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Scale of water resources development and sustainability: Small is beautiful, large is great

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Dedicated to the memory of Vít Klemeš (1932–2010), a real expert on water and wine

Vít Klemeš: Quotations from one of his last talks

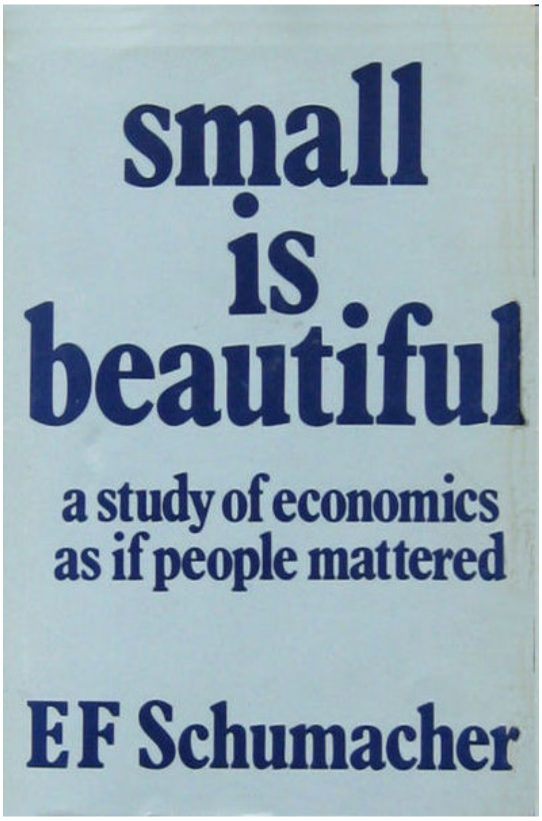
- *Nothing can be green without water – except 'green' politics*
- *[A] new infectious disease has sprung up – a* ***WATER-BORN SCHIZOPHRENIA****:*
  - *on the one hand, we are daily inundated by the media with reports about* ***water-caused disasters****, from destructive droughts to even more destructive floods, and with complaints that 'not enough is done' to mitigate them*
  - *and, on the other hand, attempts to do so by any* ***engineering means*** *– and so far no other similarly effective means are usually available – are invariably denounced as '****rape of nature****' (often by people with only the foggiest ideas about their functioning), and are opposed, prevented, or at least delayed by never ending 'environmental assessments and reassessments'*
- *In the present* ***'green' propaganda, all dams are evil*** *by definition, ranking alongside Chernobyls, Exxon Valdezes, 'rape of the environment', AIDS, cancer and genocide*

Source: Klemes (2007)

Vít Klemeš: Quotations from one of his last talks (2)

- *I shall close with a* ***plea*** *to all of you, hydrologists and other water professionals,* ***to stand up for water, hydrology and water resource engineering****, to restore their good name,* ***unmask the demagoguery hiding behind the various 'green' slogans***
- *As in any sphere of human activity, errors with adverse effects were and will be made in our profession as well (think of the human toll of errors made in the medical profession – and nobody is vilifying hospitals and advocating tearing down medical clinics)*
- *But, on the whole, our profession has nothing to be ashamed of – from the times of the ancient Mesopotamia, Greece and Rome to the present, it has done more good for mankind than all its critics combined. This is not a revelation: this is a historical fact*
- *So,* ***be brave, be proud, be heretics if necessary, and above all, use your common sense***

Source: Klemes (2007)



large is great

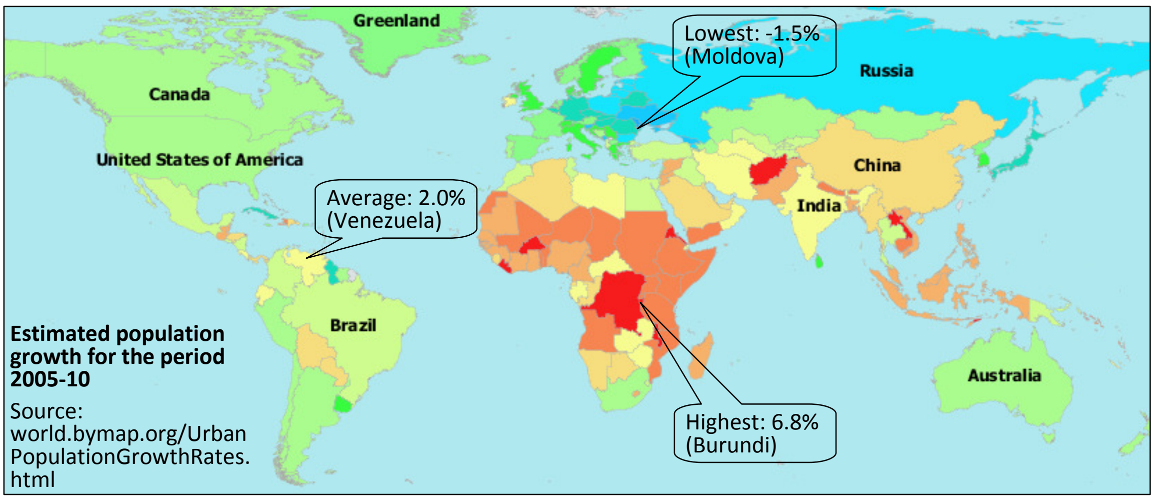
questioning "ecologics" as if people mattered

Featuring
8 facts and 9 fallacies

Fact 1: World population is large and keeps growing

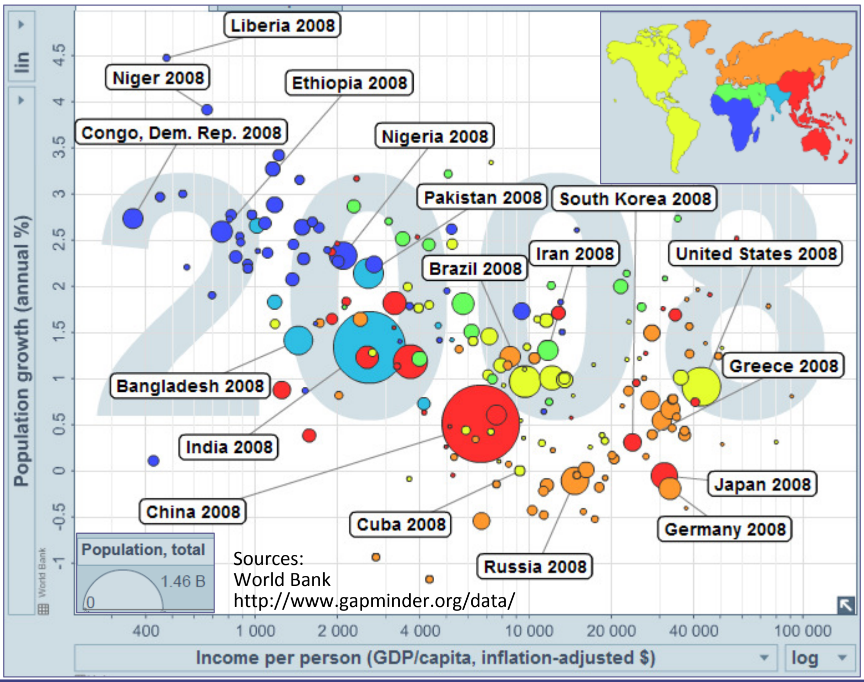
The rate of growth varies

- Very high rate (> 5% in the last 5 years) at 10 countries, mostly African and Southern Asian (Burundi, Laos, Liberia, Afghanistan, Eritrea, ...)
- Negative rate in 27 countries, mostly Eastern European (Moldova, Montenegro, Ukraine, Slovenia, Georgia, Russia, ...)

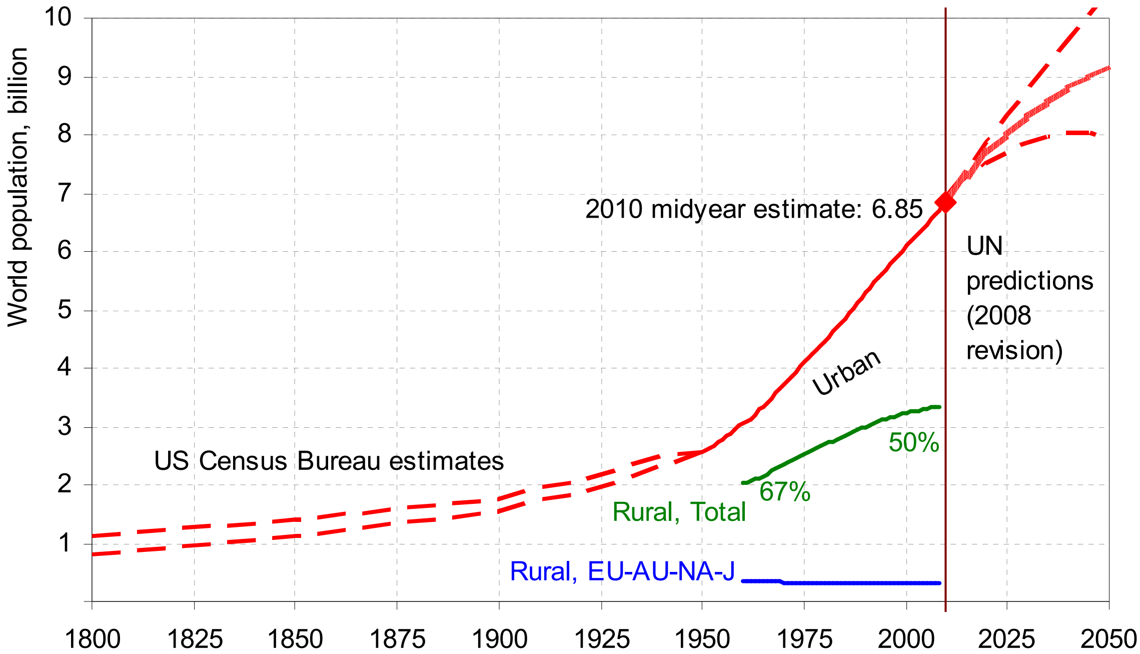


Population growth: Quantifiable determinants

- The rate of population growth is negatively correlated to the income (gross domestic product—GDP)
- Evidently, other non-quantifiable factors (cultural, birth control) influence growth rate



World population: Historical evolution and future

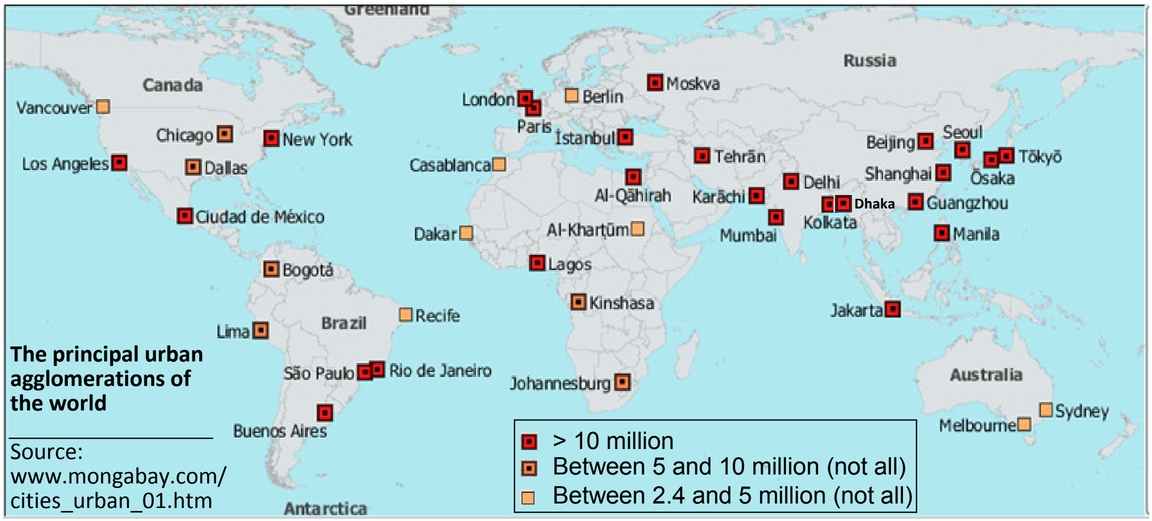


Sources: esa.un.org/unpp/p2k0data.asp; www.census.gov/ipc/www/worldhis.html; www.census.gov/ipc/www/idb/worldpop.php

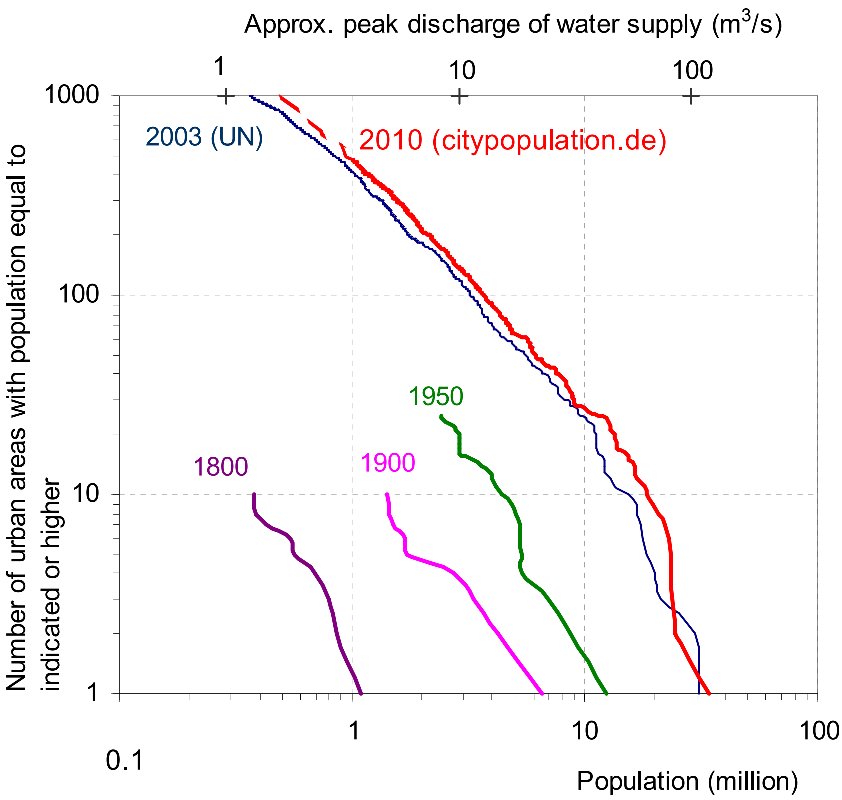
Fact 2: People prefer to live in large cities

Currently there are:

- 26 cities with population over 10 million (megacities and megalopolitan conurbations)
- 63 cities with population over 5 million
- 476 cities with population over 1 million
- ~1000 cities with population over 500 000



Large cities: distribution and historical evolution



Sources:
www.mongabay.com/cities_urban_01.htm
www.citypopulation.de/world/Agglomerations.html
geography.about.com/library/weekly/aa011201f.htm

Life in large cities has advantages: Personal testimony

Positive qualities related to the city, as reflected in language

- Πόλις (polis) = city
- Πολίτης (polites) = citizen
- Πολιτεία (politeia) = state, republic
- Πολιτική (politike) = policy, politics
- Πολιτισμός (politismos) = civilization (< civil < Latin civis = townsman)

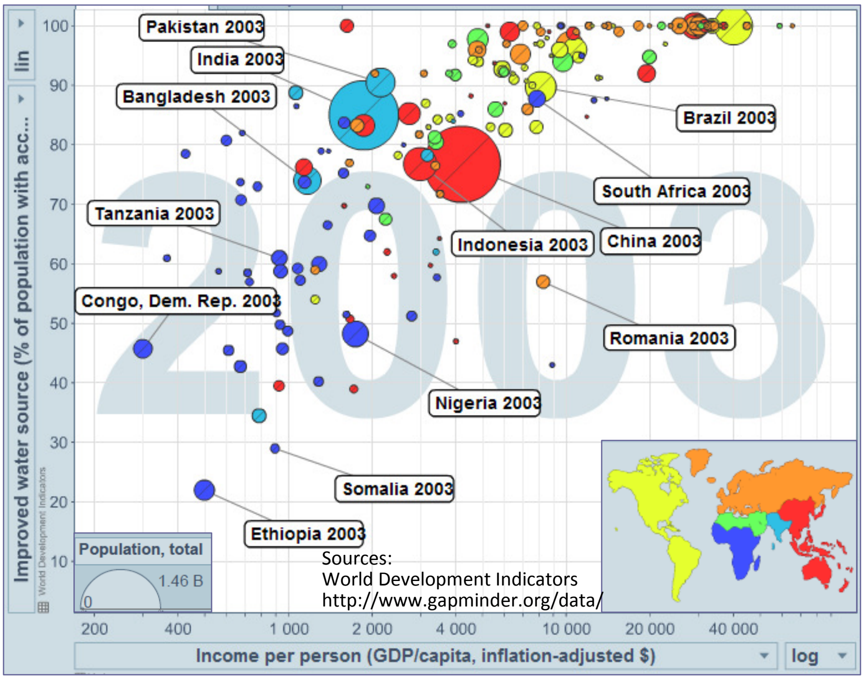
Fact 3: People need water to drink and develop high living standards

- Disparities in water supply among different areas in the globe are marked
- In developed countries any person has water supply through house connections and consumes typically 150-200 L/d and in some cases up to 1000 L/d
- In developing countries it constitutes only a target to provide 'reasonable access' to water: 20 L/d per capita at a distance of less than 1 km
- 18% of the world population (> 1 billion) do not meet this 'standard' (Howard and Bartram, 2003)
- Comparison with standards in the Athens of the 7th century BC (2 × 20 L/d, 740 m according to Solon's legislation; Koutsoyiannis *et al.*, 2008b) indicates a stagnancy, or even regression, over 27 centuries
- In addition, an astonishing misunderstanding of hydrological processes and the real nature of water problems is typically demonstrated, as, e.g., in the so-called **European Declaration for a New Water Culture**:

  "We live in times of crisis in which the international community must pause to reflect and decide which model of ***global governance*** *we must take on board for the 21st century. We must face up to the* ***ever worsening crisis of social and environmental unsustainability in the world****. With reference to water resources,* ***the systematic destruction and degradation of water ecosystems and aquifers has already led to dramatic social repercussions. 1 100 million people with no guaranteed access to drinking water, and the breakdown of the hydraulic cycle*** *and health of rivers, lakes and wetlands are two* ***consequences of this crisis****"*
  (www.unizar.es/fnca/euwater/index2.php?idioma=en)

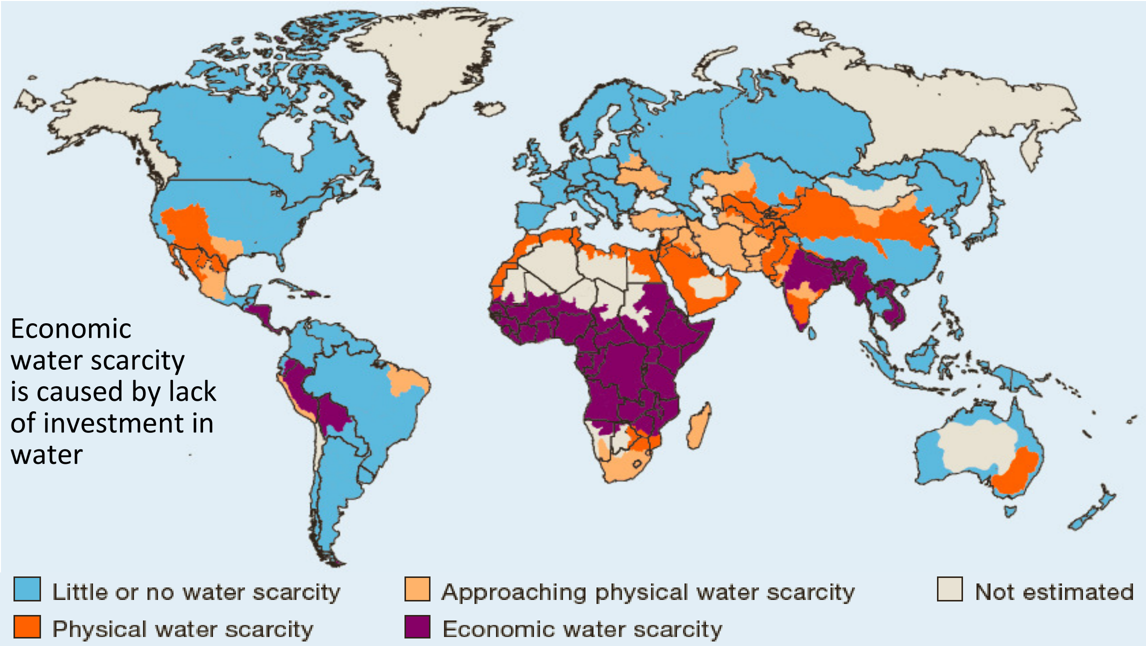
Disparities in water supply among different areas

- In developed countries, 100% of the population has proper water supply
- In developing countries, this percentage depends on the income (GDP)
- This percentage is very low in African countries



Water scarcity is economically driven*

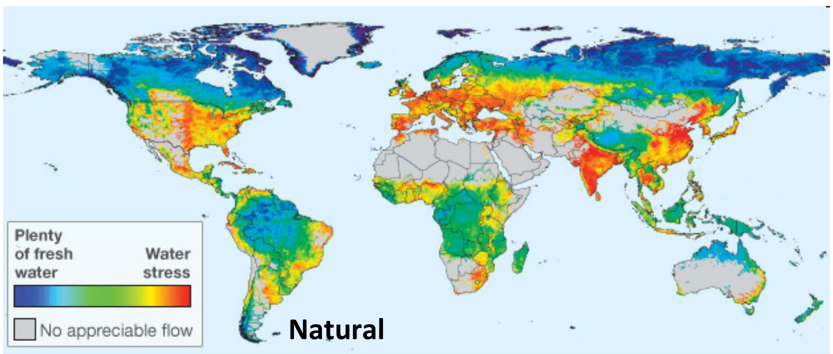
*except for desert areas

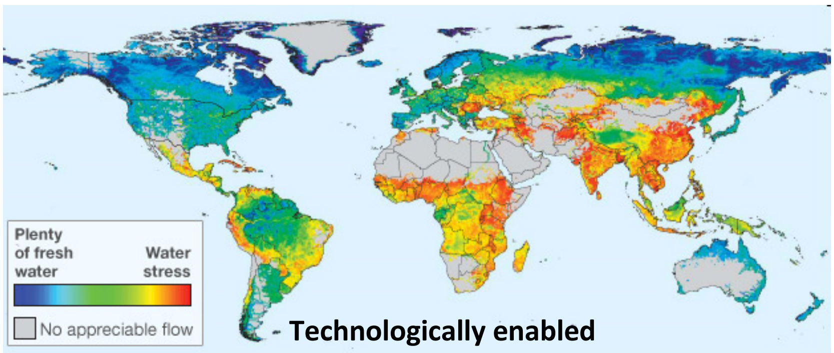


Source: Comprehensive Assessment of Water Management in Agriculture (2007)

Water scarcity = lack of technological infrastructure for water

- Vörösmarty *et al.* (2010), who constructed these graphs, advocate, for developing countries, *“integrated water resource management that expressly balances the needs of humans and nature”*
- However, they do not seem to suggest technological means different from those already used in developed countries
- They also imply that negative impacts of dams can be reversed: *“Engineers ... can re-work dam operating rules to maintain economic benefits while simultaneously conveying adaptive environmental flows for biodiversity”*

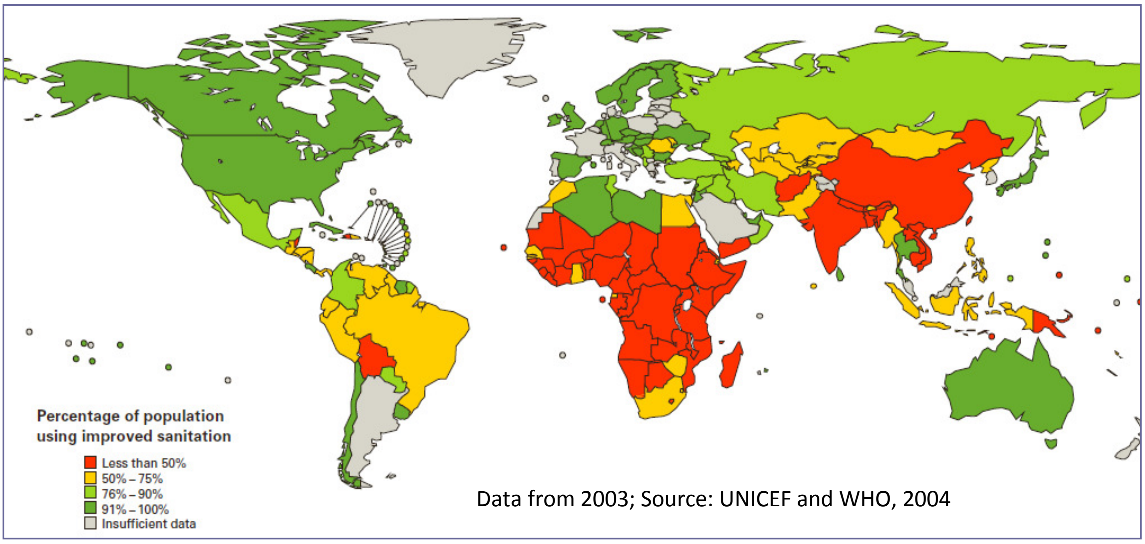




Source: Vörösmarty *et al.* (2010) as adapted in www.bbc.co.uk/news/science-environment-11435522

Fact 4: People need water for health

Half of the urban population in Africa, Asia, and Latin America suffers from diseases associated with inadequate water and sanitation (Vörösmarty *et al.*, 2005)



Data from 2003; Source: UNICEF and WHO, 2004

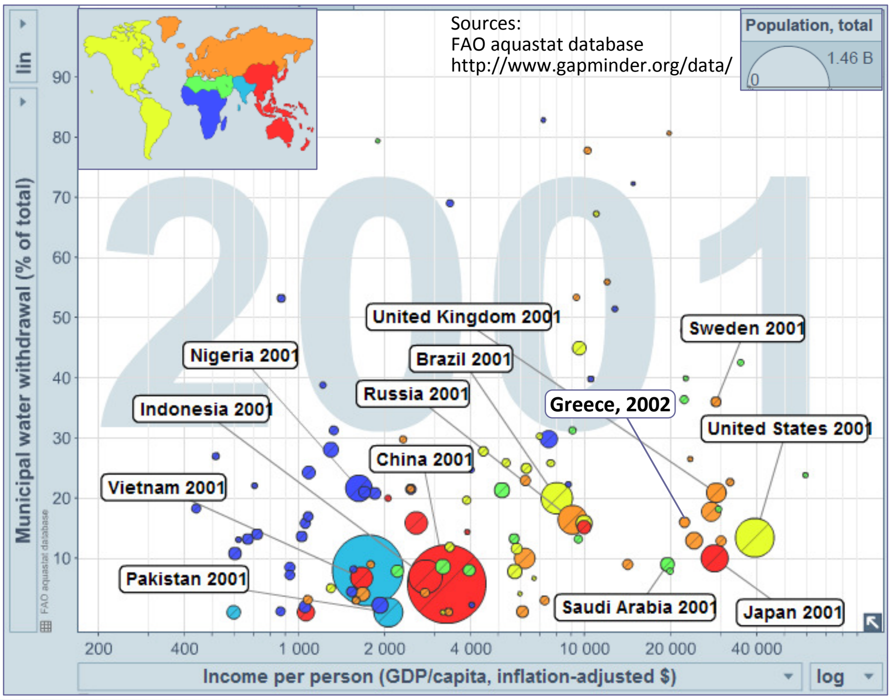
Economic progress will lead to improved water availability and sanitation in developing countries

A characteristic encouraging example: Athens (population 4.5 million)

- Due to dry climate, the water supply in Athens depends on a large-scale engineered system (**four reservoirs**) bringing water from **distances > 200 km**; investments for the constructions have always been given highest priority
- Up to the 1970s, the city did not have a proper sewer system; even big apartment blocks were served by sewage tanks emptied by sewage trucks
- A master plan elaborated in 1979 by the English engineering firm J. D. & D. M. Watson suggested that the entire replacement of sewage tanks with a sewer network system would be prohibitively expensive and that the tanks should remain in the less densely populated areas
- However, 10 years after, the sewage tanks were entirely replaced by a modern sewer network system
- Today the city has proper sewer network and wastewater treatment

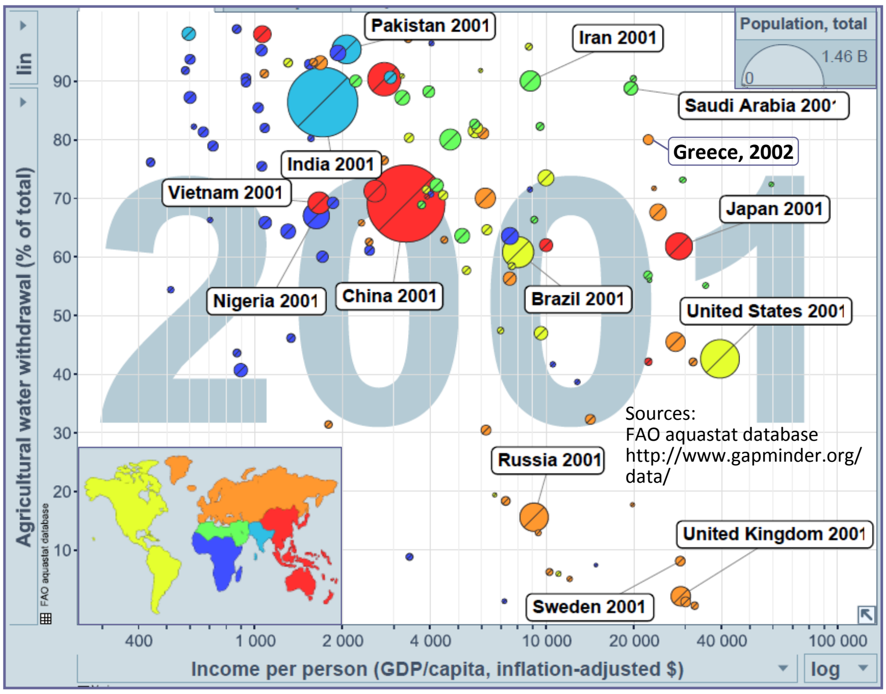
Drinking water and sanitation represent a small percent of the total water needs

- Municipal water supply has the highest quality requirements
- However, in terms of quantity, it constitutes a small percentage of total water withdrawals



Fact 5: People need water to eat (to produce food)

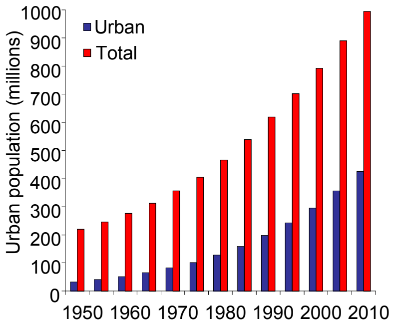
- Most of water consumed worldwide goes to irrigation
- The portion of agricultural water use depends on climate—not on income

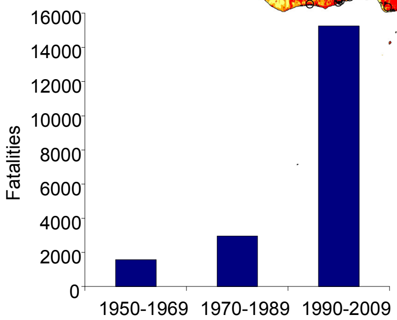


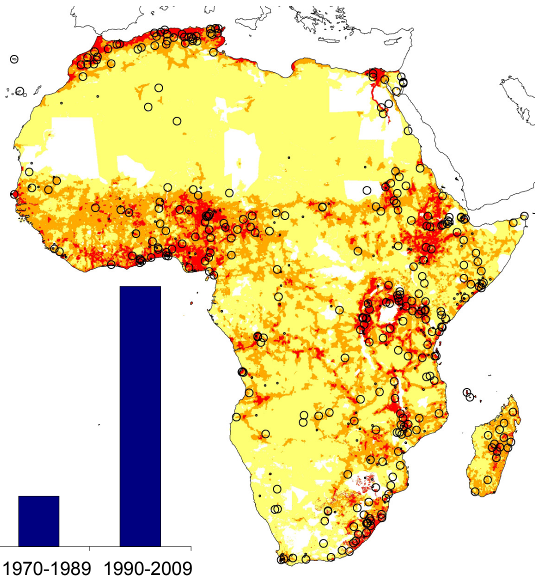
Fact 6: People need to be protected from floods

- When urbanization is not combined with urban water infrastructure, the results are tragic
- Engineering infrastructure should include flood protection works and urban planning

Population growth in the period 1960-2000 in Africa: yellow, less than 100 inhabitants per cell (2.5'); orange, 100-1000; red, more than 1000. The figure also shows the location of floods (dots) and deadly floods (large circles) in the period 1985-2009 (Di Baltrassare *et al.*, 2010)







Fact 7: People need to be protected from droughts and “food availability decline” (famines)

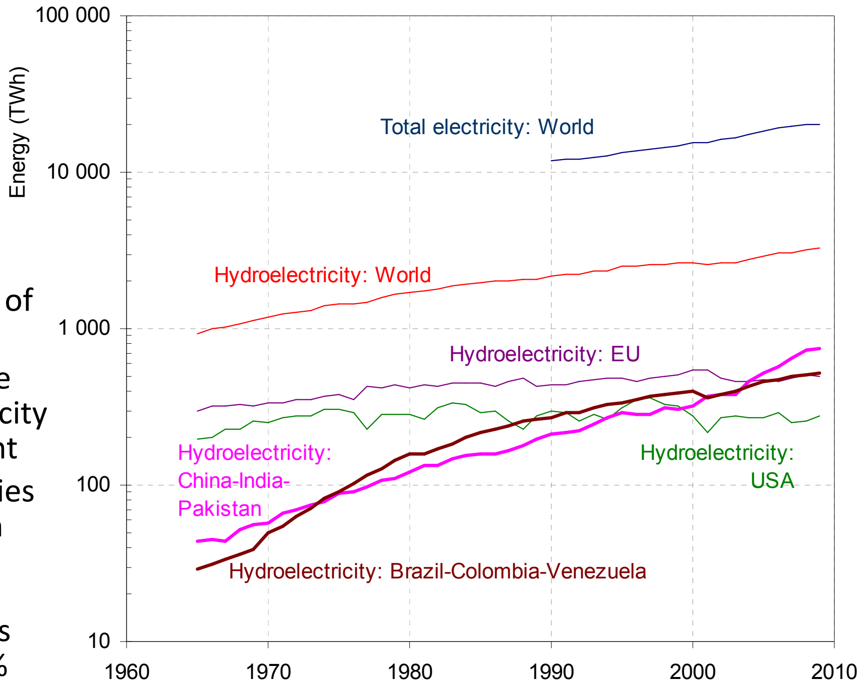
Period	Area	Fatalities (million)	Fatalities (% of world population)
1876-1879	India China Brazil Africa Total	10 20 1 ? >30	>2.2%
1896-1902	India China Brazil Total	20 10 ? >30	>1.9%
1921-1922	Soviet Union	9	0.5%
1929	China	2	0.1%
1983-1985	Ethiopia	≤1	0.02%

Sources: de Marsily (2008); Devereux (2000)

- Long-lasting droughts of large extent are intrinsic to climate (cf. Hurst-Kolmogorov dynamics)
- Such droughts may have dramatic consequences, even to human lives, as shown in the table, which refers to drought-related historical famines
- Large-scale water infrastructure, which enables multi-year regulation of flows, is a weapon against droughts and famines
- As shown in table, famines and their consequences have been alleviated through the years owing to improving water infrastructure and international collaboration

Fact 8: People need water for energy

- Electricity and hydro-electricity increase by 3% and 2.6% per year, respectively
- Hydroelectricity represents ~16% of world electricity
- In Europe and the USA hydroelectricity has been stagnant
- In several countries in Asia and South America the increase of hydroelectricity is spectacular (> 6% per year)



Data source: www.bp.com/productlanding.do?categoryId=6929&contentId=7044622

Why Europe's hydroelectric production has been stagnant?

Country*	Economically feasible hydro potential (TWh/year)	Production from hydro plants (TWh/year)	Exploitation percentage (%)
Germany	25	25	100
France	72	70	97
Italy	55	52	95
Switzerland	36	34	94
Spain	40	35	88
Sweden	85	68	80
Norway**	180	120	67
…			
Greece	15	4.7	31

The most developed countries have already developed almost all economically feasible hydro potential

* Data from Leckscheidt and Tjaroko (2003) in general and Stefanakos (2008) for Greece
** Norway's hydroelectricity production is about ~99% of its total electricity (data from www.bp.com/productlanding.do?categoryId=6929&contentId=7044622)

Why Greece's hydroelectric production has been stagnant?

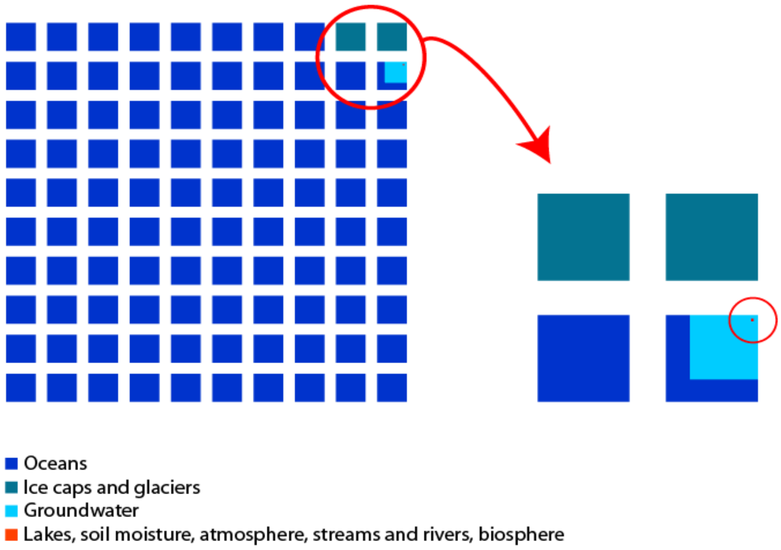
- Greece's low exploitation percentage of hydropower potential (31%) would allow for spectacular development of hydroelectricity, as, e.g., in Southern American countries
- The multi-purpose character of hydropower projects would also help resolve water scarcity problems
- However in the last decades, the mimetism of the Greek society and the Greek politicians for European stereotypes did not enable any development
- This mimetism is very strong in the Greek 'greenery', which fanatically opposes water resources development
- The most impressive example, illustrating this Greek tragedy, is the Mesochora project (170 MW, 340 GWh/year, investment 500 M€) in the Upper Acheloos River (Koutsoyiannis, 1996; Stefanakos, 2008)
- The dam and the hydropower plant have been constructed and are ready for use since 2001
- However, they have not been put in operation, thus causing a loss of 25 M€/year for the national economy (assuming the lowest price of renewal energy, i.e. 73 €/MWh imposed by decree in Greece)

Is there potential for hydroelectric development worldwide?

Continent	Economically feasible hydro potential (% of world)	Exploitation percentage (%)
Europe	10	75
North & Central America	13	75
South America	20	30
Asia	45	25
Africa	12	8

Source: Leckscheidt and Tjaroko (2003)

Fallacy 1: Groundwater constitutes the vast majority of freshwater

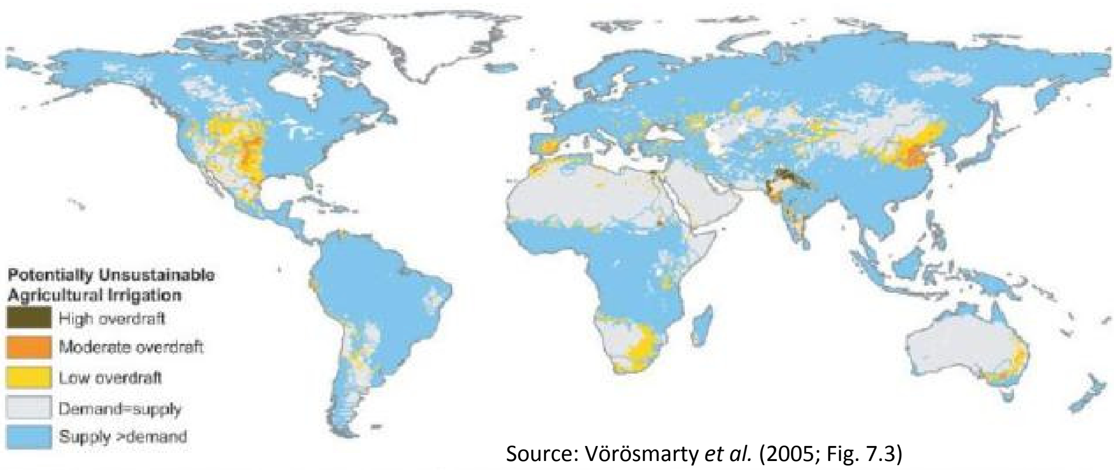


Percentage view of where water is located
Source: www.xist.org/earth/gen_water.aspx
See also: http://ga.water.usgs.gov/edu/watercyclehi.html

- Figures like this shown here would be useful if water resources were **nonrenewable reserves**
- Freshwater is renewable and **its availability is sustainable**
- Fluxes matter much more than storages
- Surface water flux to oceans is 44 700 km^3/year
- Groundwater flux to oceans is 2 200 km^3/year (~20 times less)

Groundwater, surface water and sustainability

- *"For most parts of the planet, [the Non-sustainable Water Use] will refer to the 'mining' of groundwaters, especially in arid and semiarid areas, where recharge rates to the underground aquifer are limited"* (Vörösmarty et al., 2005)
- However, the situation is much safer in surface water withdrawal: even in the most extreme (but not advisable) case, when a river or a reservoir dries, water withdrawal will necessarily stop (until water appears again



Source: Vörösmarty *et al.* (2005; Fig. 7.3)

Fallacy 2: Water transfer is non-sustainable

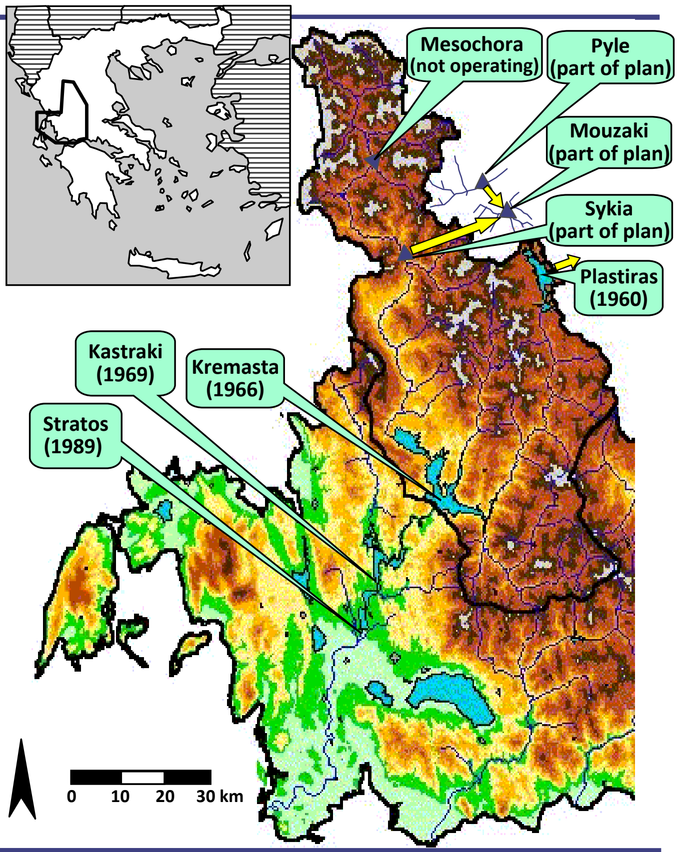
- "*[Non-sustainable Water Use] can also embody the interbasin transport of fresh water from water rich to water poor areas*" (Vörösmarty *et al.*, 2005, p. 169)
- "*Interbasin water transfers represent yet another form of securing water supplies that can greatly alleviate water scarcity*" (Vörösmarty *et al.*, 2005, p. 184)
- Question 1: What does the stereotype of 'interbasin transport' represent?
  - Is it 'interbasin transport' when water is transferred between two neighbouring catchments of different streams, each having an area of, say, 1 km^2, at a length of, say, 1 km?
  - Is it not 'interbasin transport' when water is transferred between two neighbouring sub-catchments of the same river, each having an area of, say, 10^4 km^2, at a length of, say, 100 km?
- Question 2: What is the essential difference of 'interbasin transport' from 'intrabasin transport'?
- Question 3: Can water be used by humans (as opposed to fish) without having been transported?
- Question 4: Is it non-sustainable to alleviate water scarcity?
- Question 5: Is it not sustainable to substitute transferred surface water for water from overexploited groundwater sources?

Fallacy 3: Virtual water trade is more sustainable than real water transfer

- Virtual water is the water 'embodied' in a product, i.e., the water needed for the production of the product; it is also known as 'embedded water' or 'exogenous water', the latter referring to the fact that import of virtual water into a country means using water that is exogenous to the importing country (to be added to a country's 'indigenous water'; Hoekstra, 2003)
- "*[V]irtual water trade is a realistic, sustainable and more environmentally friendly alternative to real water transfer schemes*" (Hoekstra, 2003)
- Question 1: Assuming that virtual water transfer is realistic and sustainable, why real water transfer is not?
- Question 2: Can the two transfer options, virtual water and real water, be compared in general and stereotypical terms (i.e. without referring to specifics, such as quantity, distance, energy, etc.)?
- Question 3: Is it really more sustainable and more environmentally friendly to transport agricultural products at distances of thousands of kilometres, wasting fossil fuel energy, than to transfer water at distances of a few kilometres, producing energy, boosting local agriculture, improving local economy and strengthening the resilience in crisis situations? (cf. the current global economical crisis and Greece's crisis in particular)

An interesting case: The Acheloos interbasin transfer plan

- Acheloos is the biggest in discharge river of Greece (4370 hm^3/year; Koutsoyiannis *et al.*, 2001)
- The river flows are regulated since the 1960s
- The plan includes the transfer (by a 17.4 km long tunnel) of ~15% (600 hm^3/year) of the Acheloos flows to Thessaly, the biggest and most water-deficient plain of Greece
- It also includes four hydropower plants; two can be reversible, boosting production by up to 1000 GWh/year (converted to equivalent primary energy; Koutsoyiannis, 1996)



The Acheloos interbasin transfer plan: Opposition

- The project is under construction for more than 2 decades (since 1988), but it cannot be completed
- Greek and European 'greeneries' fanatically fight against the project
- A Google search for *Acheloos crime* would reveal that the project is regarded as a crime against the environment
- Some of the documents are monumental in misinformation and 'green' propaganda and irrationality
- Even a virtual 'trial of Acheloos' was organized in 1996 by Greenpeace, WWF and three other 'green' NGOs

Acheloos interbasin transfer vs. virtual water trade

Virtual water trade balance of Greece
(hm^3/year)

	Exports	Imports	Balance
Albania	83.4	4.7	+78.7
Croatia	16.7	3.0	+13.7
Cyprus	52.0	5.3	+46.7
Egypt	5.4	91.4	-86.0
France	45.0	541.9	-496.9
Italy	242.3	171.3	+71.0
Morocco	0.9	4.9	-4.0
Spain	36.1	121.6	-85.5
Tunisia	1.1	4.2	-3.1
Turkey	30.9	143.1	-112.2
Rest Europe	1 662.3	890.5	+771.8
Rest MENA	49.5	42.7	+6.8
Rest World	165.3	2 337.5	-2 172.2
Total	2 390.9	4 362.0	-1 971.1

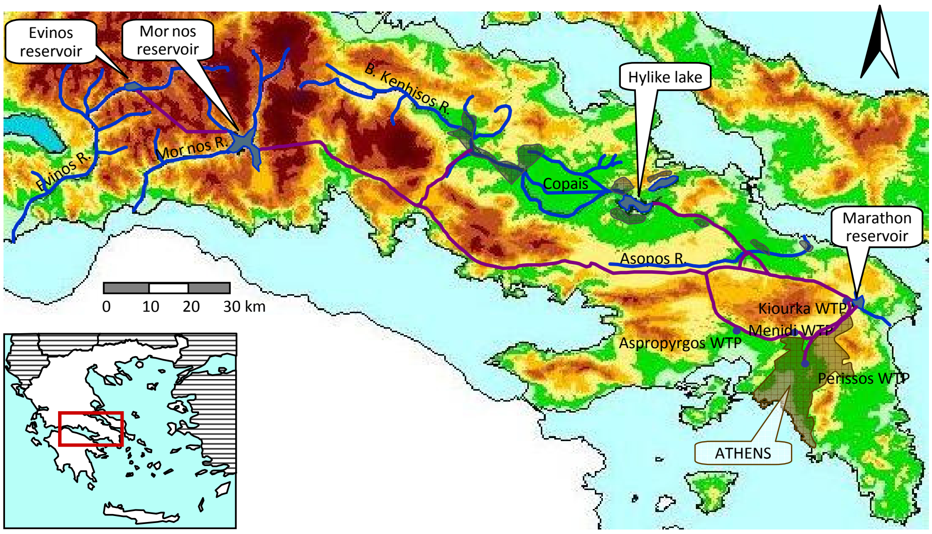
- The total transfer of virtual irrigation water (exports + imports) is 6 750 hm^3/year, roughly equal to the total real irrigation water used in Greece (6 860 hm^3/year; Koutsoyiannis *et al.*, 2008a)
- The Acheloos planned interbasin transfer of real water is one order of magnitude less, 600 hm^3/year
- The negative balance of virtual water (-1 971 hm^3/year) reflects the fact that Greece, traditionally an agricultural country, has become counterproductive

Source: Roson and Sartori (2010)

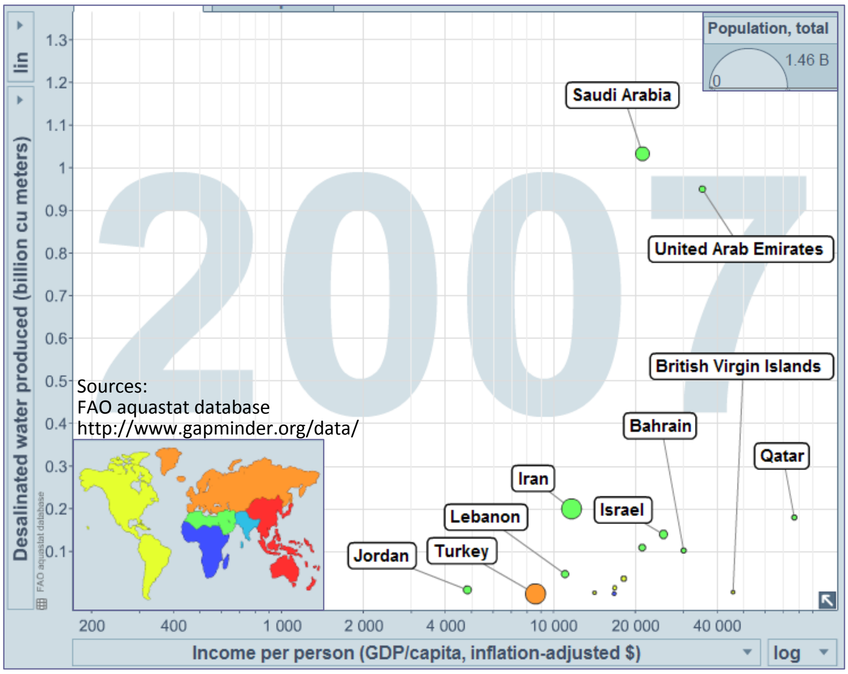
Note: Worldwide, international virtual water trade in crops has been estimated at 500-900 km^3/year, while current rates of water consumption for irrigation total 1 200 km^3/year (Vörösmarty *et al.*, 2005)

What crime? Acheloos interbasin transfer compared to transfers for the water supply of Athens

- Interbasin transfer from one river compared to four for Athens
- Transfer distance of 17.4 km compared to more than 200 km for Athens
- Interbasin transfer quantity of 600 hm^3/year vs. ~450 hm^3/year plus virtual water > 3 000 hm^3/year for Athens
- Substantial energy production vs. substantial energy consumption for Athens



Fallacy 4: Seawater may become a future freshwater resource by desalination



- Currently, only rich countries, mostly oil producing, have large-scale desalination plants
- Desalination is costly and requires vast amounts of energy
- In the future, depletion of oil will make desalination even more costly
- Therefore it is not a sustainable technology (although it may be useful in small-scale installations, e.g. small islands)

Fallacy 5 (The crescendo or irrationalism, propaganda, and hypocrisy): Hydroelectric energy is not renewable

- “*Hydro electricity is NOT renewable. Hydro dams irreversably destroys wild river environments - while the water is renewable, wild rivers are not. Dams have a finite lifetime, but the wild river cannot be replaced*” (http://tinyurl.com/2vgsd87)
- “*Hydro power is not renewable. Hydroelectric power depends on dams, and dams have a limited life—not because the concrete crumbles, but because the reservoir fills with silt.*” (http://tinyurl.com/35yobgl)
- Greek legislation “*The hydraulic power generated by hydroelectric plants, which have a total installed capacity more than 15 MWe*, is excluded from the provisions of this Act*” (Act 3468/2006 on the Production of Electricity from Renewable Energy Sources, Art. 27, par. 4, http://tinyurl.com/3237kpd)
- Question 1: Even assuming that dams have destroyed river environments, does this make the energy they produce non-renewable?
- Question 2: Does any human construction (including wind turbines and solar panels) have unlimited life?
- Question 3: Will energy production stop if a reservoir is silted? (Will the hydraulic head disappear?)
- Question 4: Why Greek legislation **excludes** large-scale hydropower stations—but, notably, not in reporting to the EU about progress in achieving renewable energy targets? (Hint: Think of who will get the money and how)

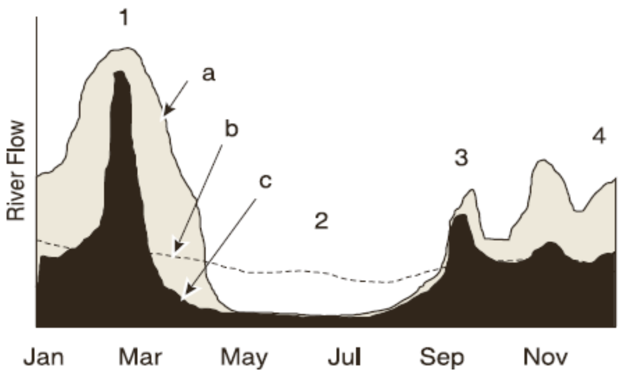
* Originally this limit was 20 MW and a later law changed it to 15 MW

Fallacy 6: Environmental problems created by dams are irresolvable

Environmental concerns about dams have helped find solutions for real problems, such as:

- Improved ecological functioning (permanent flow for habitats downstream, improved conditions for habitats in reservoir, passages of migratory fish)
- Sediment management by appropriate design and operation (**sediment routing, by-pass or pass-through**, sediment **dredging** and transport downstream; e.g. Alam, 2004)
- Revision/increase of non-emptied reservoir storage for improved quality of water, ecosystems and landscape (Christofides *et al.*, 2005)
- Re-naturalization of outflow regime (see below)

21st century re-naturalization of dammed river flows (from Vörösmarty *et al.*, 2005)
(a) natural flow regime
(b) typical 20th century flow distortion after damming
(c) partially re-naturalized flow regime, which retains important hydrologic characteristics: (1) peak wet season flood, 2) baseflow during the dry season, (3) flushing flow at the start of the wet season to cue life cycles, and 4) variable flows during the early wet season



Fallacy 7: Large-scale energy storage is beyond current technology

- *"Engineers haven't yet developed energy storage devices suitable for storing solar and wind power"* (Kerr, 2010)
- However, pumping water to an upstream location consuming available energy, which will be retrieved later as hydropower, is a proven and very old technology with very high efficiency (Koutsoyiannis *et al.*, 2009)
- This feature of hydropower makes it unique among all renewable energies
- This technology can be implemented even in small autonomous hybrid systems (e.g. Bakos, 2002)
- However (for reasons explained below) it is substantially more advantageous in large-scale projects

Fallacy 8: Hydroelectric energy has worse characteristics than wind and solar energies

- Large-scale hydroelectric energy has unique characteristics among all renewable energies
  - It is the only fully controllable/regulated (as contrasted to the highly variable and uncontrollable wind and solar, and even small-scale hydro, energy)
  - It offers high-value primary energy for peak demand
  - It offers the unique option of energy storage, which is an essential need for an energy system that includes renewable energy production
- In addition, it offers the only energy conversion with really high efficiency
  - Hydro (large-scale): 90-95%
  - Wind turbines
    - Betz limit 59% (theoretical upper limit)
    - achieved in practice 10-30%
  - Solar cells
    - commercially available (multicrystalline Si) ~14-19%
    - best research cells (three junction concentrators) 41.6%
  - Non-renewable (for comparison)
    - combined cycle plants (gas turbine plus steam turbine) ~60%
    - combustion engines 10-50%

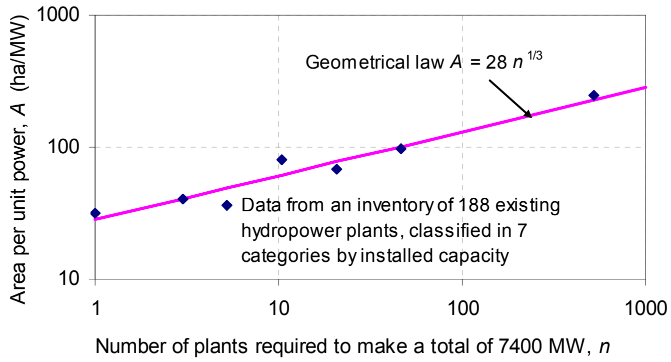
Fallacy 9: Small hydropower plants are better than large

- The debate about large- vs. small projects seems to has been won by the latter; this is evident from everyday news, from scientific documents and, particularly from legislation
- Thus, many countries/states consider small hydropower plants as a renewable and large as a non-renewable energy resource, where the border between the two is
  - 15 MW in Greece
  - 30 MW in California and Maine (Égré *et al.*, 1999; Égré and Milewski, 2002)
  - 80 MW in Vermont (Égré *et al.*, 1999)
  - 100 MW Rhode Island and New Jersey (Égré *et al.*, 1999; Égré and Milewski, 2002)
- In Greece, a total of 250 small hydropower plants have been licensed with a total installed capacity of 430 MW (Douridas, 2006)
- Notably, the installed capacity of the old Kremasta hydropower plant in Acheloos is 437 MW

Scale, geometry and environmental impacts

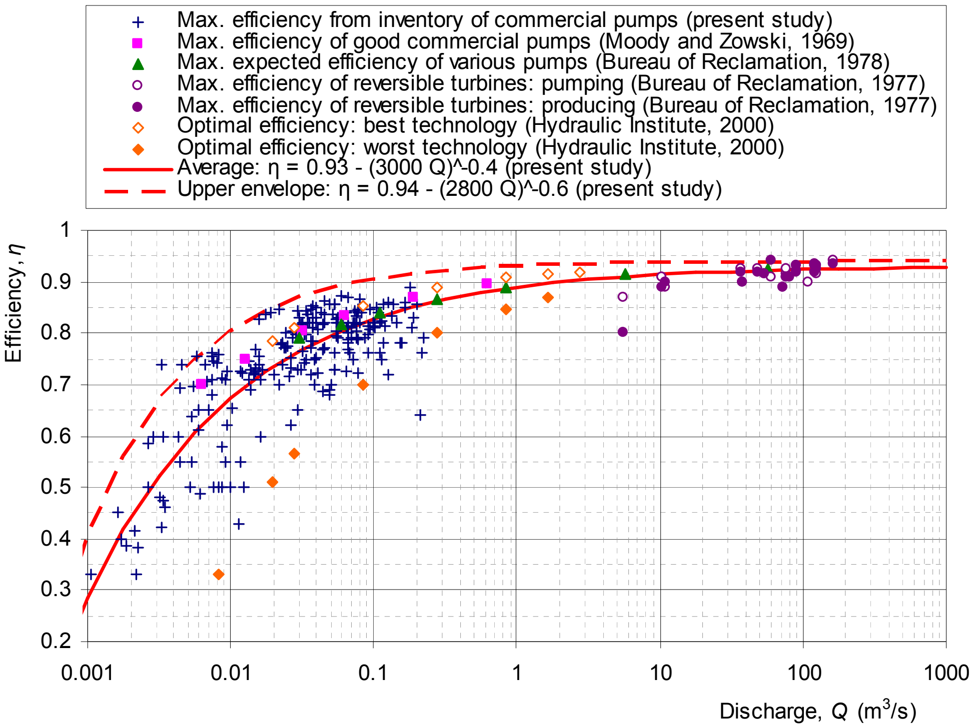
- Elementary knowledge of geometry reveals that if a certain volume *V* is divided in *n* geometrically similar shapes, the total area is proportional to $n^{1/3}$ and the total perimeter is proportional to $n^{2/3}$ (both increasing functions of *n*)
- This simple truth has implications on several fields, from the area occupied by reservoirs to the hydraulic losses in conduits, turbines and pumps
- Question: What is less damaging for the environment? One large power plant, on one river (Acheloos), with an installed capacity of 437 MW, or 250 small power plants on 200 rivers and creeks, with a total installed capacity of 430 MW (1.7 MW each on the average)?

Statistical analysis on existing hydropower projects, shows that the average reservoir area per MW is larger in small projects and fully supports the simple theoretical geometrical argument (data from Goodland, 1995, quoted in Égré and Milewski, 2002)



Scale and efficiency of pumps and turbines

This graph, constructed from commercial and bibliographic data for pumps and reversible turbines, shows the increase of efficiency for increasing scale, quantified by discharge *Q*

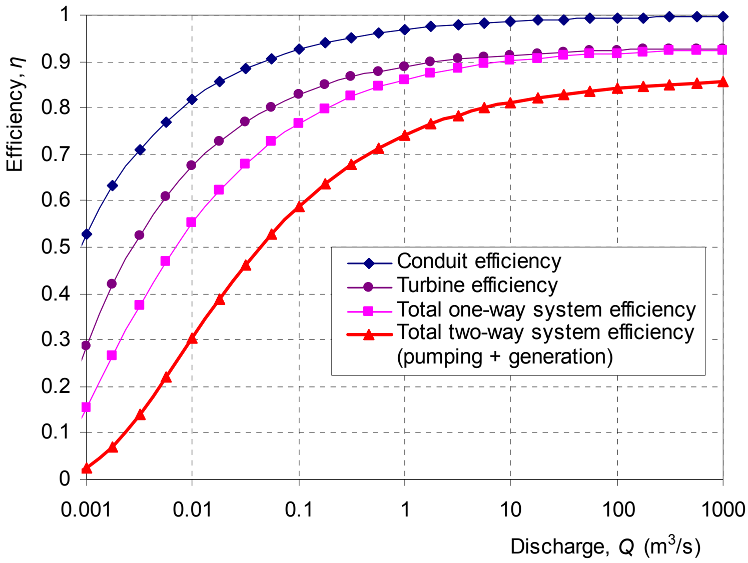


Only large-scale systems can efficiently store energy

The example below, calculated using plausible assumptions and commercial pump/turbine characteristics, shows that for large discharge (> 10 m^3/s) we can achieve efficient storage of energy ($\eta > 0.8$), while for discharge $Q < 1$ m^3/s the efficiency degrades rapidly

Assumptions

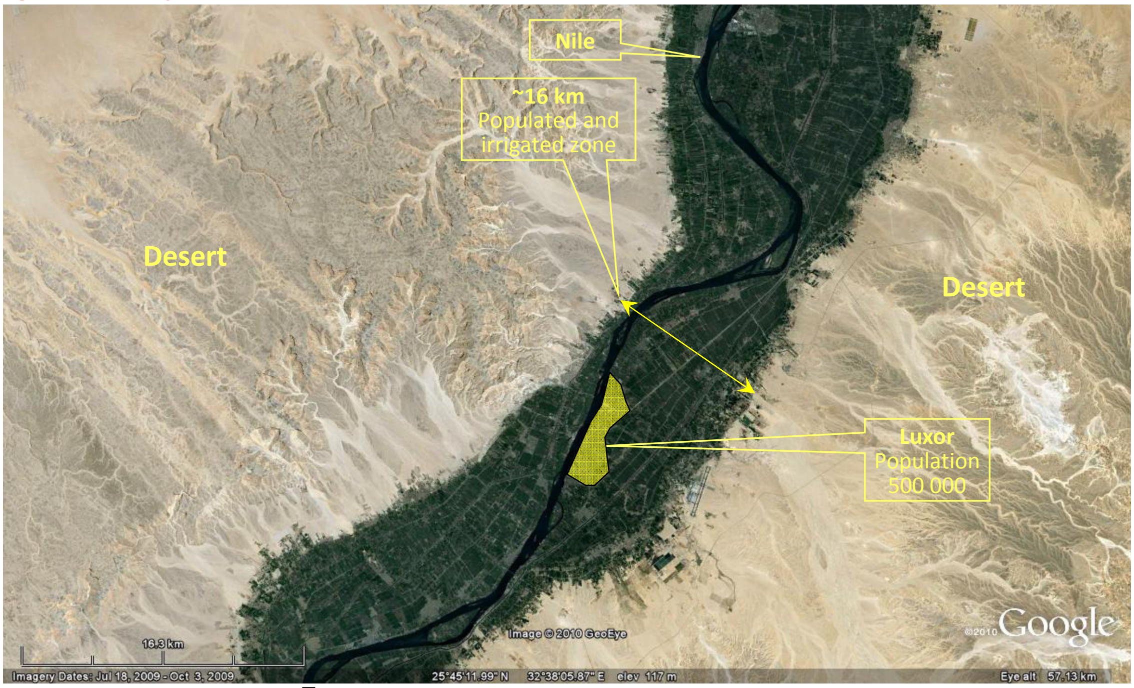
- Turbine/pump efficiency according to the average curve [$\eta = 0.93 - (3000 \text{ m}^{-3} \text{ s } Q)^{-0.4}$]
- Conduit length 2 km and roughness 1 mm
- Hydraulic head 100 m
- Conduit velocity V varying as a power function $V(Q)$ of the discharge Q with $V(0.001 \text{ m}^3/\text{s}) = 0.6$ m/s, $V(1000 \text{ m}^3/\text{s}) = 2.5$ m/s



Conclusions

- Yes, more dams
  - → to meet increased water and food supply needs
- Yes, more hydropower plants
  - → to meet energy needs using the most effective renewable technology
- Yes, more reversible (pumped storage) plants
  - → to meet energy storage needs
  - → to make possible the replacement of fossil-fuel-based energy with renewable (and, thus, highly varying and uncertain) energy
- Yes, more water transfer projects
  - → to supply water to large cities
  - → to replace virtual water by real water and trade by local production
- Yes, large-scale water projects
  - → because only these are energy-efficient and multi-purpose
  - → because they can be less damaging for the environment than small-scale projects

"Nothing can be green without water – except 'green' politics" (Vít Klemeš)



⇩ **To Aswan dam** (hydroelectricity, storage of irrigation water, flood control)

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