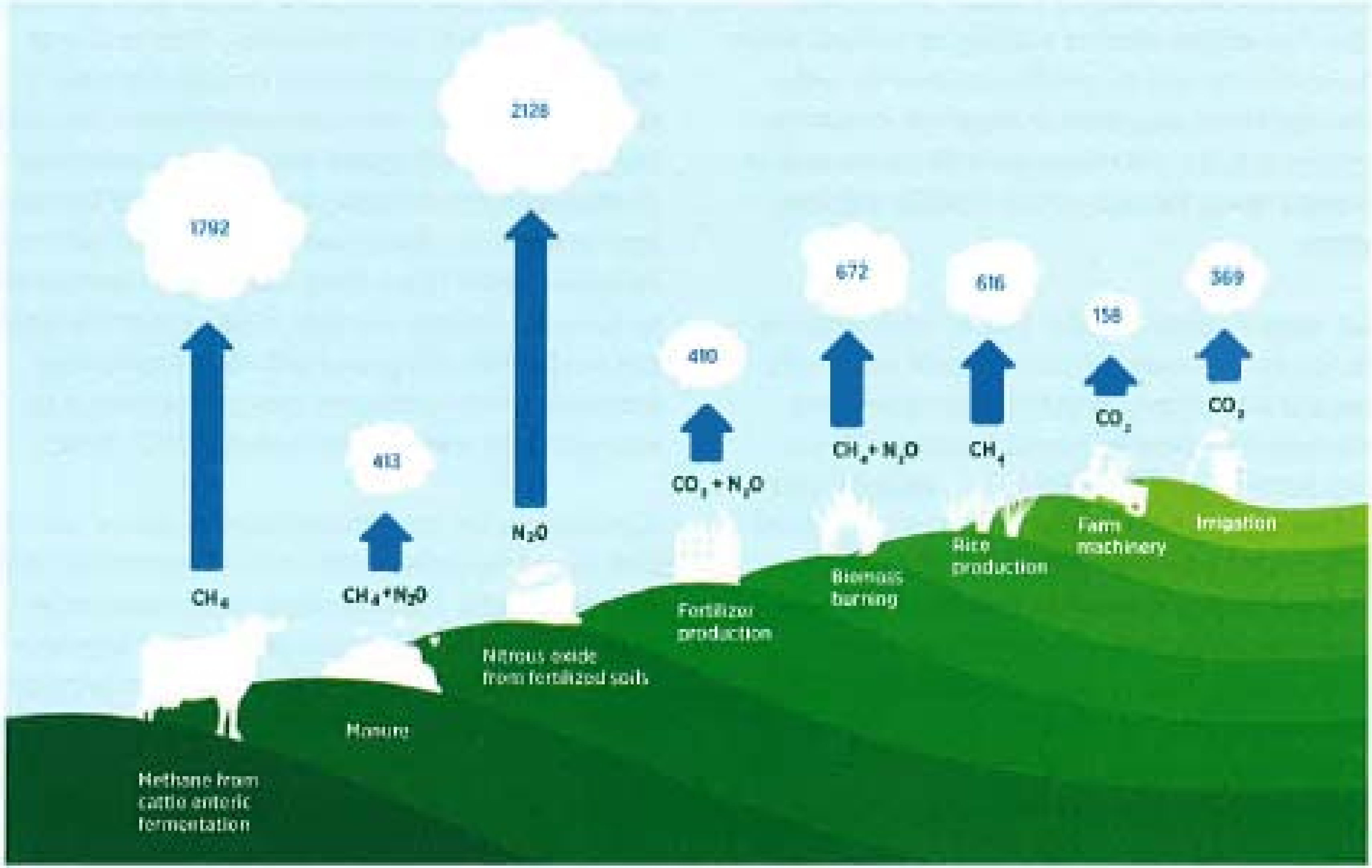


Source: J. Ramirez-Vallejo and P. Rogers, 2006.

Agriculture and Climate Feedbacks

FIGURE 18.5

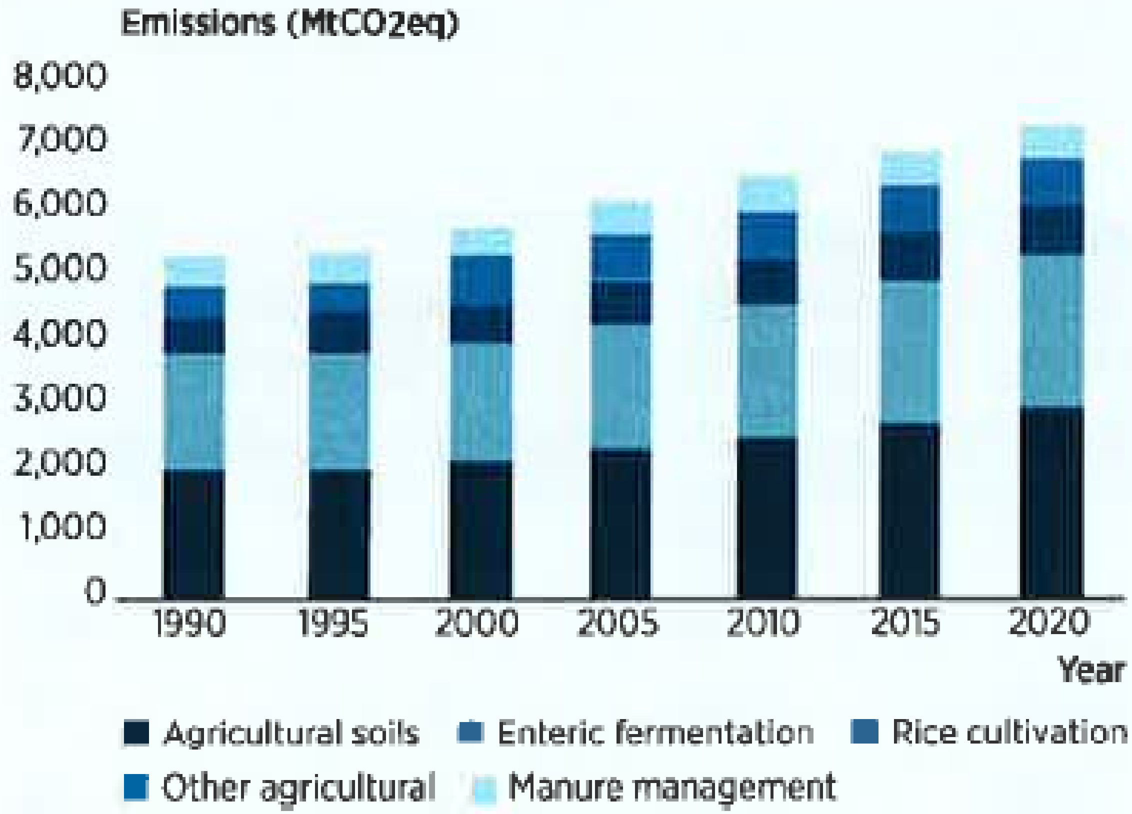
Sources of agricultural greenhouse gases excluding land use change



Source: Bellarby *et al.* (2008 fig. 2, p. 7).

FIGURE 18.6

Total greenhouse gas emissions from the agricultural sector by source



Source: US-EPA (2006).

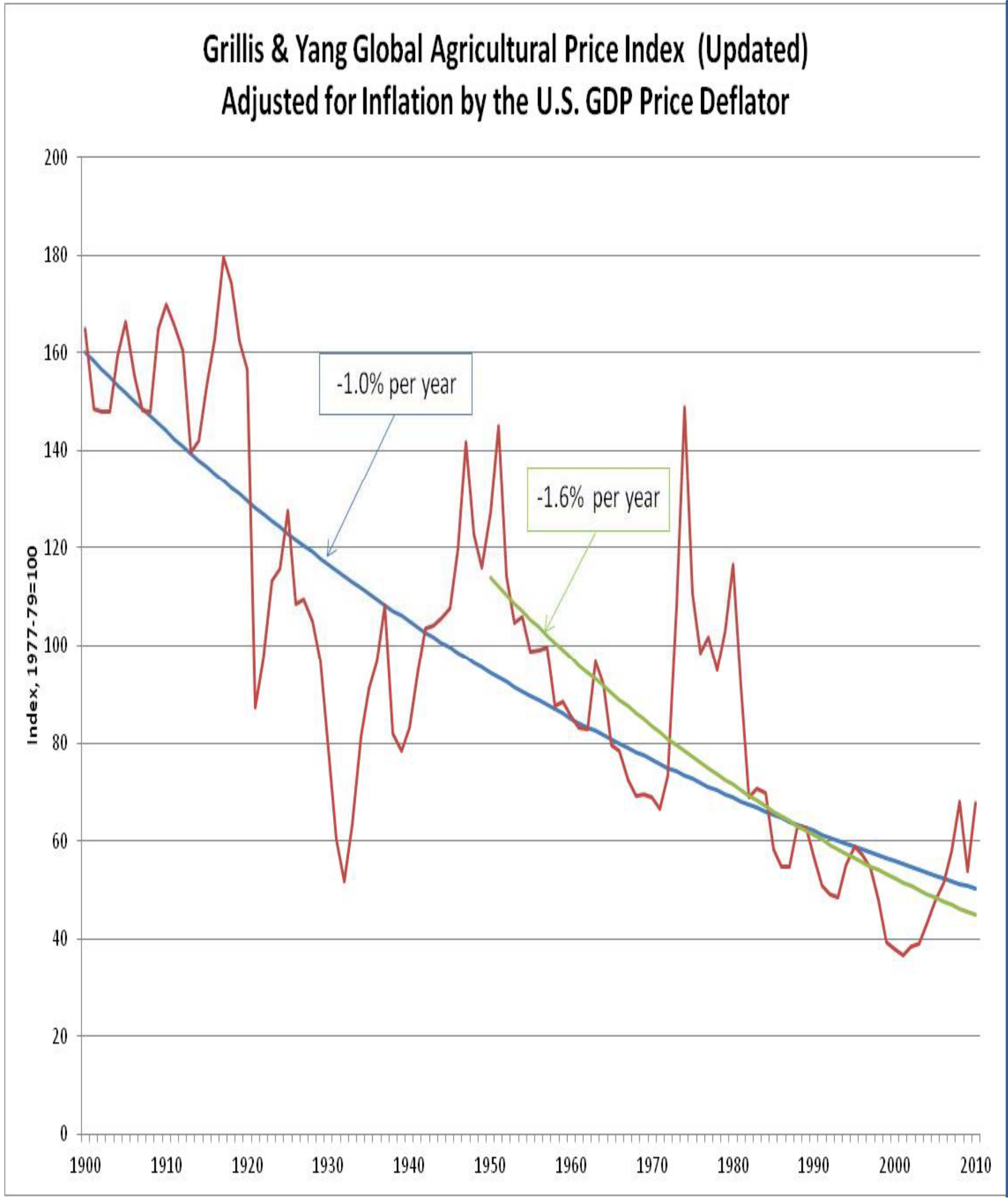
Water, Energy, and Food Security

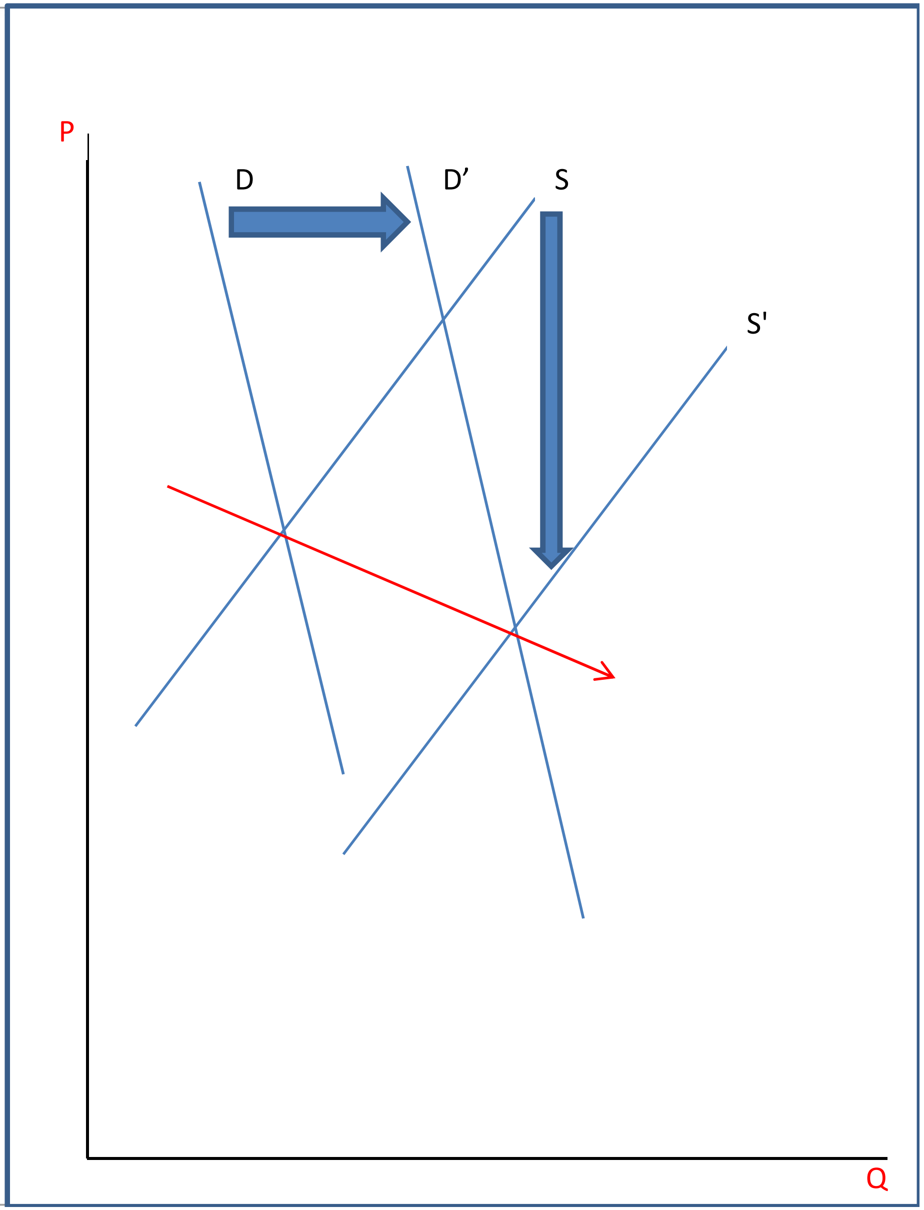
SOME FACTOIDS

Table 1. Status of selected global parameters.

People in the world (2011)[10]	**7 billion**
Undernourished people (2010)[11]	**0.9 billion**
Overweight people over age 20 (2008)[12]	**1.5 billion**
People living on less than USD 1.25 per day (2005)[13]	**1.4 billion**
People living in dryland areas (2007)[14]	**2 billion**
People dependent on degrading land[15]	**1.5 billion**
Losses due to climatological events (extreme temperature, drought, forest fire) (2010)[16]	**USD 7.5 billion**
Area of agricultural land (2009)[17]	**4.9 billion hectares**
Area of croplands, pasture and grazing lands devoted to raising animals[18]	**3.7 billion hectares**
Annual growth in world agricultural production (1997-2007)[19]	**2.2%**
Food produced for human consumption lost or wasted annually[20]	**1.3 billion tonnes**

The 20th Century decline in food prices





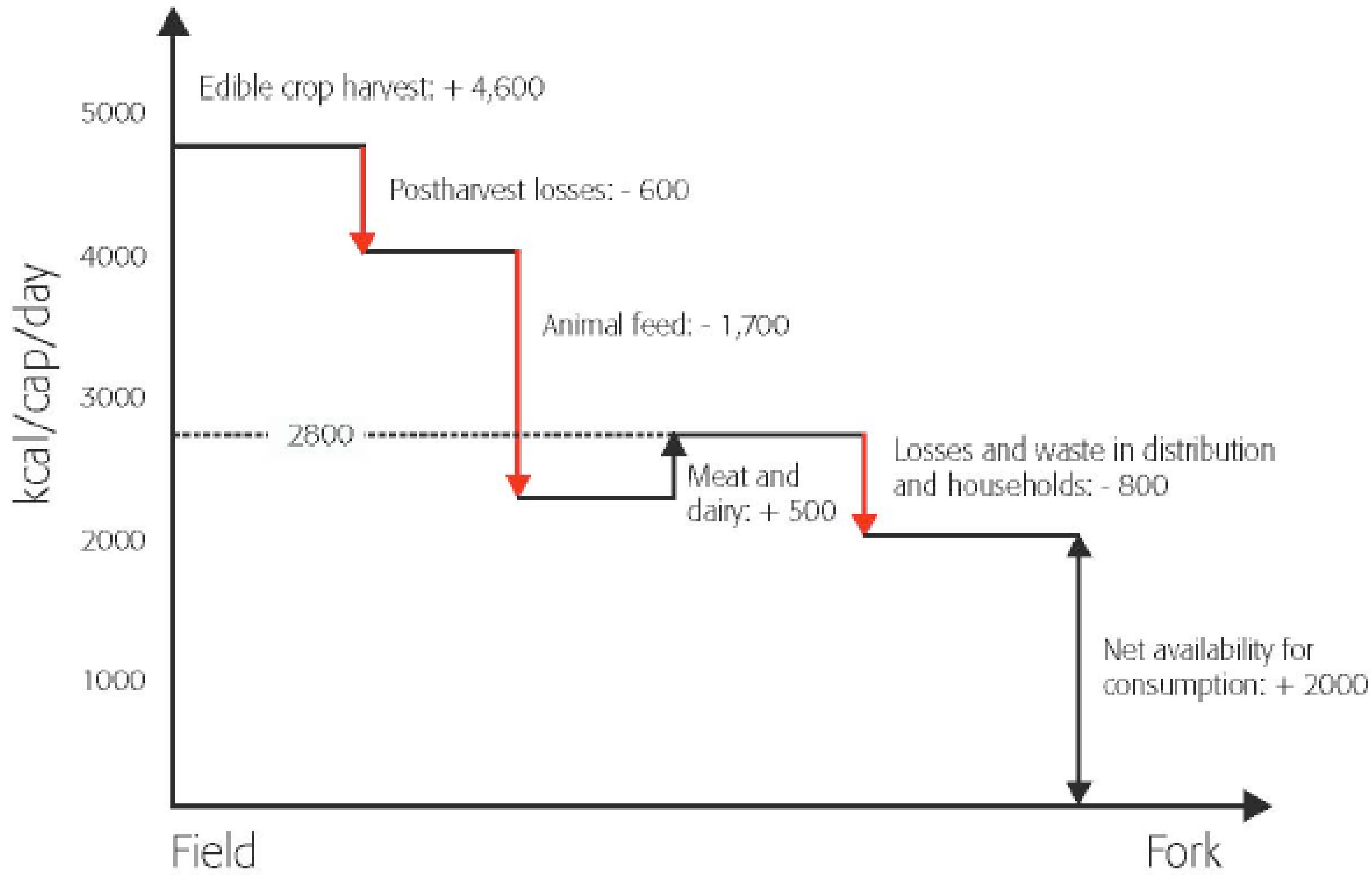
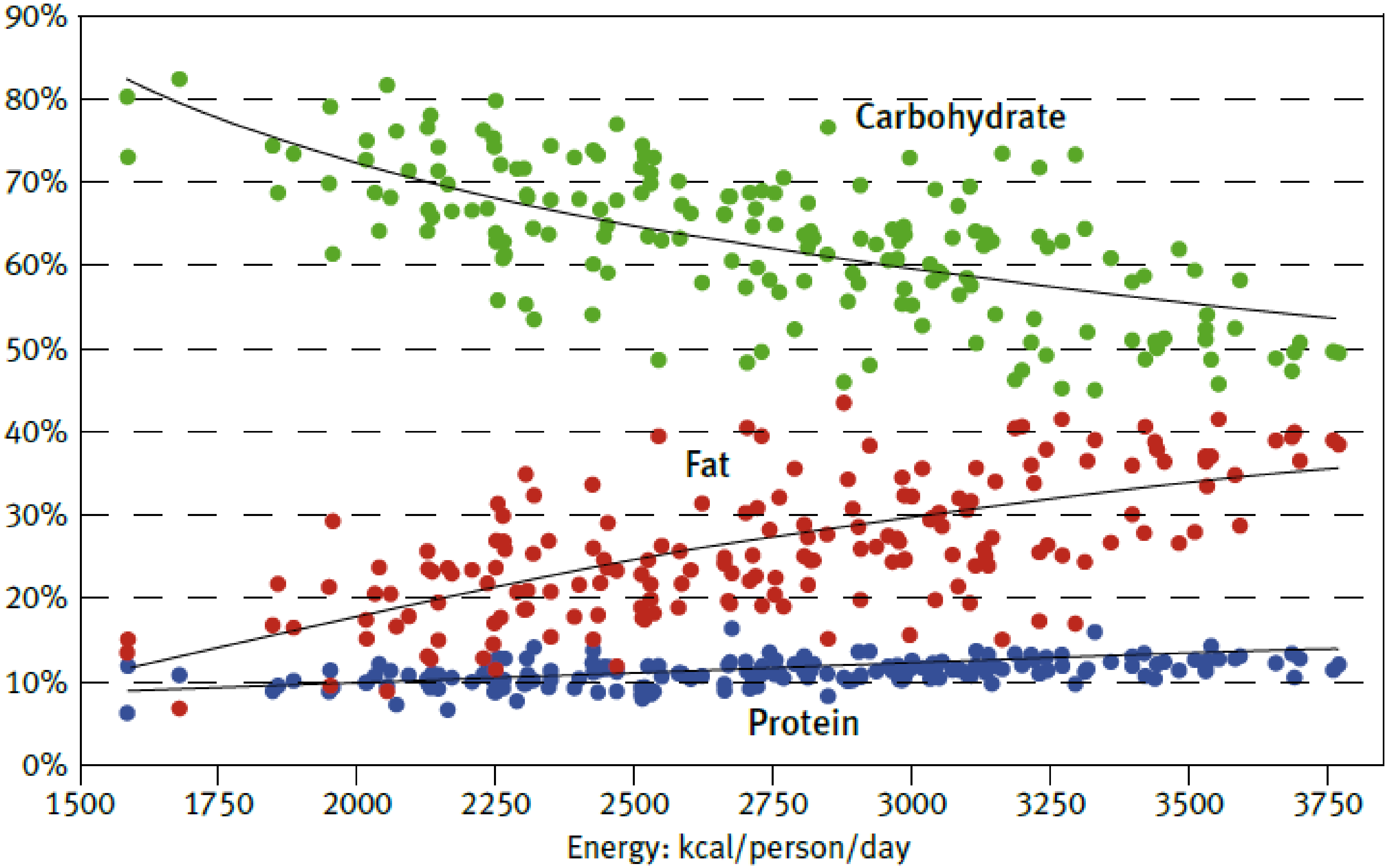


Figure 5

From field to fork: estimation of food losses, conversion and wastage in the world food chain.

Source: Lundqvist et al. (2008) from Smil (2000)

Guyomard et al., p. 8, 2011



Sus Ag and Climate, p. 9

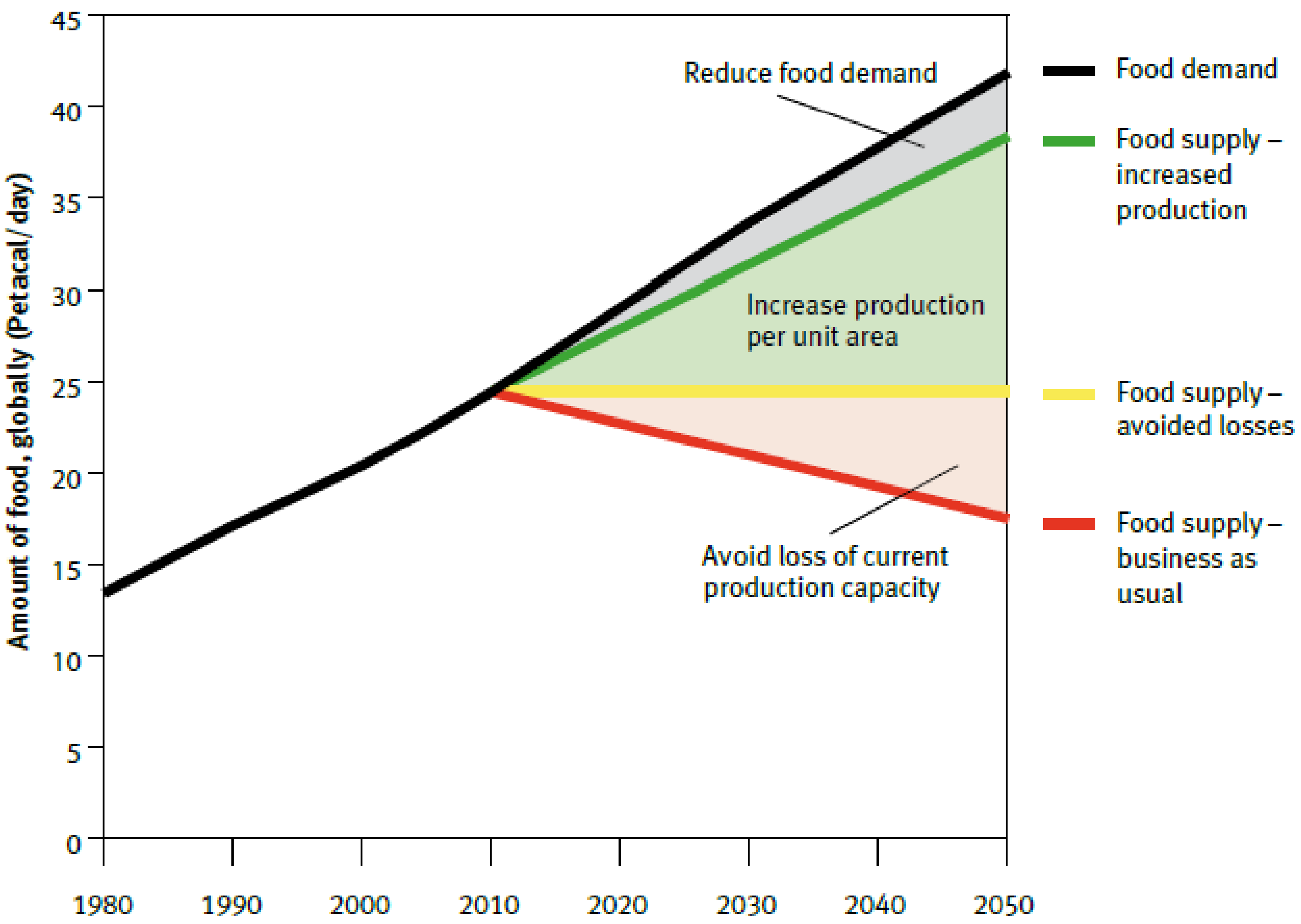
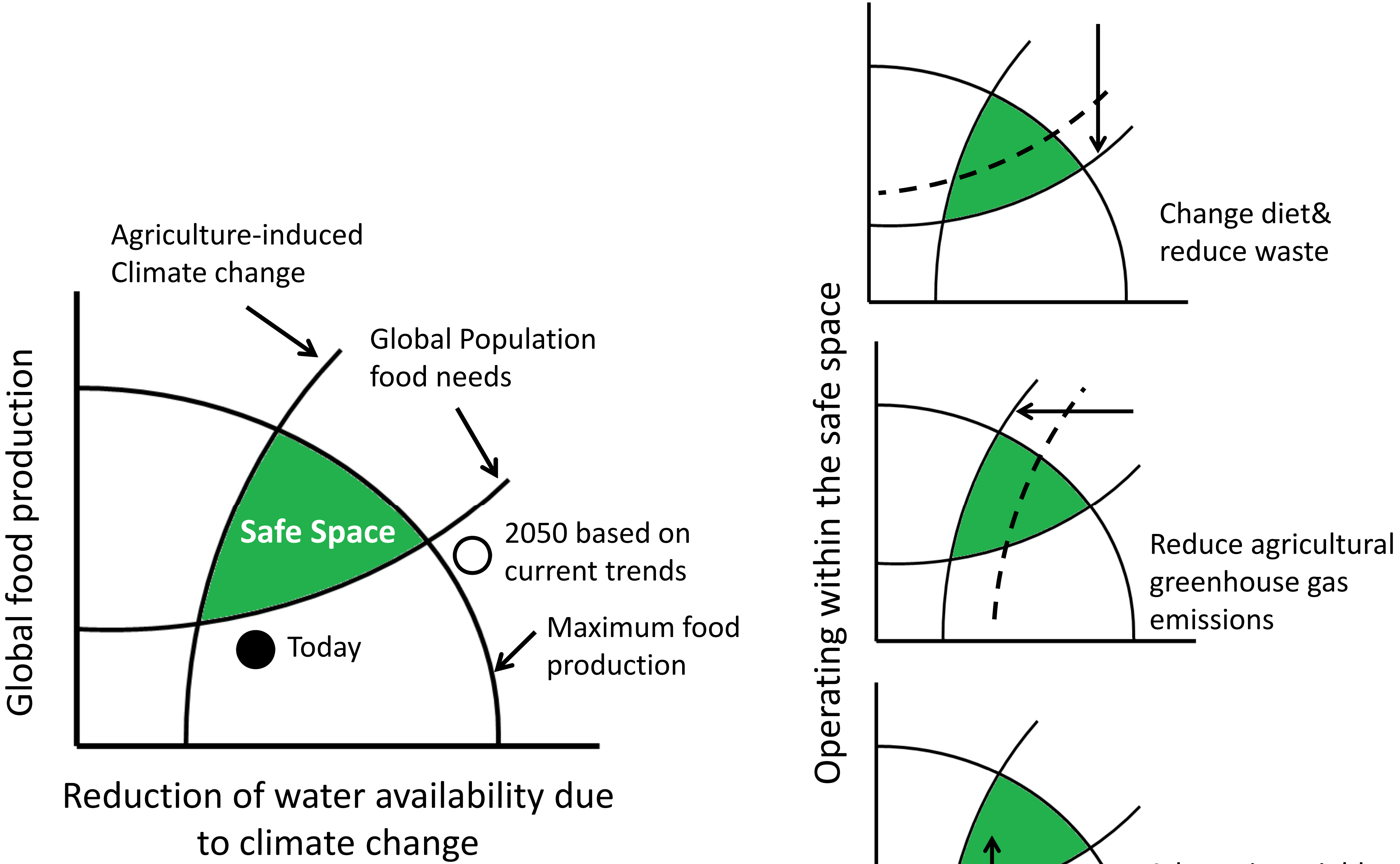


Figure 10. Balancing food supply and demand. Globally, food demand will grow in the future due to population growth and changing

Sus Ag Climate, p. 19



Based on Commission on Sustainable Agriculture and Climate Change, p. 7, 2012.

Valuing water and the role of economic thinking in managing urban water resources

Valuing water and the role of economic thinking in managing water resources: Boston Harbor

- 2.1 million in MWRA service area
- 1973 demand reached 300 mgd and exceeded the safe-yield of the system
- In 1986 $3.8 billion WWTP completed and an average water and sewer bill was $116/hh/yr
- By 2008 the bill had risen to $1,132 /hh/year and system demand had declined to 200 mgd
- Pricing works!

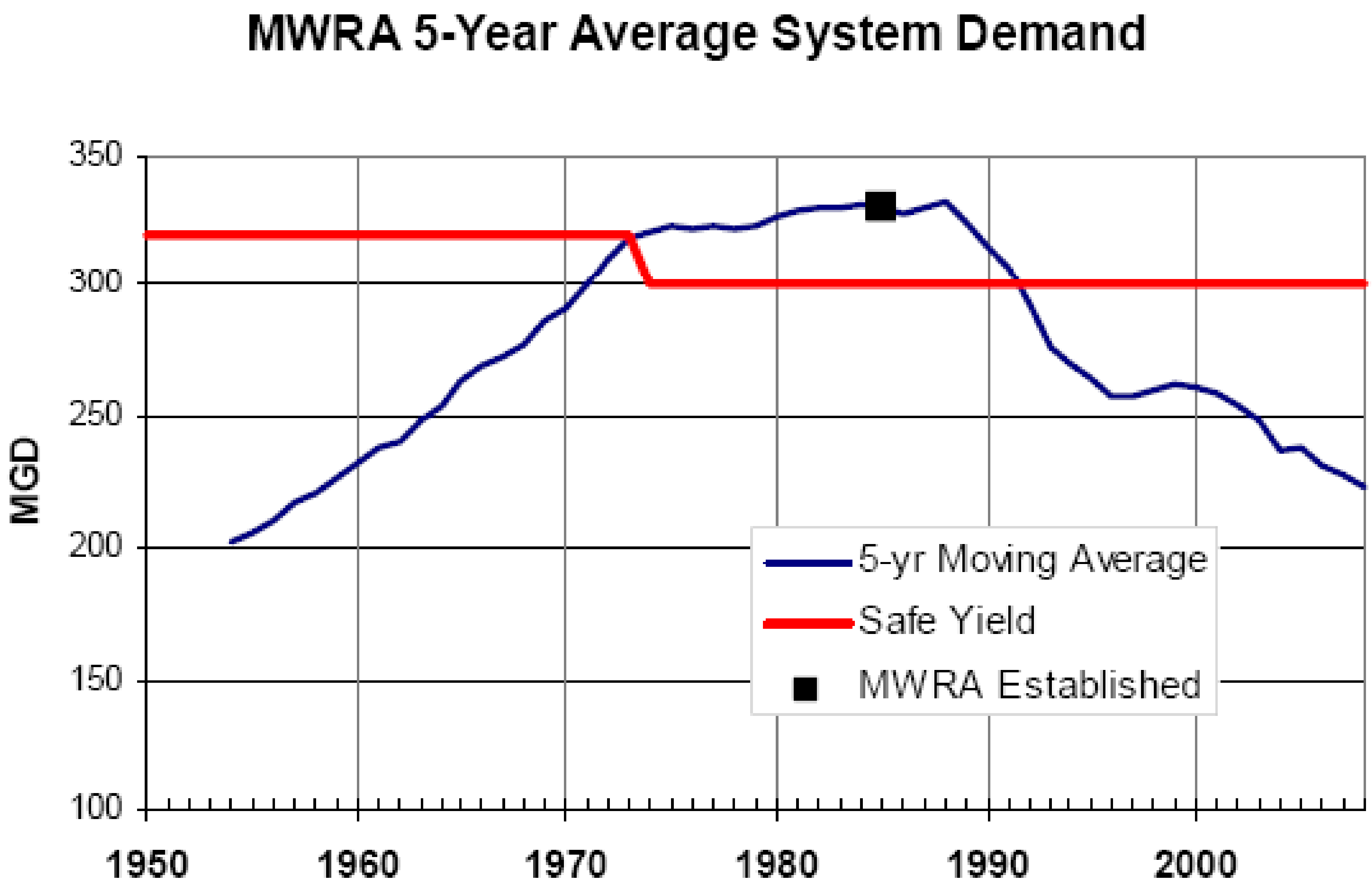
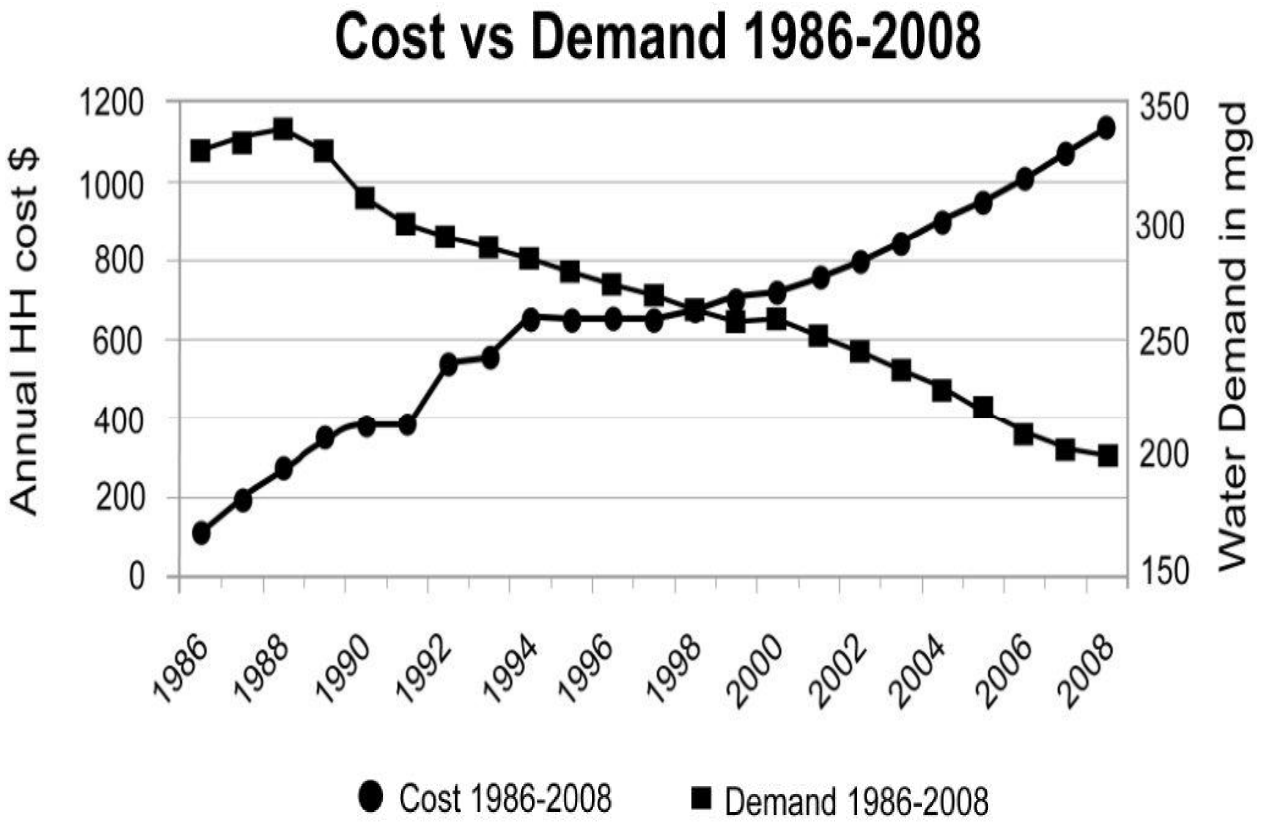


Figure 1 – MWRA Reservoir Withdrawals


Cost vs Demand 1986-2008
Annual HH cost $
Water Demand in mgd
1200
1000
800
600
400
200
0
350
300
250
200
150
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Cost 1986-2008
Demand 1986-2008

Matching Supply with Demand

Not a theoretically sound approach as value of the water increases with scarcity

McKINSEY STUDIES (2009)

China and India dominate all discussions on resource use in the 21st century (all those $20 bills lying on the ground)

Opportunity of India's urbanization to 2030

5 times – the number by which GDP will have multiplied by 2030

590 million people will live in cities, nearly twice the population of the United States today

270 million people net increase in working-age population

70 percent of net new employment will be generated in cities

91 million urban households will be middle class, up from 22 million today

68 cities will have population of 1 million plus, up from 42 today; Europe has 35 today

$1.2 trillion capital investment is necessary to meet projected demand in India's cities

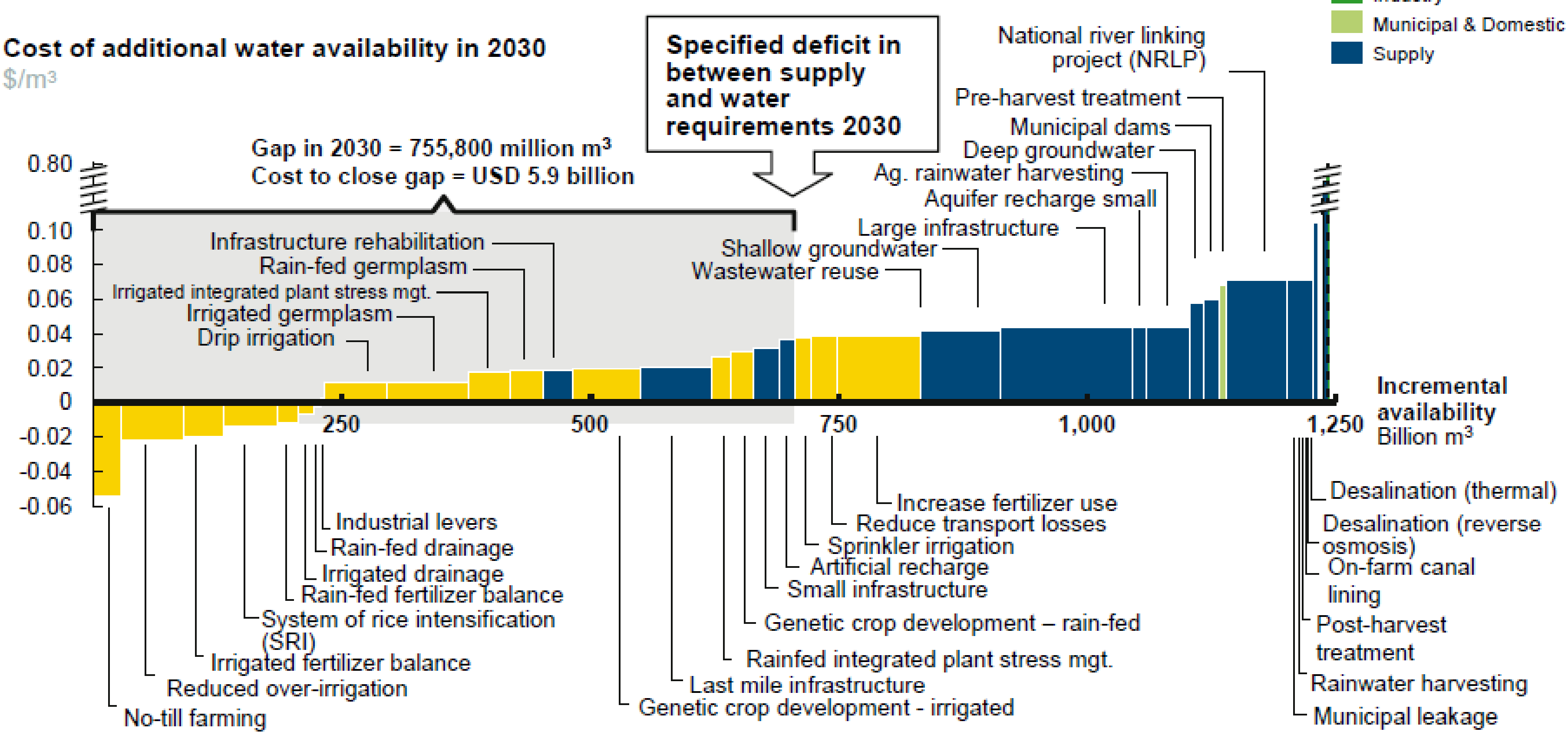
700–900 million square meters of commercial and residential space needs to be built—or a new Chicago every year

2.5 billion square meters of roads will have to be paved, 20 times the capacity added in the past decade

7,400 kilometers of metros and subways will need to be constructed – 20 times the capacity added in the past decade

Exhibit V

India – Water availability cost curve



SOURCE: 2030 Water Resources Group

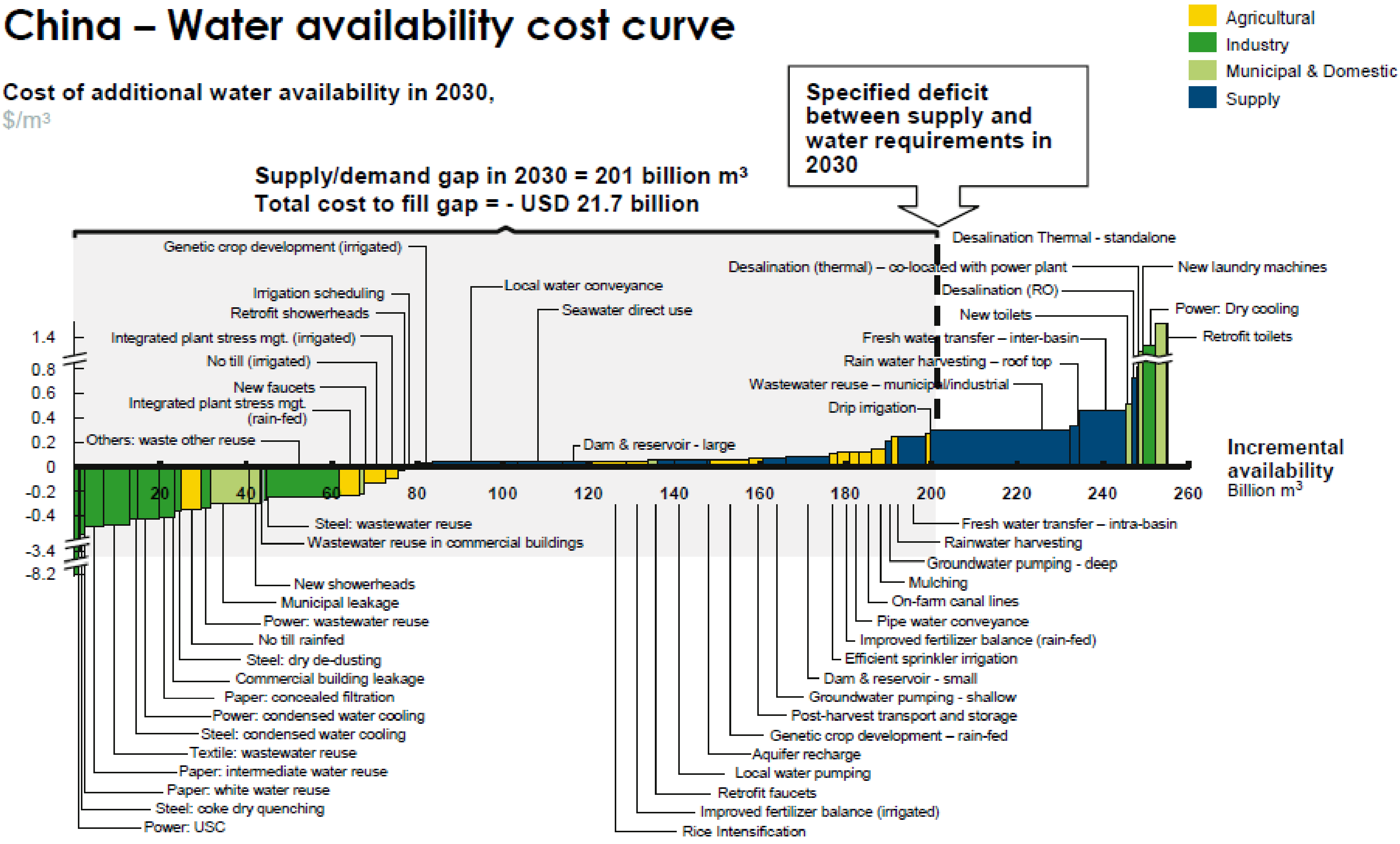
China’s Urban Growth until 2025

- 350 million people added to urban population
- One billion urban dwellers
- 221 cities with more than one million people
- Five billion square meters of road paved
- Forty billion square meters of floor space built
- 50,000 skyscrapers; equivalent 10 New Yorks
- 170 mass-transit systems built
- GDP increased by a factor of 5

McKinsey Global institute, Preparing for China’s Urban Billion, McKinsey & Company, 2009, frontispiece.

Exhibit 24

China – Water availability cost curve



SOURCE: 2030 Water Resources Group

The Infrastructure Challenge:
How Large Is It Really?

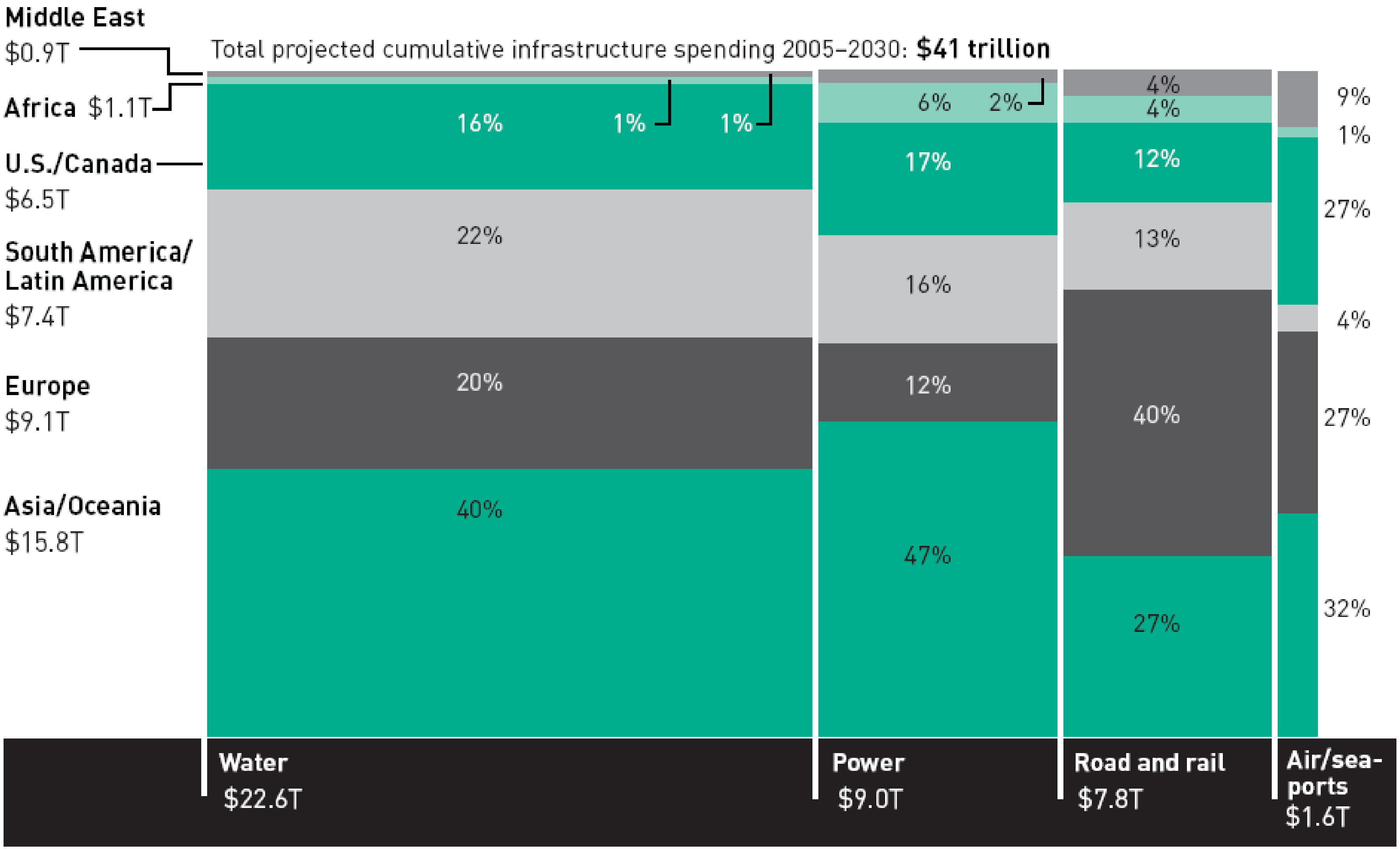
Gaping Reminders of Aging and Crumbling Pipes

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 global GDP in 2005.

Current Financial Disaster is Crying out for Government Investment in Infrastructure

- Water and Sewer looks like a good place to invest.
- The Cadmus Group (August 2008) estimated that $1 invested in water and sewer infrastructure increases Gross Domestic Product in the long run by $6.35 (9.7% rate of return).
- One job in water and sewer infrastructure creates 3.68 jobs in the national economy to support that job.
- They claim that these are larger than for highways.

Six Steps to Enhance Water and Food Security

Water Crisis: Myth or Reality (Rogers et al., 2006)

1. Conserve irrigation water: technical changes.
Using water saving technologies such as center-pivots and drip can greatly reduce water use by as much as two thirds, and double crop yields. In a given setting these technologies have the potential to expand the water resource base by significant amounts.

2. Invest in water infrastructure: maintenance issues.
In many settings water is lost due to non-beneficial evaporation and seepage due to poor maintenance of both irrigation systems and urban systems. As water becomes more scarce (and valuable) improving maintenance practices reduces losses

3. Exploit advanced desalination technology
Due to the rapid development and the reduction in cost of desalination it is certainly now cost-effective for municipal and industrial uses in most parts of the world and may be close break-even for irrigating horticultural products.

4. Wastewater Recycling: cuts water demand.
Taking advantage of the new low cost desalination techniques enables urban areas to recycle their wastewater for potable and non-potable uses. This will relieve the pressure for new sources for urban areas leaving more water for food and ecosystem use.

5. Water pricing: toward full socio-economic costing.
In most parts of the world water is underpriced with huge subsidies from the governments. This leads to overuse of the resource. Policies need to be set in place to gradually raise the water tariffs to cover full economic costs and ultimately full economic and environmental costs. This will require major social and political efforts, but will in the long-run result in substantial savings of water. Also increased charges for water will make the newer technologies for substituting for water sources via desalination more economically attractive and will also enable utilities to implement maintenance and conservation technologies which are currently uneconomical.

6. Ship virtual water: rationalize food trade.

One of the major ways of conserving water and increasing water and food security is by exploiting the potential for using the virtual water embedded in imported food and agricultural products. One other way is by direct importation of water. For conventional foodstuffs, however, nothing comes close to relying on importation of virtual water. Bulk water imports are "bulky" virtual water imports are much more efficient.

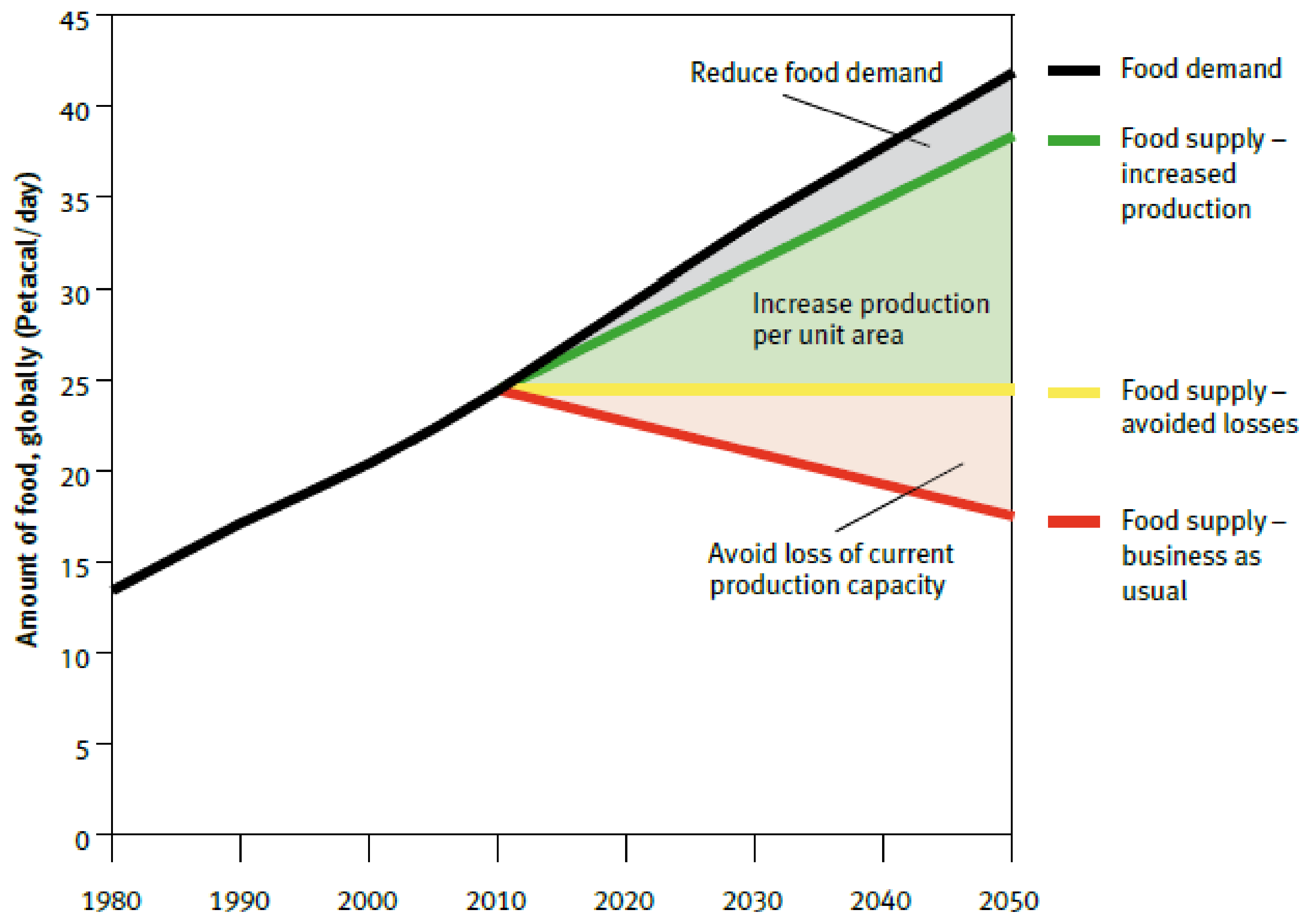


Figure 10. Balancing food supply and demand. Globally, food demand will grow in the future due to population growth and changing

Sus Ag Climate, p. 19. Discuss here the 6 steps mapped on this

The Romans Ignored The AD 202 GAO Report!

Source: InfoRoma, 2004. www.inforoma.it

DEFERRED MAINTENANCE?