Will the Global Population Have Enough Water to Sustain Itself?

Hans-Peter Plag
Mitigation and Adaptation Research Institute
Old Dominion University
Norfolk, VA

Kang Wang

Likely No.

Evelyn Roeloffs

This might be rephrased to **emphasize protection of biodiversity** rather than just supporting expanding human population.

It should be noted that fresh water use for unconventional hydrocarbon extraction has significant impacts in regions where water is scarce, so that **accurate assessment of water resources** in those areas is crucial.

Kristy Tiampo

Not as things stand now. The numbers are against us - groundwater mining and population expansion are depleting resources while contaminating a valuable commodity.

Jeanne Sauber

More specific: How is the **global distribution of water** changing and how will this impact individual countries ability to sustain their water needs.

Cynthia Ebinger

Many areas have already reached crisis point, with increasing aridity meaning that agricultural output cannot support the population. As sealevel rises, **freshwater** resources in the coastal zone will be **compromised**.

Will the Global Population Have Enough Water to Sustain Itself?

Hans-Peter Plag
Mitigation and Adaptation Research Institute
Old Dominion University
Norfolk, VA

Will the Global Population be Able to Govern and Manage Water and its Usage Sustainably?

Will the Global Population Have Enough Water to Sustain Itself?

Hans-Peter Plag
Mitigation and Adaptation Research Institute
Old Dominion University
Norfolk, VA

Will the Global Population be Able to Govern and Manage Water and its Usage Sustainably?

- Demands and Needs:
  - *What is water used for?*
  - *How are humans governing and managing water usage?*
- Supplies:
  - *How is fresh water distributed in space and time and what is its quality?*
  - *How large are the flows of fresh water and are these flows changing?*
  - *How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?*
  - *Are water quality reduction through direct and indirect human impacts limiting the availability of useable water?*
- Geodesy's contribution:
  - *Create knowledge relevant to water governance and management*

Demands and Needs

What is water used for?

http://www.unwater.org/publication_categories/world-water-development-report/

Demands and Needs

What is water used for?

Human demands for water are usually broken down into five major water use sectors:

- Food and agriculture, which accounts for the majority of water withdrawals globally;
- Energy, for which the quantities of water used (consumptively and non-consumptively) are rarely reported and thus are poorly known;
- Industry, which covers an exceptionally broad range of income-generating activities with equally broad impacts on both the quantity and the quality of local water resources and the environment;
- Human settlements, which includes water for drinking and household uses such as cooking, cleaning, hygiene and some aspects of sanitation;[1] and
- Ecosystems, whose water demands are determined by the water requirements to sustain or restore the benefits for people (services) that societies want ecosystems to supply.

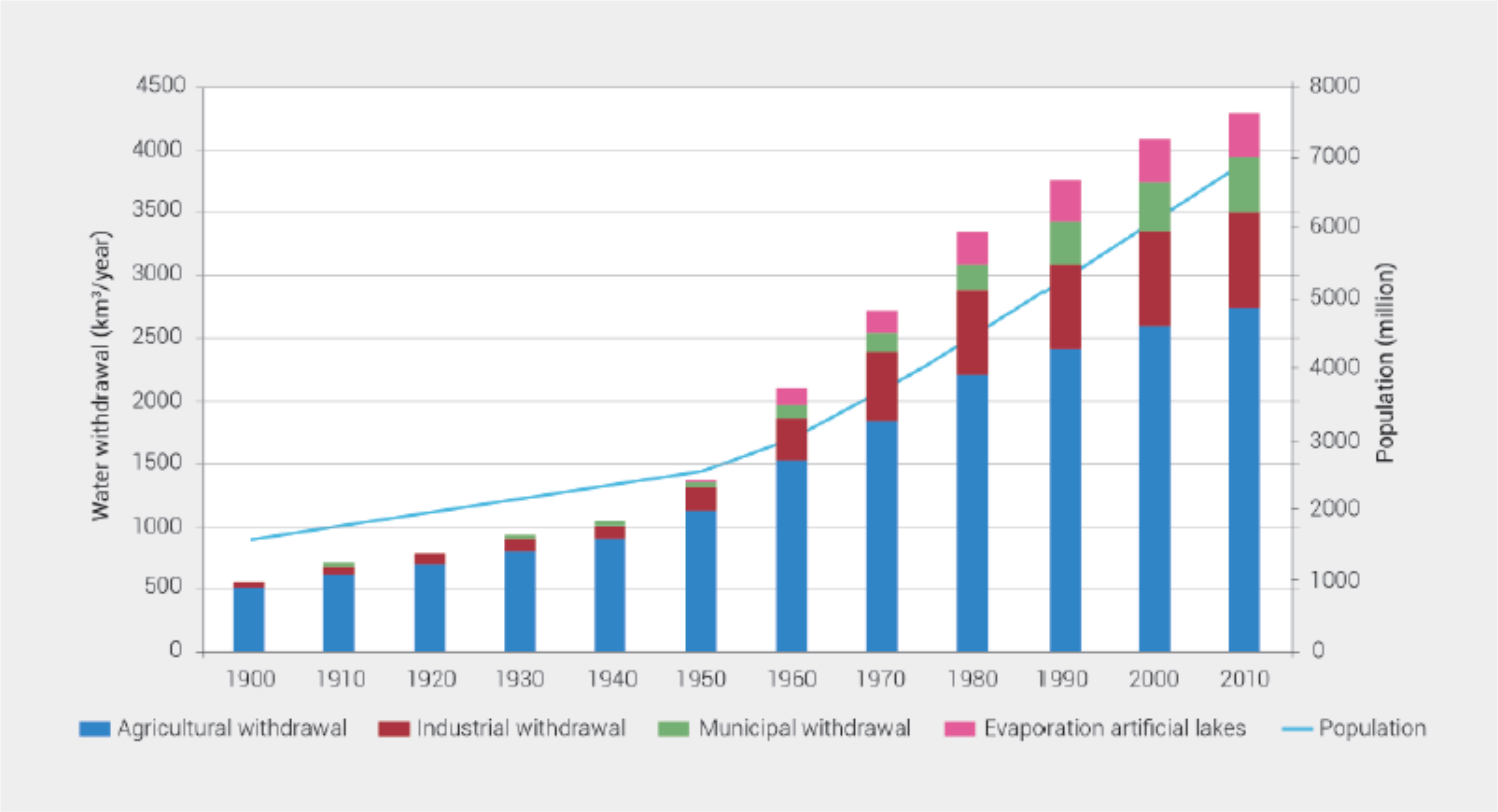
UNWWDR, 2012

http://www.unwater.org/publication_categories/world-water-development-report/

Demands and Needs

What is water used for?

Figure 31. Water withdrawal and global population over time in agriculture, industry and municipalities, 1900–2010



Source: FAO (2016a).

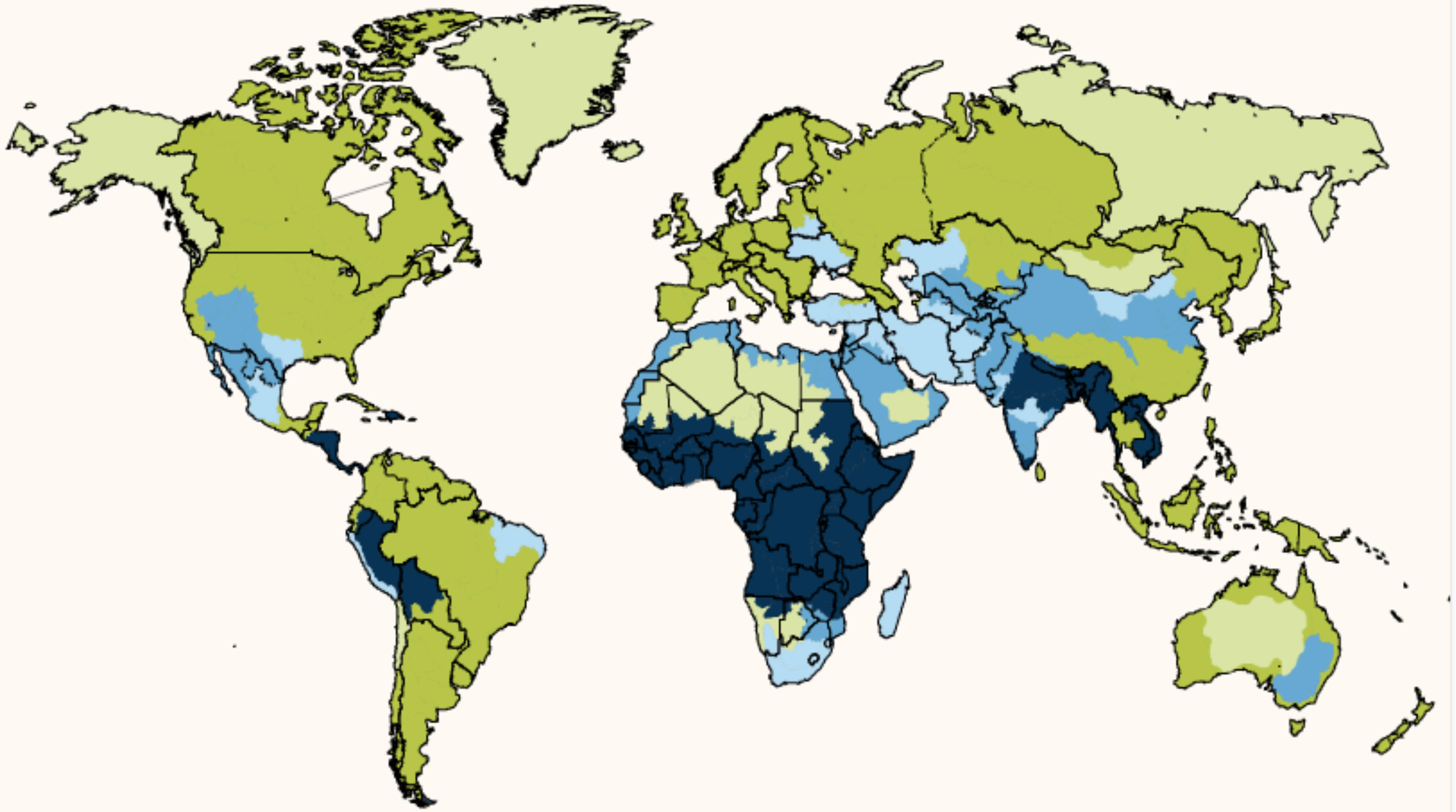
Figure 31 compares global water withdrawal over time in three sectors: agriculture (including irrigation, livestock watering and cleaning, aquaculture), industry and municipalities. Note that all withdrawals are not the same in that agriculture consumes water, whereas industry and municipalities only use water that is increasingly recycled for other purposes.

Demands and Needs

What is water used for?

FIGURE 1.1

Global physical and economic surface water scarcity



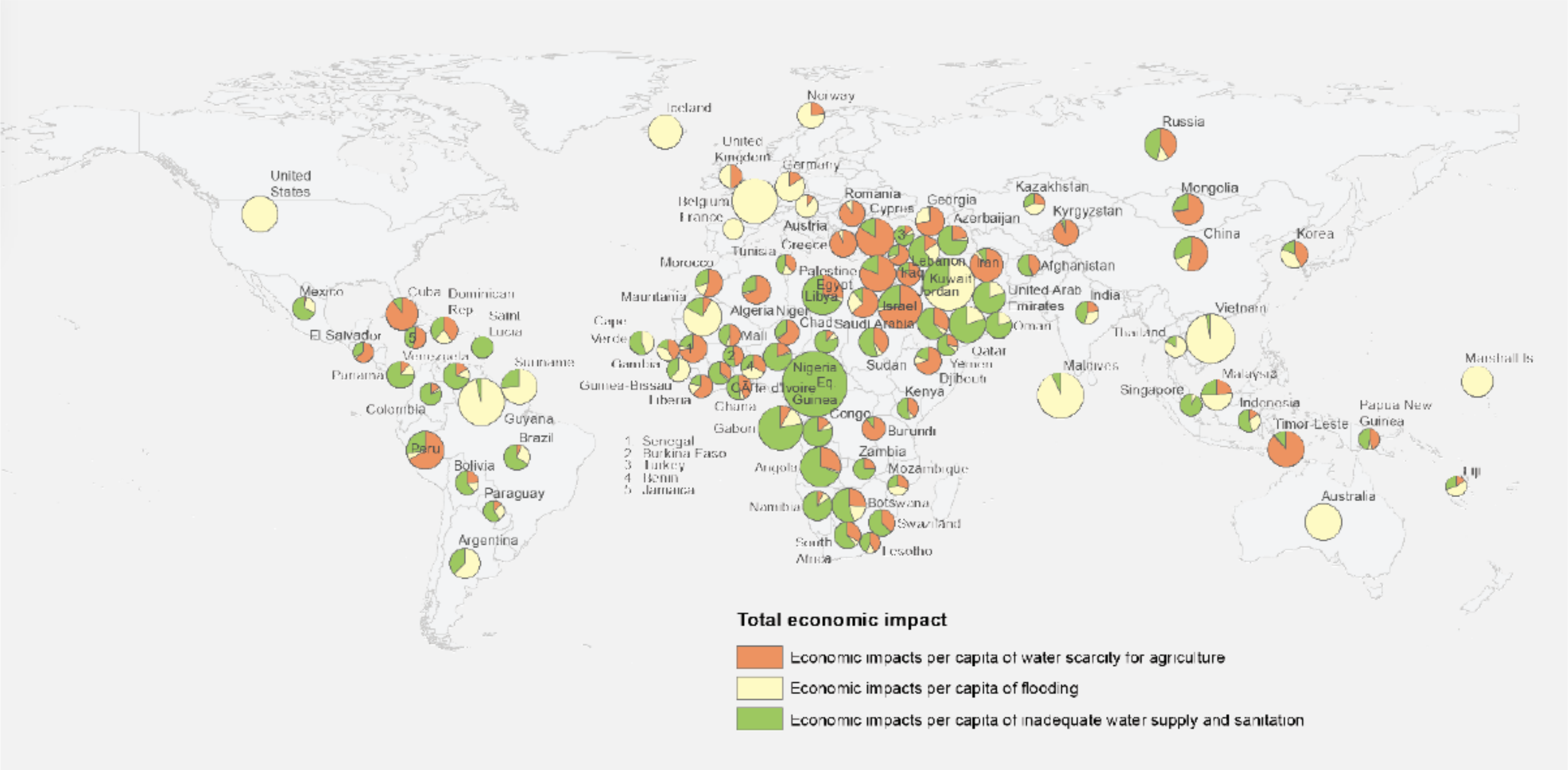
- Little or no water scarcity
- Physical water scarcity
- Approaching physical water scarcity
- Economic water scarcity
- Not estimated

Definitions and indicators

- Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- Physical water scarcity (water resources development is approaching or has exceeded sustainable limits). More than 75% of river flows are withdrawn for agriculture, industry and domestic purposes (accounting for recycling of return flows). This definition – relating water availability to water demand – implies that dry areas are not necessarily water scarce.
- Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- Economic water scarcity (human, institutional and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Source: Comprehensive Assessment of Water Management in Agriculture (2007, map 2, p. 11).

Figure 43. Relative economic impact of water insecurity



Source: Sadoff and others (2015).

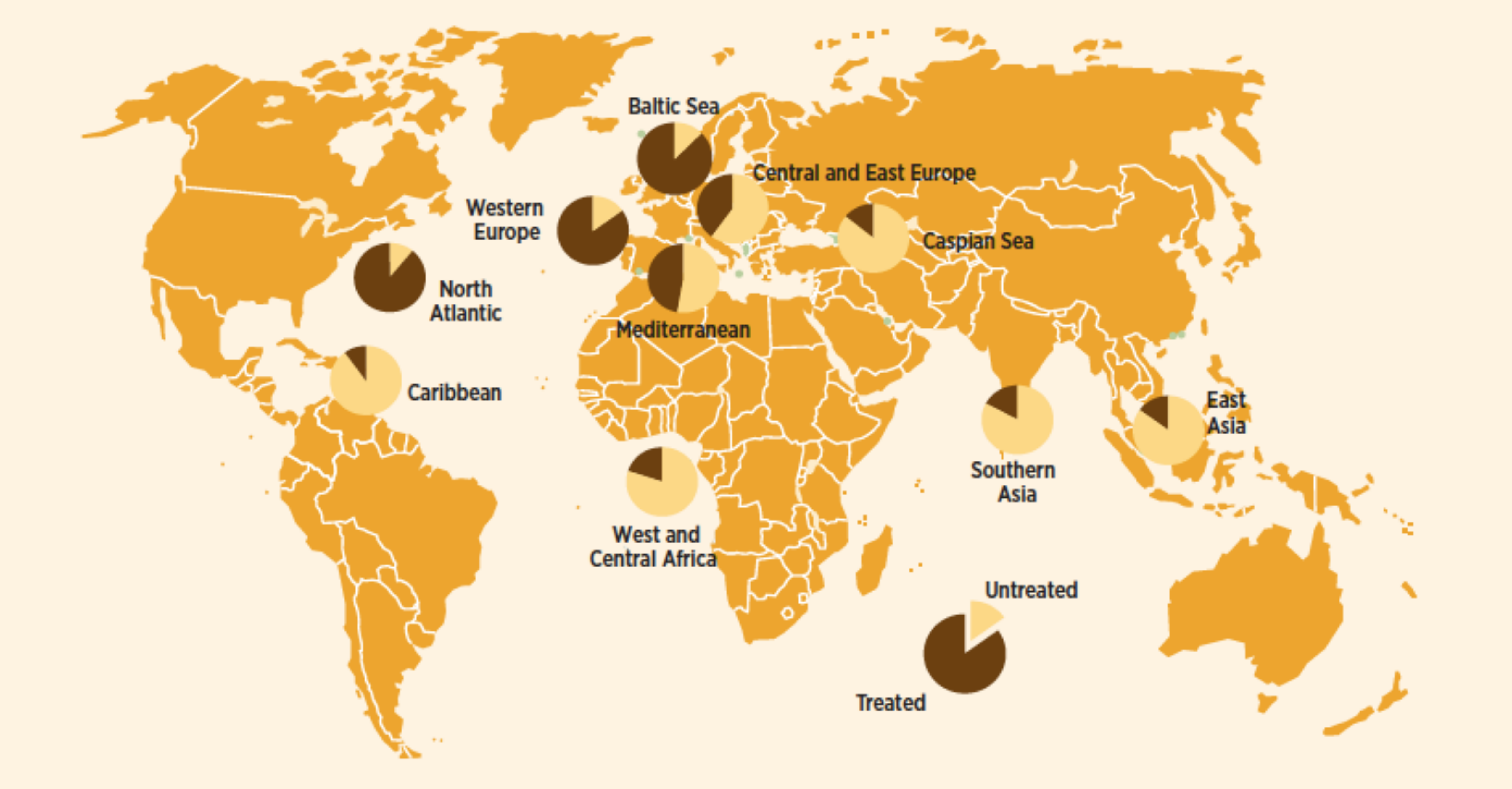
Note: Three economic indicators were standardized to the same total economic impact globally: water scarcity to agriculture (orange), flood damage to property (yellow), and inadequate water supply and sanitation (green).

Demands and Needs

What is water used for?

FIGURE 2.9

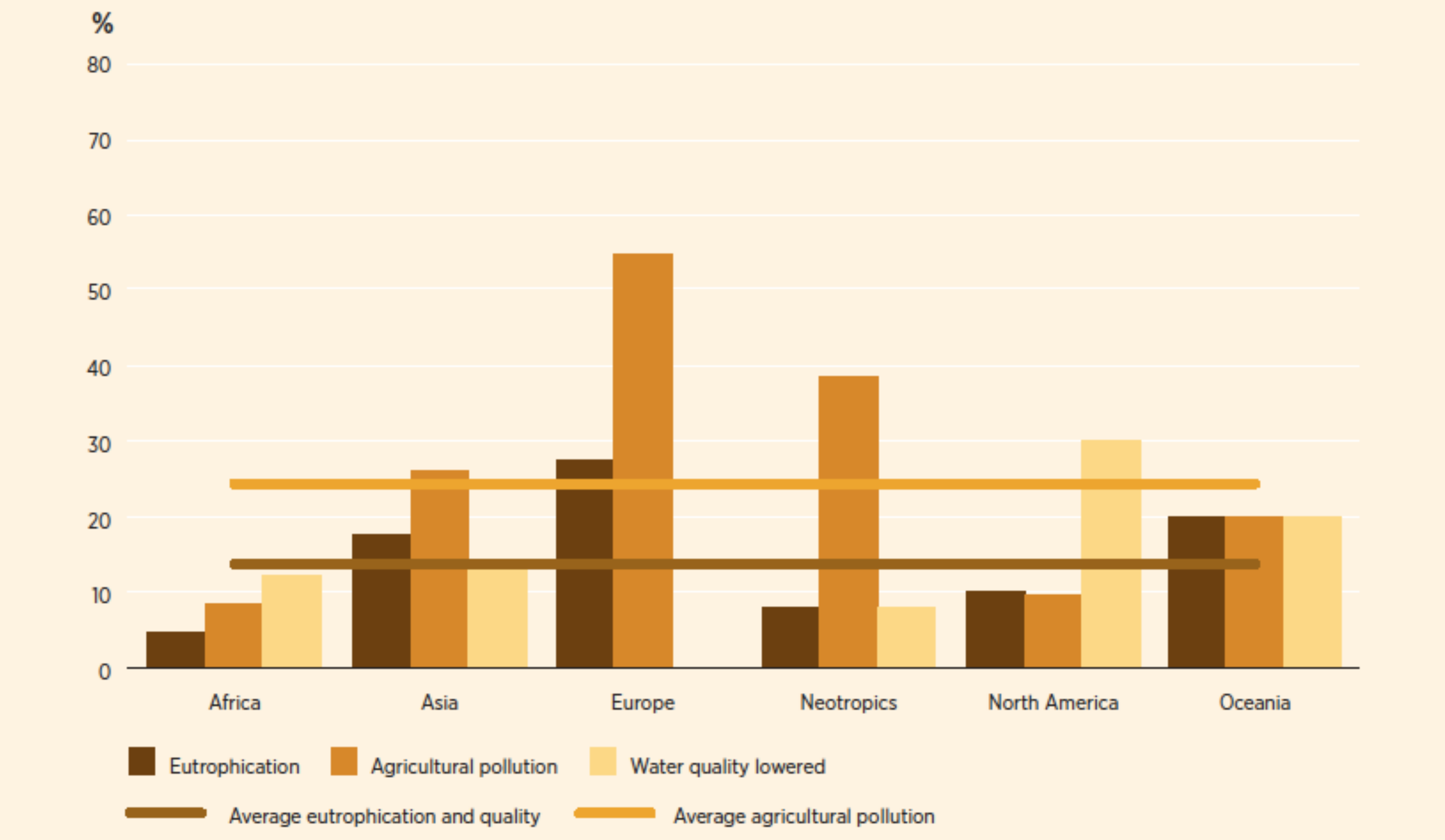
Ratio of treated to untreated wastewater discharged into water bodies



Note: Ratio of wastewater treatment (March 2010).
Source: UNEP/GRID-Arendal (http://maps.grida.no/go/graphic/ratio-of-wastewater-treatment1, adapted from a map by H. Alhenius with sources UNEP-GPA [2004]).

FIGURE 2.2

Wetlands water quality state changes by continent



Source: FAO (2008, p. 50).

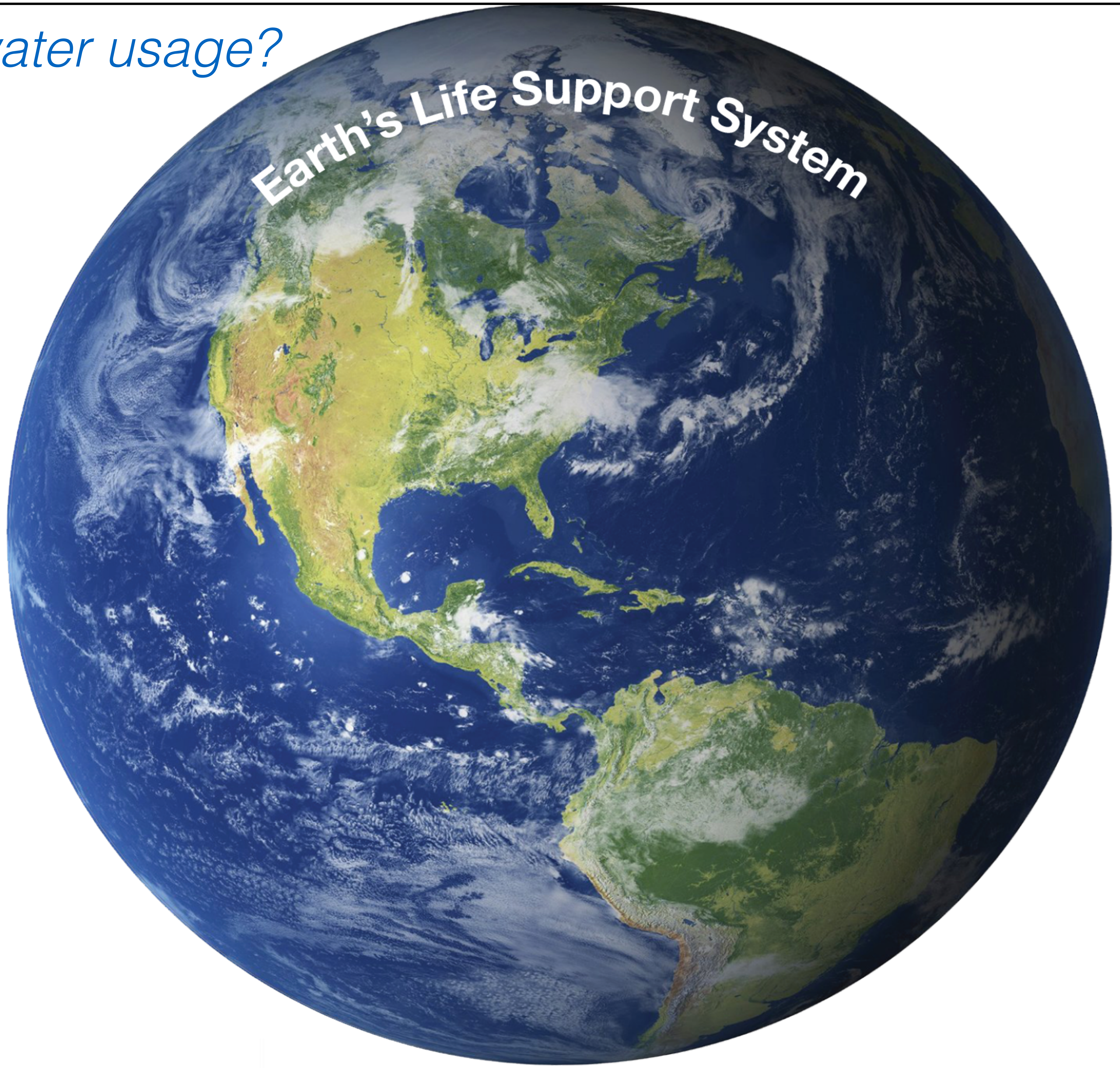
Demands and Needs

How are humans governing and managing water usage?

Demands and Needs

How are humans governing and managing water usage?

Conceptual Framework:
Earth is a Life-Support System

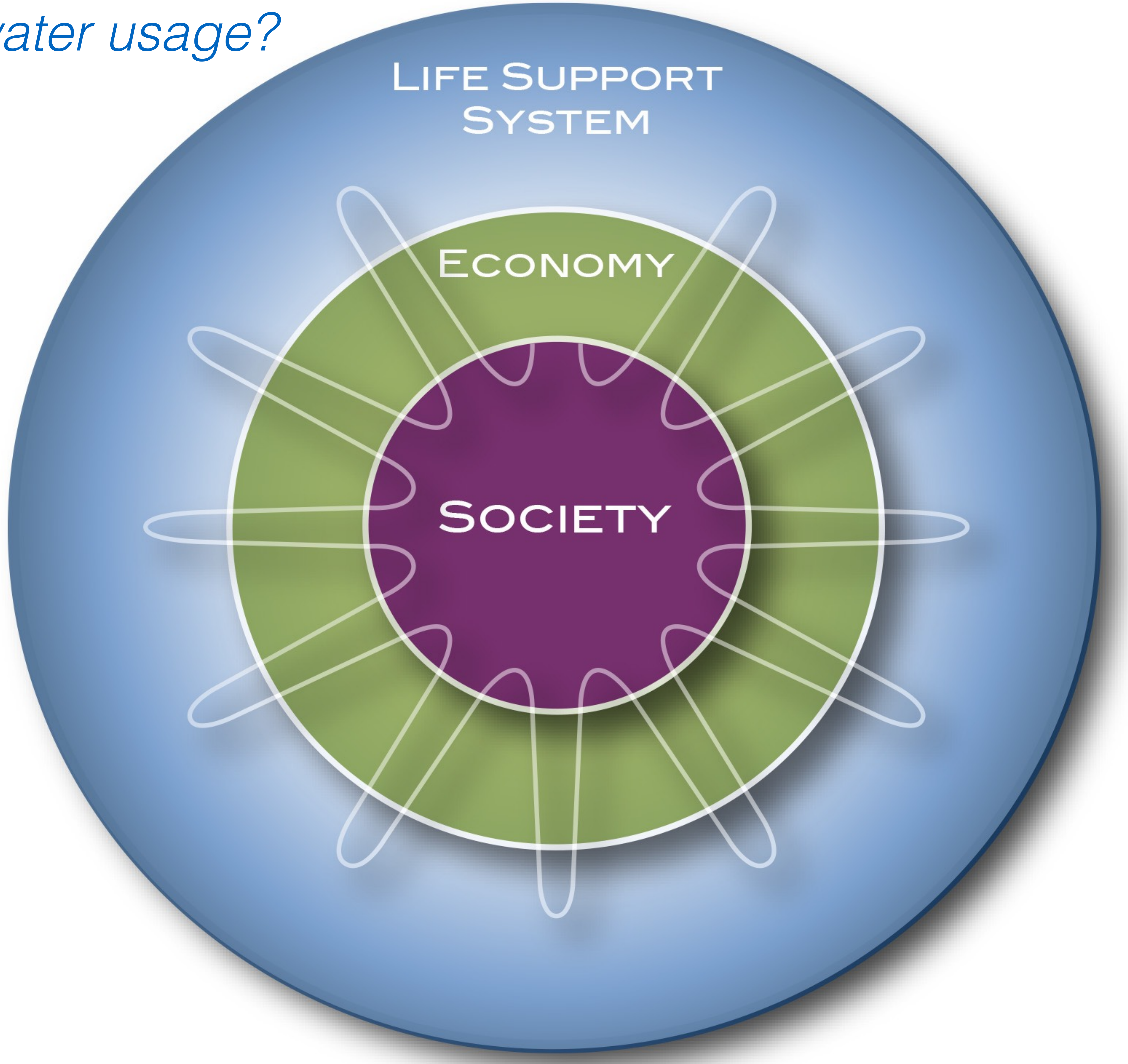


Demands and Needs

How are humans governing and managing water usage?

Conceptual Framework:
Earth is a Life-Support System

Everything is about Flows (physiology)



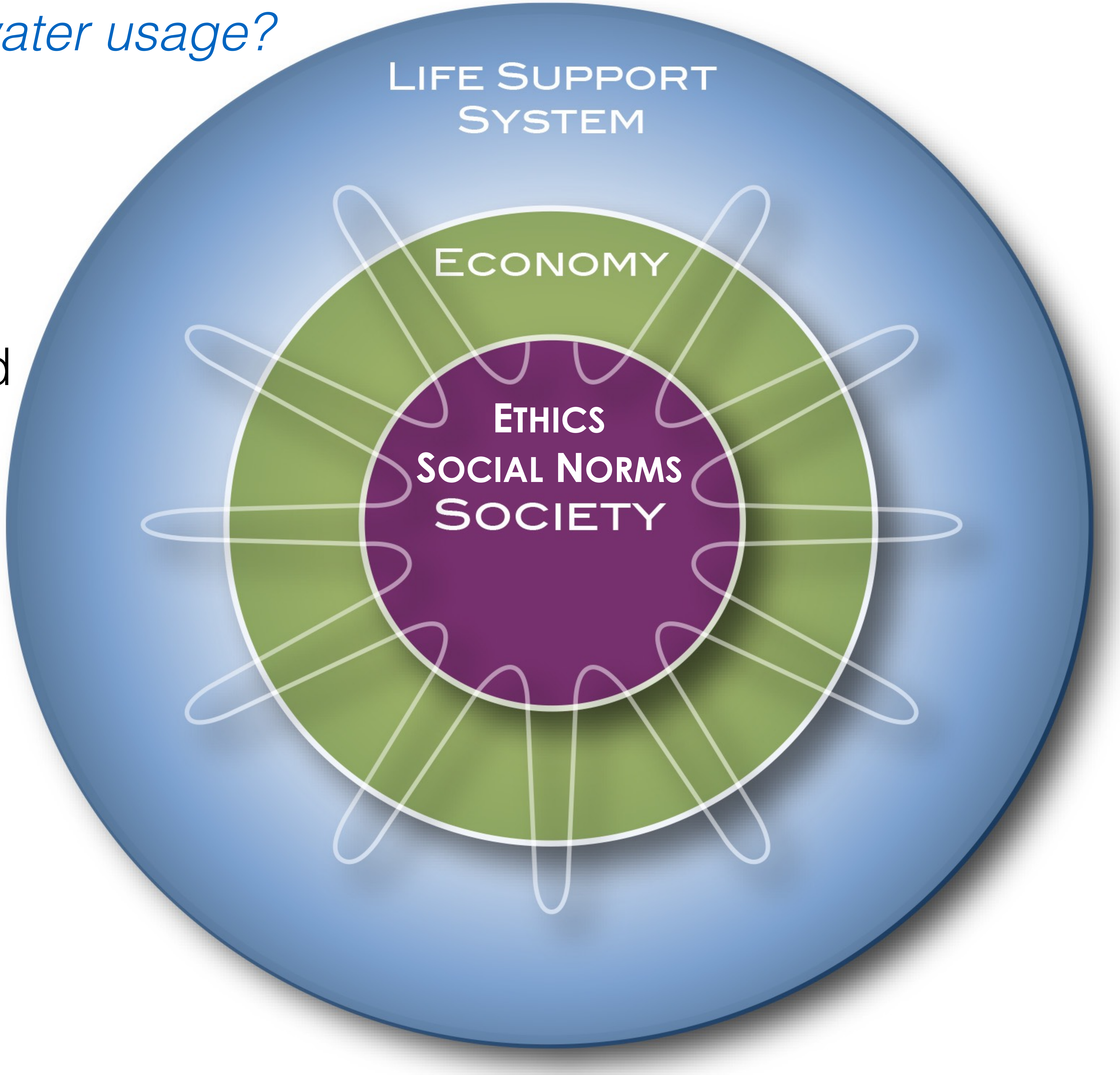
Demands and Needs

How are humans governing and managing water usage?

Conceptual Framework:
Earth is a Life-Support System

Everything is about Flows (physiology)

For human communities, flows are regulated by social norms, ethics, and - recently - mainstream economic rules,



Demands and Needs

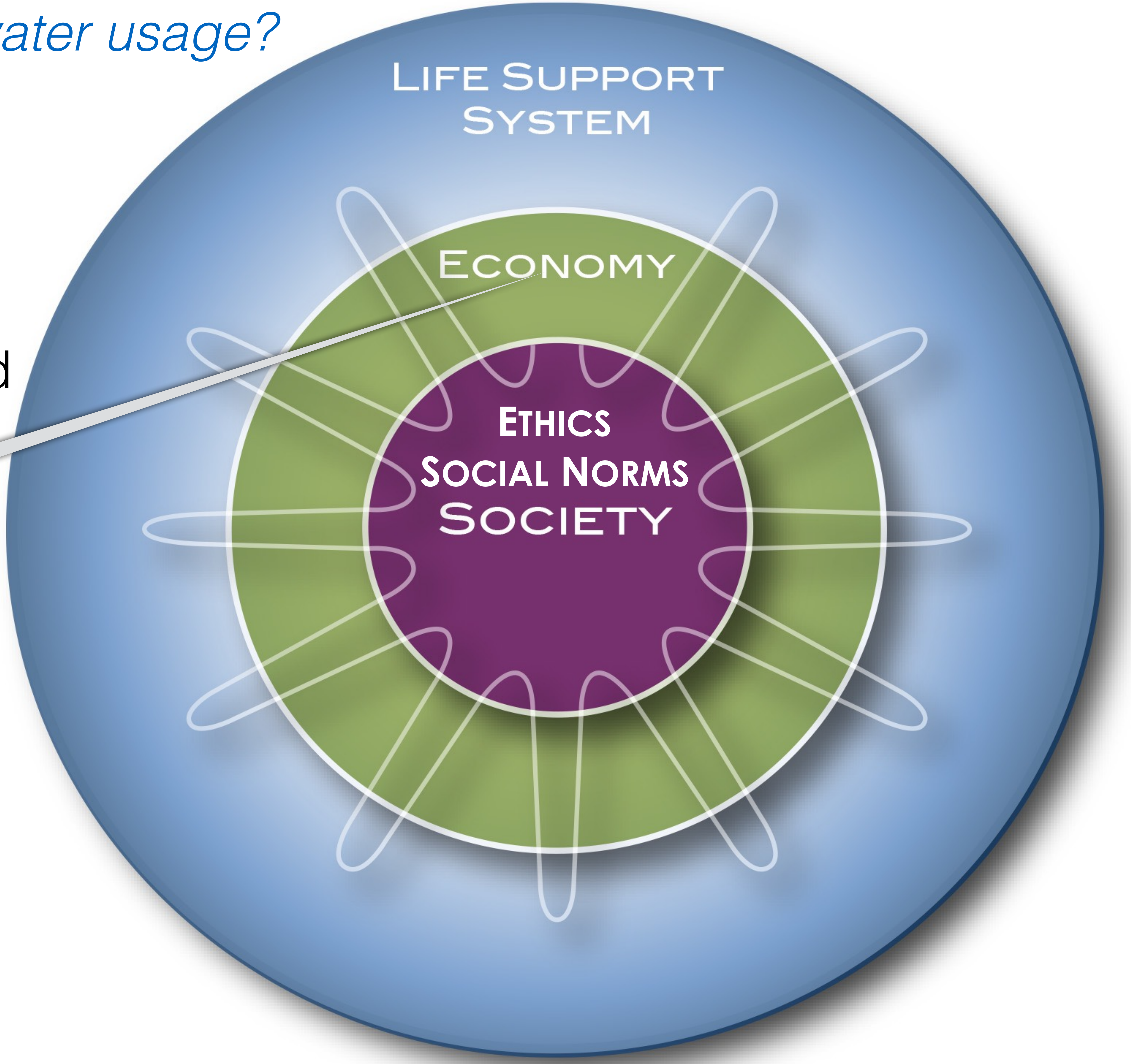
How are humans governing and managing water usage?

Conceptual Framework:
Earth is a Life-Support System

Everything is about Flows (physiology)

For human communities, flows are regulated by social norms, ethics, and - recently - mainstream

Limitations in the flows between a community and its life-support system limit the growth of the community



Demands and Needs

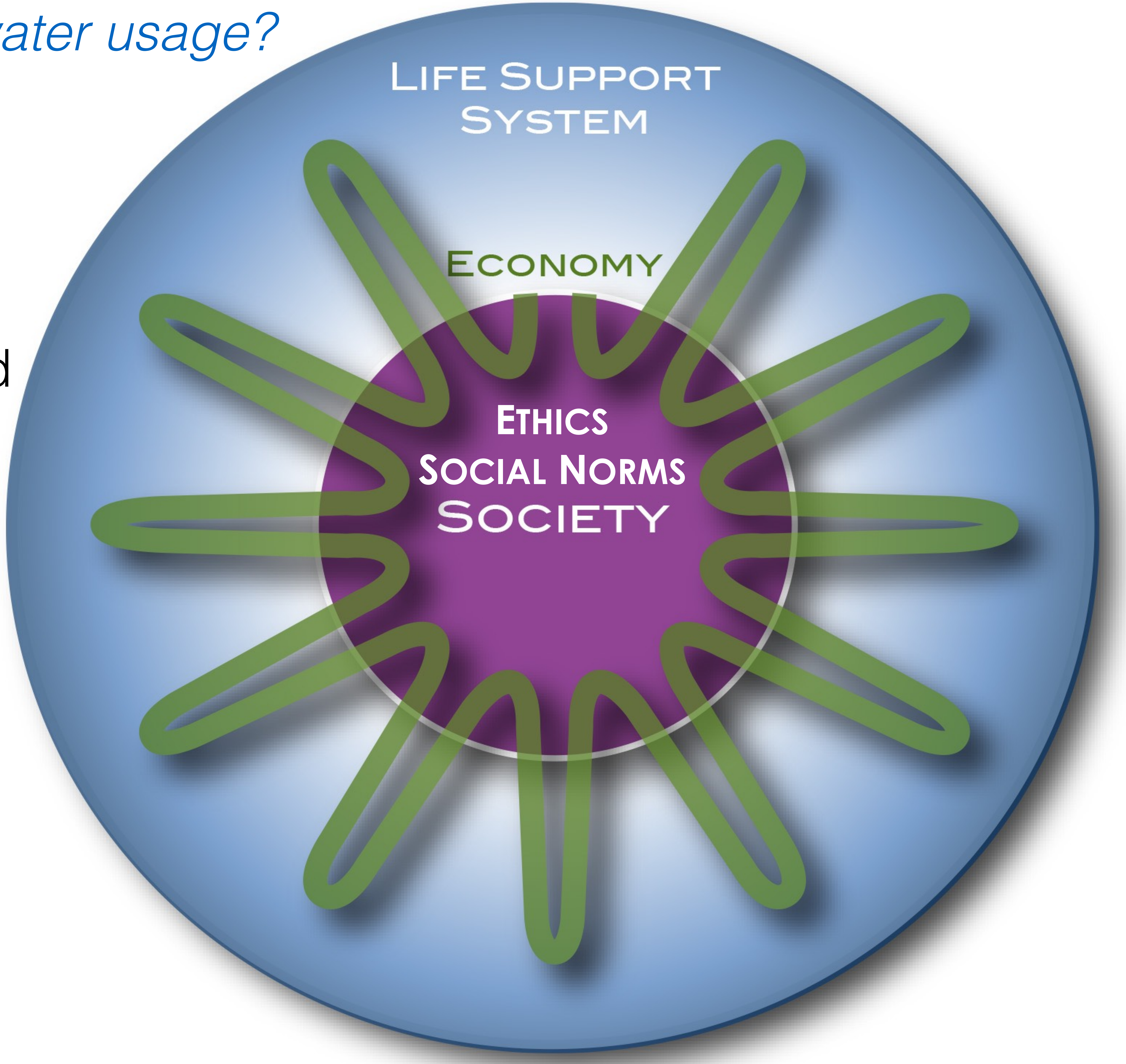
How are humans governing and managing water usage?

Conceptual Framework:
Earth is a Life-Support System

Everything is about Flows (physiology)

For human communities, flows are regulated by social norms, ethics, and - recently - mainstream economic rules,

Flows have accelerated by many orders of magnitude in the last 100 years



Demands and Needs

How are humans governing and managing water usage?

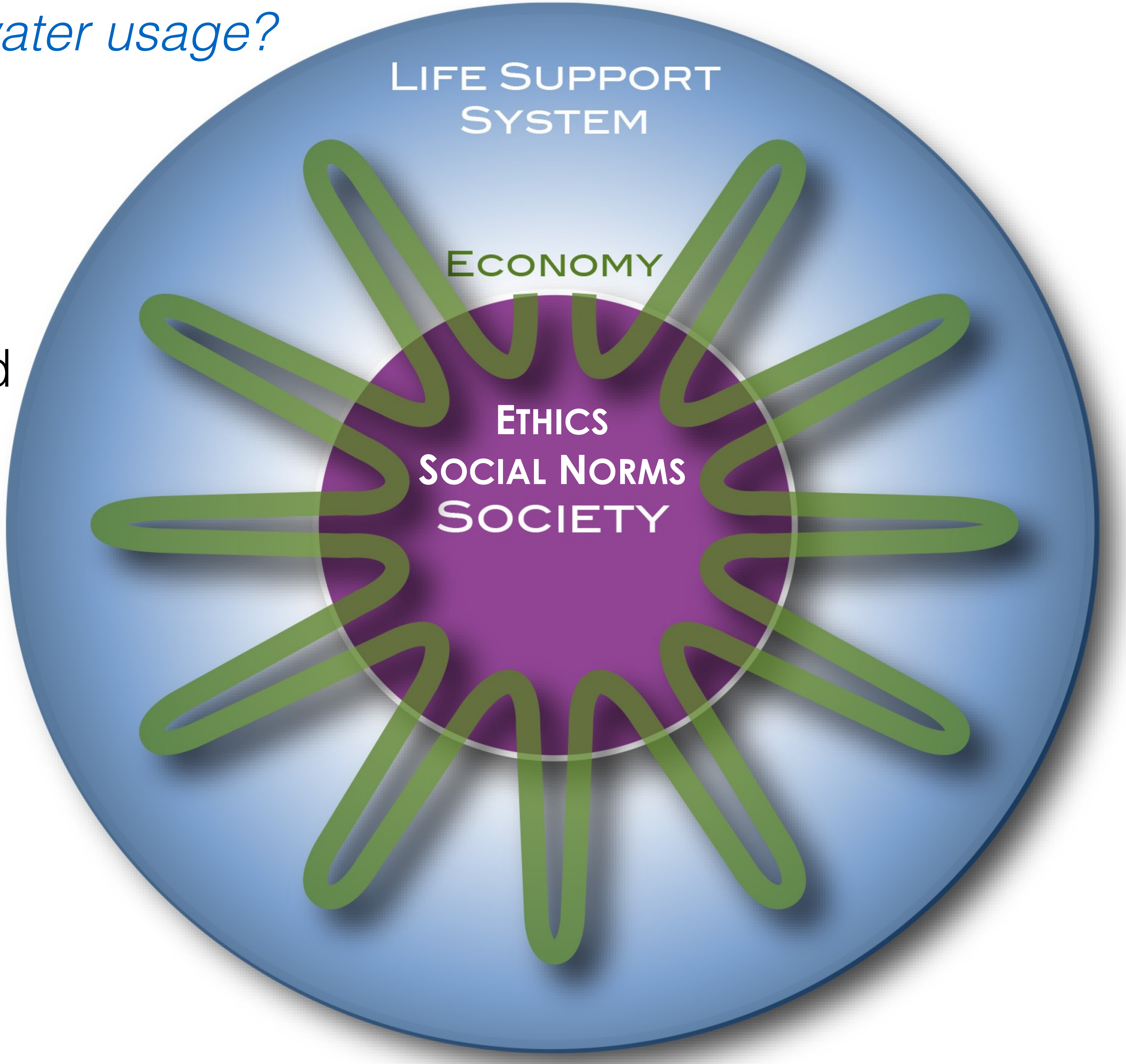
Conceptual Framework:
Earth is a Life-Support System

Everything is about Flows (physiology)

For human communities, flows are regulated by social norms, ethics, and - recently - mainstream economic rules,

Flows have accelerated by many orders of magnitude in the last 100 years

Flows from society into the Earth's life-support system are as important as the flows from the life-support system to society.



Demands and Needs

How are humans governing and managing water usage?

Conceptual Framework:
Earth is a Life-Support System

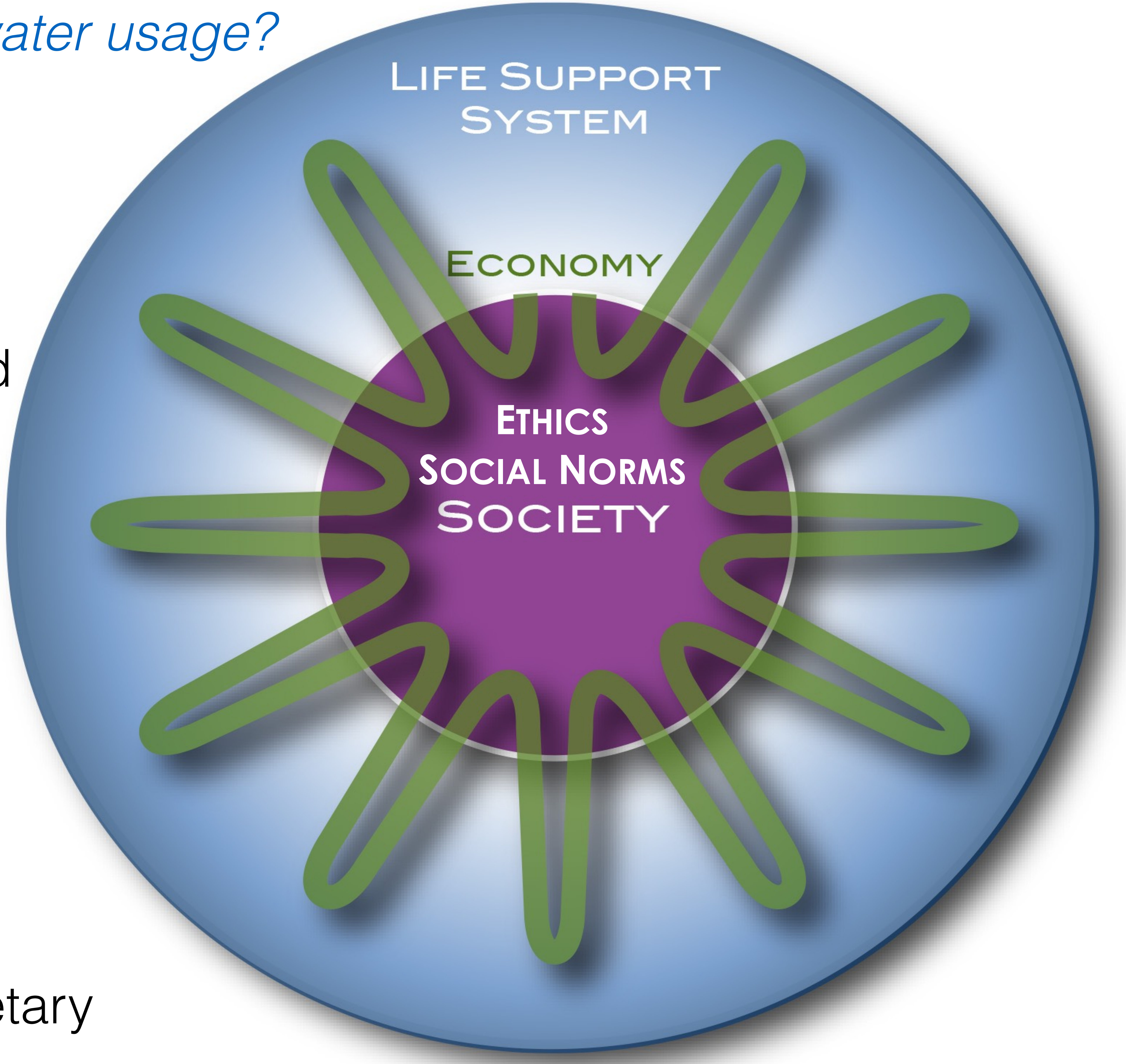
Everything is about Flows (physiology)

For human communities, flows are regulated by social norms, ethics, and - recently - mainstream economic rules,

Flows have accelerated by many orders of magnitude in the last 100 years

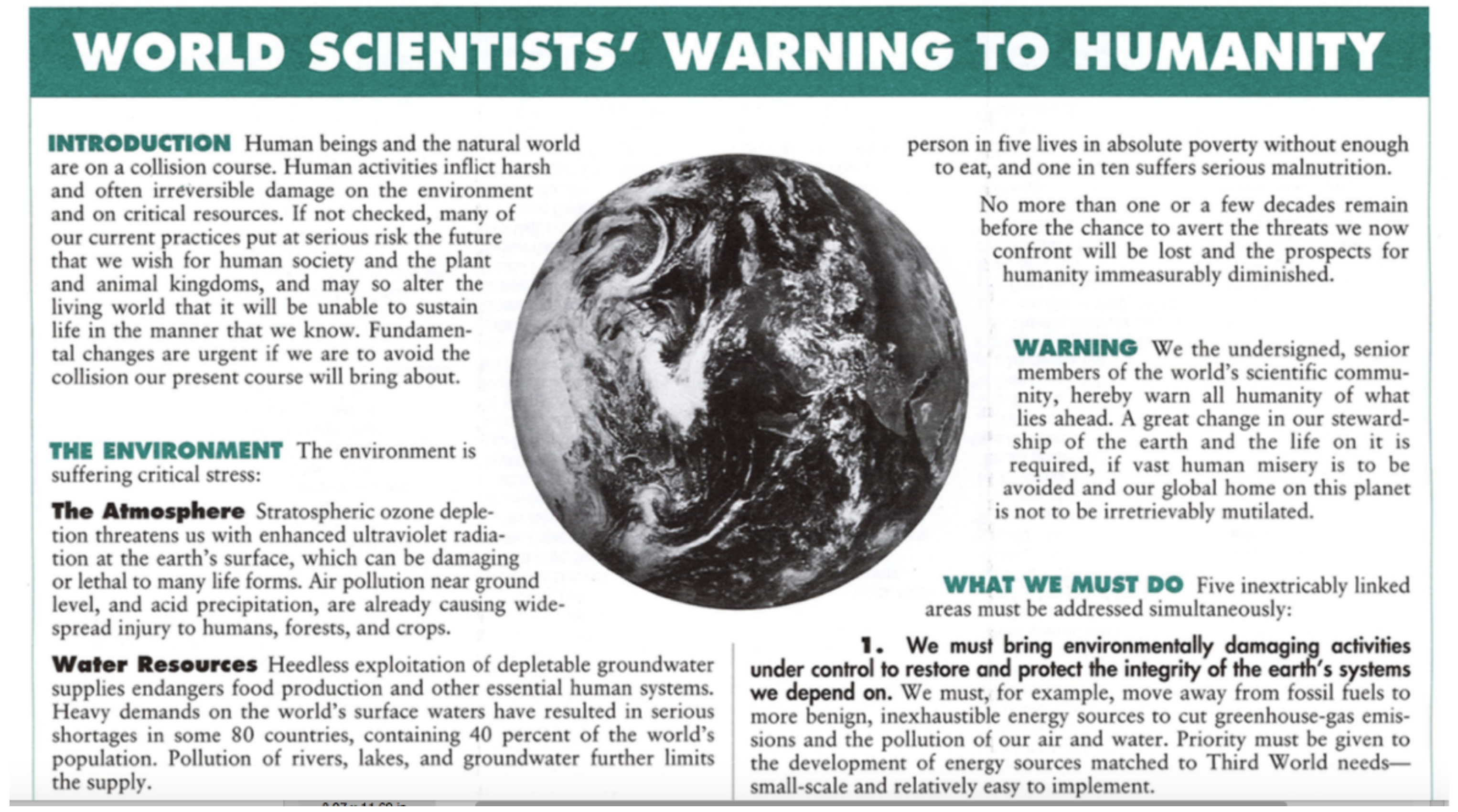
Flows from society into the Earth's life-support system are as important as the flows from the life-support system to society.

Flows also change the anatomy of the planetary life-support system.



Demands and Needs

How are humans governing and managing water usage?



WORLD SCIENTISTS' WARNING TO HUMANITY

INTRODUCTION Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about.

THE ENVIRONMENT The environment is suffering critical stress:

The Atmosphere Stratospheric ozone depletion threatens us with enhanced ultraviolet radiation at the earth's surface, which can be damaging or lethal to many life forms. Air pollution near ground level, and acid precipitation, are already causing widespread injury to humans, forests, and crops.

Water Resources Heedless exploitation of depletable groundwater supplies endangers food production and other essential human systems. Heavy demands on the world's surface waters have resulted in serious shortages in some 80 countries, containing 40 percent of the world's population. Pollution of rivers, lakes, and groundwater further limits the supply.

person in five lives in absolute poverty without enough to eat, and one in ten suffers serious malnutrition.

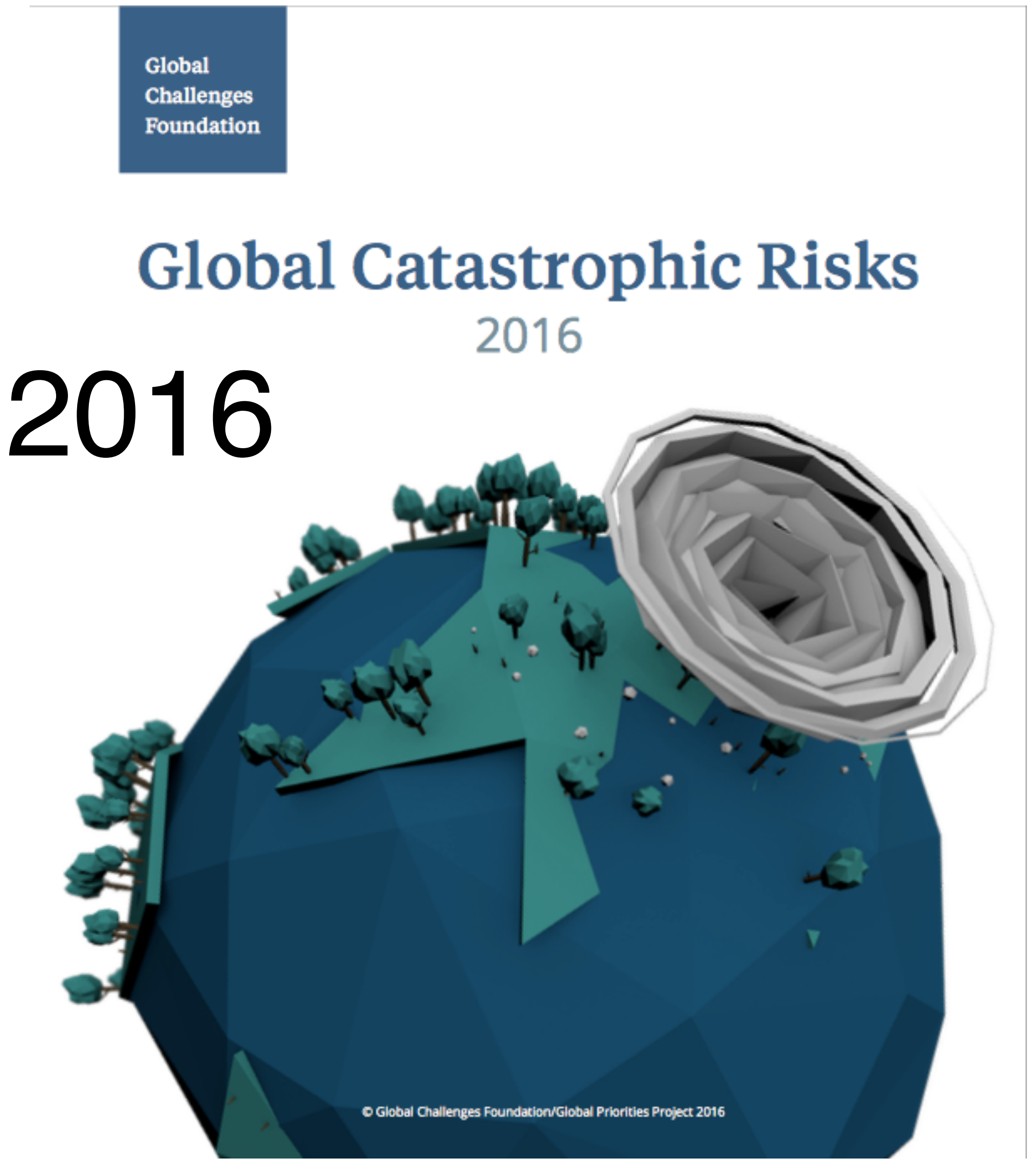
No more than one or a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished.

WARNING We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the earth and the life on it is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated.

WHAT WE MUST DO Five inextricably linked areas must be addressed simultaneously:

1. We must bring environmentally damaging activities under control to restore and protect the integrity of the earth's systems we depend on. We must, for example, move away from fossil fuels to more benign, inexhaustible energy sources to cut greenhouse-gas emissions and the pollution of our air and water. Priority must be given to the development of energy sources matched to Third World needs—small-scale and relatively easy to implement.

1992



2016

ipcc
INTERGOVERNMENTAL PANEL ON climate change

GLOBAL WARMING OF 1.5 °C

an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Summary for Policymakers

2018

This Summary for Policymakers was formally approved at the First Joint Session of Working Groups I, II and III of the IPCC and accepted by the 48th Session of the IPCC, Incheon, Republic of Korea, 6 October 2018.

World Scientists' Warning to Humanity: A Second Notice

2017

WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THOMAS M. NEWSOME, MAURO GALETTI, MOHAMMED ALAMGIR, EILEEN CRIST, MAHMOUD I. MAHMOUD, WILLIAM F. LAURANCE, and 15,364 scientist signatories from 184 countries

Trajectories of the Earth System in the Anthropocene

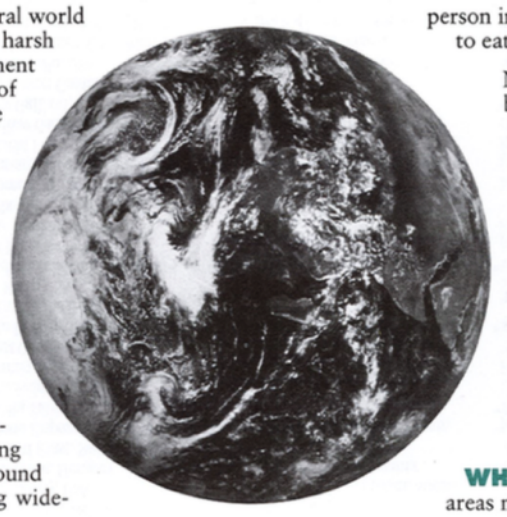
2018

Will Steffen[a,b,1], Johan Rockström[a], Katherine Richardson[c], Timothy M. Lenton[d], Carl Folke[a,e], Diana Liverman[f], Colin P. Summerhayes[g], Anthony D. Barnosky[h], Sarah E. Cornell[a], Michel Crucifix[i,j], Jonathan F. Donges[a,k], Ingo Fetzer[a], Steven J. Lade[a,b], Marten Scheffer[l], Ricarda Winkelmann[k,m], and Hans Joachim Schellnhuber[a,k,m,1]

How are humans governing and managing water usage?

WORLD SCIENTISTS' WARNING TO HUMANITY

INTRODUCTION Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about.



THE ENVIRONMENT The environment is suffering critical stress:

The Atmosphere Stratospheric ozone depletion threatens us with enhanced ultraviolet radiation at the earth's surface, which can be damaging or lethal to many life forms. Air pollution near ground level, and acid precipitation, are already causing widespread injury to humans, forests, and crops.

Water Resources Heedless exploitation of depletable groundwater supplies endangers food production and other essential human systems. Heavy demands on the world's surface waters have resulted in serious shortages in some 80 countries, containing 40 percent of the world's population. Pollution of rivers, lakes, and groundwater further limits the supply.

person in five lives in absolute poverty without enough to eat, and one in ten suffers serious malnutrition.

No more than one or a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished.

WARNING We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the earth and the life on it is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated.

WHAT WE MUST DO Five inextricably linked areas must be addressed simultaneously:

1. We must bring environmentally damaging activities under control to restore and protect the integrity of the earth's systems we depend on. We must, for example, move away from fossil fuels to more benign, inexhaustible energy sources to cut greenhouse-gas emissions and the pollution of our air and water. Priority must be given to the development of energy sources matched to Third World needs—small-scale and relatively easy to implement.

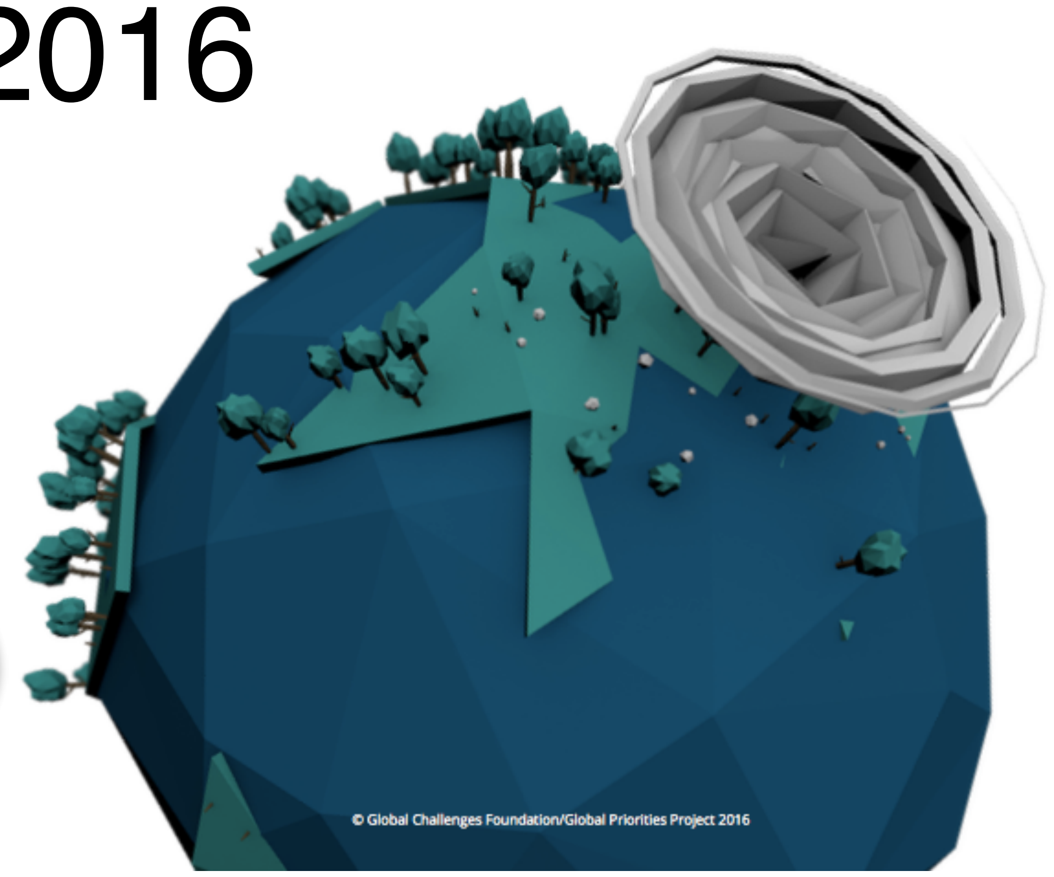
Water Resources Heedless exploitation of depletable groundwater supplies endangers food production and other essential human systems. Heavy demands on the world's surface waters have resulted in serious shortages in some 80 countries, containing 40 percent of the world's population. Pollution of rivers, lakes, and groundwater further limits the supply.

1992

Global Challenges Foundation

Global Catastrophic Risks

2016



2016

ipcc
INTERGOVERNMENTAL PANEL ON climate change

GLOBAL WARMING OF 1.5 °C

an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Summary for Policymakers

2018

This Summary for Policymakers was formally approved at the First Joint Session of Working Groups I, II and III of the IPCC and accepted by the 48th Session of the IPCC, Incheon, Republic of Korea, 6 October 2018.

World Scientists' Warning to Humanity: A Second Notice

2017

WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THOMAS M. NEWSOME, MAURO GALETTI, MOHAMMED ALAMGIR, EILEEN CRIST, MAHMOUD I. MAHMOUD, WILLIAM F. LAURANCE, and 15,364 scientist signatories from 184 countries

Trajectories of the Earth System in the Anthropocene

2018

Will Steffen[a,b,1], Johan Rockström[a], Katherine Richardson[c], Timothy M. Lenton[d], Carl Folke[a,e], Diana Liverman[f], Colin P. Summerhayes[g], Anthony D. Barnosky[h], Sarah E. Cornell[a], Michel Crucifix[i,j], Jonathan F. Donges[a,k], Ingo Fetzer[a], Steven J. Lade[a,b], Marten Scheffer[l], Ricarda Winkelmann[k,m], and Hans Joachim Schellnhuber[a,k,m,1]

Demands and Needs

How are humans governing and managing water usage?

WORLD SCIENTISTS' WARNING TO HUMANITY

INTRODUCTION Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about.

THE ENVIRONMENT The environment is suffering critical stress:

The Atmosphere Stratospheric ozone depletion threatens us with enhanced ultraviolet radiation at the earth's surface, which can be damaging or lethal to many life forms. Air pollution near ground level, and acid precipitation, are already causing widespread injury to humans, forests, and crops.

Water Resources Heedless exploitation of depletable groundwater supplies endangers food production and other essential human systems. Heavy demands on the world's surface waters have resulted in serious shortages in some 80 countries, containing 40 percent of the world's population. Pollution of rivers, lakes, and groundwater further limits the supply.

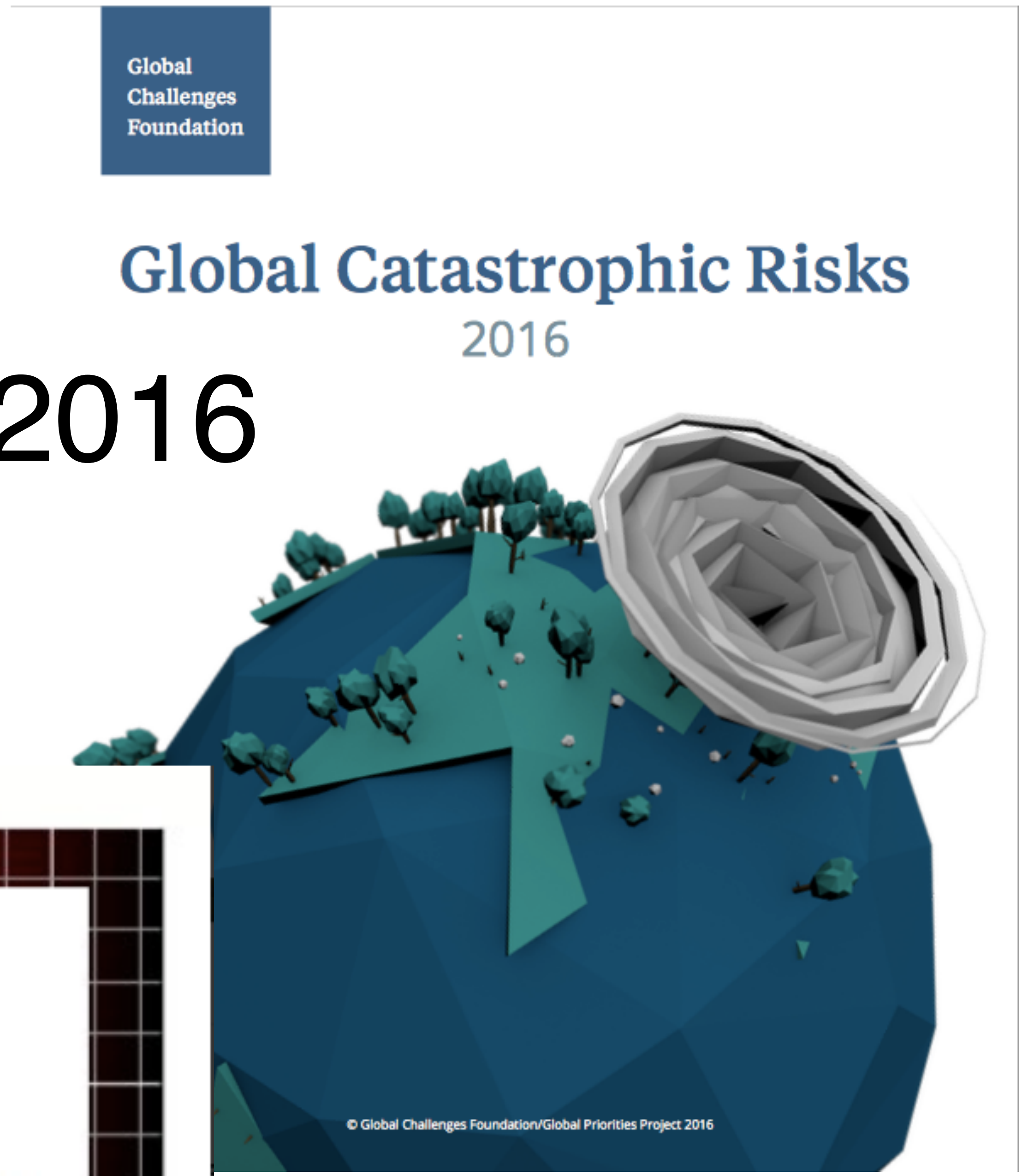
person in five lives in absolute poverty without enough to eat, and one in ten suffers serious malnutrition.

No more than one or a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished.

WARNING We the undersigned, senior members of the world's scientific community, hereby warn all humanity of what lies ahead. A great change in our stewardship of the earth and the life on it is required, if vast human misery is to be avoided and our global home on this planet is not to be irretrievably mutilated.

WHAT WE MUST DO Five inextricably linked areas must be addressed simultaneously:

1. We must bring environmentally damaging activities under control to restore and protect the integrity of the earth's systems we depend on. We must, for example, move away from fossil fuels to more benign, inexhaustible energy sources to cut greenhouse-gas emissions and the pollution of our air and water. Priority must be given to the development of energy sources matched to Third World needs—small-scale and relatively easy to implement.



2016

ipcc
INTERGOVERNMENTAL PANEL ON climate change

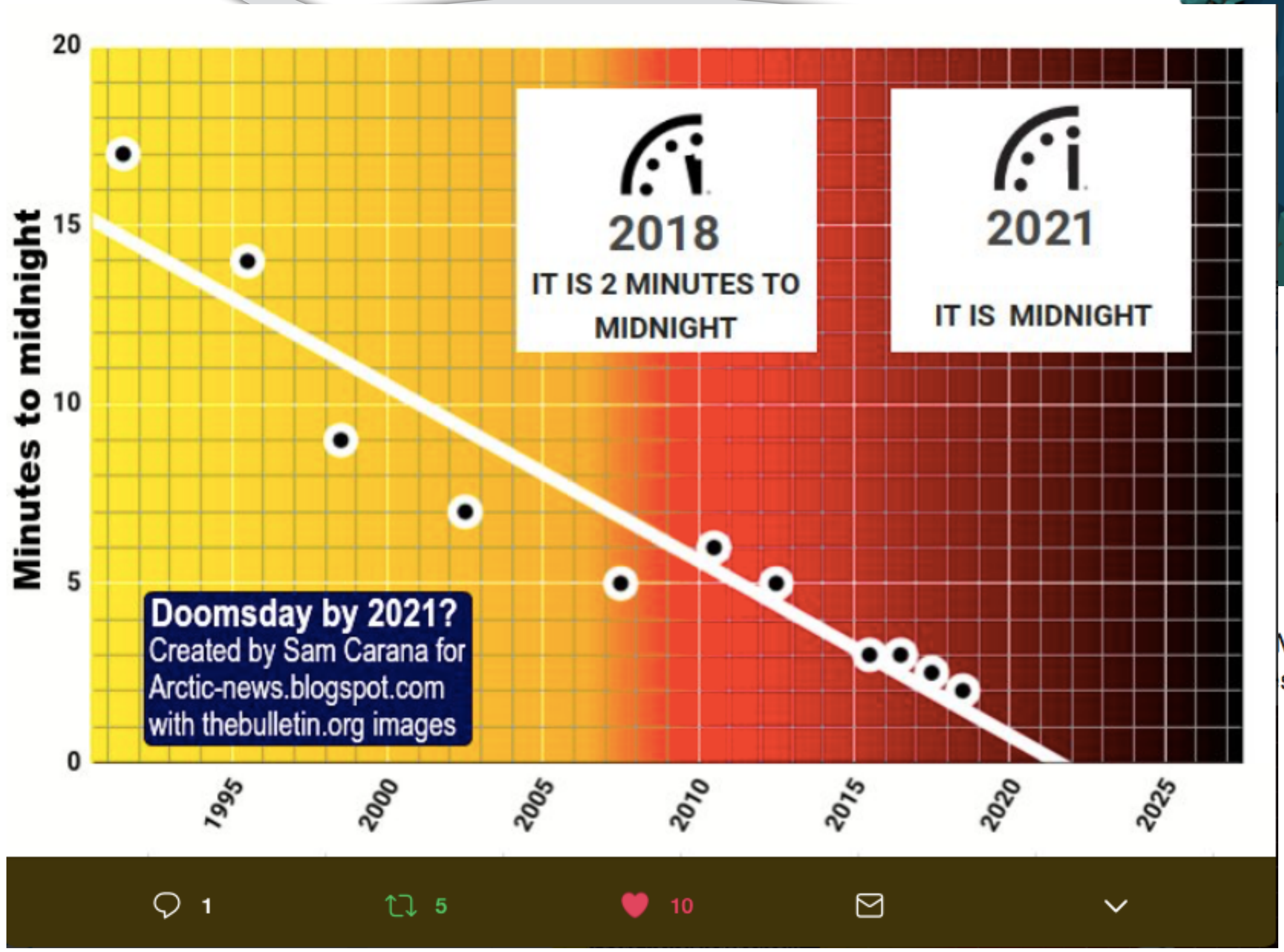
GLOBAL WARMING OF 1.5 °C

an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

Summary for Policymakers

This Summary for Policymakers was formally approved at the First Joint Session of Working Groups I, II and III of the IPCC and accepted by the 48th Session of the IPCC, Incheon, Republic of Korea, 6 October 2018.

2018



Bulletin of the Atomic Scientists

MGIR, EILEEN CRIST,

s

Trajectories of the Earth System in the Anthropocene

Will Steffen[a,b,1], Johan Rockström[a], Katherine Richardson[c], Timothy M. Lenton[d], Carl Folke[a,e], Diana Liverman[f], Colin P. Summerhayes[g], Anthony D. Barnosky[h], Sarah E. Cornell[a], Michel Crucifix[i,j], Jonathan F. Donges[a,k], Ingo Fetzer[a], Steven J. Lade[a,b], Marten Scheffer[l], Ricarda Winkelmann[k,m], and Hans Joachim Schellnhuber[a,k,m,1]

2018

Demands and Needs

How are humans governing and managing water usage?

Demands and Needs

How are humans governing and managing water usage?

Each Goal comes with up to 10 Targets and each Target with up to 2 Indicators.

Demands and Needs

How are humans governing and managing water usage?

Each Goal comes with up to 10 Targets and each Target with up to 2 Indicators.

Demands and Needs

How are humans governing and managing water usage?

Chapter IV. Beyond Sustainable Development Goal 6: Connections across the 2030 Agenda

A. Water and society

B. Water and the environment

C. Water and the economy

http://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018-on-water-and-sanitation/

Demands and Needs

How are humans governing and managing water usage?

http://www.unwater.org/publication_categories/sdg-6-synthesis-report-2018-on-water-and-sanitation/

Demands and Needs

How are humans governing and managing water usage?

Human criteria and principles

Normative content of the right (criteria)

Procedural aspects (HR principles)

AVAILABILITY

QUALITY

AFFORDABILITY

ACCEPTABILITY

ACCESSIBILITY

ACCESS TO INFORMATION

NON-DISCRIMINATION

ACCOUNTABILITY

PARTICIPATIO
N

SUSTAINABILIT
Y

Alabaster, 2018

How are humans governing and managing water usage?

A Legally binding HR obligation

Alabaster, 2018

Demands and Needs

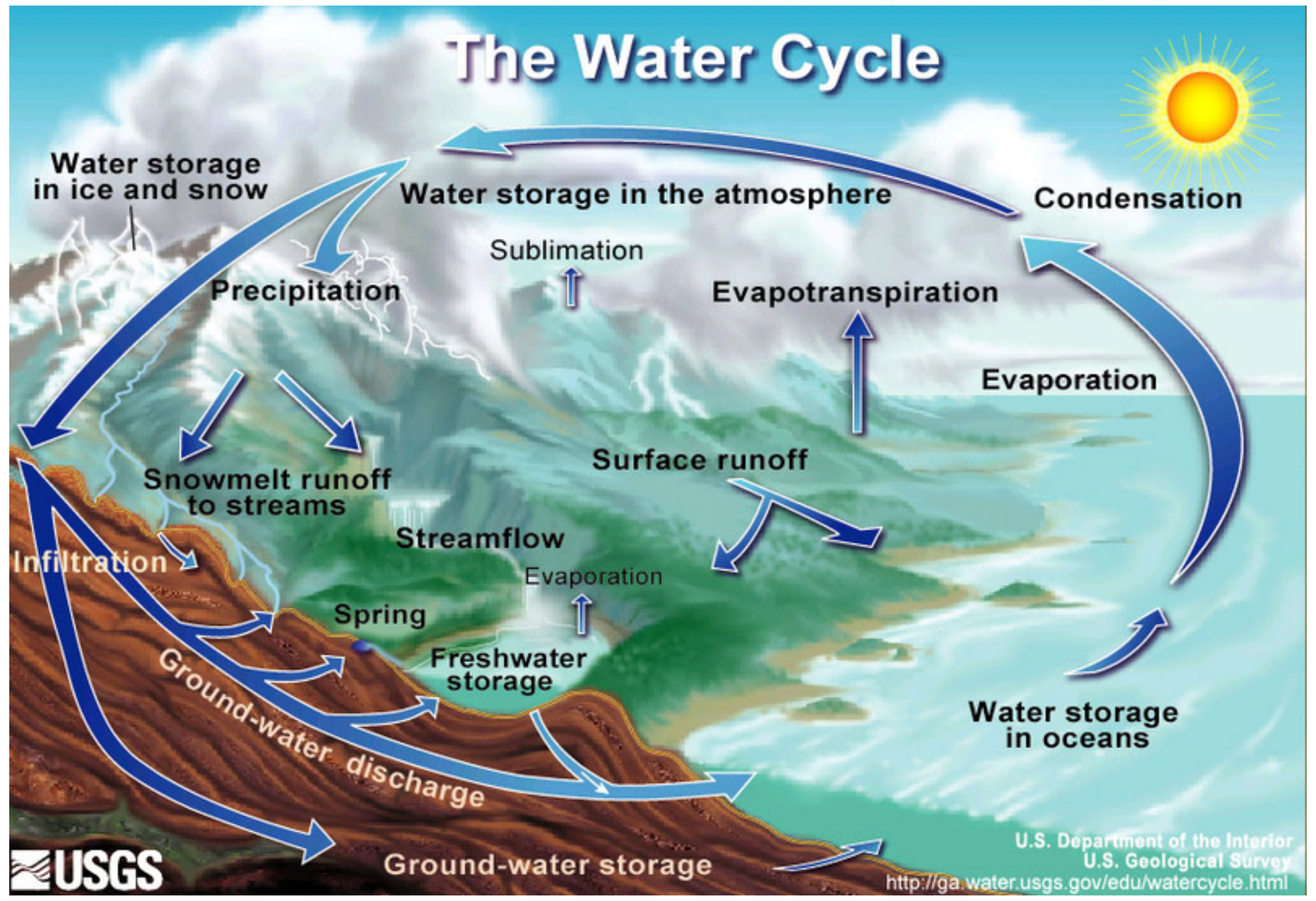
How are humans governing and managing water usage?

Increasing challenges with water allocation.
Example:
Nile River

https://www.cnn.com/2018/10/19/africa/ethiopia-new-dam-threatens-egypts-water/index.html

Supplies

How is fresh water distributed in space and time and what is its quality?



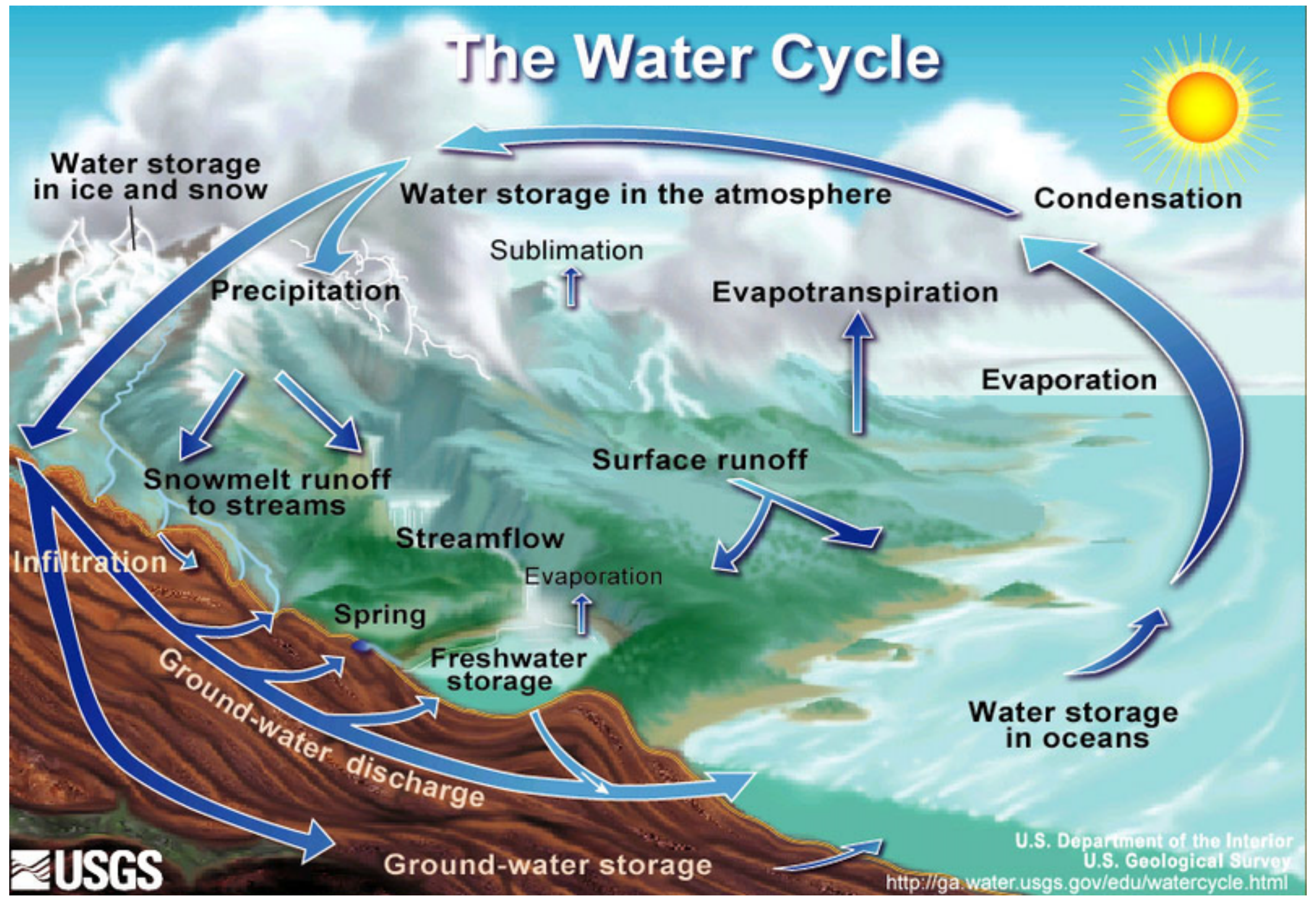
https://scied.ucar.edu/longcontent/water-cycle

Table 1: Amounts of water in the cycle

Reservoir	Volume	% of a larger reservoir
All of Earth's water	1,386,000,000 to 1,460,000,000 km^3	NA
Oceans	1,338,000,000 to 1,400,000,000 km^3	97% of total water
Freshwater	35,030,000 km^3	2.5 to 3% of total water
Ice and Snow	43,400,000 km^3	2.5-3% of fresh water
Ice caps, glaciers, and permanent snow	24,064,000 to 29,000,000 km^3	68.7% of fresh water about 2% of total water
Antarctic ice & snow	29,000,000 km^3	about 90% of all ice
Greenland	3,000,000 km^3	about 10% of all ice
Mountain Glaciers	100,000 km^3	-
Ground water (saline+fresh)	23,400,000 km^3	-
Ground water (saline)	-	54% of ground water
Ground water (fresh)	10,530,000 km^3	30.1% of fresh water 46% of ground water
Surface Freshwater	350,300 km^3	1% of fresh water
Lakes	-	87% of surface fresh water
Swamps	-	11% of surface fresh water
Rivers	-	2% of surface fresh water
Atmosphere	12,000 to 15,000 km^3	-

Supplies

How large are the flows of fresh water and are these flows changing?



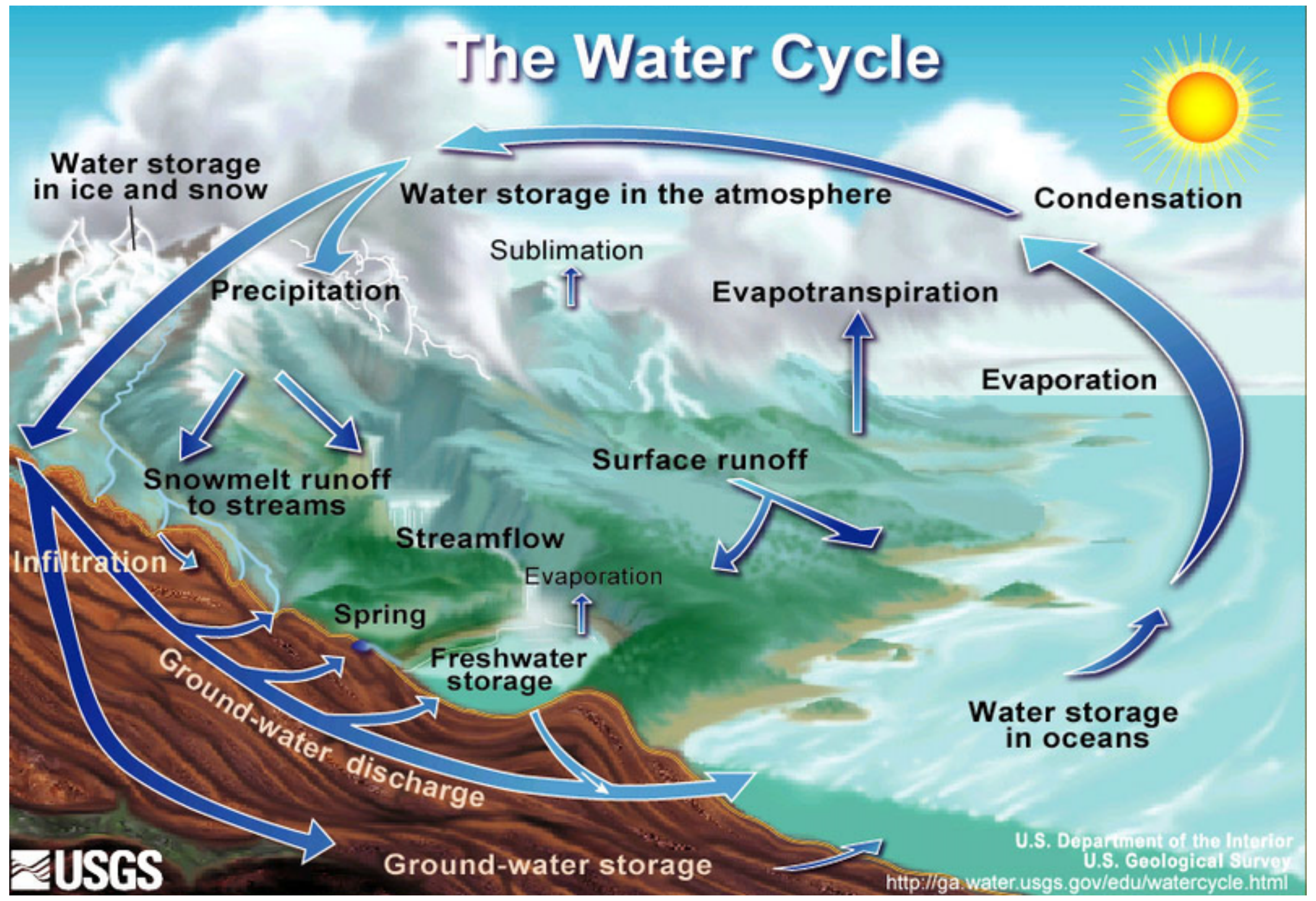
https://scied.ucar.edu/longcontent/water-cycle

Table 2: Flows between reservoirs

Process	From/to Reservoir	>Flow Rate
Precipitation	Atmosphere to Ocean/Land	505,000 km^3/year
Ocean precipitation	Atmosphere to Ocean	398,000 km^3/year
Land precipitation (except snow?)	Atmosphere to Land/surface	96,000 to 107,000 km^3/year
Evapotranspiration	Ocean and Land/surface and Plants to Atmosphere	505,000 km^3/year
Ocean evaporation	Ocean to Atmosphere	434,000 km^3/year
Land evaporation	Land/surface to Atmosphere	50,000 km^3/year
Transpiration	Plants to Atmosphere	21,000 km^3/year
Uptake by plants	Land/surface to Biota	21,000 km^3/year
Runoff	Land/surface to Ocean	36,000 km^3/year
Melting	Ice/snow to Land/surface	11,000 km^3/year
Snowfall (on land only?)	Atmosphere to Ice/Snow	11,000 km^3/year
Percolation	Underground to and from (??) Land/surface	100 km^3/year

Supplies

How large are the flows of fresh water and are these flows changing?



https://scied.ucar.edu/longcontent/water-cycle

Table 3: Residence times in reservoirs

Reservoir	Residence Time (average)
Oceans	3,000 to 3,230 years
Glaciers	20 to 100 years
Seasonal Snow Cover	2 to 6 months
Soil Moisture	1 to 2 months
Groundwater: Shallow	100 to 200 years
Groundwater: Deep	10,000 years
Lakes	50 to 100 years
Rivers	2 to 6 months
Atmosphere	9 days

Supplies

How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?

Supplies

How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?

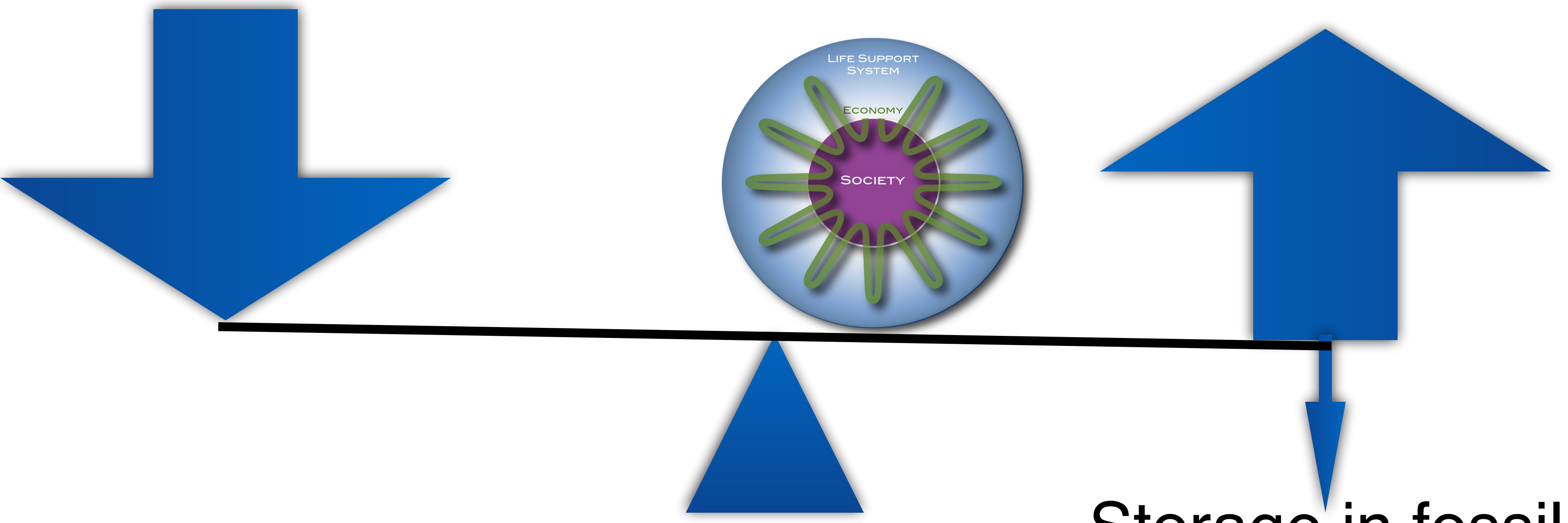
Energy flows from fossil fuels => human activities => life-support system.
This impacts other flows in a “re-engineered” system and amplifies imbalances:

In a Dissipative System, small changes in a sub-system can change the characteristics of the system …

Supplies

How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?

Energy flows from fossil fuels => human activities => life-support system.
This impacts other flows in a “re-engineered” system and amplifies imbalances:



Imbalance on the order of 10^{-10}

Last 200 Million years

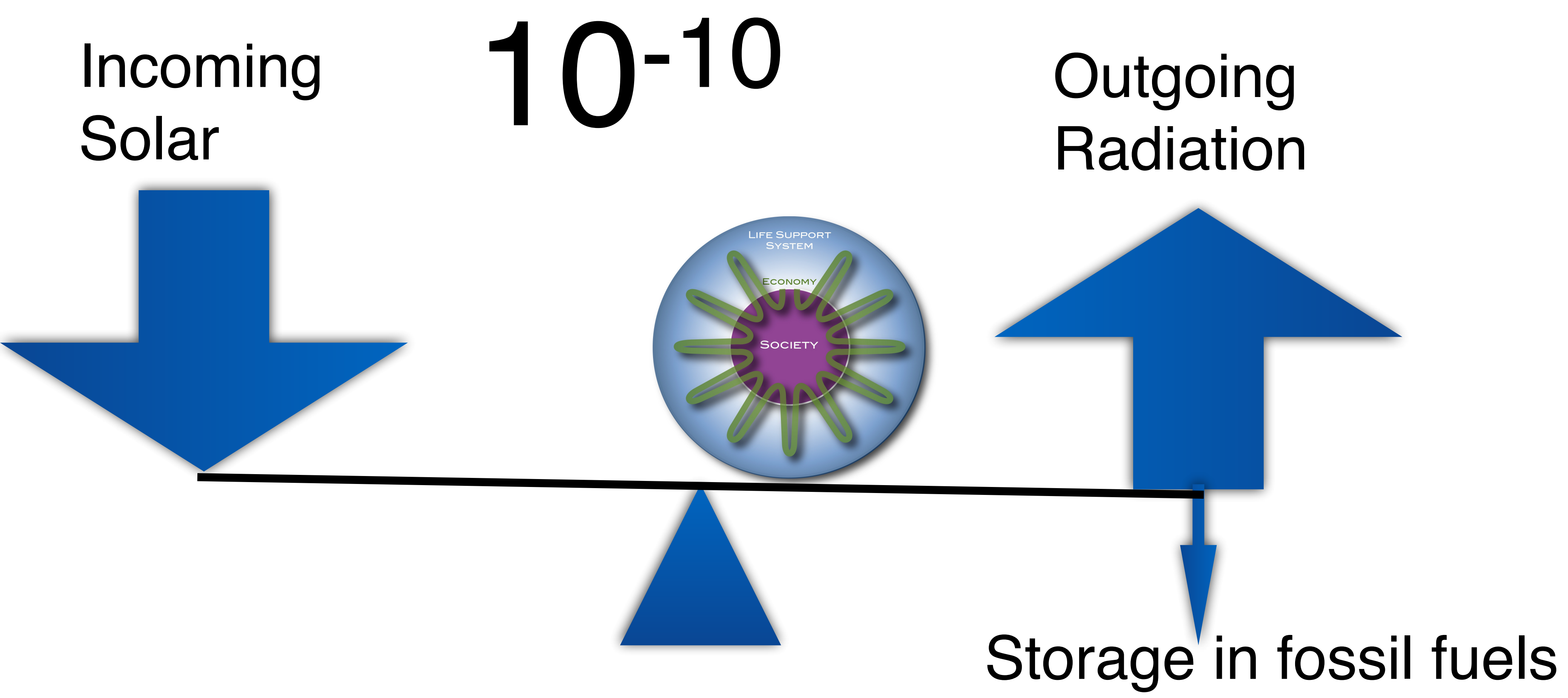
Total energy storage in 200 Myrs:
Order 100-1000 ZetaJoules

In a Dissipative System, small changes in a sub-system can change the characteristics of the system …

Supplies

How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?

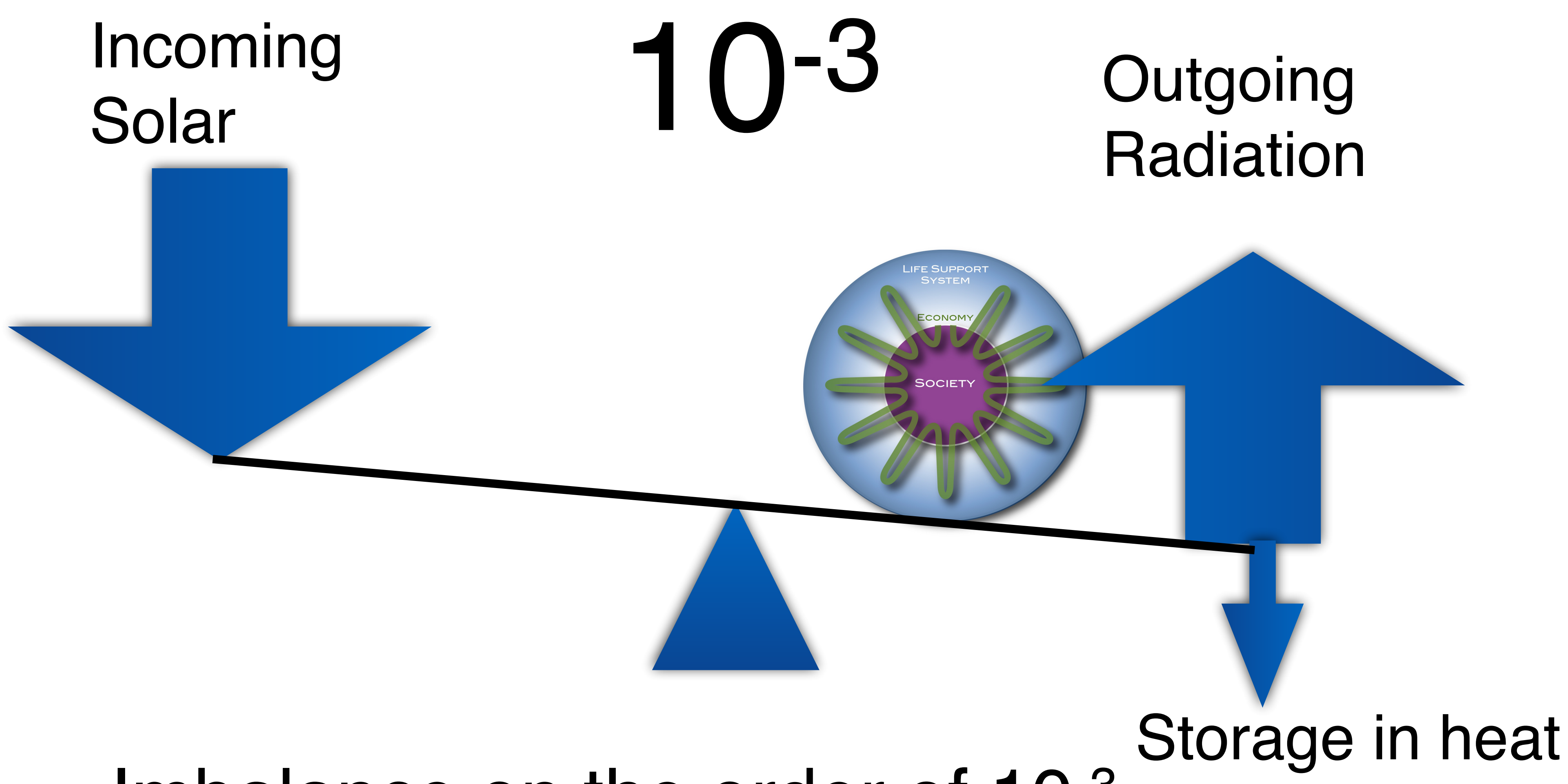
Energy flows from fossil fuels => human activities => life-support system.
This impacts other flows in a “re-engineered” system and amplifies imbalances:



Imbalance on the order of 10^{-10}

Last 200 Million years

Total energy storage in 200 Myrs:
Order 100-1000 ZetaJoules



Imbalance on the order of 10^{-3}

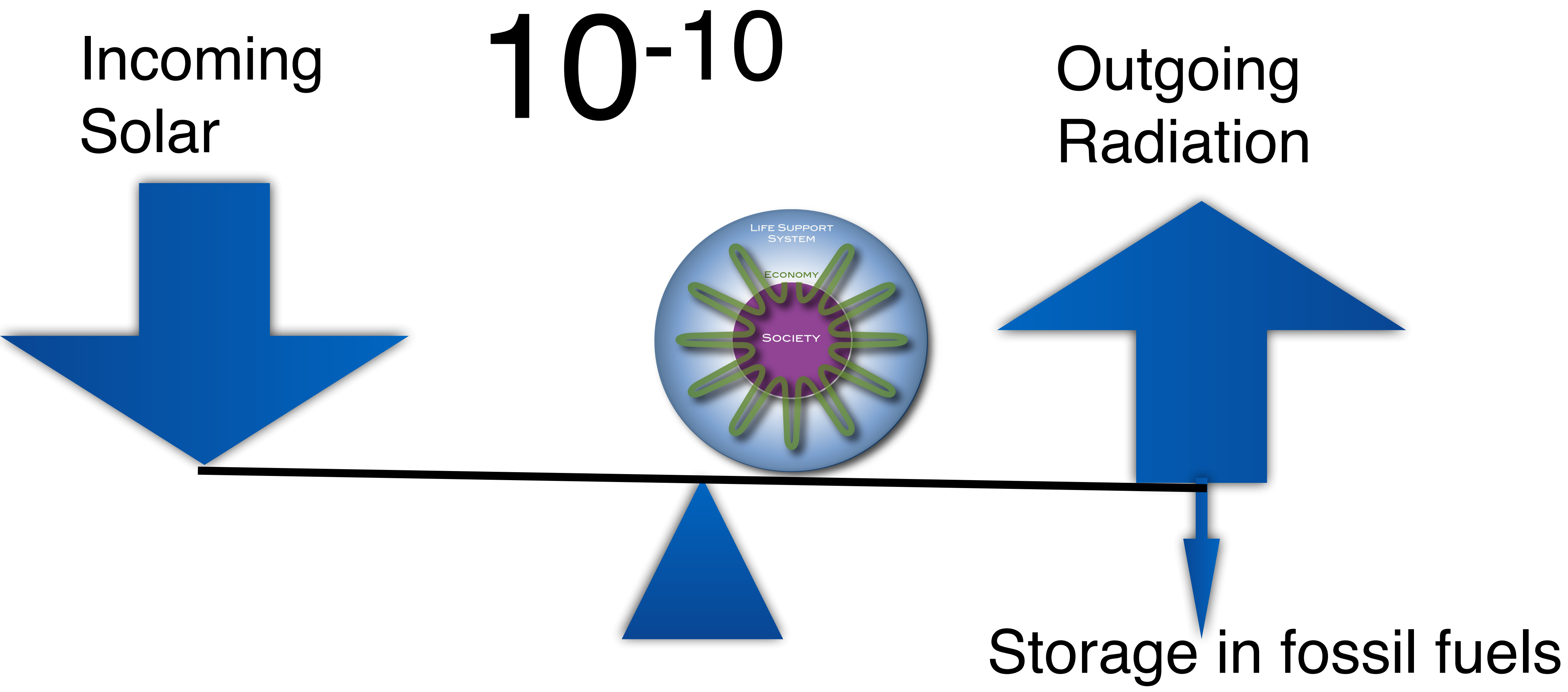
Last 70 years

Total energy storage per century:
Order 1000 ZetaJoules

Supplies

How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?

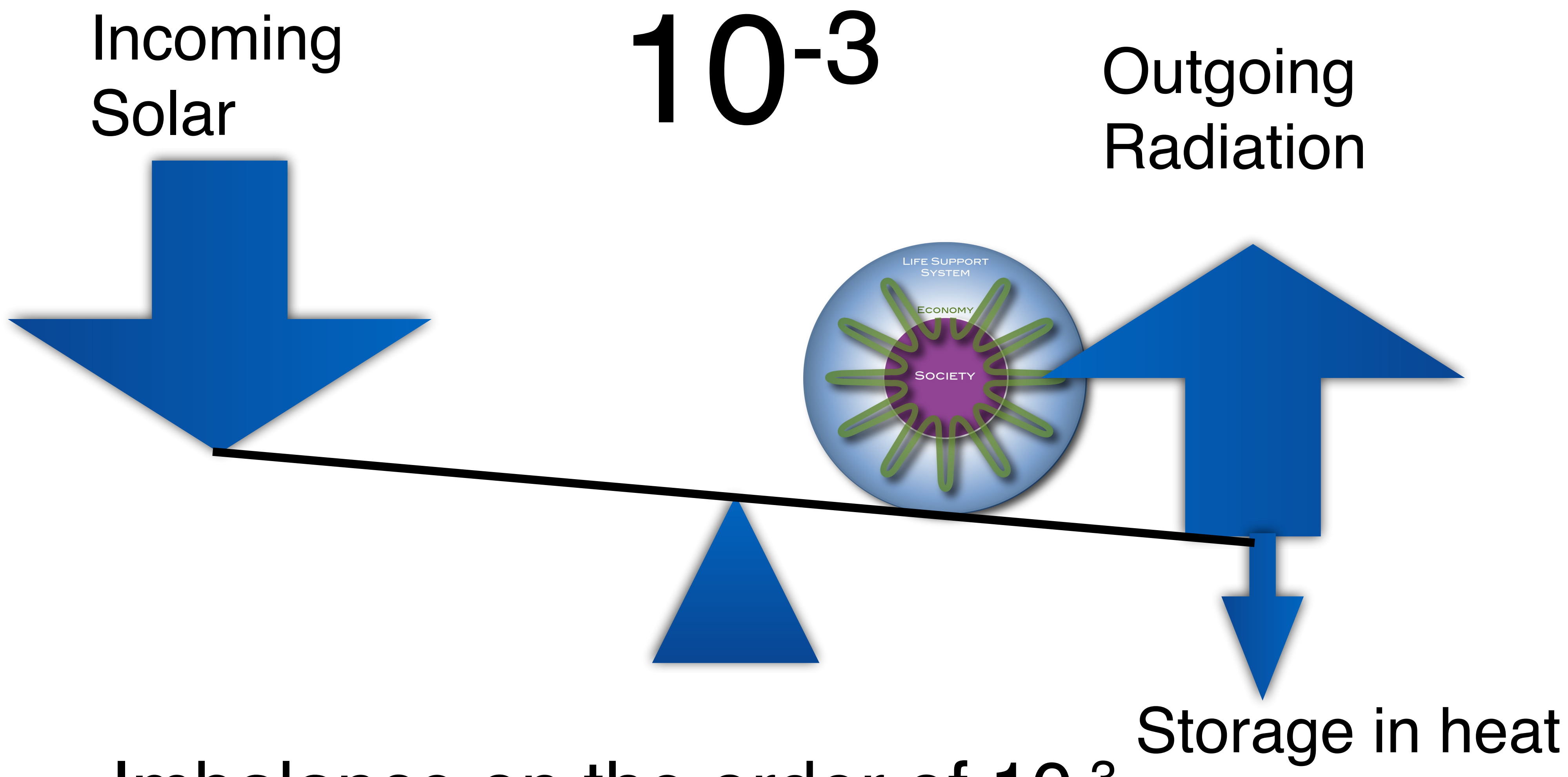
Energy flows from fossil fuels => human activities => life-support system.
This impacts other flows in a “re-engineered” system and amplifies imbalances:



Imbalance on the order of 10^{-10}

Last 200 Million years

Total energy storage in 200 Myrs:
Order 100-1000 ZetaJoules



Imbalance on the order of 10^{-3}

Last 70 years

Total energy storage per century:
Order 1000 ZetaJoules

What increased the Earth’s energy imbalance by a factor of 10^6 to 10^7?

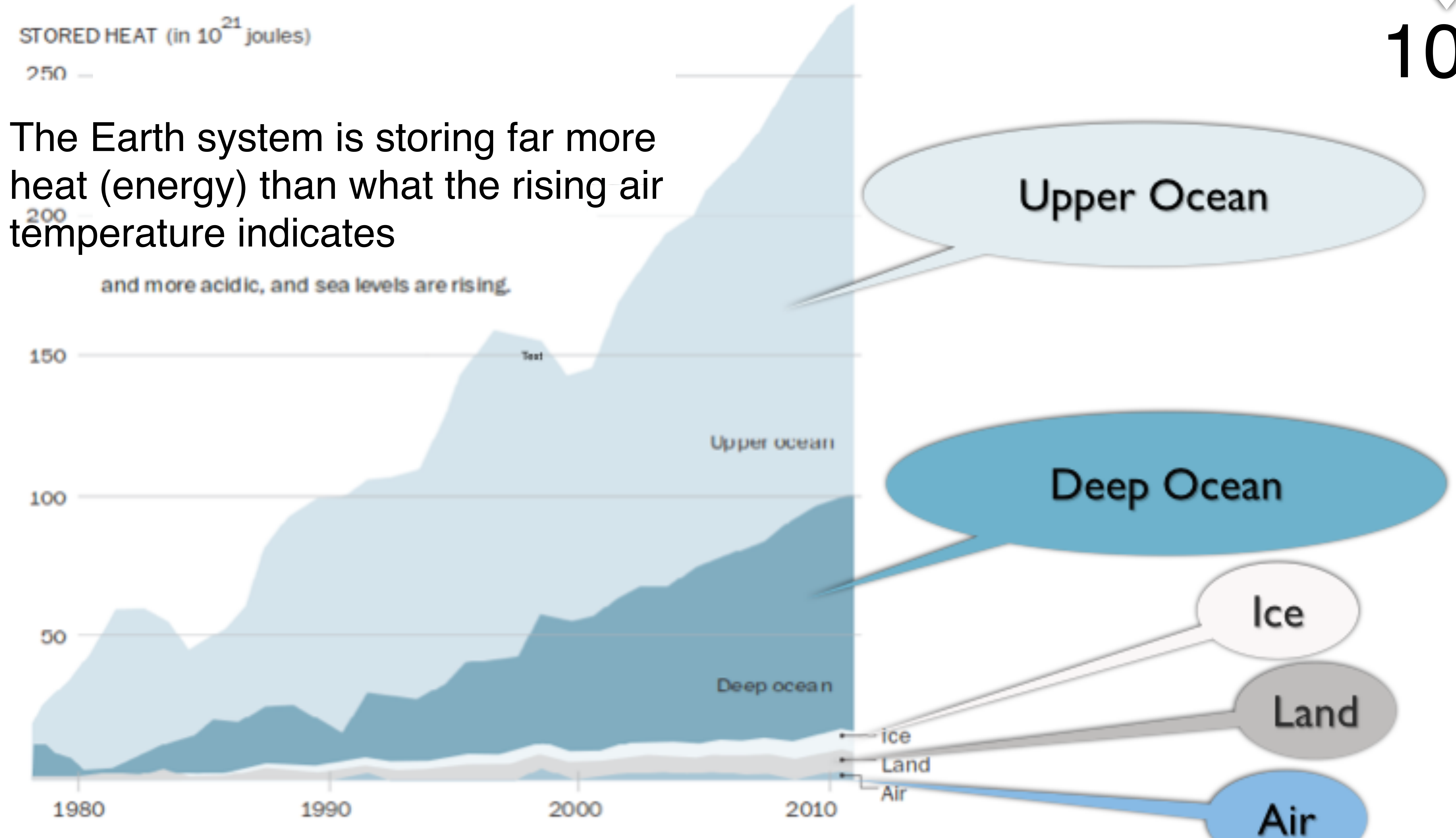
Earth's Energy Imbalance

- Long-term due to photosynthesis: 10-100 MegaWatt
- Today: 300-320 TeraWatt

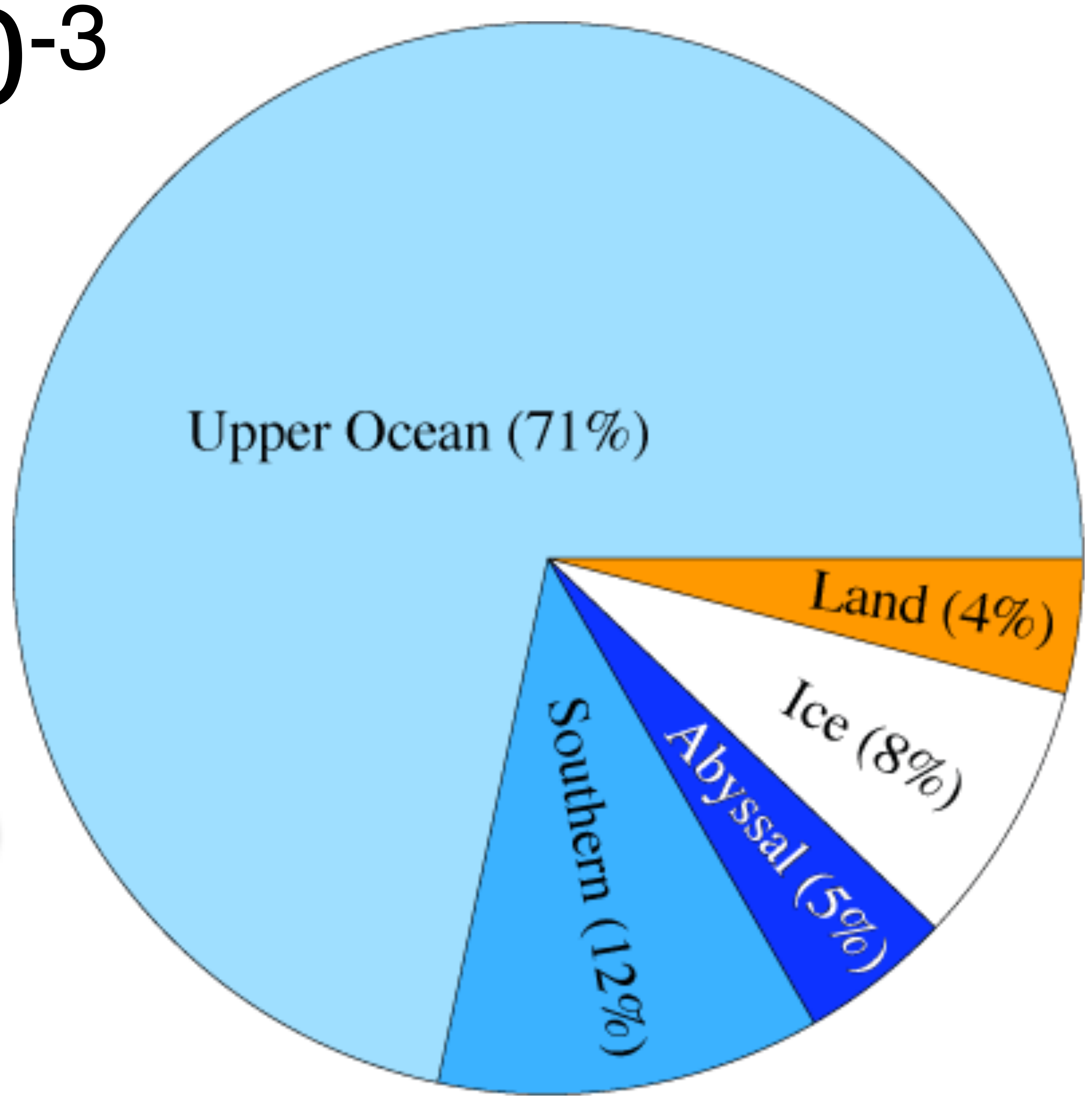
10^{-10} to 10^{-9}

10^{-3}

The Earth system is storing far more heat (energy) than what the rising air temperature indicates



SOURCE: IPCC Fifth Assessment Synthesis Report. GRAPHIC: Patterson Clark - The Washington Post. Published Nov. 2, 2014.



The Pool-House Effect

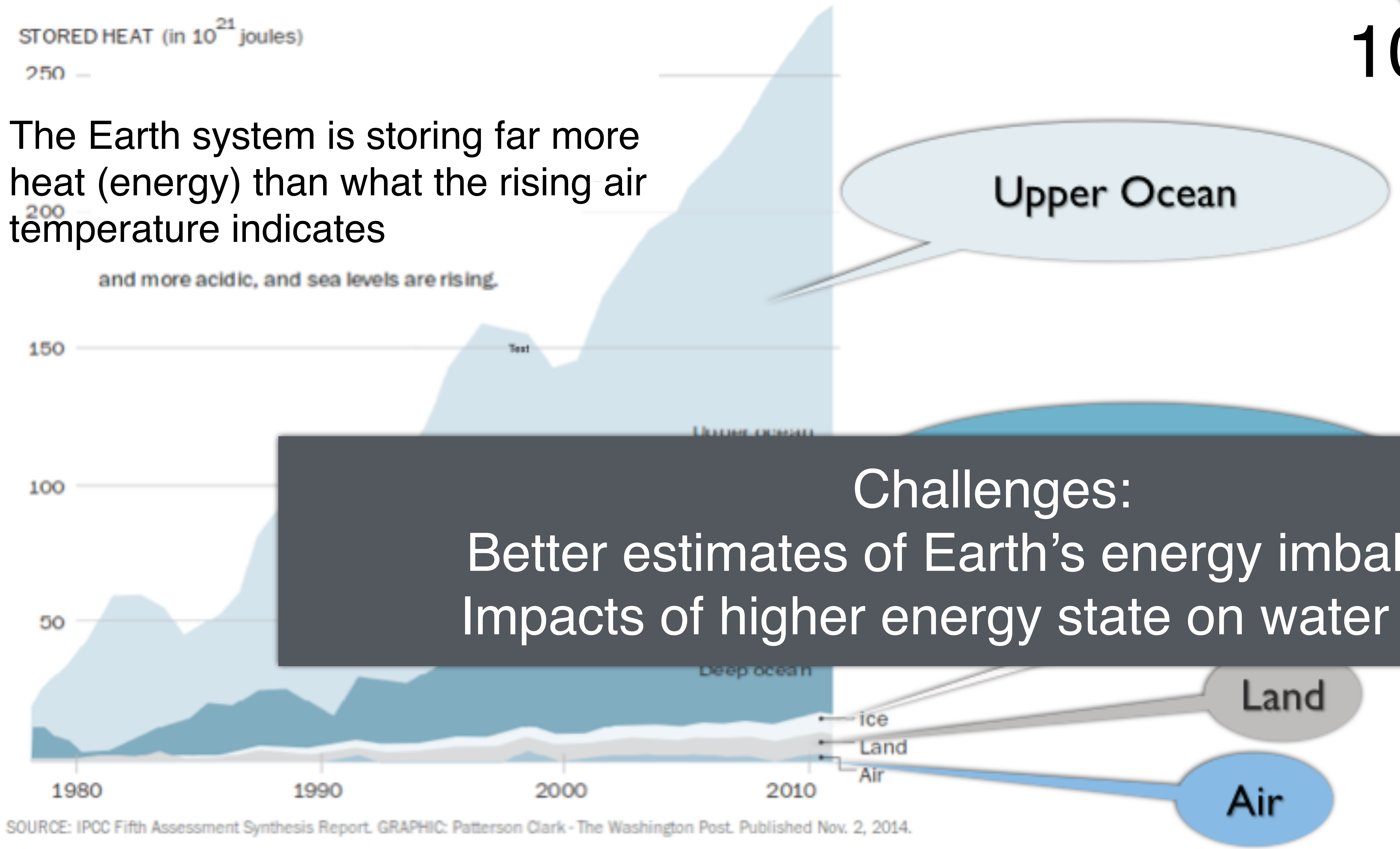
Supplies

Earth's Energy Imbalance

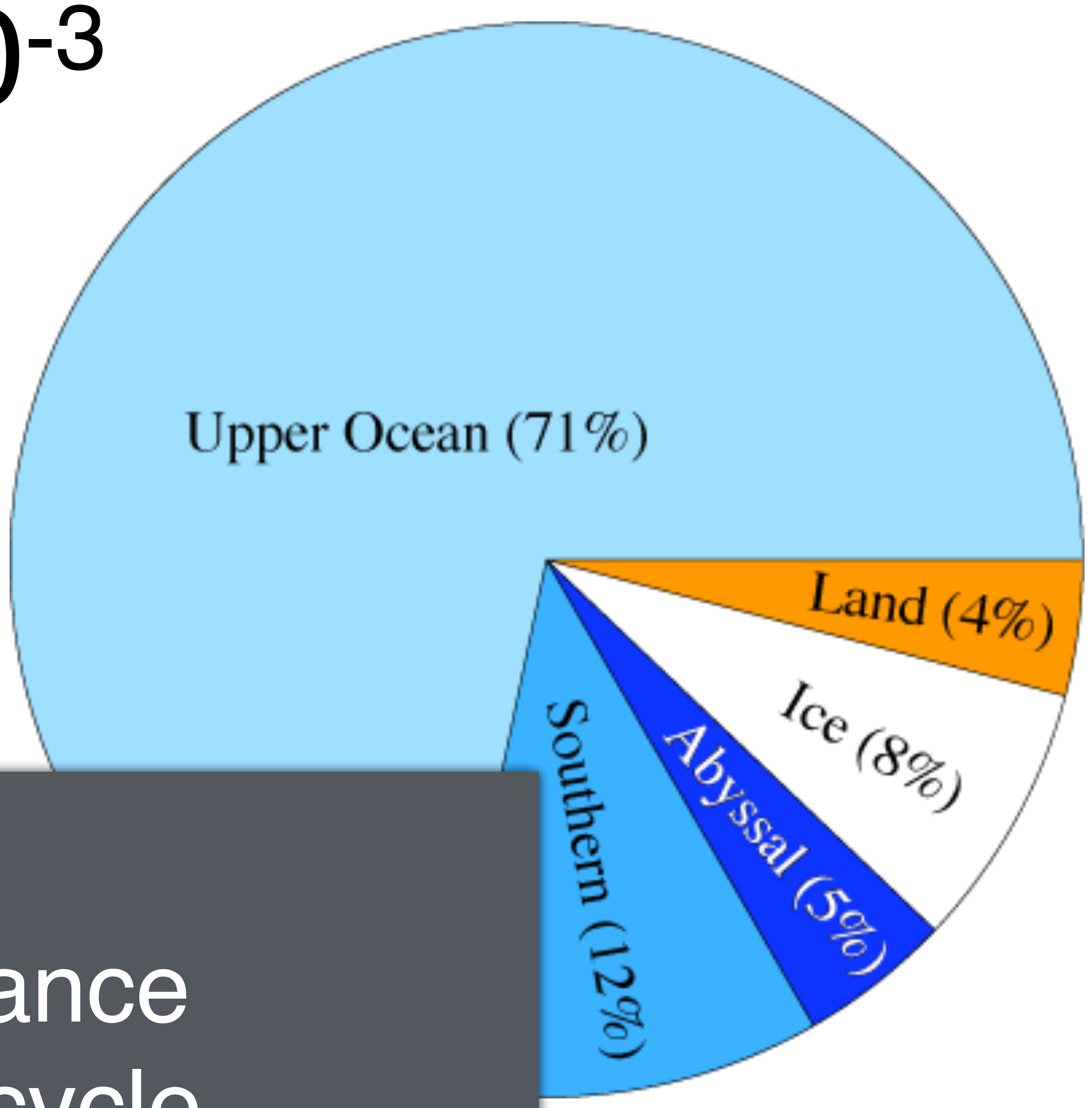
- Long-term due to photosynthesis: 10-100 MegaWatt
- Today: 300-320 TeraWatt

10^{-10} to 10^{-9}

10^{-3}



The Earth system is storing far more heat (energy) than what the rising air temperature indicates

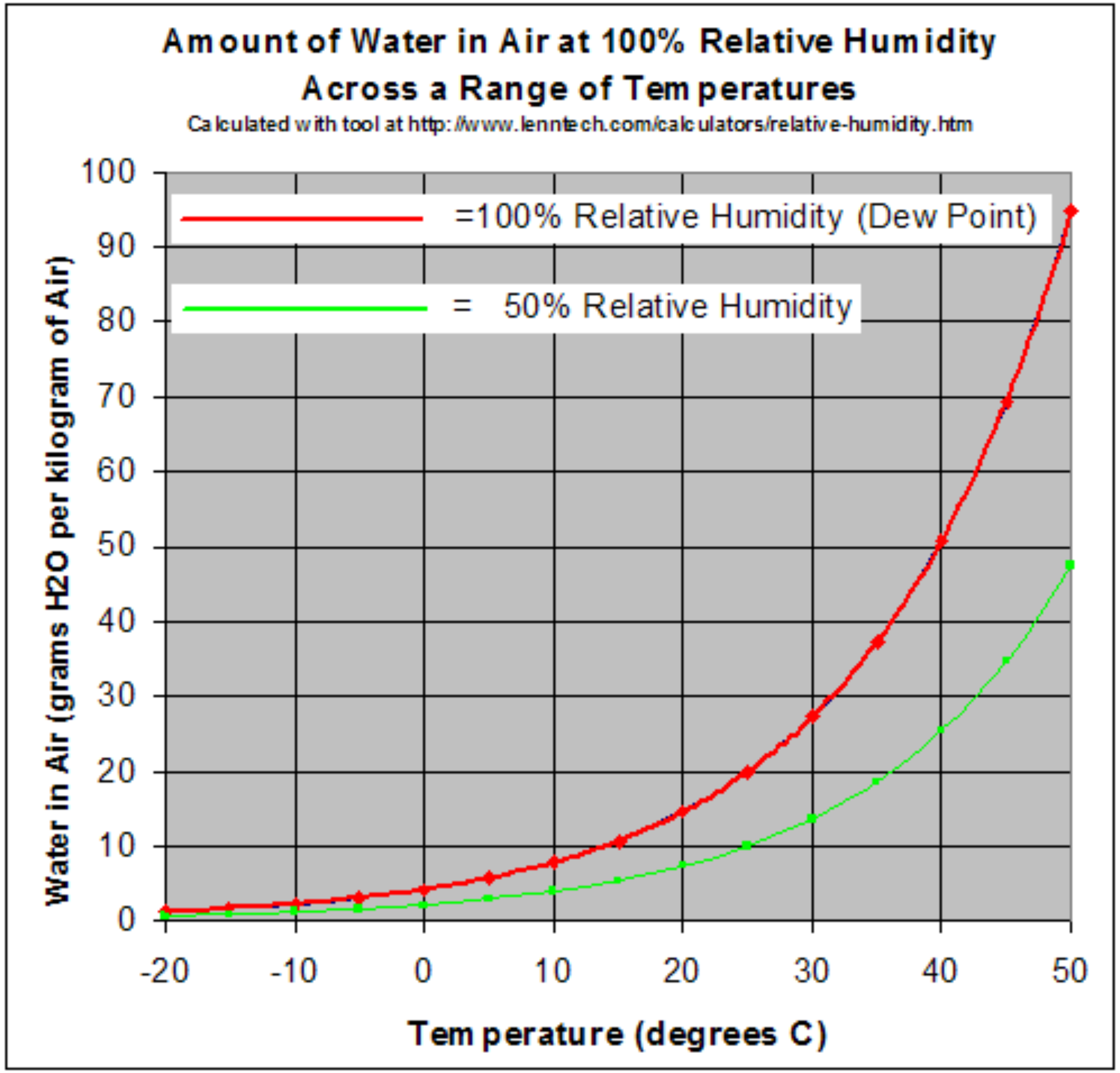


The Pool-House Effect

Challenges:
Better estimates of Earth's energy imbalance
Impacts of higher energy state on water cycle

Supplies

How is the coupled energy-water cycle going to impact the flows under a high Earth energy imbalance?



Temperature		Max. Water Content	
(°C)	(°F)	(10^{-3} kg/m^3)	(10^{-3} lb/ft^3)
-25	-13	0.64	0.040
-20	-4	1.05	0.066
-15	5	1.58	0.099
-10	14	2.31	0.14
-5	23	3.37	0.21
0	32	4.89	0.31
5	41	6.82	0.43
10	50	9.39	0.59
15	59	12.8	0.8
20	68	17.3	1.07
30	86	30.4	1.9
40	104	51.1	3.2
50	122	83.0	5.2
60	140	130	8.1

Maximum atmospheric water content depends on air temperature:

$$W_{\max} = f(T^3)$$

Are water quality reduction through direct and indirect human impacts limiting the availability of useable water?

THE TEXAS TRIBUNE OUR PICKS DATA EVENTS NEWSLETTERS DONATE LOG IN

#TTEVENTS NOV 20 AUSTIN & THE LEGISLATURE *A Preview of the 86th Session* FULL DETAILS →

Dropping Lake Levels Mean Rising Water Quality Issues

As lake and river levels continue to drop due to the intense 13-month drought, concerns about water quality are growing across Texas. It's an issue that affects fish — and humans.

BY LARA LAPIN NOV. 1, 2011 5 AM

REPUBLISH

≡ SECTIONS SEARCH THE AUSTIN CHRONICLE

NEWS FOOD MUSIC SCREENS ARTS QUEER EVENTS CLASS

DAILY NEWS

Water Boil Order Could End This Weekend

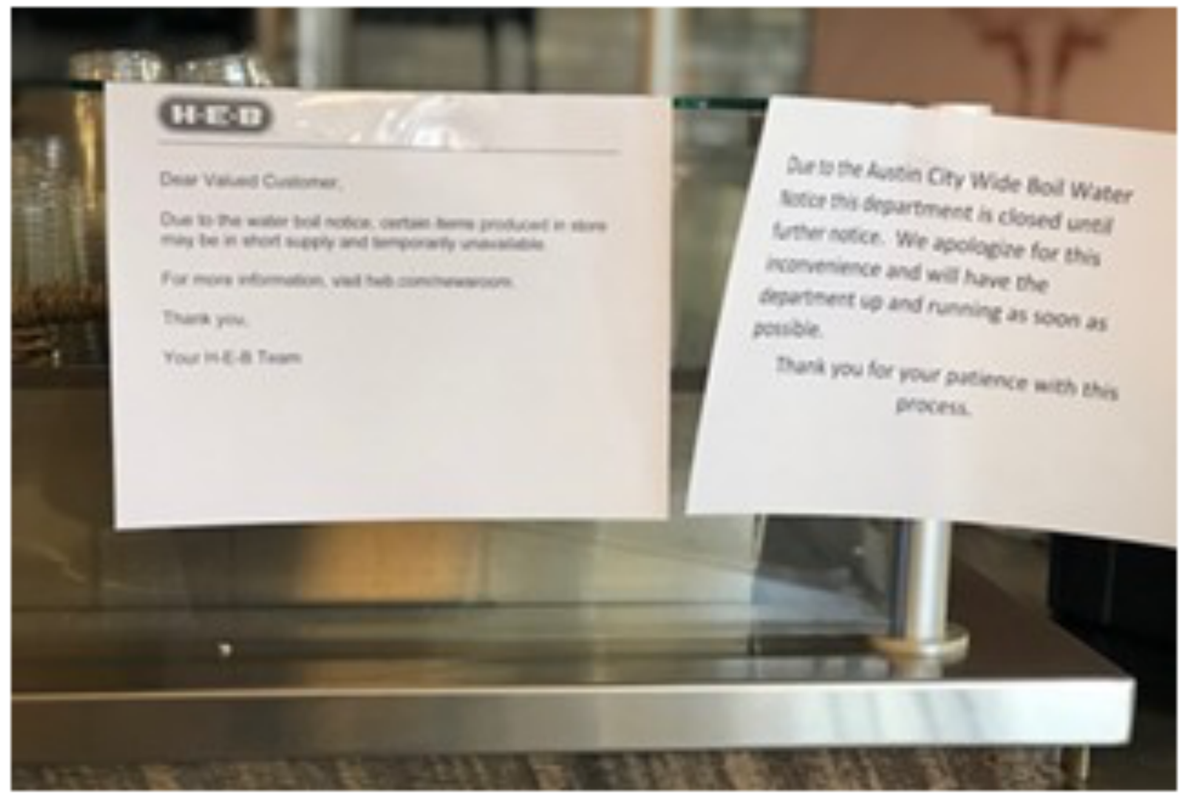
City issues official notice on water quality

BY MARY TUMA, 11:21AM, WED. OCT. 24, 2018

Tweet G+ print write a letter

Update, Wednesday, Oct. 24, 11:05am

While the water boil notice has so far been a precautionary measure, the city is now issuing an **official notice** as required by the **Texas Commission on Environmental Quality** regulatory orders. Up until now, Austin Water had not exceeded regulatory turbidity standards.



The boil water notice has forced many Austin businesses to curtail services. Here: a notice posted at the H-E-B Hancock Center deli counter.

Turbidity – or water cloudiness – has no health effect on its own, but it can interfere with disinfection and provide a passage for microbial growth. The high turbidity was only a brief spike and the levels are now back to what they were yesterday. Despite the official TCEQ notice, the spike doesn't require any changes to the precautionary measures already in place and does not put the public at additional risk, say city officials. Keep doing what

Supplies

Are water quality reduction through ... *uman impacts limiting the availability of useable water?*

Floods and turbidity impact water quality

Droughts impact water quality

THE TEXAS TRIBUNE

OUR PICKS DATA EVENTS NEWSLETT

#TTEVENTS NOV 20 AUSTIN & THE LEGISLATURE

A Preview of the 86th Session

FULL DETAILS →

Dropping Lake Levels Mean Rising Water Quality Issues

As lake and river levels continue to drop due

about water quality are growing across Te

BY LARA LAPIN NOV. 1, 2011 5 AM

SEARCH THE AUSTIN CHRONICLE

NEWS FOOD MUSIC SCREENS ARTS QUEER EVENTS CLASS

DAILY NEWS

W ter Boil Order Could End This Weekend

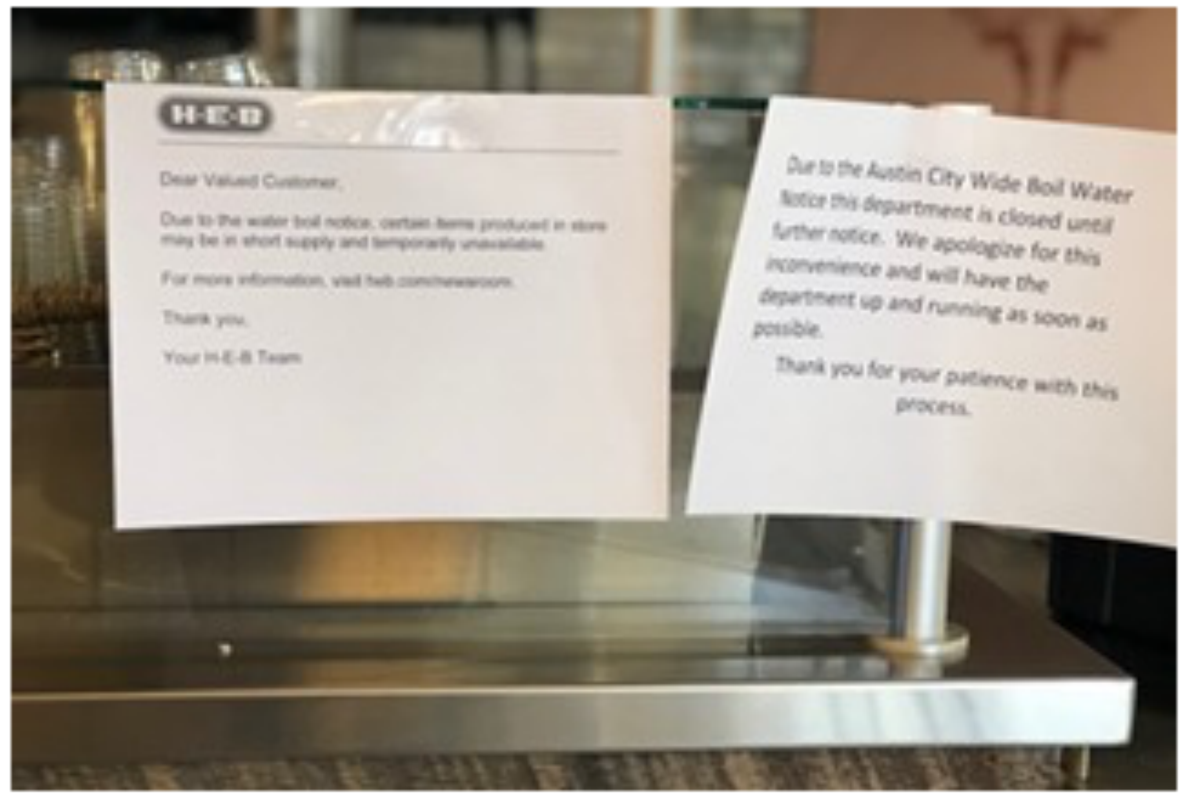
City issu s official notice on water quality

BY MARY TUMA, 1 :21AM, WED. OCT. 24, 2018

Tweet G+ print write a letter

Update, Wednesday, Oc 24, 11:05am

While the water boil notice ha so far been a precautionary measure, the city is now issuing an **official notice** as required by the **Texas Commission on Environmental Quality** regulatory orders. Up until now, Austin Water had not exceeded regulatory turbidity standards.

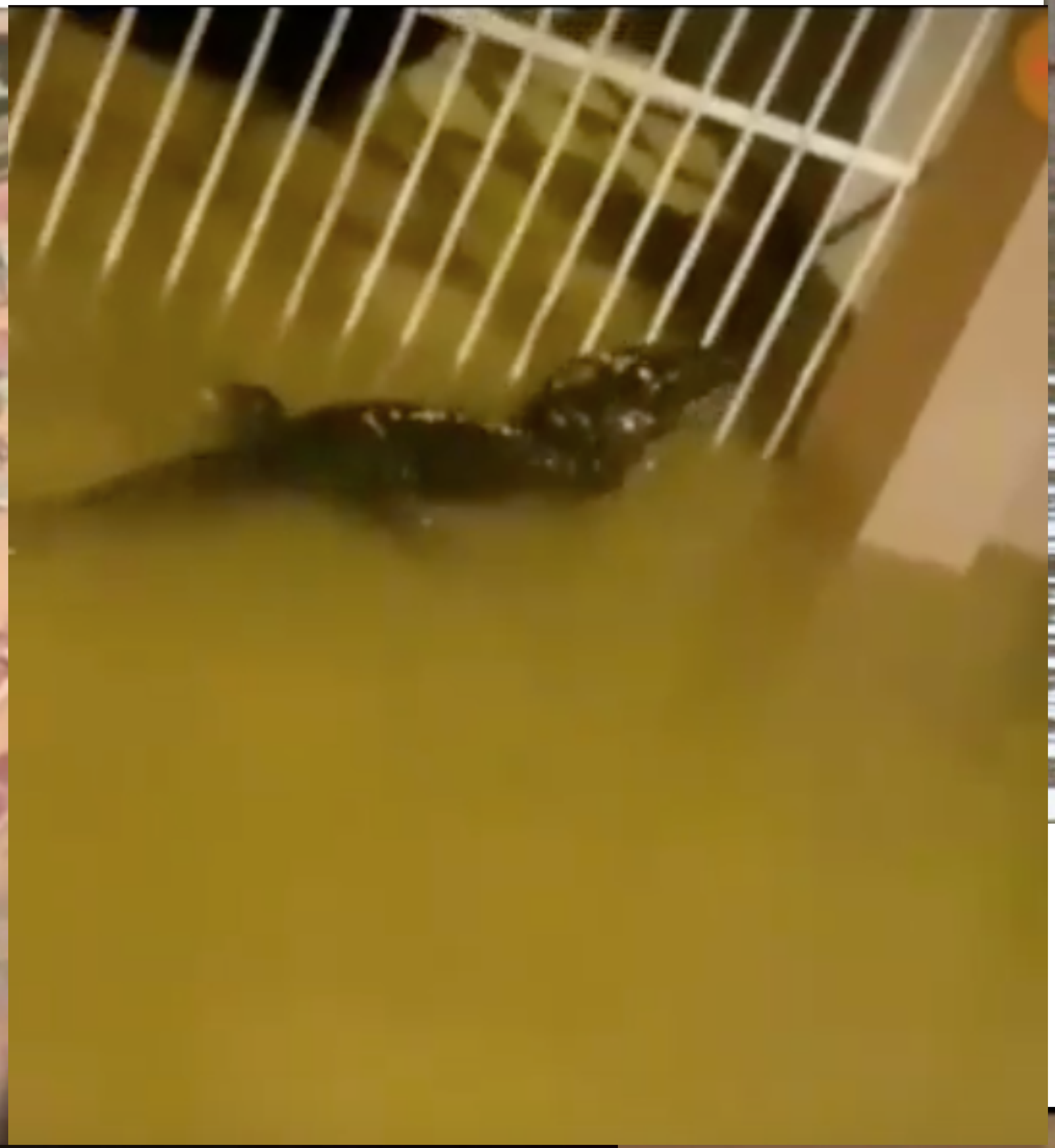


The boil water notice has forced many Austin businesses to curtail services. Here: a notice posted at the H-E-B Hancock Center deli counter.

Turbidity – or water cloudiness – has no health effect on its own, but it can interfere with disinfection and provide a passage for microbial growth. The high turbidity was only a brief spike and the levels are now back to what they were yesterday. Despite the official TCEQ notice, the spike doesn't require any changes to the precautionary measures already in place and does not put the public at additional risk, say city officials. Keep doing what

Supplies

Are water quality reduction through direct and indirect human impacts limiting the availability of useable water?



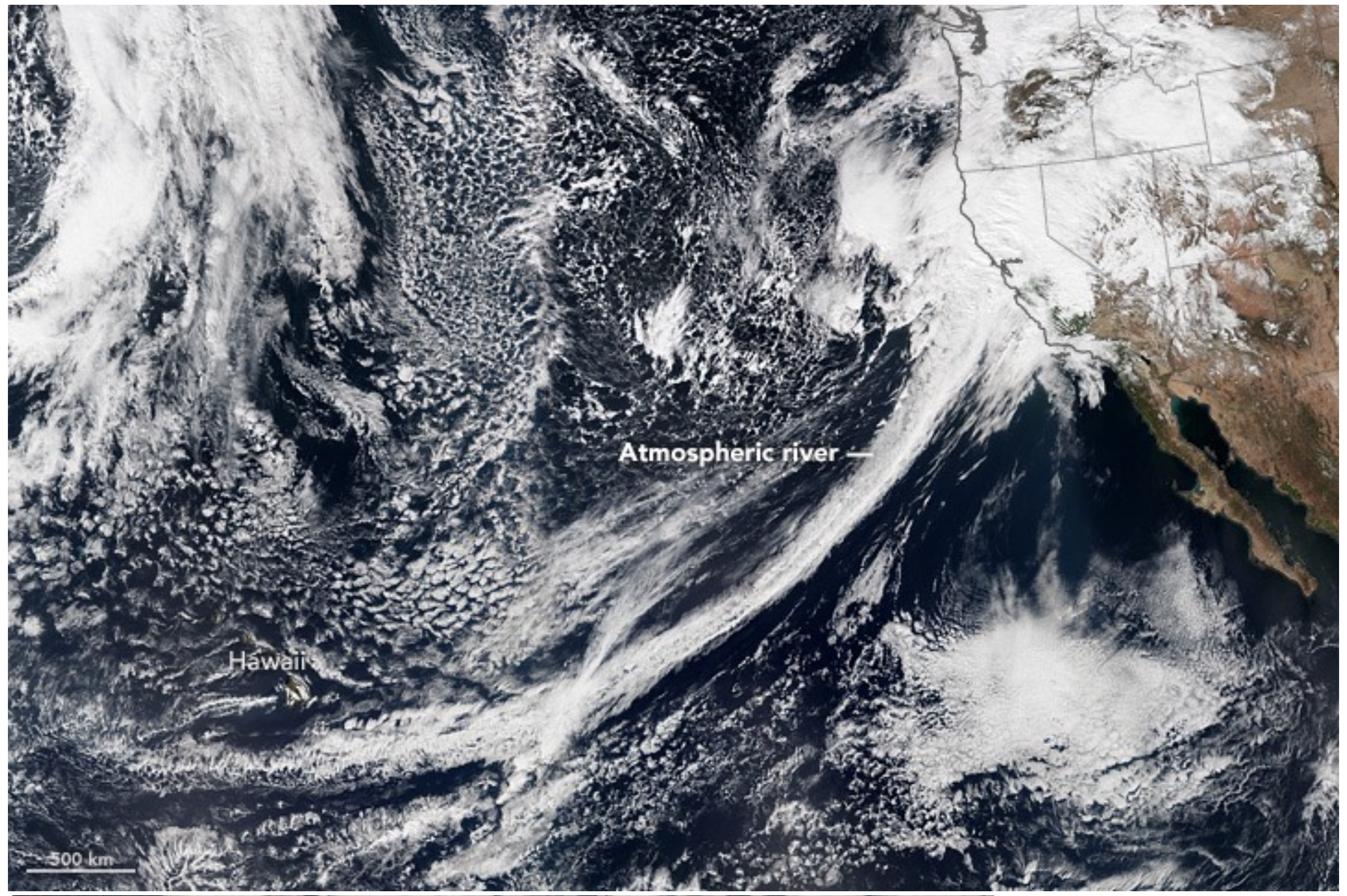
Trinidad and Tobago Flood, October 19, 2018

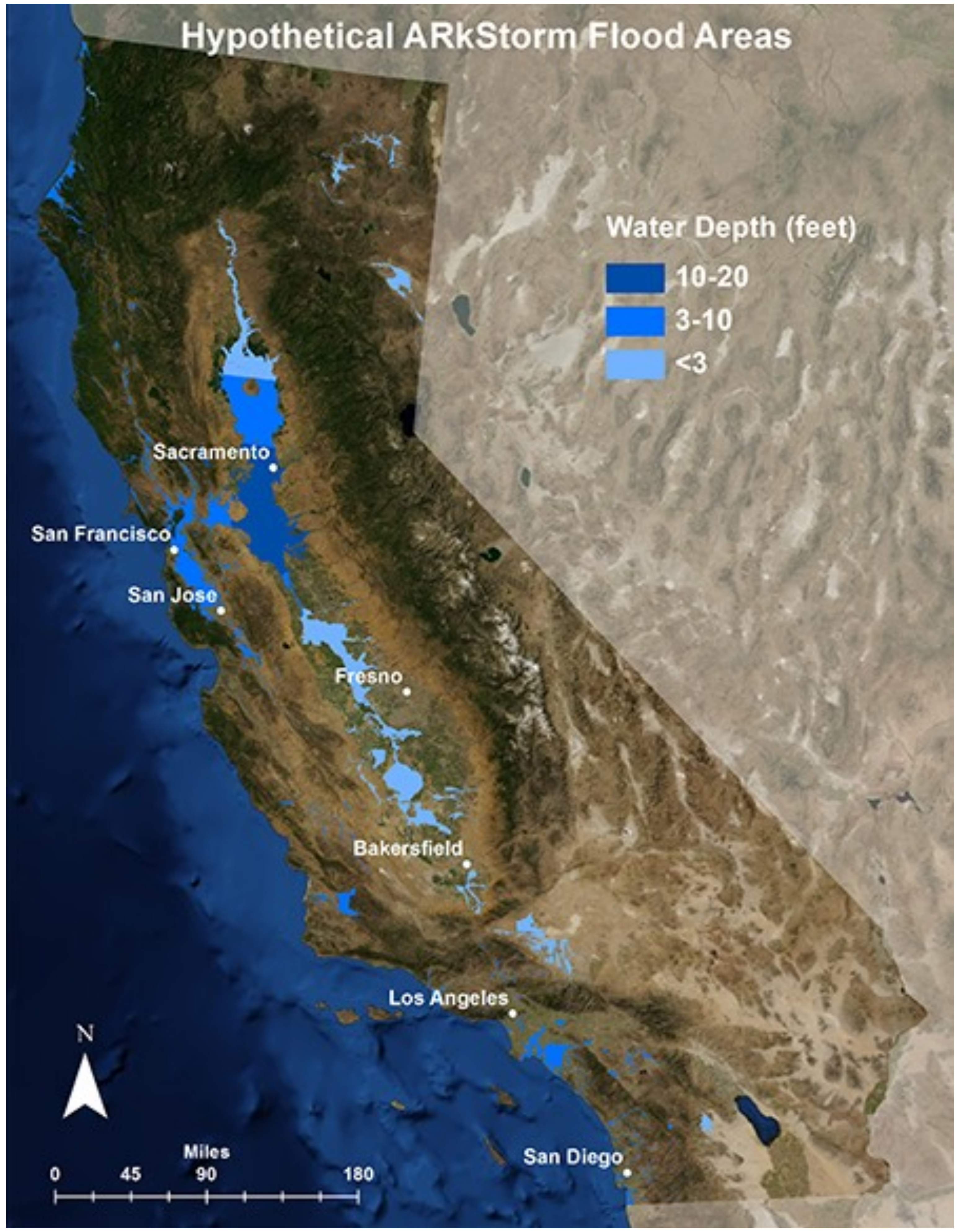
Changing Flood Risk also poses a threat to water availability and quality.

Supplies

Are water quality reduction through direct and indirect human impacts limiting the availability of useable water?

Atmospheric Rivers can cause mega floods





Energy flows determine flows in the Water Cycle …

Geodesy's Contribution

Create knowledge relevant to water governance and management

Nicole Kinsman

The earth is **unevenly instrumented**, both in the space and ground segments, for whole-earth geodetic observations of evolving hydrological changes—this may be inhibiting analysis of hydrologic changes in some regions and therefore has socioecological implications for our understanding of climate change and associated impacts. Emphasis on **more comprehensive whole-earth science**, further development of GNSS reflectometry applications, innovative opportunistic sensor leveraging and investments in a truly global geodetic observation network and workforce are critical to a full understanding of our changing planet.

Ben Phillips

Water cycle and related anthropogenic forcings are recognized more and more as important **drivers of surface change identified in geodetic observations**. Not only do we need to understand these signals to address other scientific questions such as those related to tectonics, but they also can serve as (sometimes controlled) experiments on the Earth system. Examples include loading from recent hurricanes seen in GPS networks and the influence of groundwater withdrawal in the California Central Valley on local subsidence and proximal uplift of the Sierra Nevada seen through GPS and InSAR. Settings such as the latter can present an opportunity for controlled experiments, where in situ observation of human system inputs (e.g., well logs) can be used to help validate models.

Evelyn Roeloffs

Since the previous document, there has been a surge in the rate of induced earthquake activity in the central US associated with unconventional production of hydrocarbons and injection of waste fluid. Induced seismicity is a response to **artificial changes in the subsurface storage of water**, mediated by pore pressure increases and/or poroelastic stress changes. However, in some regions injection occurs without inducing earthquakes. Does injection in those regions produce aseismic deformation? If so, can we measure it? Why is the response to injection seismic in some locations, aseismic in others?

Geodesy's Contribution

Create knowledge relevant to water governance and management

Susan Owen

Airborne **LiDAR** for accurate snow measurements that are currently being used by California for the water resource management. Also, space-based observations GNSS and Signals of Opportunity **reflections** are a potential new way to get global snow water equivalent. Much more has been done **combining GRACE and GNSS** to measure groundwater since the last report.

Estelle Chaussard

How can we i**ntegrate GRACE, InSAR, and GPS** for multi scale analysis of groundwater depletion and to better **help water management**? Can we track water from surface load change on the solid earth to groundwater infiltration in porous aquifers (track water throughout its cycle)? How does pore pressure changes influence secondary hazards (landslides, volcanic eruption, earthquakes); and can we use fracking as "controlled experiment"?

Create knowledge relevant to water governance and management

Hans-Peter Plag

Knowing the flows is fundamental for an understanding of the planetary physiology.

There is a need for an **integrated Earth system** information/knowledge base.
"Information integration creates consciousness."

Understanding modern global change as a **syndrome** requires an integrated (big) database and **AI-based analyses**

Geodesy's Contribution

Create knowledge relevant to water governance and management

Grand Challenge 1 - Key Questions:

- How do the cryosphere, oceans, atmosphere, and solid Earth exchange water on a wide range of time scales and spatial scales?
- In what ways is this exchange of water affected by climate change?
- What is the impact of climate change on continental water storage?
- What are the responses of the solid Earth to the redistribution of water?
- How does atmospheric moisture change in space and time?
- How does the redistribution of water at the surface impact ground water storage?

Long-term Goals for Addressing Key Questions:

- Integrate multiple ground-based and space-based observing systems for measuring vertical and horizontal land deformation, snow height, and gravity.
- Develop methods for integration of observations having different spatial and temporal resolutions.
- Maintain a stable terrestrial reference frame with sub-1 mm/yr vertical accuracy.
- Sustain multiple, concurrent, continuous satellite systems for sea-surface topography, and time-variable gravity without temporal gaps.
- Improve the spatial resolution and accuracy of space-based gravity
- observations.
- Carry out campaigns for calibration of geodetic measurements against local hydrological measurements.

Grand Challenge 1 - Key Questions:

- How large are the flows between the reservoirs in the global water cycle and how do they change spatially and temporally?
- How are these flows of water affected by changes in the energy cycle?
- What is the impact of climate change on flows of continental water and its quality?
- How do the changes in flows impact the continental water reservoirs?

Long-term Goals for Addressing Key Questions:

- How can geodetic observations be integrated into a Earth system database?
- What can geodesy contribute to a planetary flow monitoring system?
- What can geodesy contribute to a comprehensive description of the syndrome of modern global change?
- Can big data approaches, including AI be applied to the Earth system database to diagnose the "undiagnosed patient" Earth?
- How can geodesy contribute to constrain the Earth's energy imbalance?