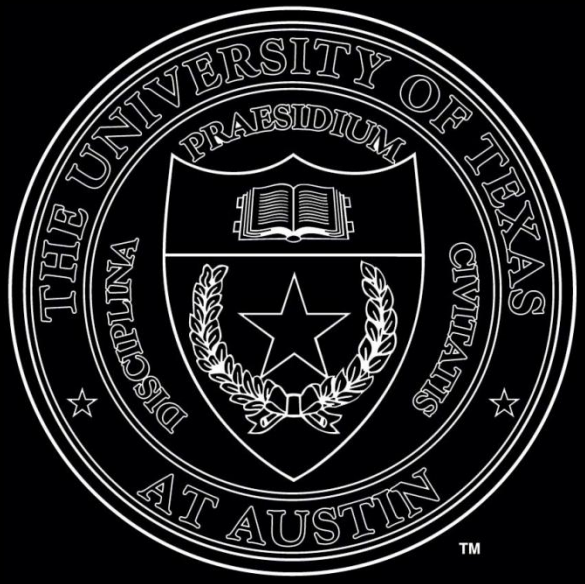



# *The Unintended Energy Impacts of Increased Nitrate Contamination from Biofuels Production*

**Kelly M. Twomey, Ashlynn S. Stillwell, and Michael E. Webber**

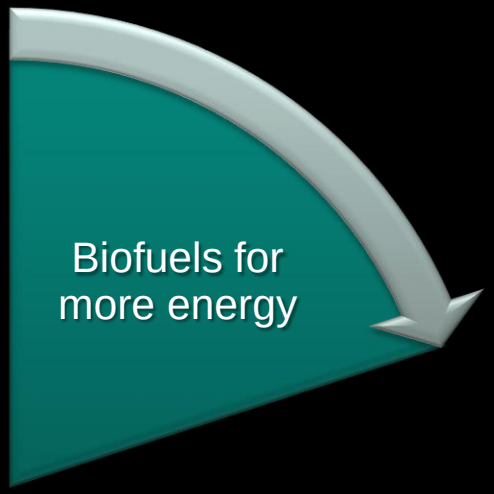
September 28, 2010

# *Key issues I will address*

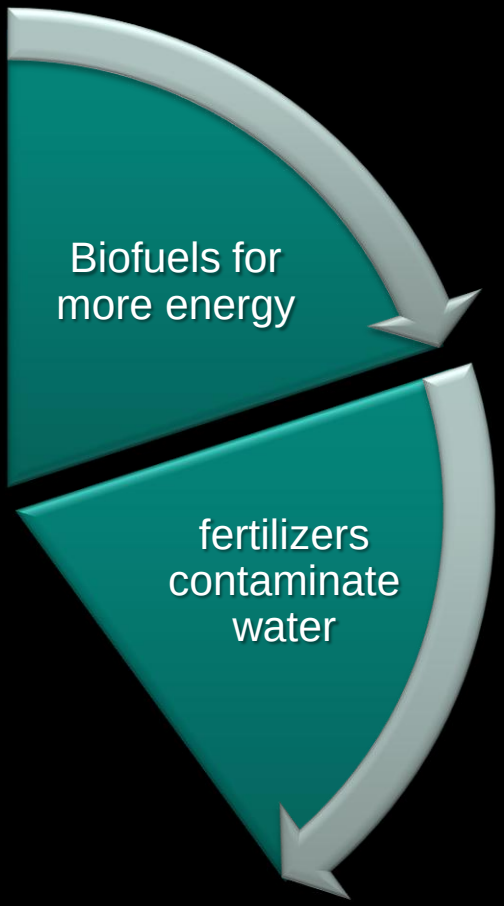
- **How will current policy influence the future expansion of biofuels?**
- **How will this expansion of biofuels impact the environment?**
- **What are the unintended consequences of these environmental impacts in the energy sector?**

# *The production of biofuels has implications "downstream"…*

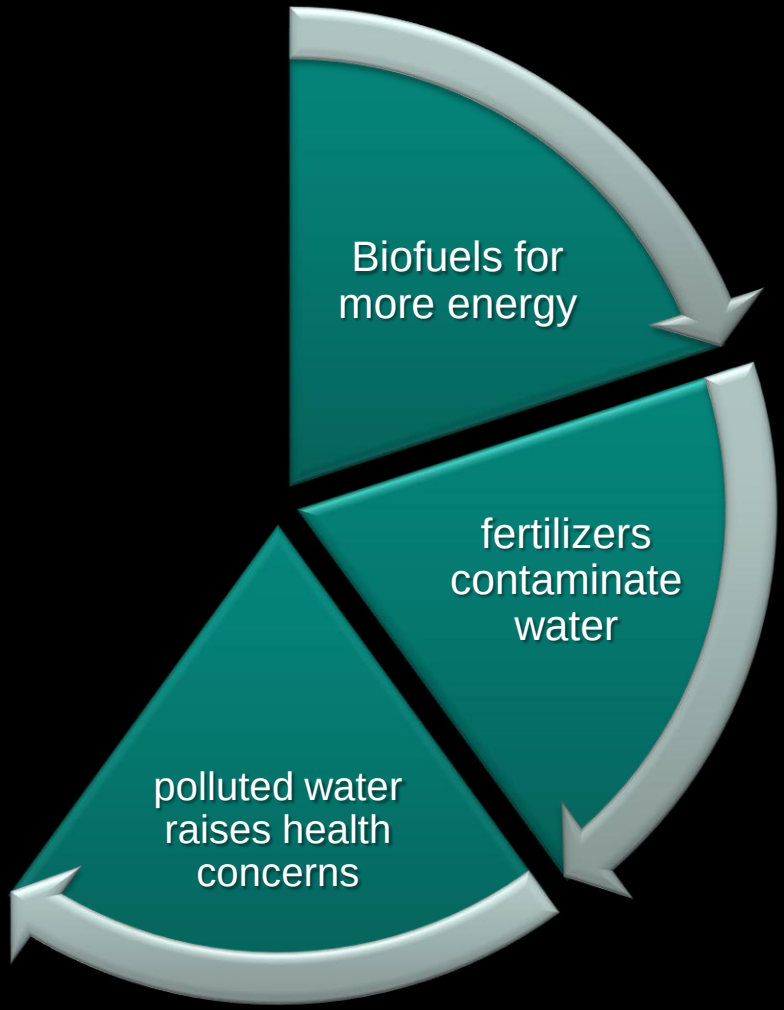
# *The production of biofuels has implications "downstream"…*



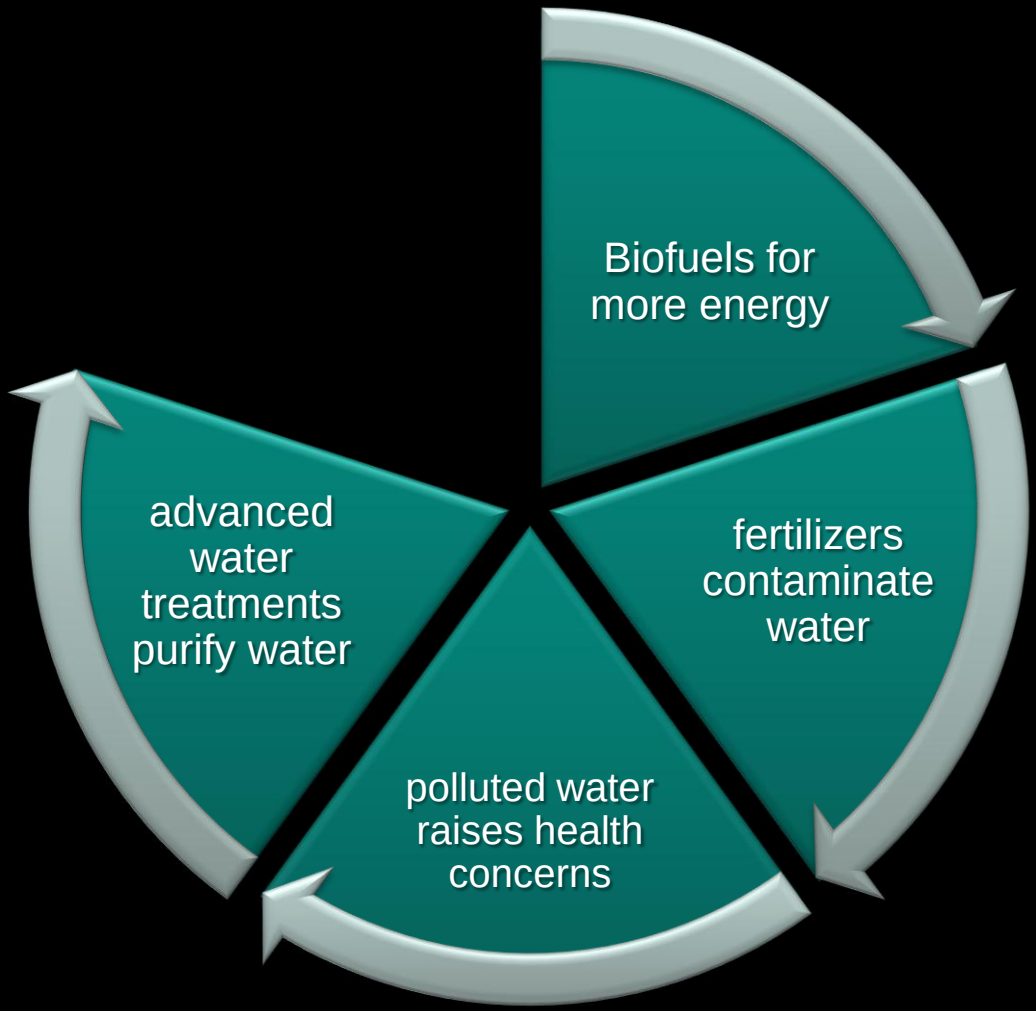
# *The production of biofuels has implications "downstream"…*



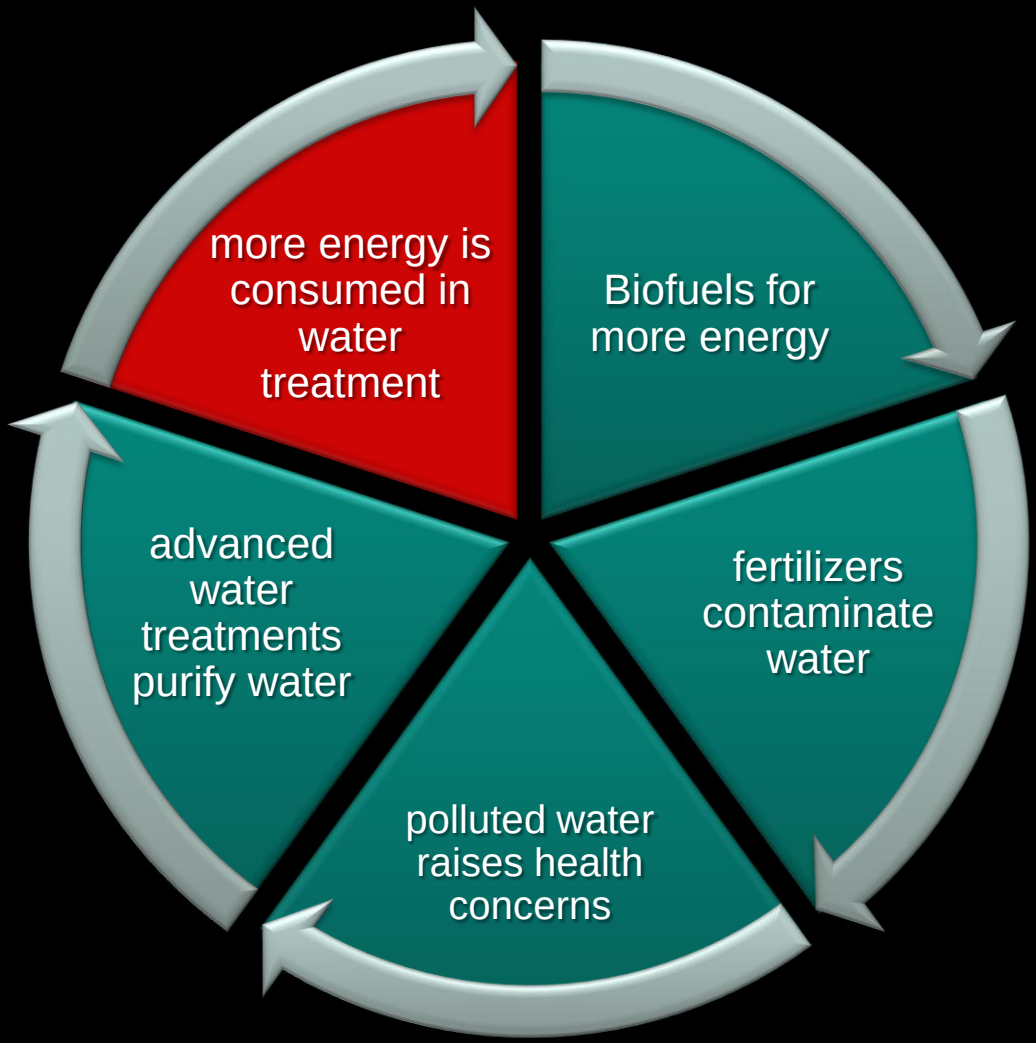
# *The production of biofuels has implications "downstream"…*



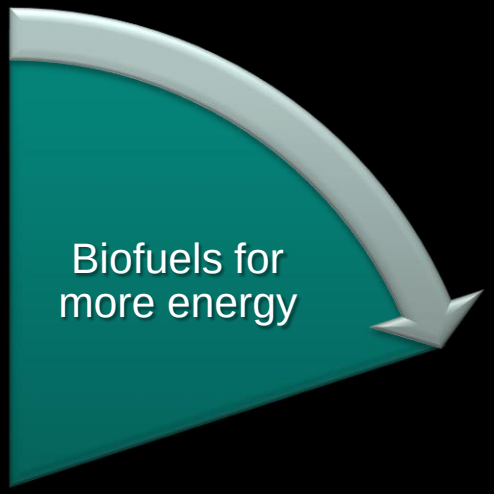
# *The production of biofuels has implications "downstream"…*



# *The production of biofuels has implications "downstream"…*



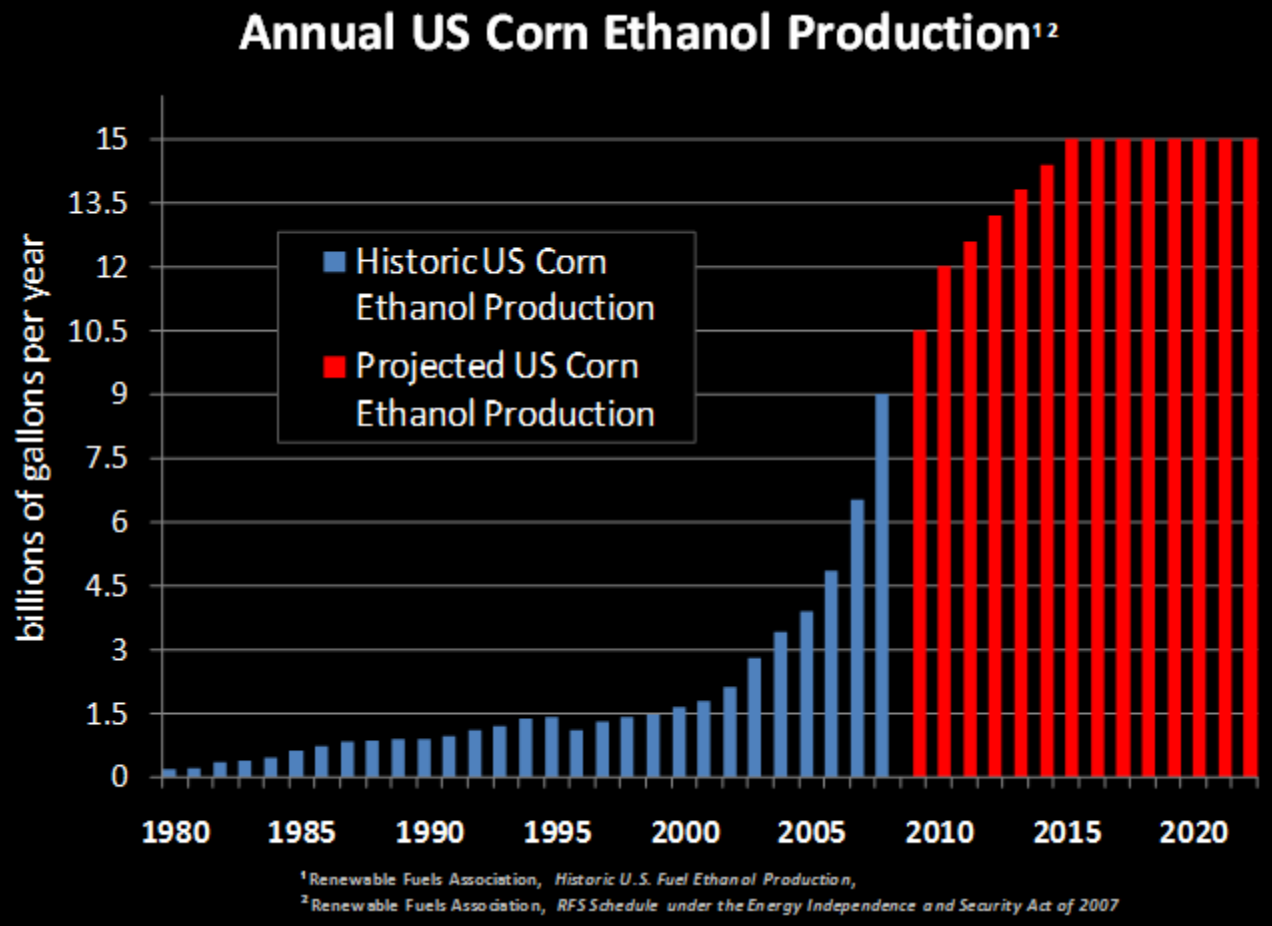
# *Current U.S. policy promotes the future expansion of biofuels*



# *The Energy Independence and Security Act of 2007 implemented a nationwide RFS*

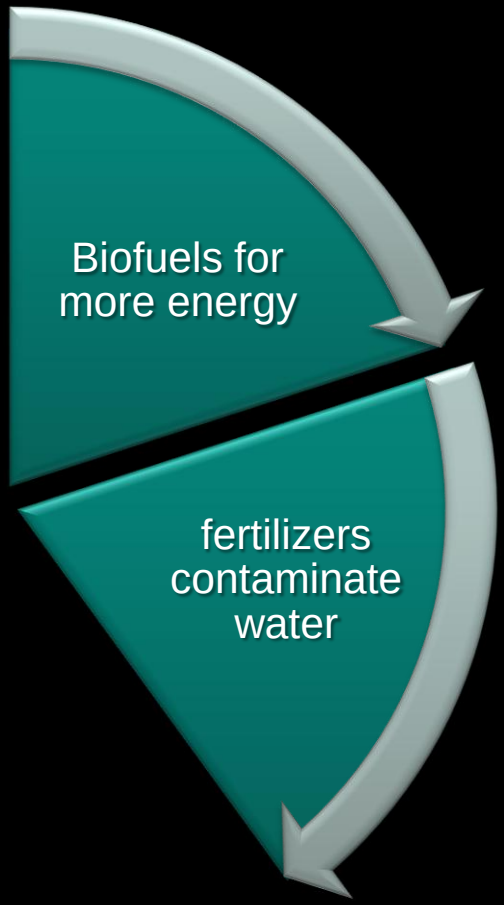
- **Corn-starch based ethanol production likely to increase to 15 billion gallons per year by 2022**
- **Advanced biofuels will contribute an additional 21 billion gallons per year**
- **Total 2022 target: 36 billion gallons of biofuels**

# *EISA 2007 will significantly increase the production of biofuels in the future*




Kelly M. Twomey
Water Energy Sustainability Symposium 11
September 28, 2010

# *Corn-starch based ethanol production has well-cited water quality implications*



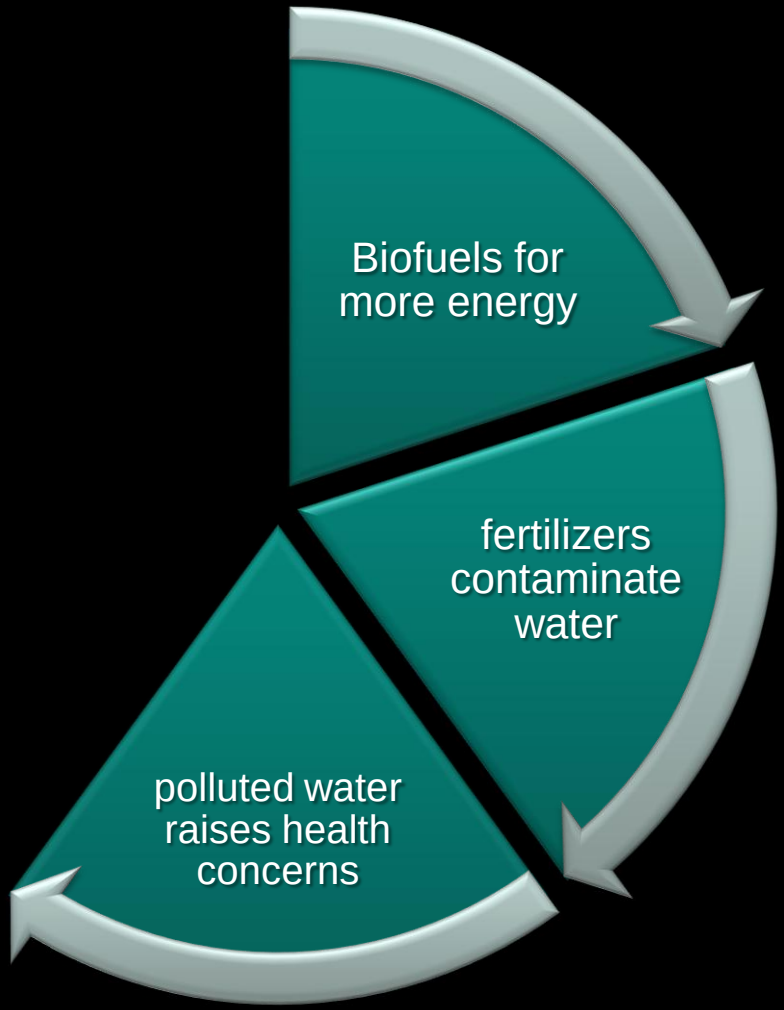
# *Corn starch based ethanol production has well-cited water quality implications*

- ↑ Corn production
- ↑ Fertilizer use
- ↑ Runoff/nutrient loading to downstream water bodies
- ↑ Increased nitrate contamination in water sources

# *Analyses predict significant increases in nitrogen loading in water due to EISA 2007*

- **37% increase in N loading nationally (Simpson *et al.*, 2008)**
- **10-34% increase average annual flux of dissolved inorganic N to the Mississippi-Atchafalaya River Basin by 2022 (Donner and Kucharik, 2008)**
- **24% increase in riverine N export to the Lake Michigan basin by 2017 (Han *et al.*, 2009)**

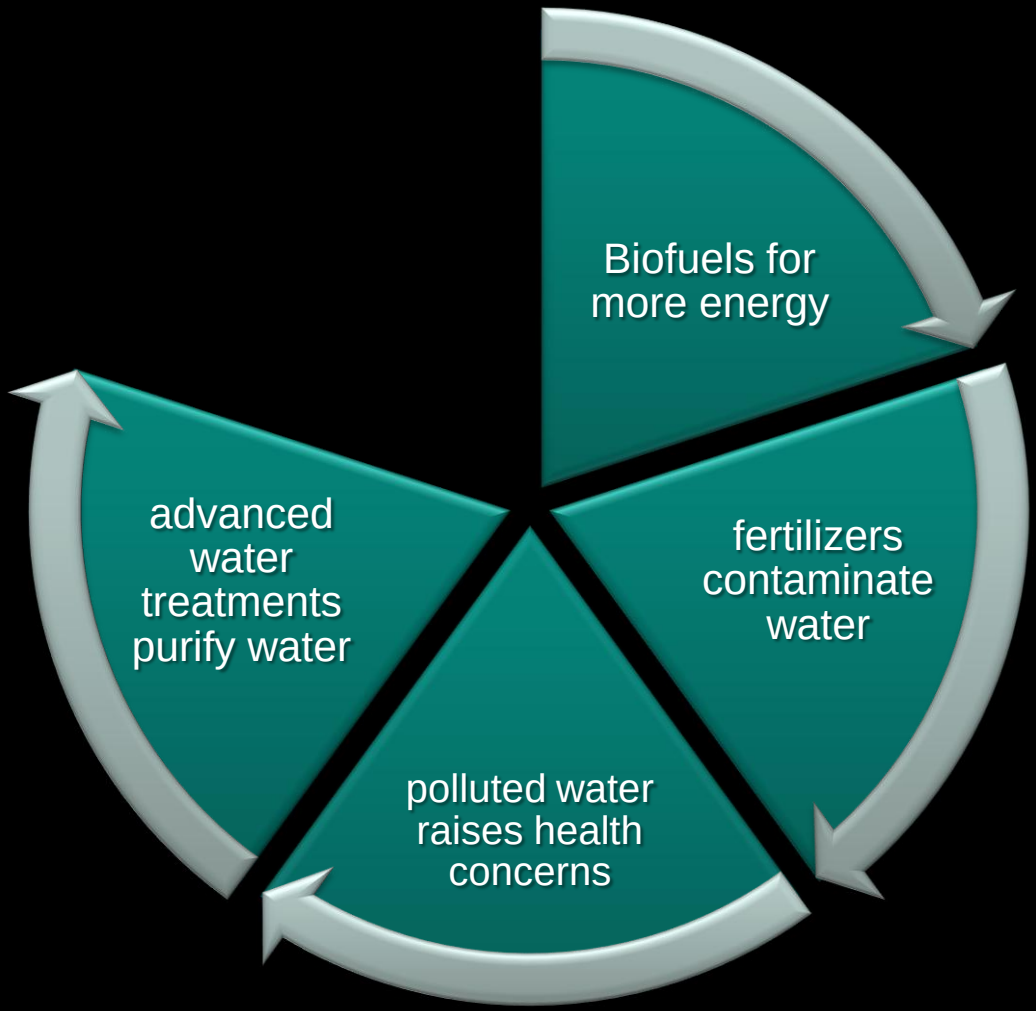
# *Nitrate contamination in drinking water has well-cited health implications*



# *Nitrate contamination in drinking water has well-cited health implications*

- **Confirmed link to methemoglobinemia aka “Blue Baby Syndrome”**
- **Confirmed link to esophagus, stomach, colon, bladder, lymphatic, and hematopoietic system cancer in animals (Ward *et al.,* 2005)**
- **Confirmed link to Alzheimer’s, Diabetes Mellitus, and Parkinson's Disease (Monte *et al.,* 2009)**
- **Potential link to cancer in humans (Ward *et al.,* 2005)**

# *Removing contaminants from water requires advanced water treatment processes*




Kelly M. Twomey
Water Energy Sustainability Symposium 17
September 28, 2010

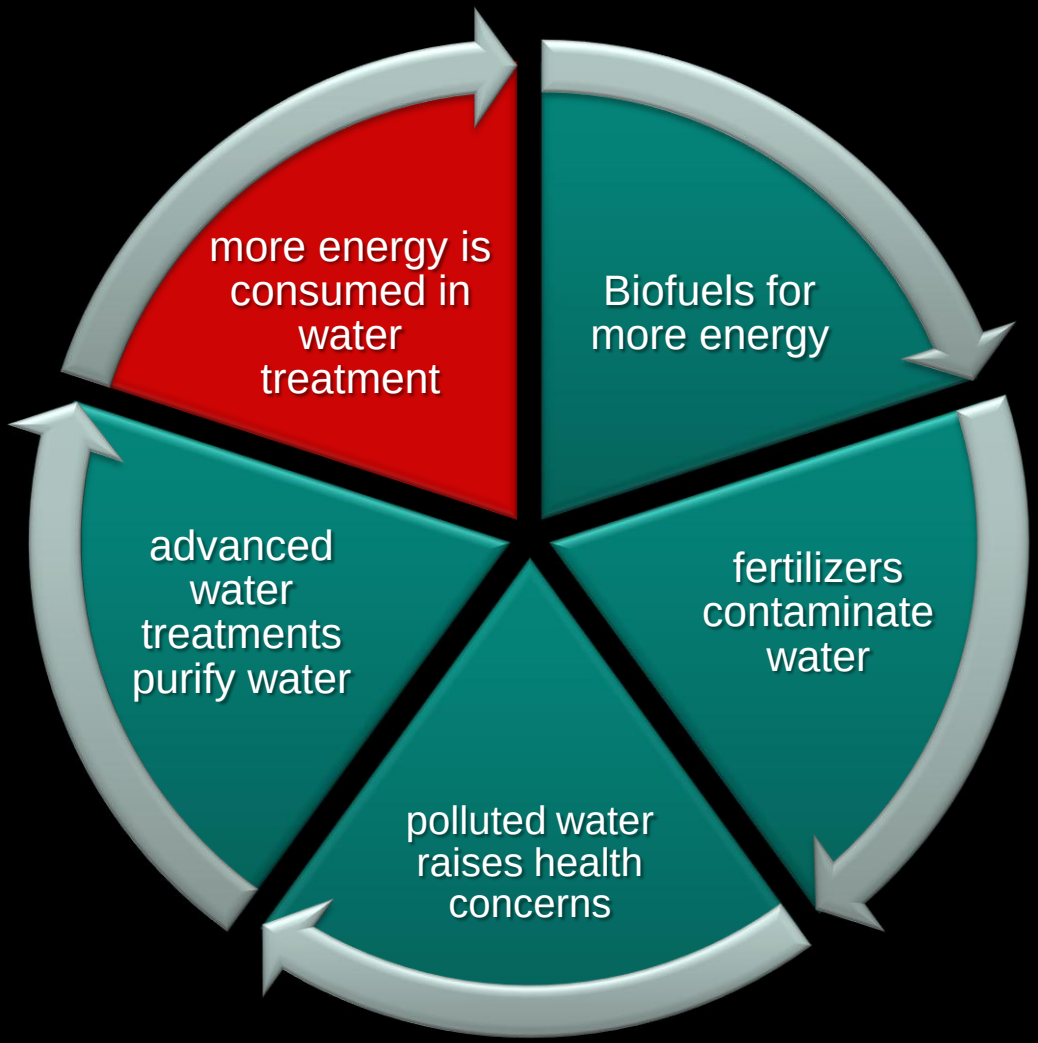
# *Water treatment processes are selected based on raw water quality*

| Clarification | Filtration | Disinfection | |
|---|---|---|---|
| Coagulation | Sand filter | Ozonation | |
| Flocculation | GAC filter | UV radiation | |
| Decantation | Dual Filter | Oxidation | |
| Flotation | | | |
| **Membrane treatments** | **Chemical Treatments** | **Thermal distillation** | **Other Treatments** |
| Prefiltration | PAC injection | Multi-flash Distillation | Electrodialysis |
| Microfiltration | | | |
| Ultrafiltration | Remineralization | Multi-effects | Biological treatment |
| Nanofiltration | Neutralization | Mechanical Vapor Compression | Ion Exchange |
| Reverse Osmosis | | | |

# *Advanced water treatment processes might be necessary to clean degraded water*

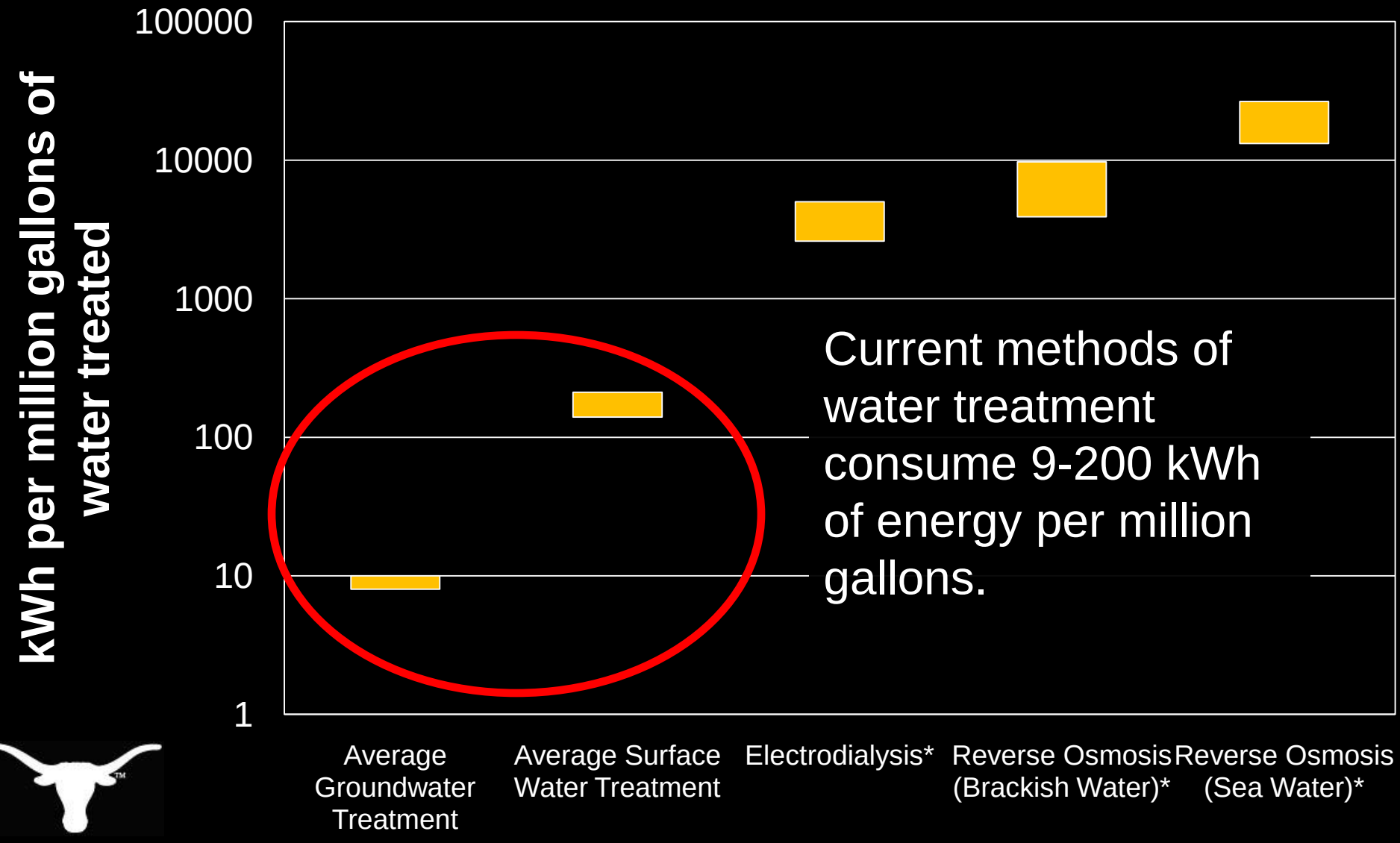
- **Membrane Treatments**
  - **High pressure gradients push water through very small membranes to remove contaminants**
- **Ion Exchange Methods**
  - **Negatively or positively charged ions are exchanged to remove ionic contaminants**
- **Electrochemical Methods**
  - **Electric currents are passed through water to kill microorganisms/dissolve contaminants**

# *Advanced water treatment processes have substantial energy costs*

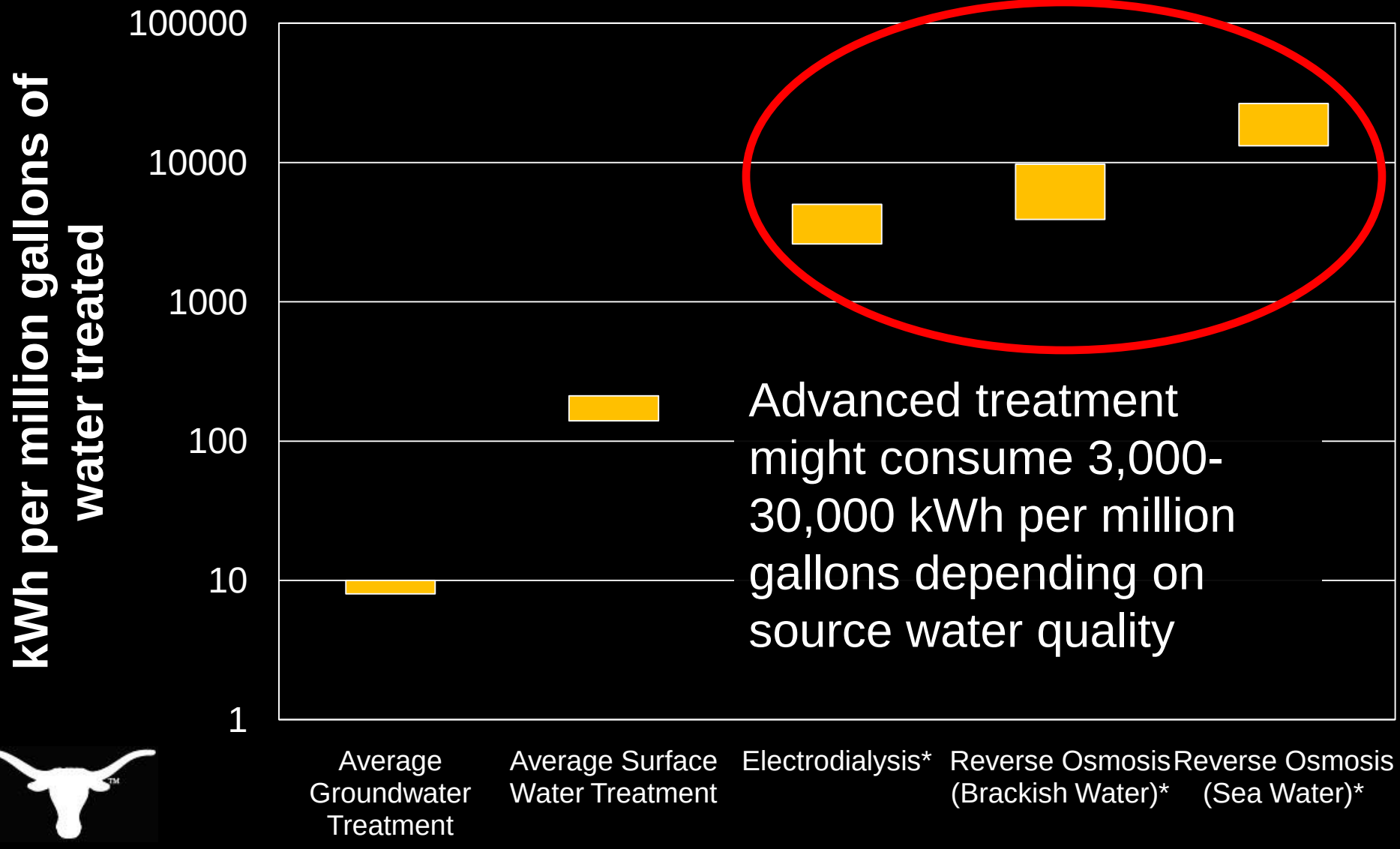



Kelly M. Twomey
Water Energy Sustainability Symposium 20
September 28, 2010

# *Water treatment processes effective for nitrate removal are very energy intensive*



# *Water treatment processes effective for nitrate removal are very energy intensive*



# *Surface water treatment is not likely to be significantly affected by EISA 2007*

**Surface water sources serve an average of 12,500 people per system**

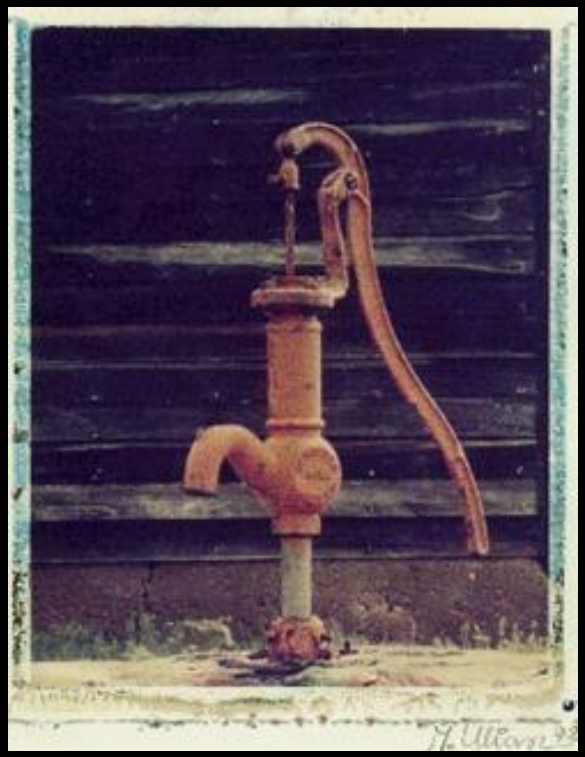
- **Mainly serve city populations**
- **Large water volumes are harder to contaminate**

( www.drinking-water.org)

# *Groundwater contamination is likely to increase as agricultural activity increases*

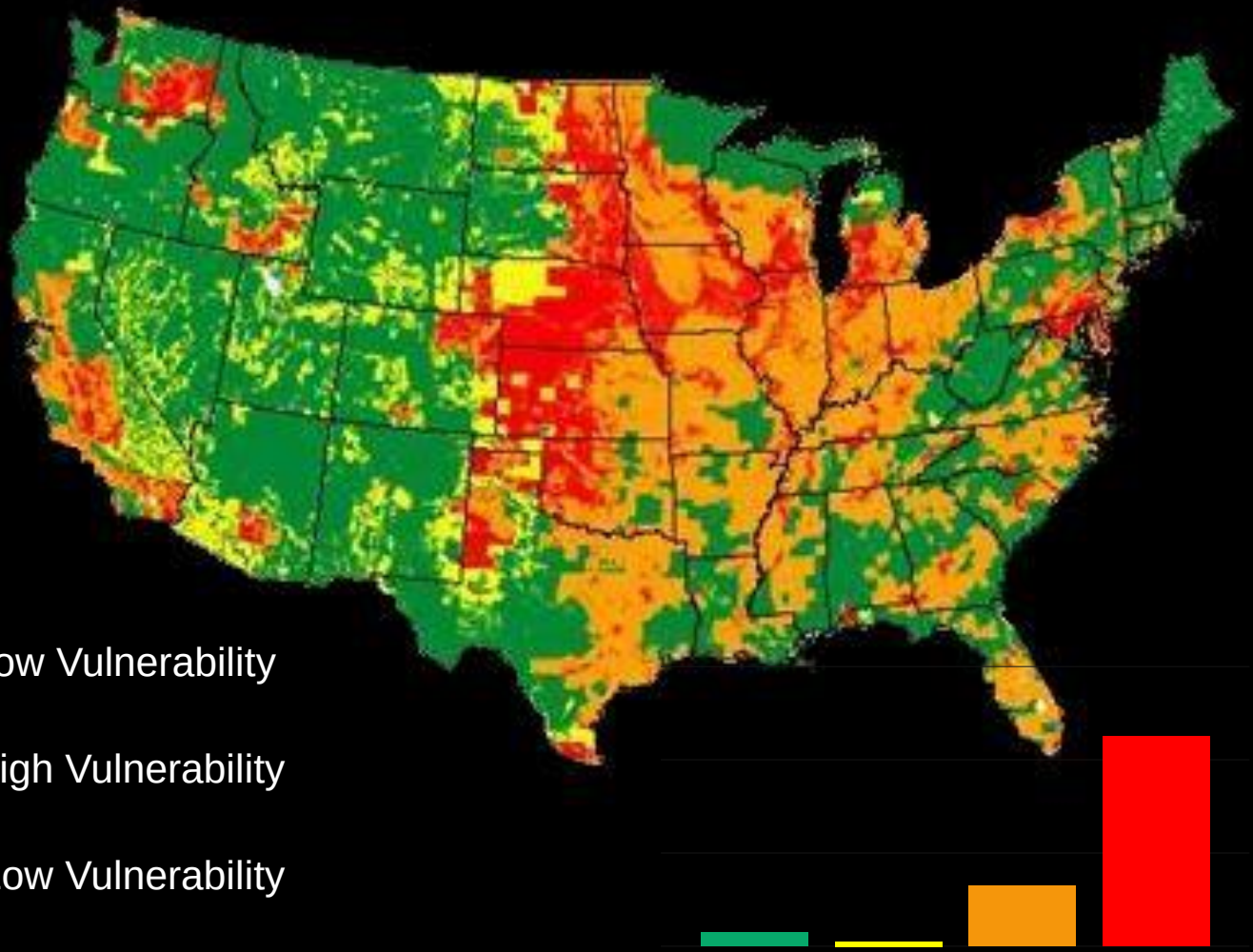
**Groundwater sources serve an average of 700 people per system**

- **Supply 98% of non-community public systems**
- **Small volumes are most susceptible to contamination**
- **24% of shallow (<5 m) groundwater wells in agricultural areas are already contaminated**



(www.cwac.net)

# *The majority of high risk groundwater wells are concentrated in the Corn Belt*




(Adapted from : Nolan B. Relating Nitrogen Sources and Aquifer Susceptibility to Nitrate in Shallow Ground Waters of the United States. Ground Water 2001;39:290.)

# *Our analysis estimates the energy that would be required to treat baseline nitrate contamination in the public water supply*

- **Scenario 1: All water delivered to affected population[a] is treated at the public water treatment facility with advanced nitrate-removal processes**
- **Scenario 2: Only a portion of the water delivered to the affected population is treated for nitrate removal at the point-of-use**

[a] 12.4 million people were supplied nitrate contaminated water from public water systems between1998-2003 according to the Environmental Working Group's *National Tap Water Quality Database.*

# *Results suggest a dramatic increase in energy requirements for nitrate removal*

**Scenario 1:**

- **12.4 million people are delivered nitrate contaminated water in public water systems**
- **634 billion gallons of contaminated water per year treated (assumes 140 gallons/person/day)**

**Standard SW treatment (baseline):**

- **111 million kWh per year**

**RO treatment for Nitrate Removal (advanced):**

- **2,500 million kWh per year**
- **Increase of 2100% over baseline**

# *Treatment for nitrate contaminated drinking water at the home offers savings*

**Scenario 2:**

- **12.4 million people are delivered nitrate contaminated water in public water systems**
- **Point-of-use systems are used to treat drinking water only**
- **57 billion gallons of contaminated drinking water per year treated (assumes 12 gallons/ person/day)**

**Standard SW treatment (baseline):**

- **10 million kWh per year**

**RO treatment for Nitrate Removal (advanced):**

- **221 million kWh per year**

# *Conclusions*

- **There will be water quality consequences as a result of EISA 2007**
- **Groundwater wells are more likely to be affected than surface water supplies**
- **Treating baseline nitrate contamination in the public water supply would elicit substantial increases in energy consumption to meet acceptable MCL**
- **Point-of-use treatment systems offer potential energy savings for treating small volumes of contaminated water (although they require more energy per volume of water treated)**

# *Questions?*

# *END*


## Kelly M. Twomey

***National Science Foundation Graduate Research Fellow***
**Thermal Fluid Systems**
**Mechanical Engineering**

**University of Texas at Austin**
kmt@mail.utexas.edu
http://www.webberenergygroup.com