Wicked Problems: Addressing The Food Energy Water Nexus

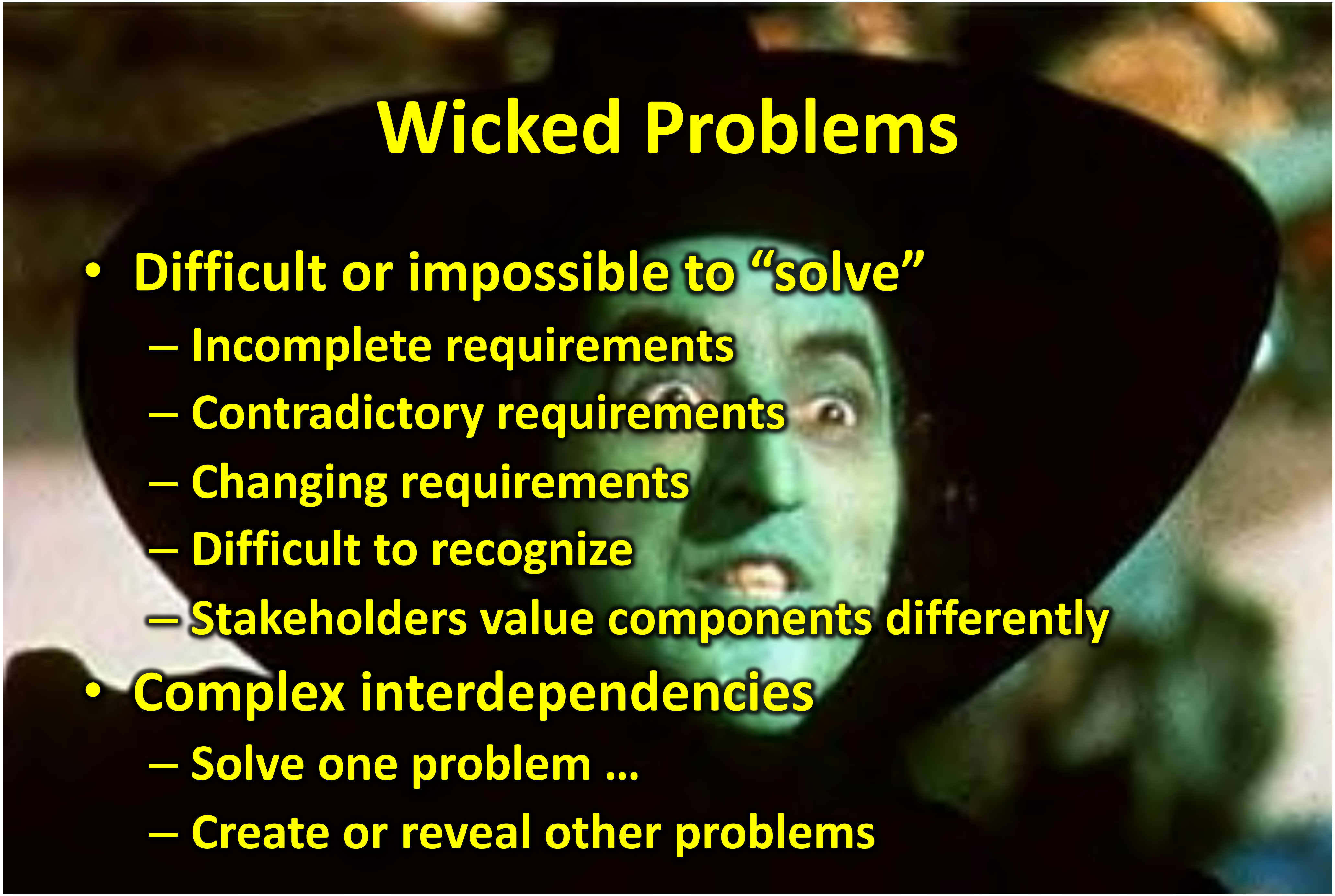
Optimizing Complex Interdependent Systems

Henry T (Hank) Kohlbrand

HT Consulting

The Dow Chemical Company (Retired)

2010 President AIChE


Wicked Problems
• Difficult or impossible to “solve”
– Incomplete requirements
– Contradictory requirements
– Changing requirements
– Difficult to recognize
– Stakeholders value components differently
• Complex interdependencies
– Solve one problem …
– Create or reveal other problems

Some Examples …

- CLIMATE CHANGE – NO AGREEMENT ON PROBLEM
- OIL/GAS PIPELINES
- ENERGY GENERATION
- WATER RESOURCE MANAGEMENT
- GENETICALLY MODIFIED ORGANISMS
- URBAN PLANNING, WASTE DISPOSAL
- NUCLEAR WASTE
- BIODIVERSITY LOSS

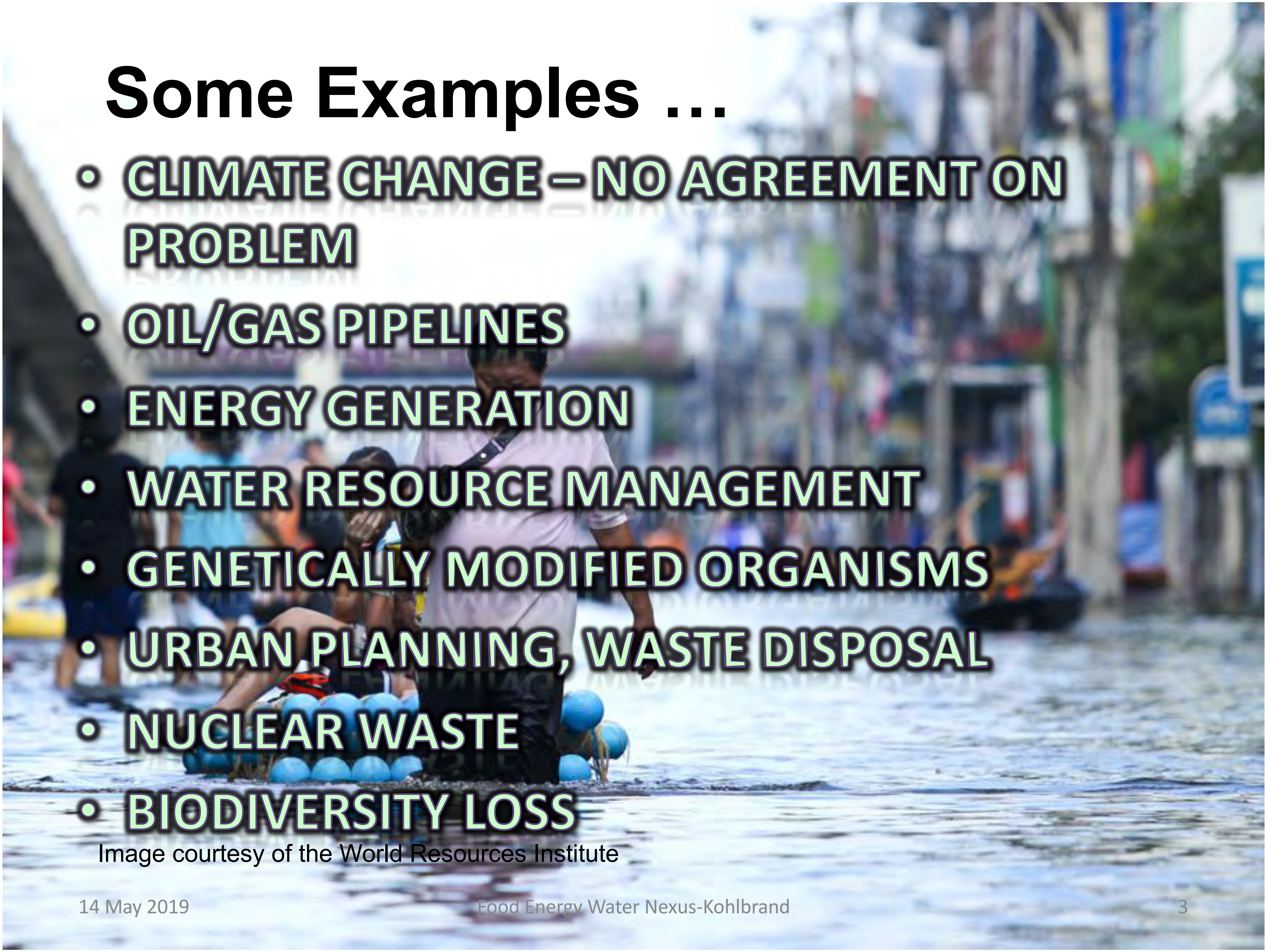
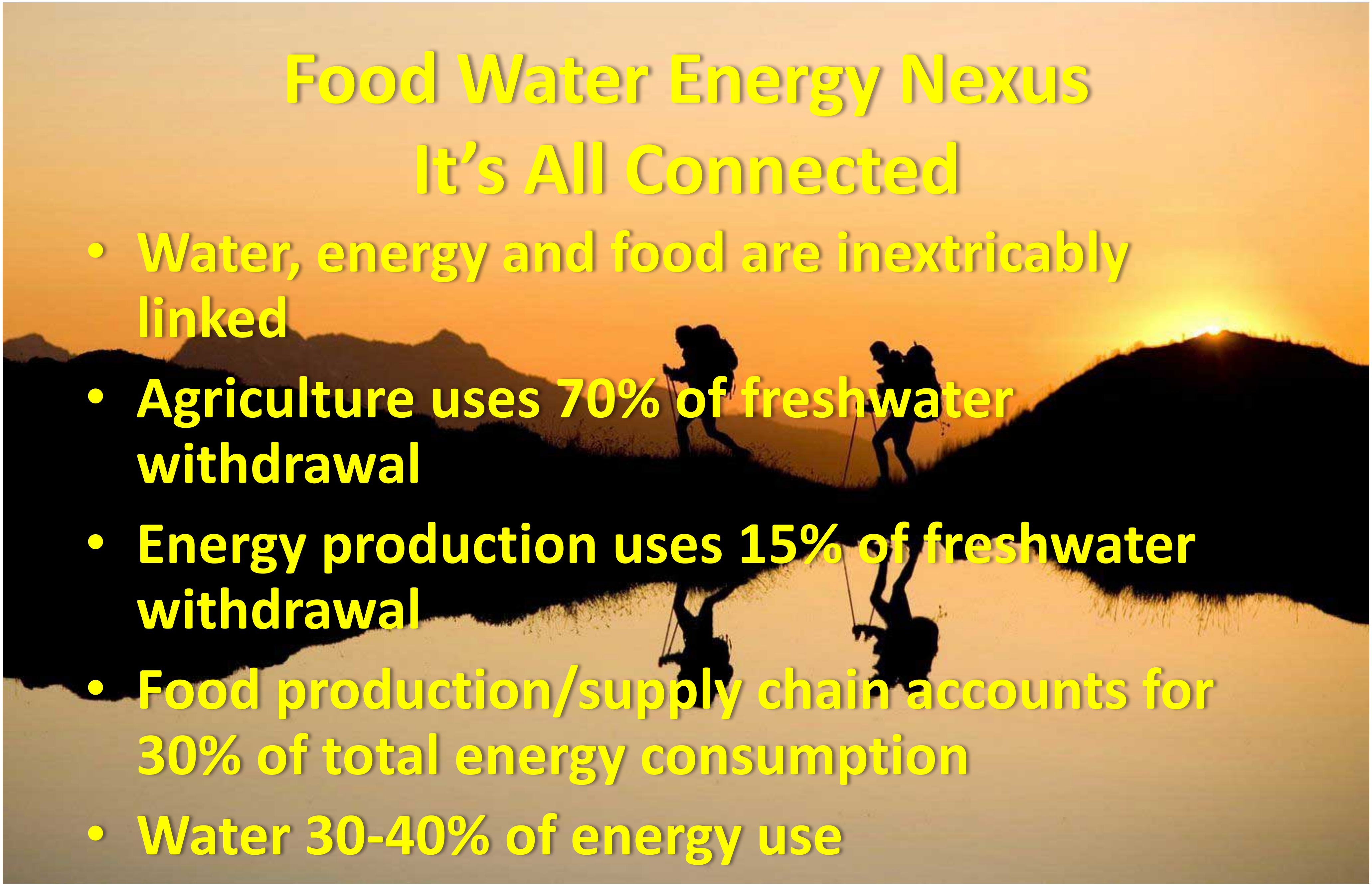


Image courtesy of the World Resources Institute

To Address these Challenges

- Look at historical process synthesis and design approaches and update them
- Learn to deal with some ambiguity
- Recognize multiple objective functions in our optimization problems
- Use multidisciplinary teams in developing new business opportunities
- Be careful how we define success



Food Water Energy Nexus
It's All Connected

- **Water, energy and food are inextricably linked**
- **Agriculture uses 70% of freshwater withdrawal**
- **Energy production uses 15% of freshwater withdrawal**
- **Food production/supply chain accounts for 30% of total energy consumption**
- **Water 30-40% of energy use**

My Interest …

- Sustainability (since early 1970’s)
- Effort AIChE/IChemE Past Presidents
- World Council of Chemical Engineering
- NSF Workshops and future funding
- Complex problem with many partial solutions

Food Energy Water Nexus

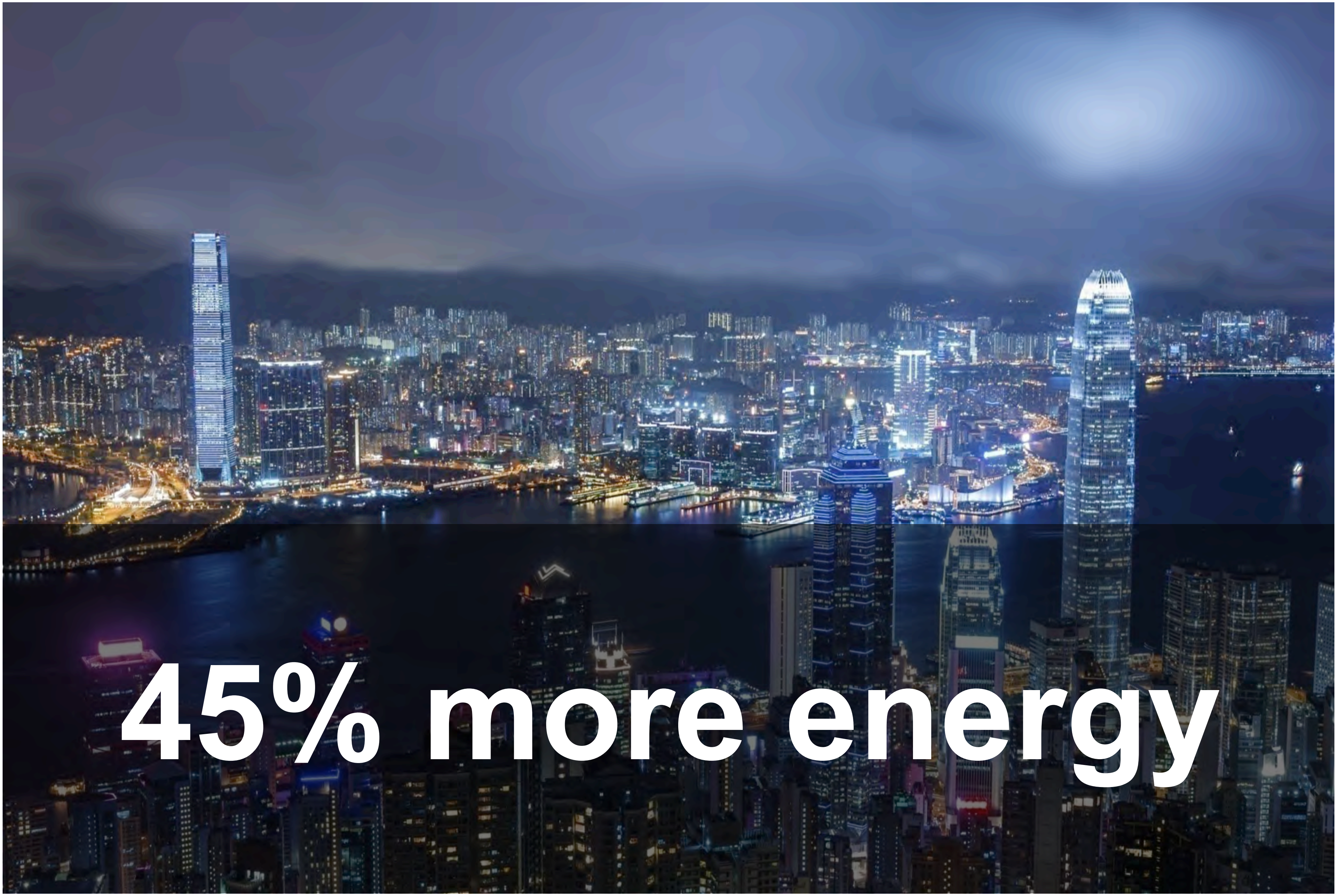
- An engineering and societal challenge
- Decisions made in one area impact others (interdependence and constrained)
- Must move to systems thinking – Impact science and government policy
- Great innovation opportunity for scientists and engineers

Multiple Objective Functions
w/geographic differences


Why Care?


By 2030,
the world's population will reach
8.3 billion


The world will need…
50% more food


45% more energy


30% more water


~40% reduction
in GHG emissions
GEORGE BRAZIL
Plumbing-Heating
Air Conditioning
TIP
TRANSPORT INTERNATIONAL POOL

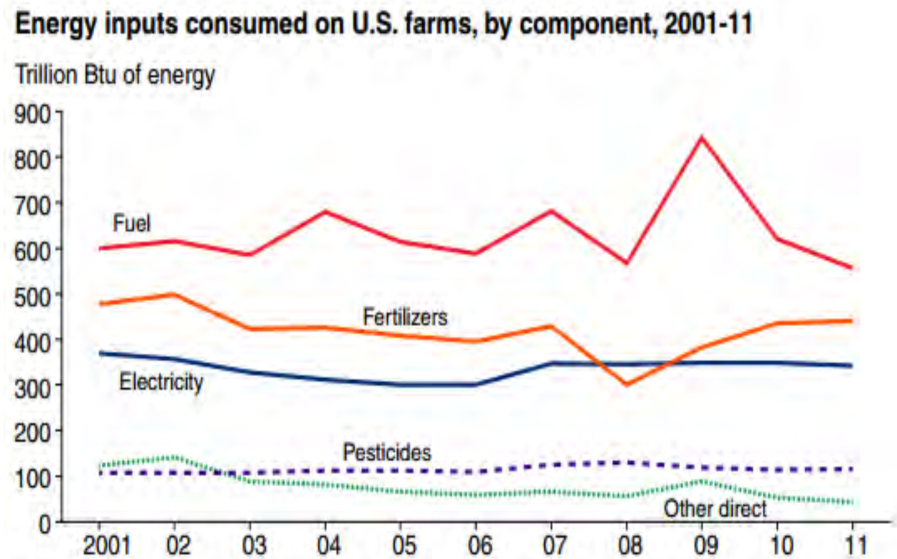
In Addition …

- Rapid urbanization - 45% increase between 1992 and 2009
- Increased living standard changes consumption patterns
- An opportunity for engineers, scientists and societal leaders

http://www.unwater.org/statistics_use.htm

ENERGY FOR FOOD

Food production and supply chain is responsible for around 30% of total global energy demand



Note: "Other direct" represents liquid petroleum and natural gas. Energy consumed is calculated by taking the total yearly expenses, divided by the average yearly price, and multiplying this amount by the energy conversion ratio. Btu = British thermal units.

Source: Miranowski (2005) and USDA, Economic Research Service calculations.

Also must take into account transport, storage, processing and other energy costs for food.

Courtesy Kate Scow

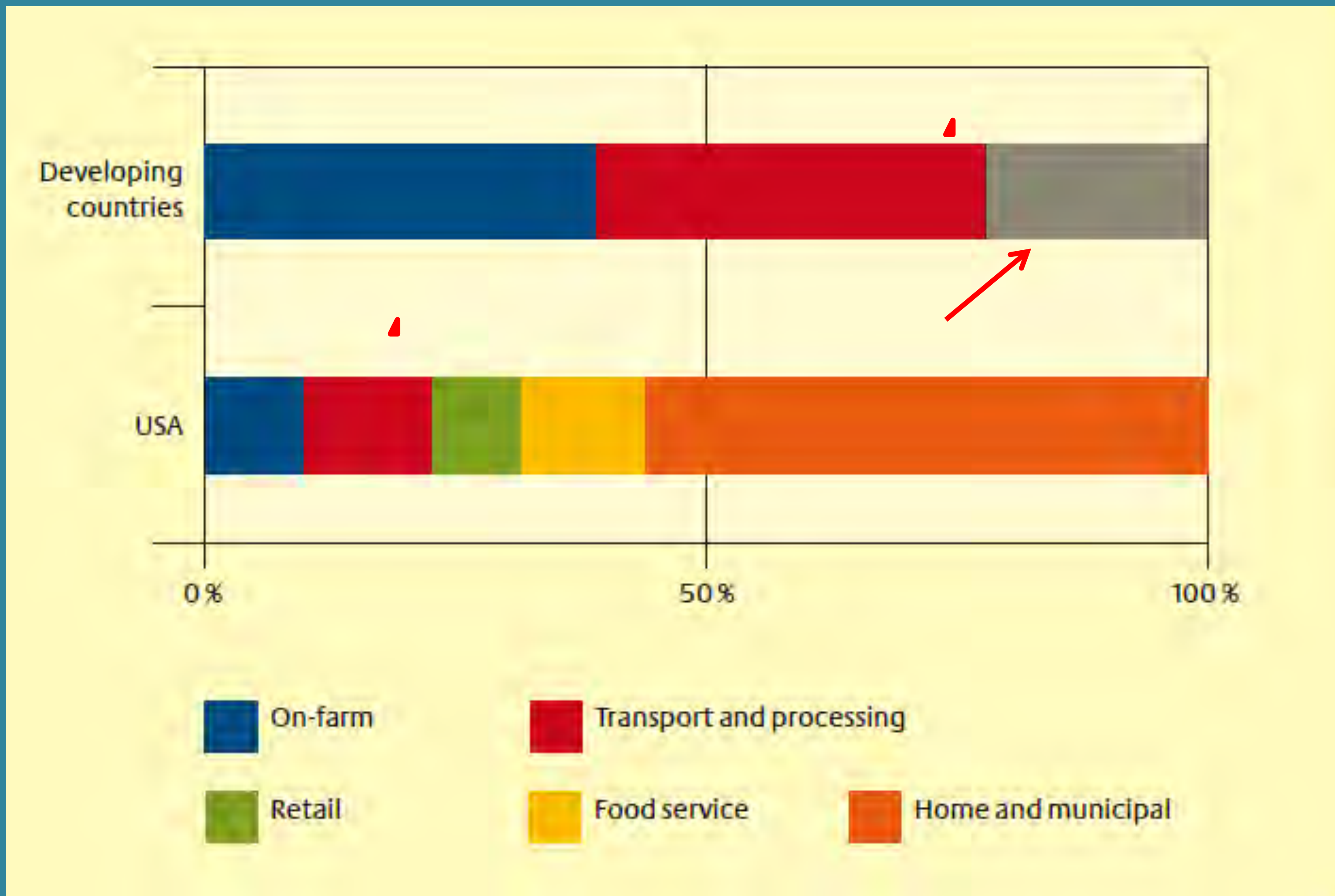
AGRICULTURAL SUSTAINABILITY INSTITUTE AT UCDAVIS

Food and Agriculture


By 2050, global demand for food could increase by 60%


One-third of the world's
food is wasted

Make up of total food waste in developed and developing countries



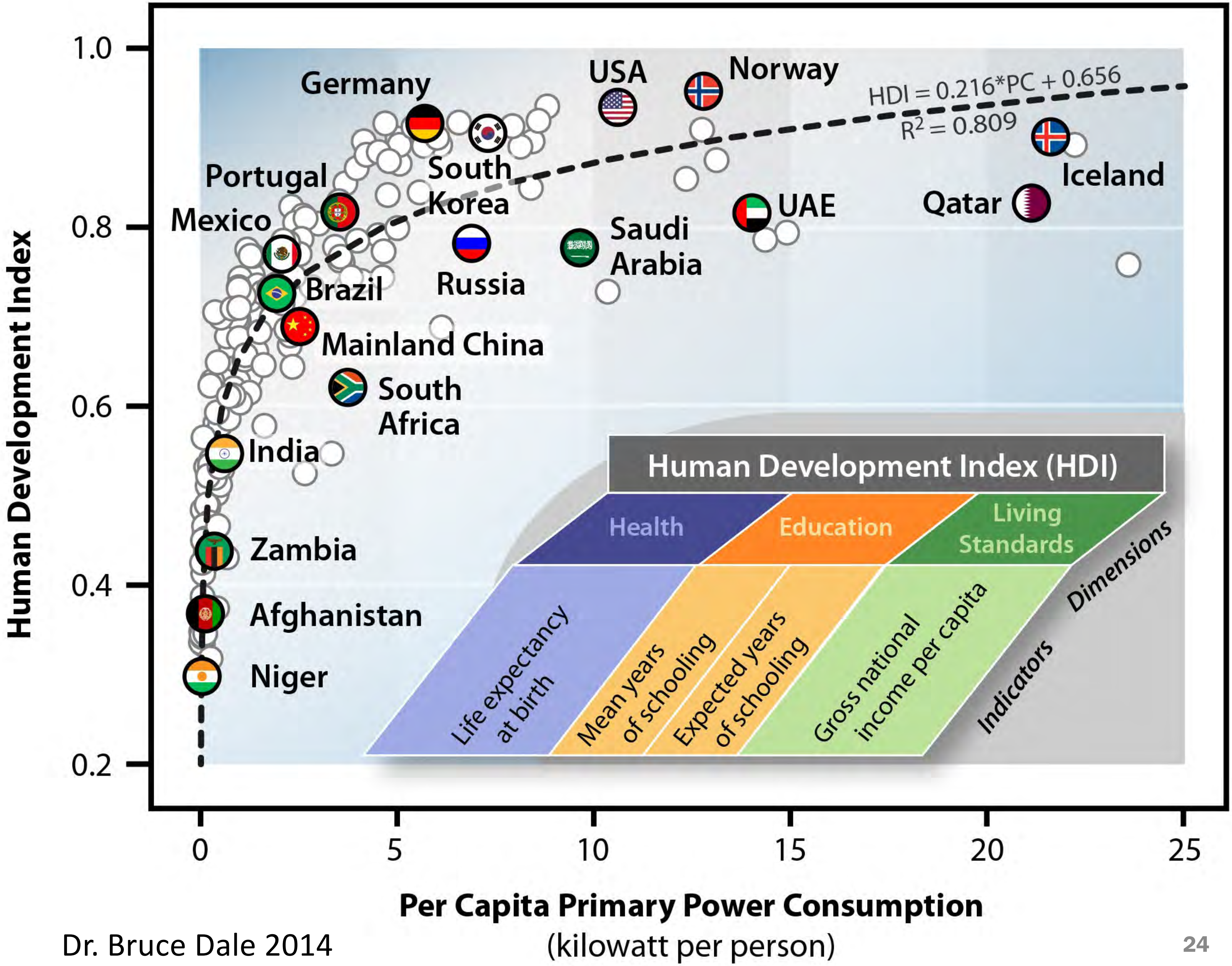
Godfray et al, Food security: The challenge of feeding 9 billion people. Science 327, 812, DOI: 10.1126/science.1185383 2010

Where Science Can Help

Improve food production, address dietary needs and reduce food waste


Energy


Global energy use is projected to grow by **two-thirds** by 2050



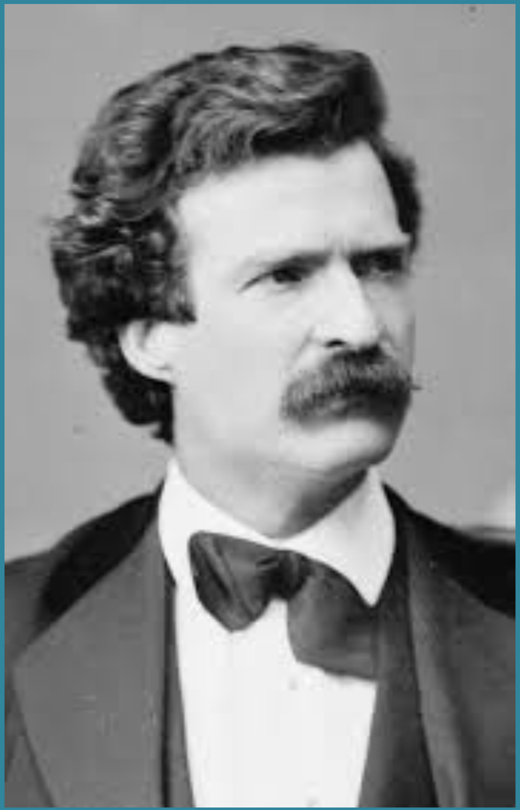
Dr. Bruce Dale 2014

Where Science Can Help

Technologies for optimizing available energy resources, reducing emissions and developing alternative energy solutions

Food Energy Water Nexus

“Whiskey is for drinking, water is for fighting over” attributed to Mark Twain



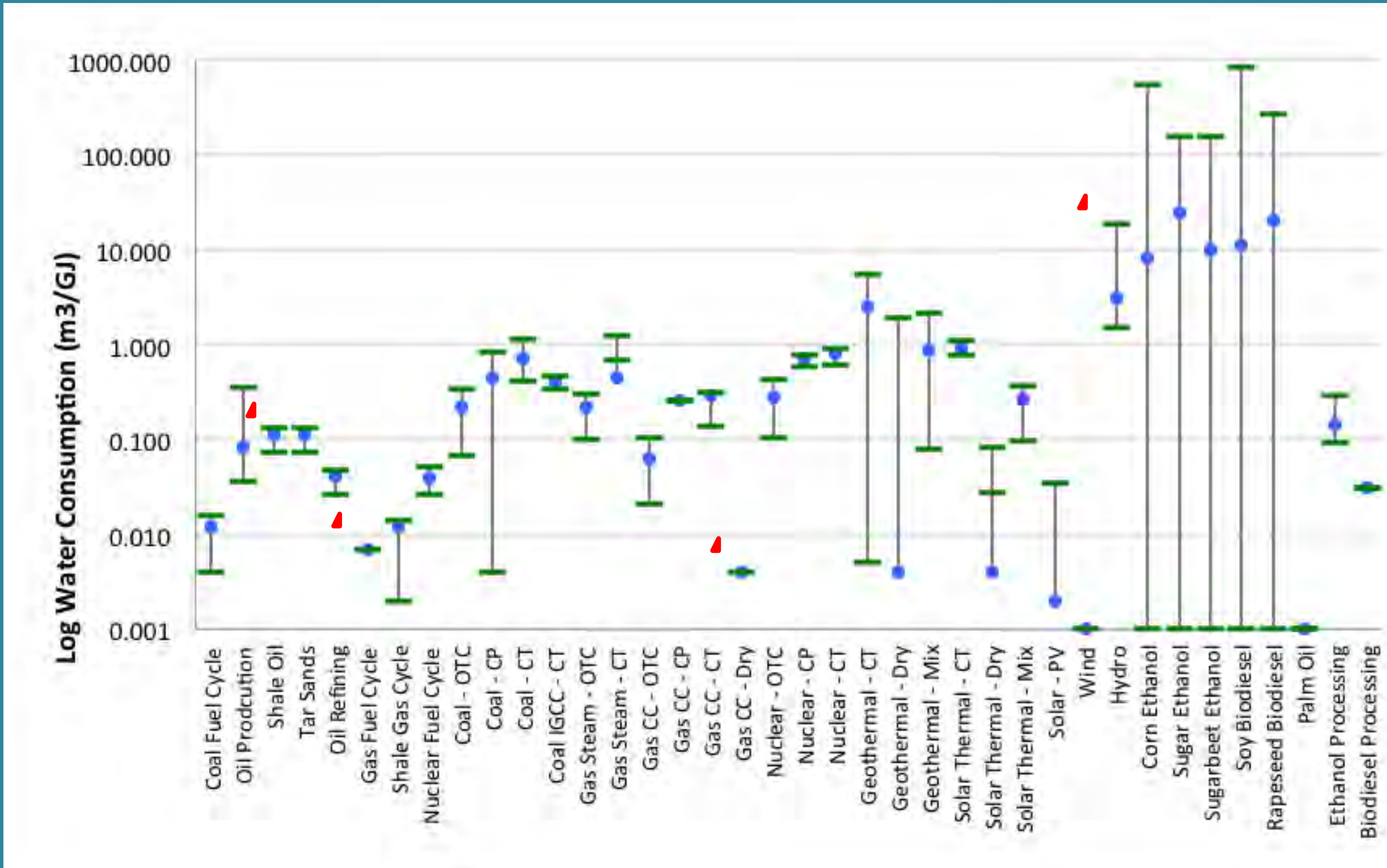

Water


1.8 billion people
will live in water-scarce regions by 2025

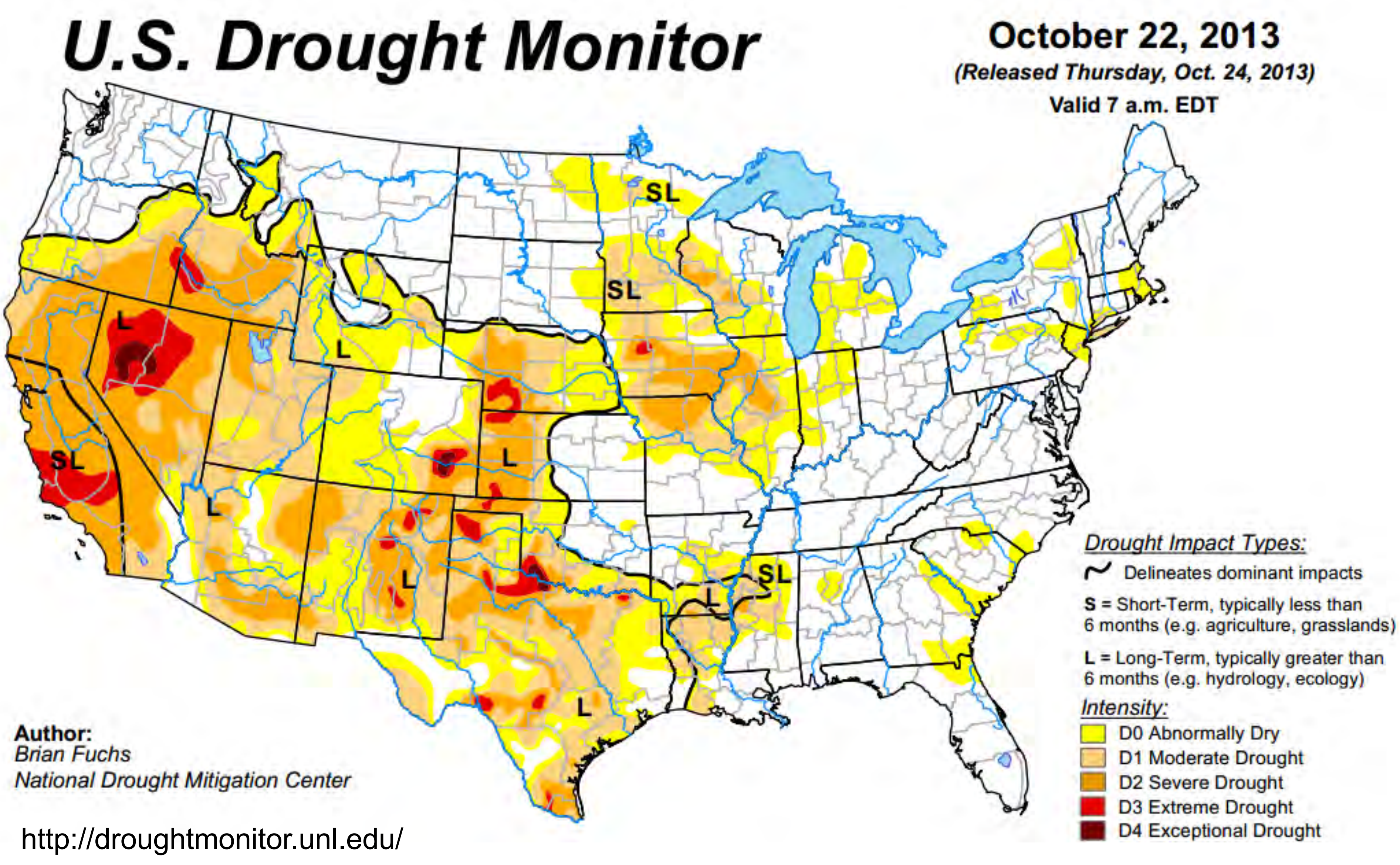

Where Science Can Help
Addressing water availability,
water quality, cost and energy efficiency

Water for energy production

Water consumption coefficients for energy technologies



Dr. Edward Spang, CWEE, University of California, Davis
A thirst for power: A global analysis of water consumption for energy production, 2012


U.S. Drought Monitor
October 22, 2013
(Released Thursday, Oct. 24, 2013)
Valid 7 a.m. EDT
SL
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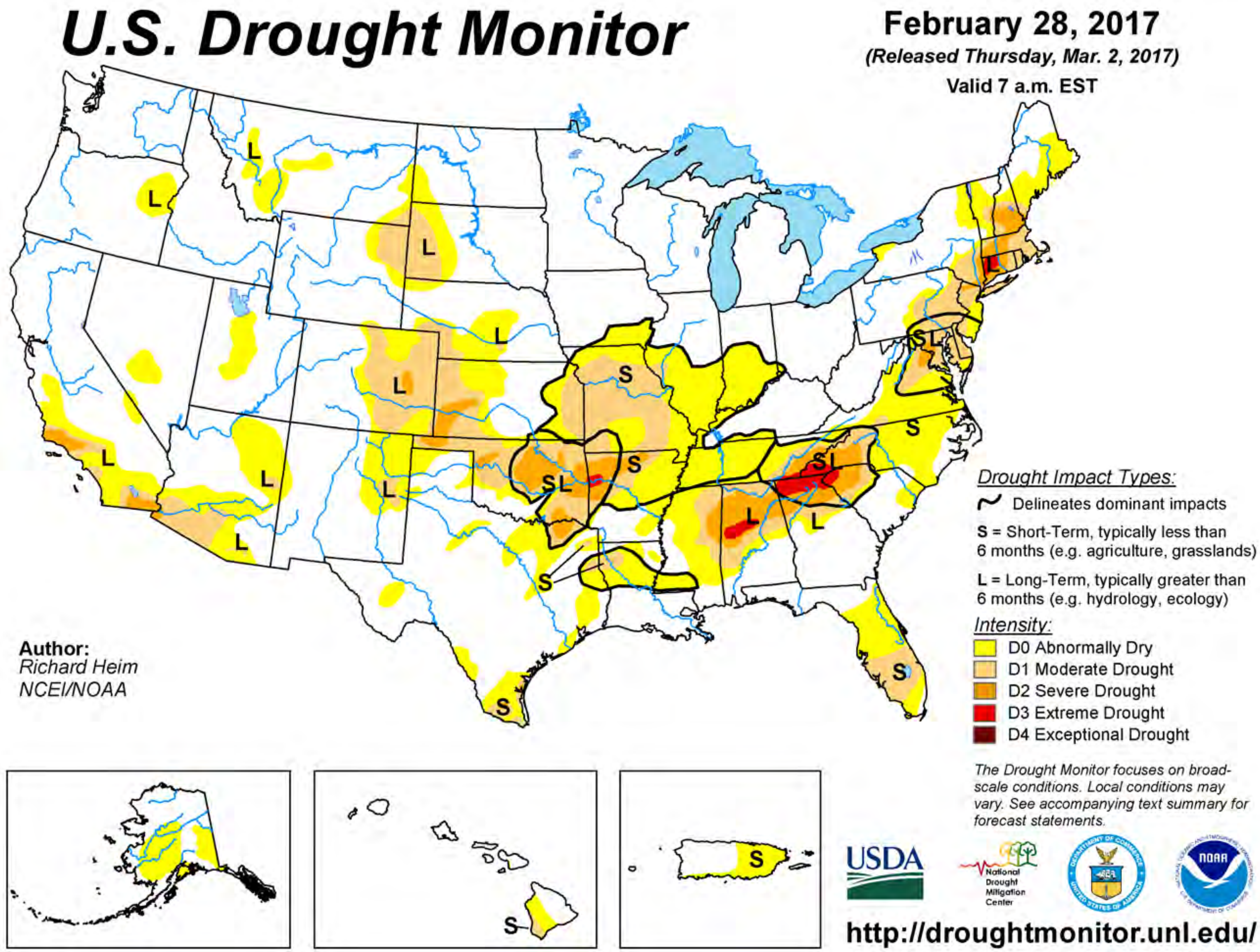
L
Drought Impact Types:
Delineates dominant impacts
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)
Intensity:
D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought
Author:
Brian Fuchs
National Drought Mitigation Center
http://droughtmonitor.unl.edu/


U.S. Drought Monitor
February 28, 2017
(Released Thursday, Mar. 2, 2017)
Valid 7 a.m. EST
Drought Impact Types:
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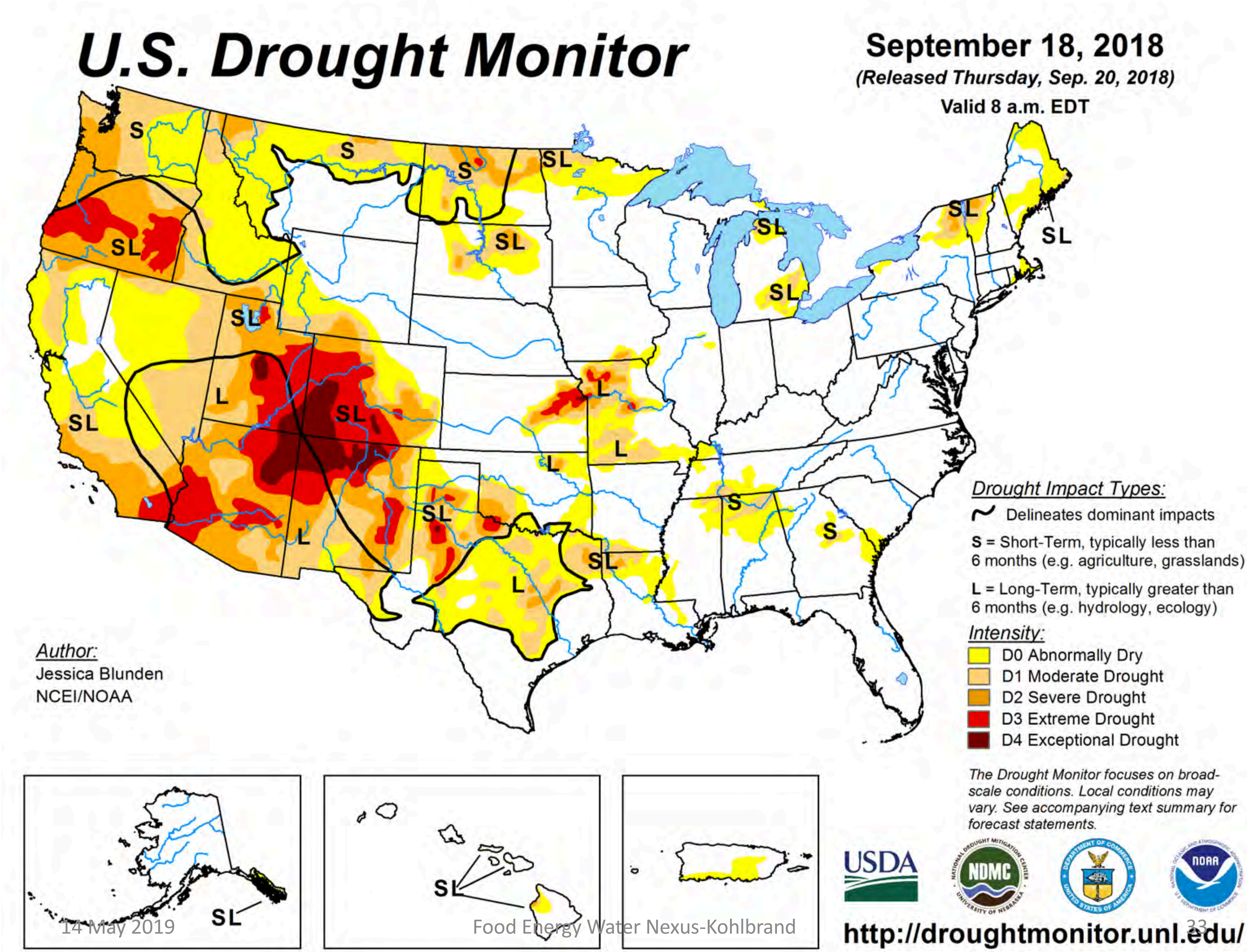
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
Author:
Richard Heim
NCEI/NOAA
USDA
National Drought Mitigation Center
http://droughtmonitor.unl.edu/


U.S. Drought Monitor
September 18, 2018
(Released Thursday, Sep. 20, 2018)
Valid 8 a.m. EDT
Drought Impact Types:
Delineates dominant impacts
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
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Author:
Jessica Blunden
NCEI/NOAA
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
USDA
NDMC
http://droughtmonitor.unl.edu/

Are we approaching "Planetary Boundaries"?
What is the "*Safe Operating Space for Humanity*"?

- Climate change
- Biodiversity loss
- Nitrogen loading
- Phosphorous loading
- Ozone depletion
- Ocean acidification
- Freshwater use
- Land use change
- Atmospheric aerosols
- Chemical pollution

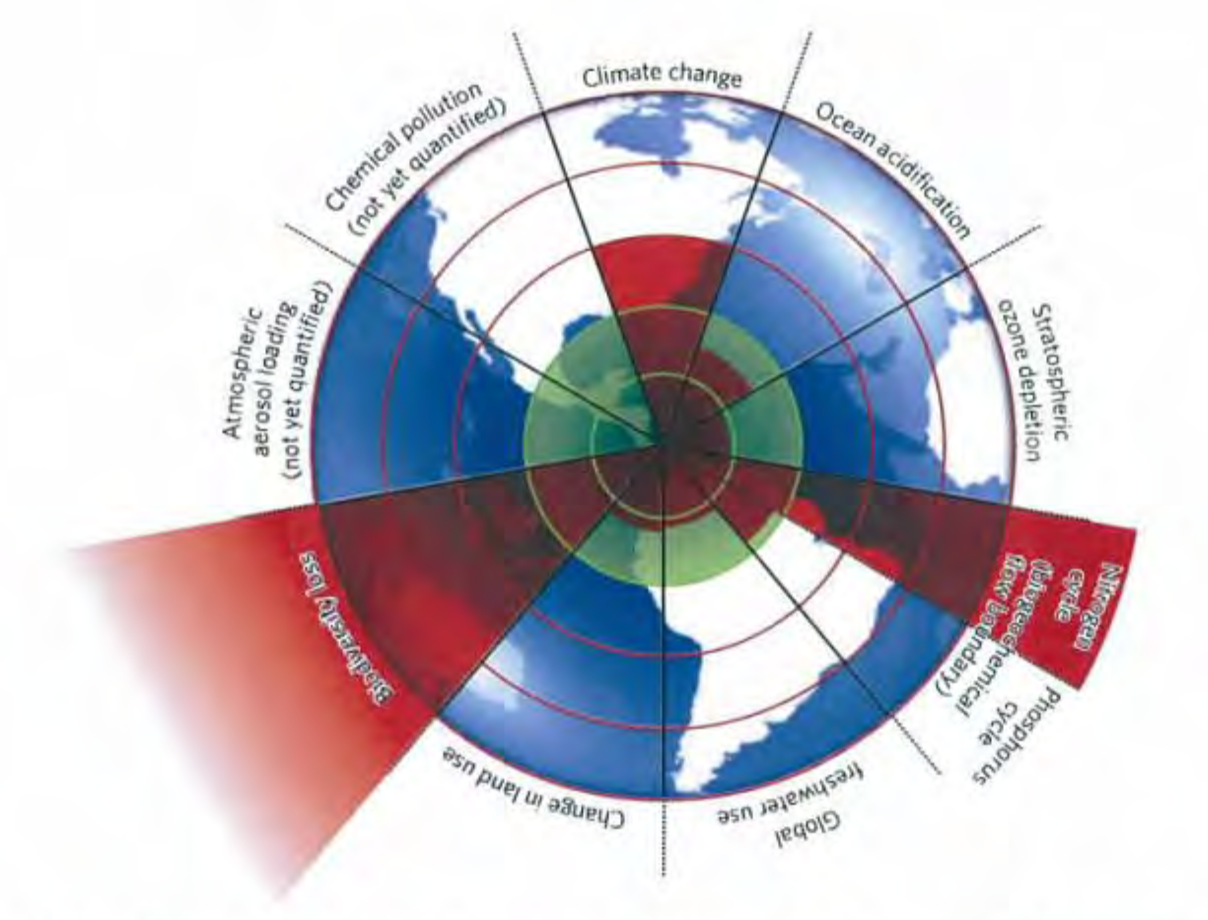

Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

J Rockstrom, et al.
Ecology and Society 14(2) 2009
Nature 2009

Observations

- Social complexity playing larger role
- Timescales
  - Sustainability – long
  - Political <4 years
  - Business 1-5 years
- Systems approaches
- Embedding life cycle thinking cradle to grave
- Footprints that look at multiple elements
- Solutions involving wider social, environmental, economic, regulatory, political, and ethical framework

Thought Experiments

Hydrogen – Sustainable Fuel

Consider Hydrogen

- Looks green – hydrogen + oxygen → water + energy
- But …
  - Where does it come from (solar, reforming?)
  - Distribution issues/Infrastructure
  - Safety & Health issues
  - Globally applicable?
- Life cycle analysis must be cradle to grave

Biofuels from Corn

Fuel Ethanol From Corn

- Renewable
- Oxygenate
- Requires a lot of energy and water to produce and distribute
- Competes with food uses
- Excellent social impact in corn producing areas
- But … may change land use (ex. grassland or forest to crops)
- Not so popular in countries that use corn for food
- What is the optimum?

Oil/Gas Pipelines

Downtown Lac Mégantic, July 2013, Quebec, Canada Toronto Star
Backen Oil, 47 died

Oil/Gas Pipelines

- Risk? To whom?
- Rail transport accidents
- Truck transport accidents
- Impact? Where? How often?
- Cropland, Water Supply, Energy Supply, Safety

Success …
Depends on your Definition of Success

- Many groups focus on a **few elements**
- Wicked problems – **difficult and fuzzy** solutions
- “Sustainability” used in many contexts by people who don’t really **understand** it

Wicked Problems

- Difficult or impossible to “solve”
  - incomplete requirements
  - Contradictory requirements
  - changing requirements
  - difficult to recognize
- Complex interdependencies
  - Solve one problem
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Chemical Engineers …

- Challenge existing heuristics for process and product development
- Understand sensitivities of product/process parameters
- Evaluate changes during the lifetime of plant or product and lifecycle assessment
- Look beyond today’s economics (true cost)
- Factor in societal considerations
- Make full use of the chemical engineering systems toolset

Wrap - up

- The FEW Nexus is important to all of us
- NSF and other funding agencies beginning to recognize importance
- Wicked problems provide innovation opportunities but introduce subjectivity
- Consider systems and broad boundaries for life-cycle analysis with multiple objective functions
- Engineering and science will provide solutions
- How will you respond?

Discussion?