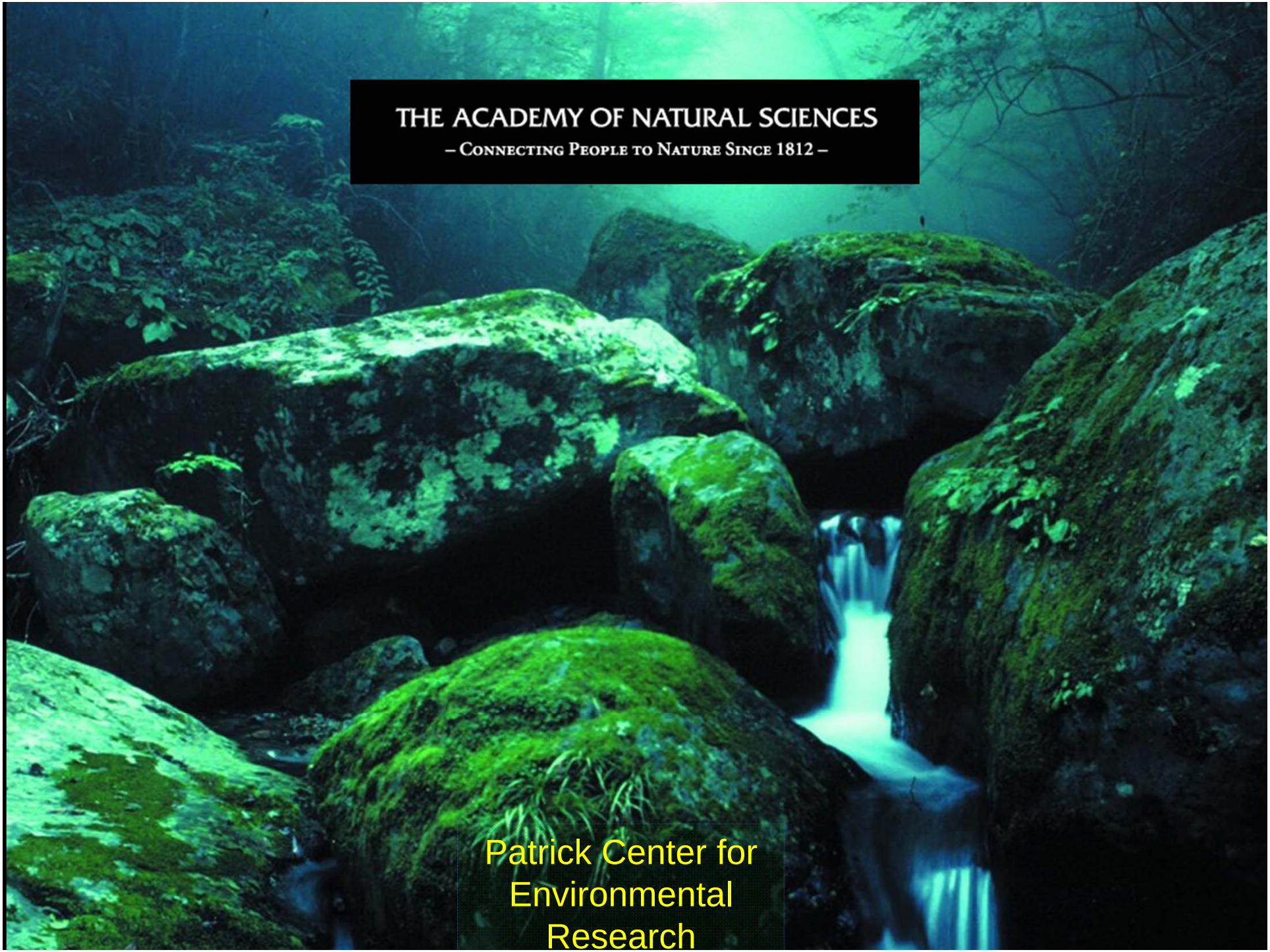

THE ACADEMY OF NATURAL SCIENCES
– Connecting People to Nature Since 1812 –
Patrick Center for Environmental Research

MISSION STATEMENT

The Patrick Center for Environmental Research, established within the Academy of Natural Sciences in 1947, is a multidisciplinary group of scientists that:

seeks to use a multi-disciplinary approach in the study of aquatic systems to understand the ecological structure and function of watersheds from headwater streams to estuaries

Process based studies versus collections based

The Patrick Center was established in 1947 by Dr. Ruth Patrick (4th from left; seen here leading the 1949 Lancaster County Conestoga Creek survey).

In addition to her many honors and awards, Dr. Patrick received the National Medal of Science in 1996 from President Clinton.

Ruth Patrick, now 103 yrs old!

Founded Patrick Center in 1947

SCIENTIFIC EXPERTISE (# of Ph.D.s)

Area	Scientist
• Biogeochemistry (2)	Velinsky, Ashley
• Wetlands Ecology (2)	Quirk, Mead
Biota	
➢ Algae (4)	Charles, Potopova, Ren, Enache
➢ Invertebrates (1)	Mead
➢ Fish (1)	Horwitz
• Ecotoxicology (2)	Velinsky, Ashley
• Ecological modeling & economics (1)	Mead
• Statistical ecology (2)	Mead, Horwitz
• Center for Environmental Policy (1)	Wall
• Asia Center for Environmental Research (1)	Goulden

Today, Patrick Center scientists use their expertise in….

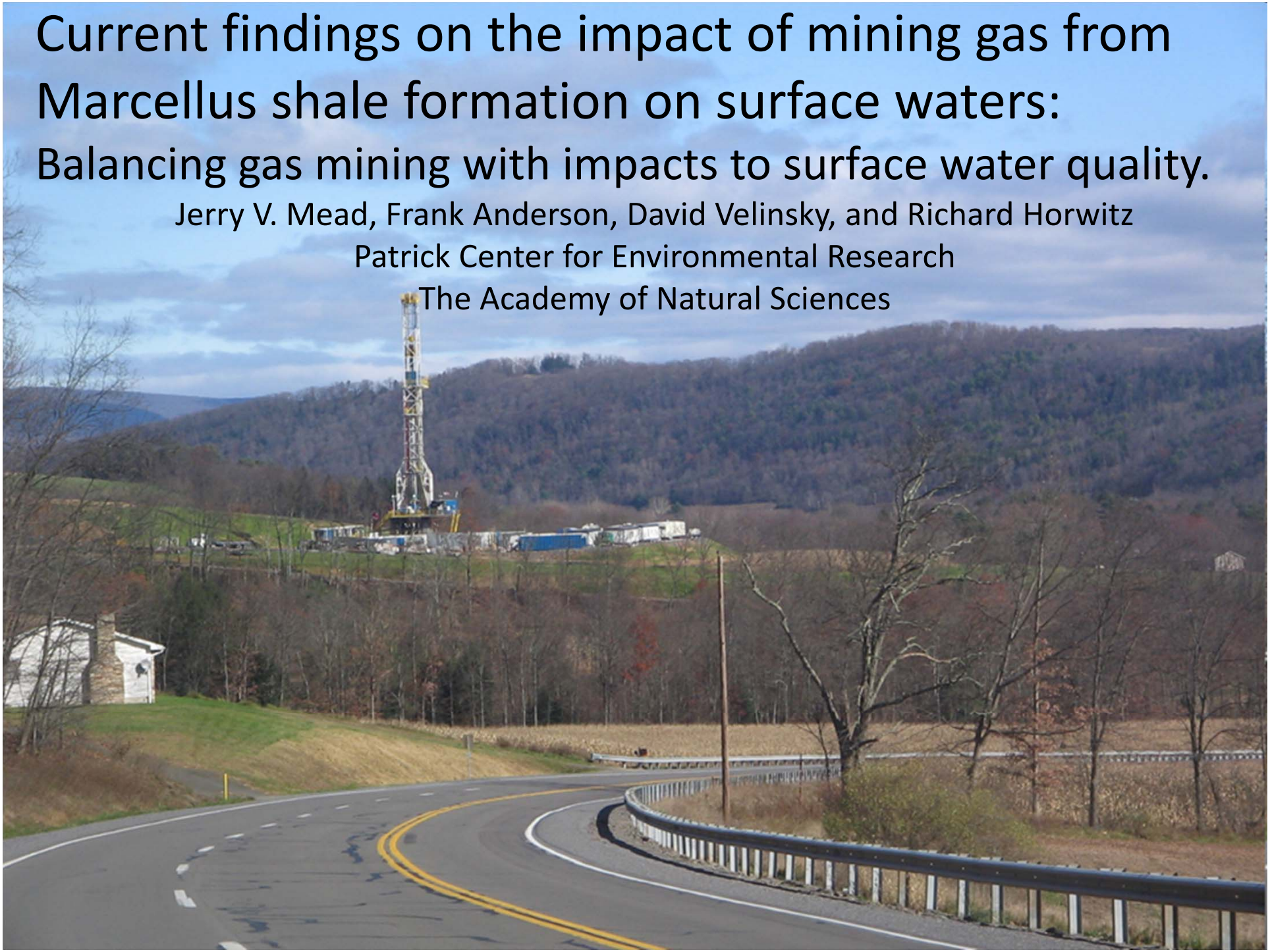
- Stream, river, wetland, and estuarine ecology,
- Assessing ecosystem health,
- Understanding stressor – response relationships,
- Restoring degraded ecosystems,
- Watershed ecology,
- Climate change, and
- Monitoring the impacts of chemical contaminants

…. to evaluate the changes we are seeing in terrestrial and aquatic ecosystems in Pennsylvania and many other sites throughout the world.

Current findings on the impact of mining gas from Marcellus shale formation on surface waters:

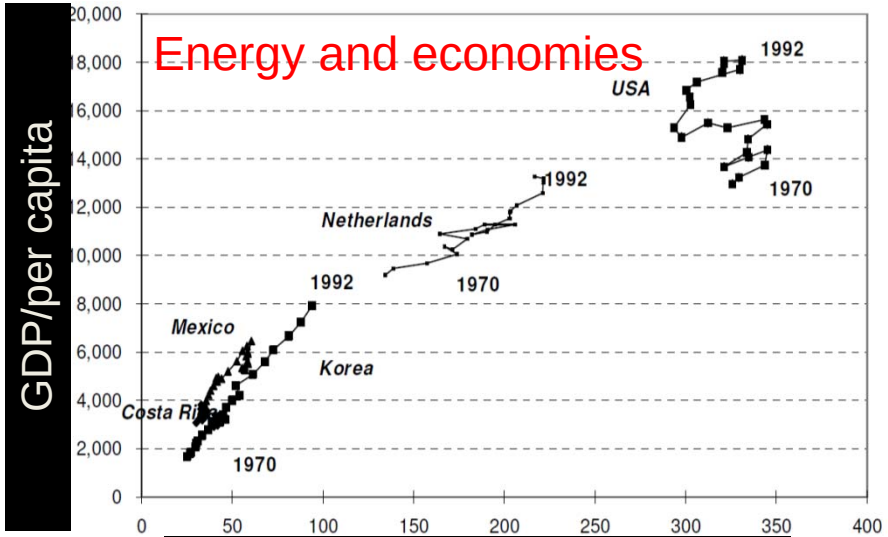
Balancing gas mining with impacts to surface water quality.

Jerry V. Mead, Frank Anderson, David Velinsky, and Richard Horwitz
Patrick Center for Environmental Research
The Academy of Natural Sciences

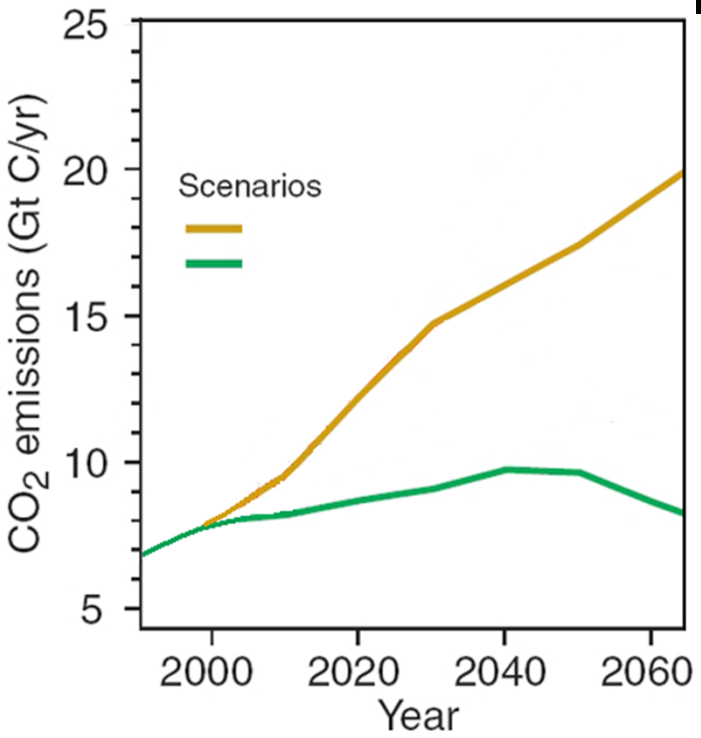


Energy use, global economy, and climate change

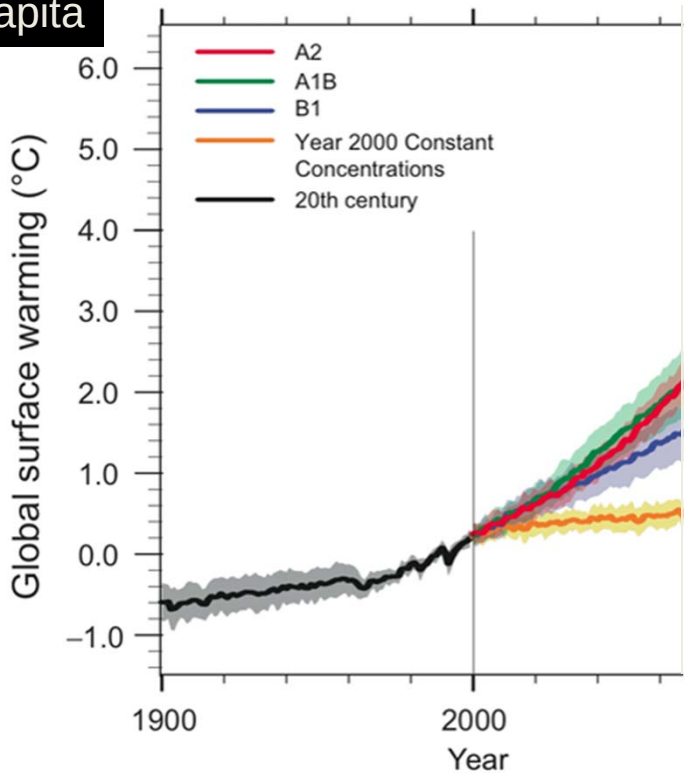
Energy and economies



CO_2 emissions

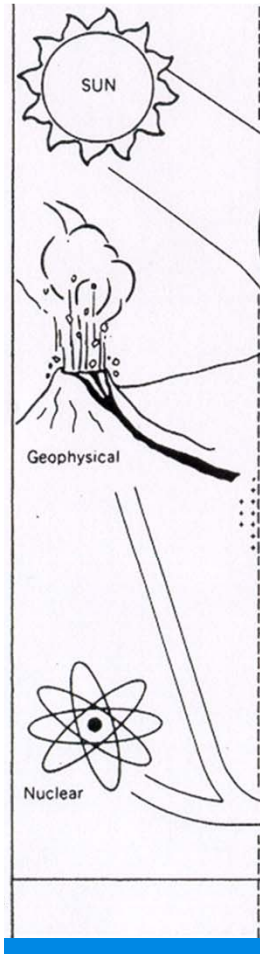


Climate change



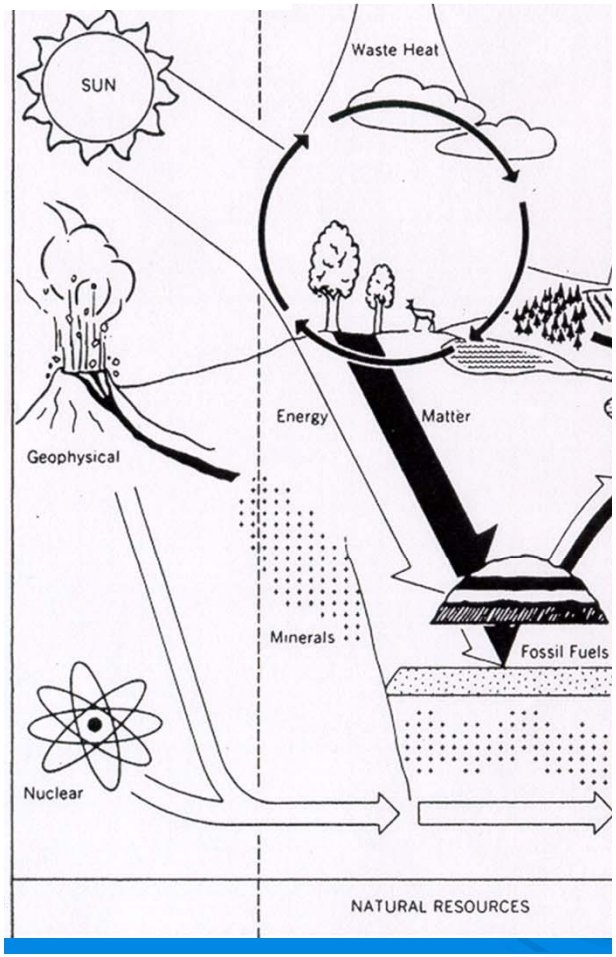
This is how real economies work

Energy Sources



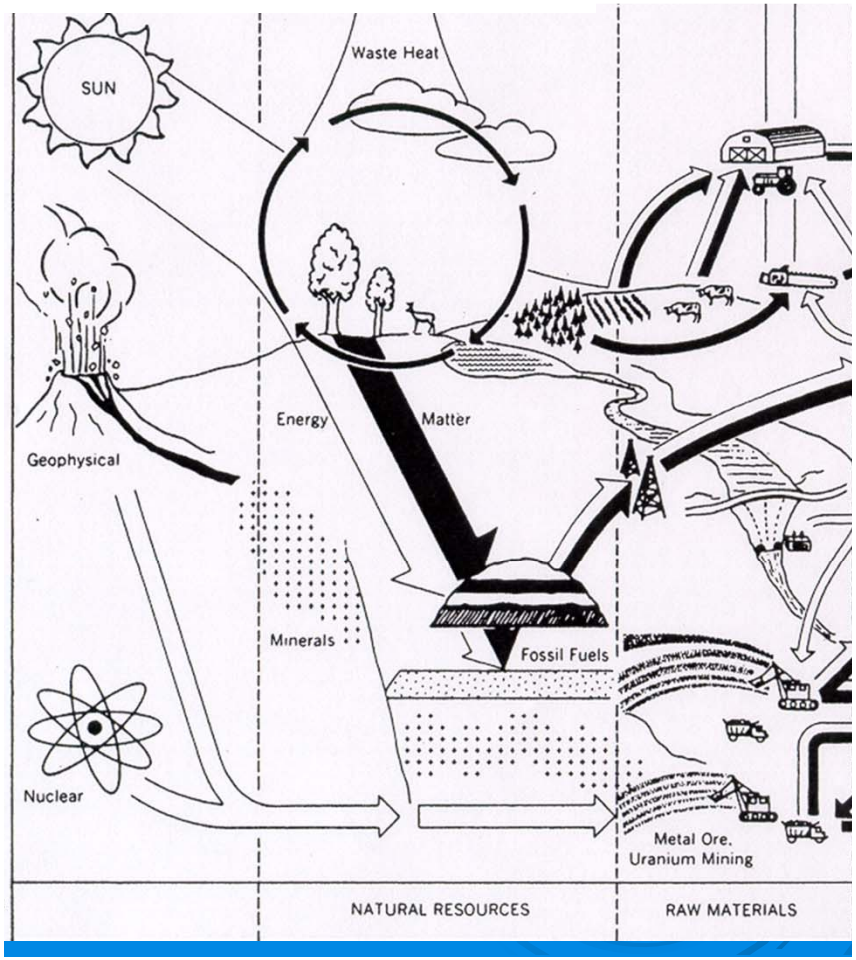
This is how real economies work

Raw Materials



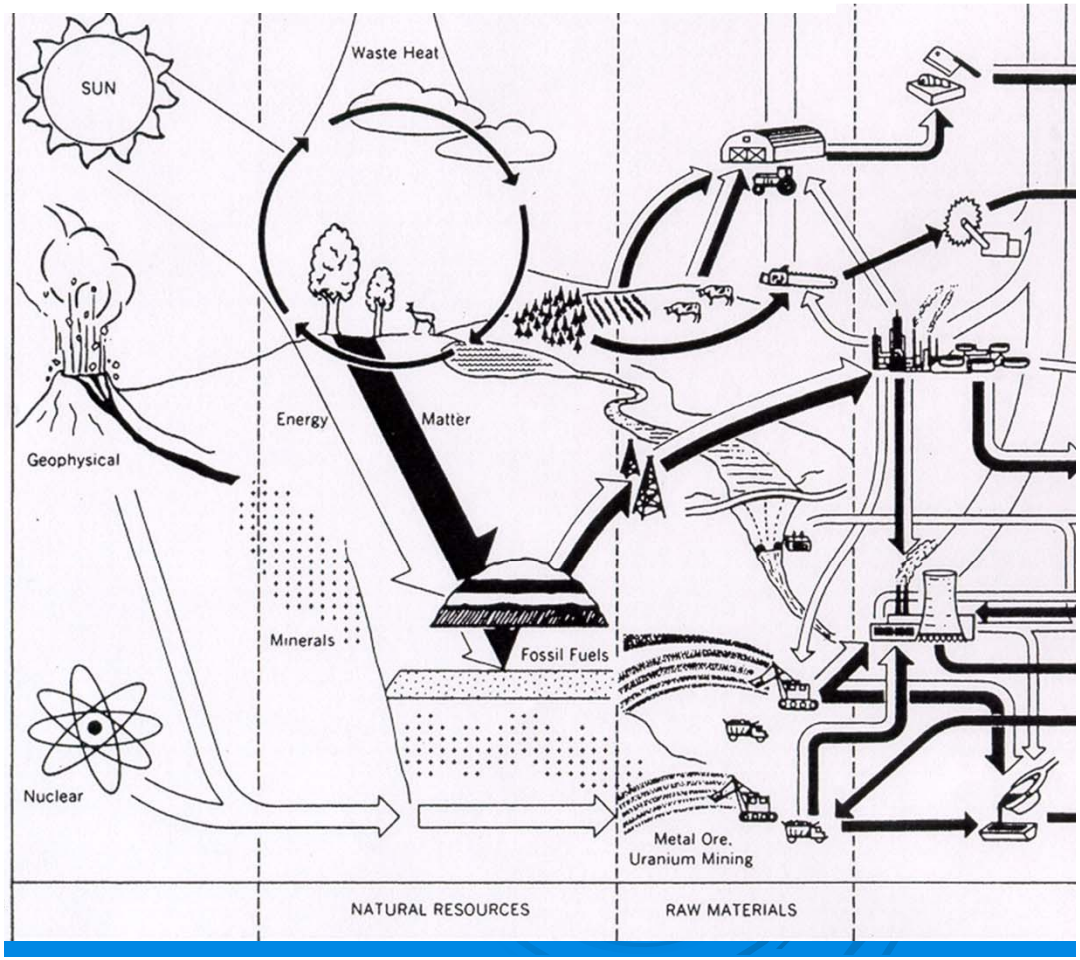
This is how real economies work

Exploitation



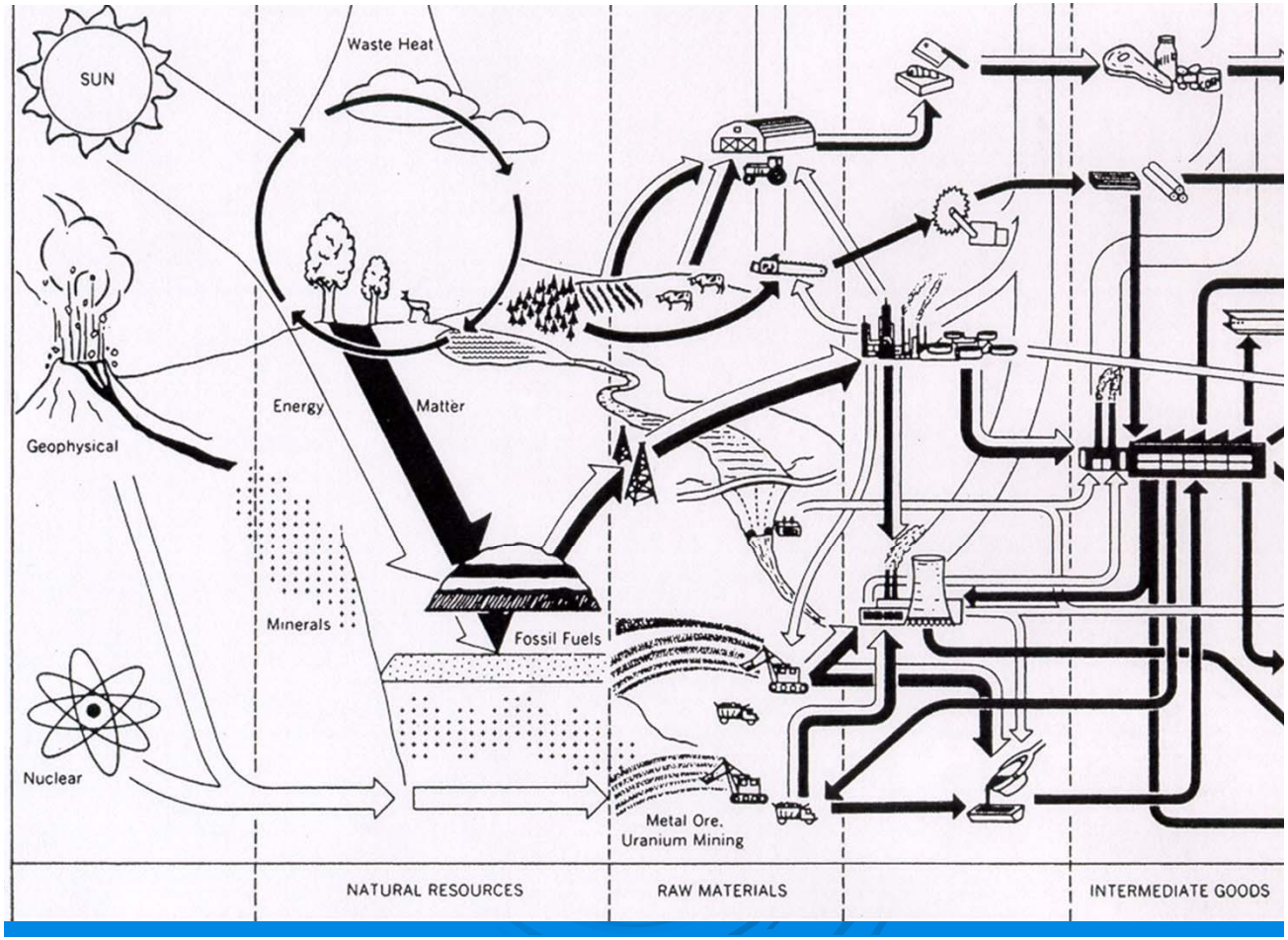
This is how real economies work

Processing



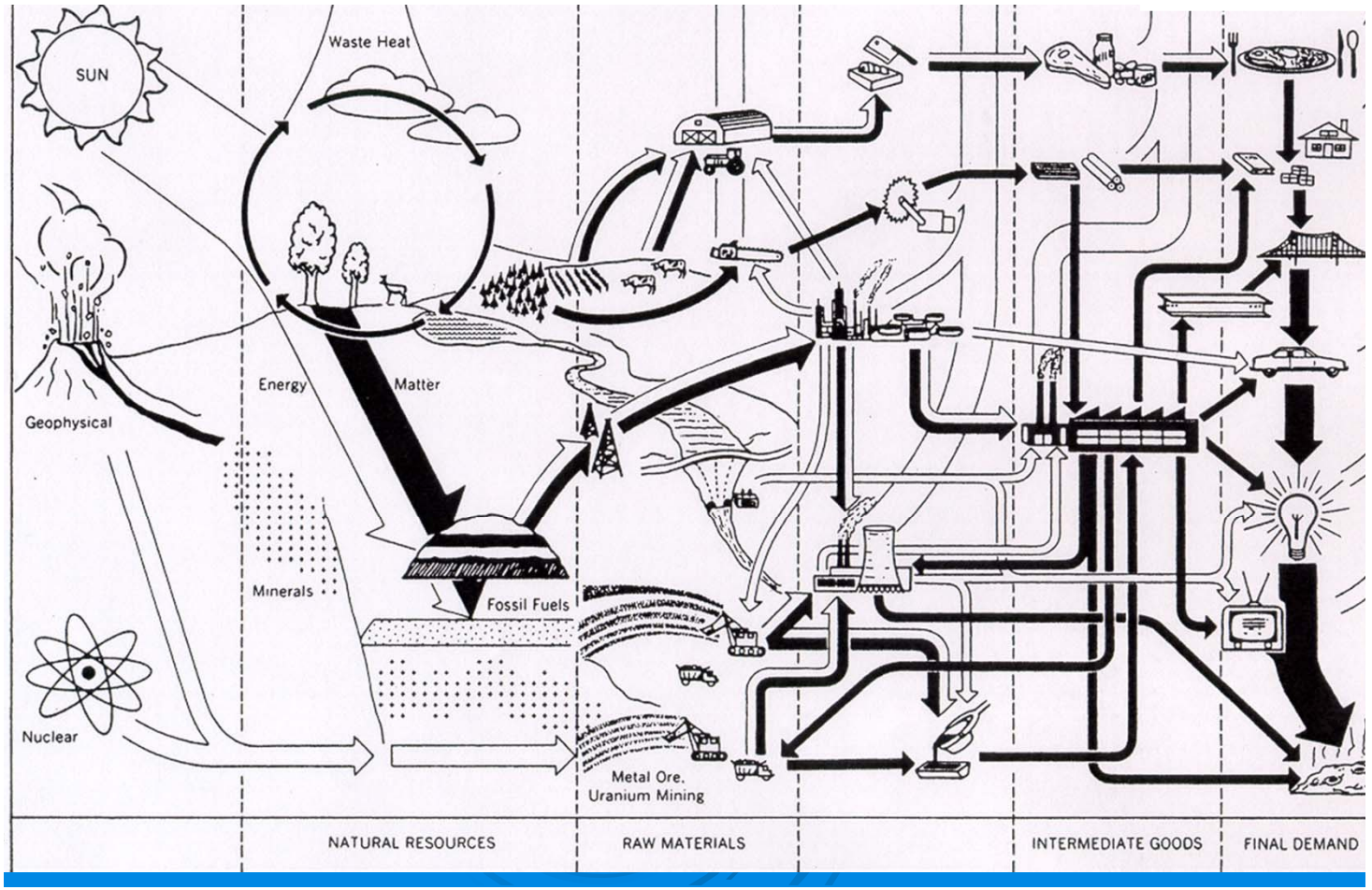
This is how real economies work

Manufacture

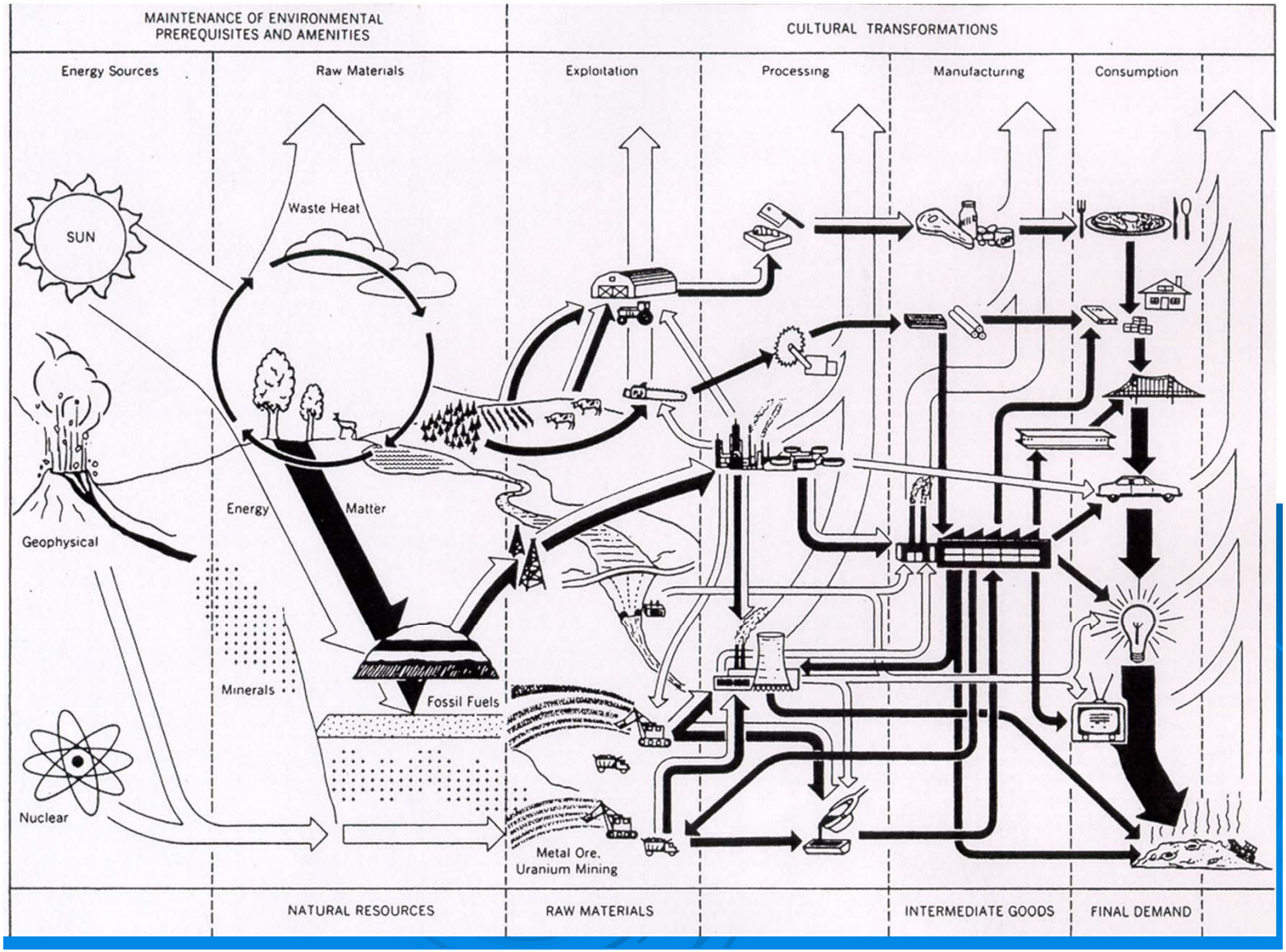


This is how real economies work

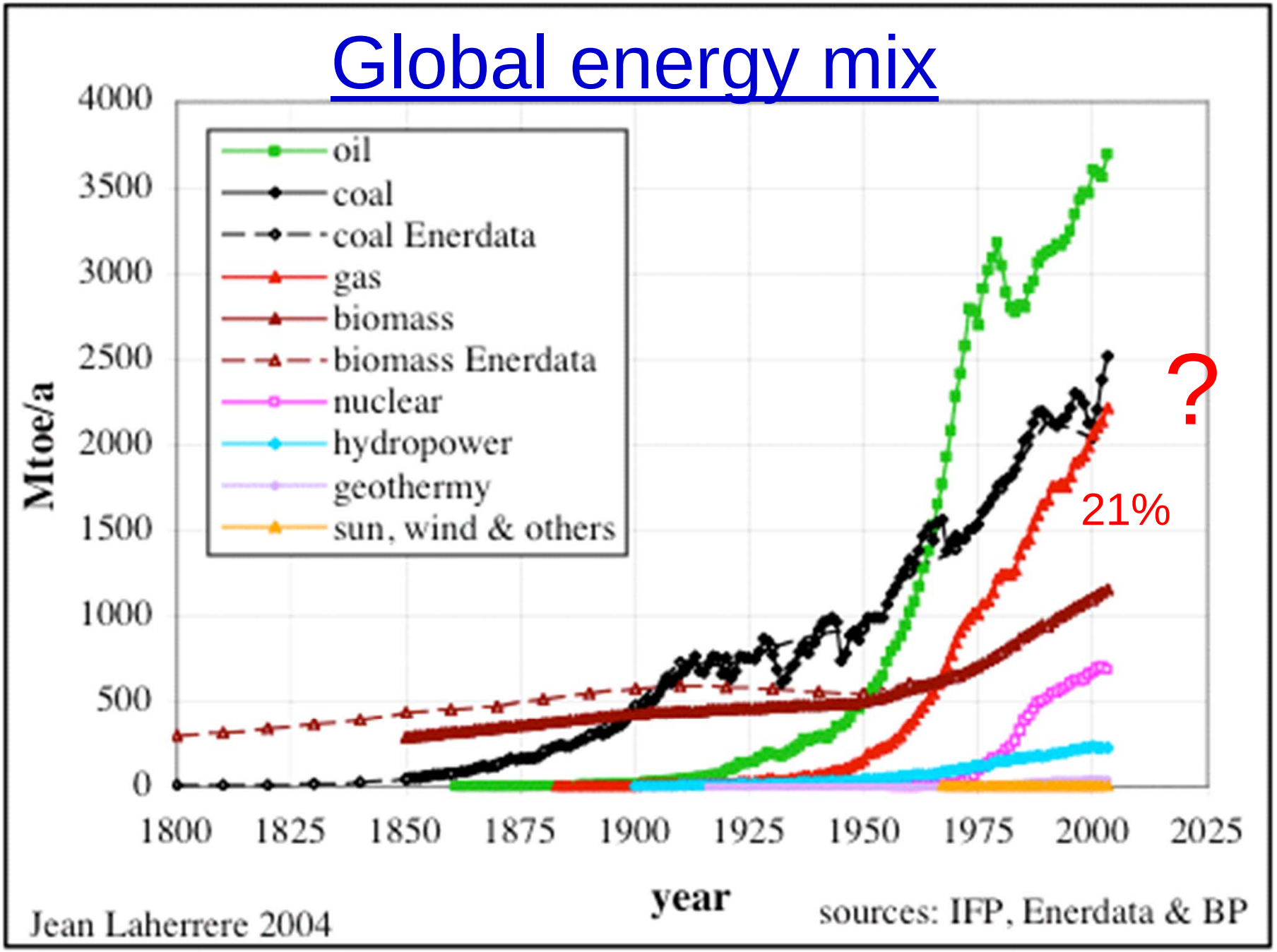
Consumption



This is how real economies work

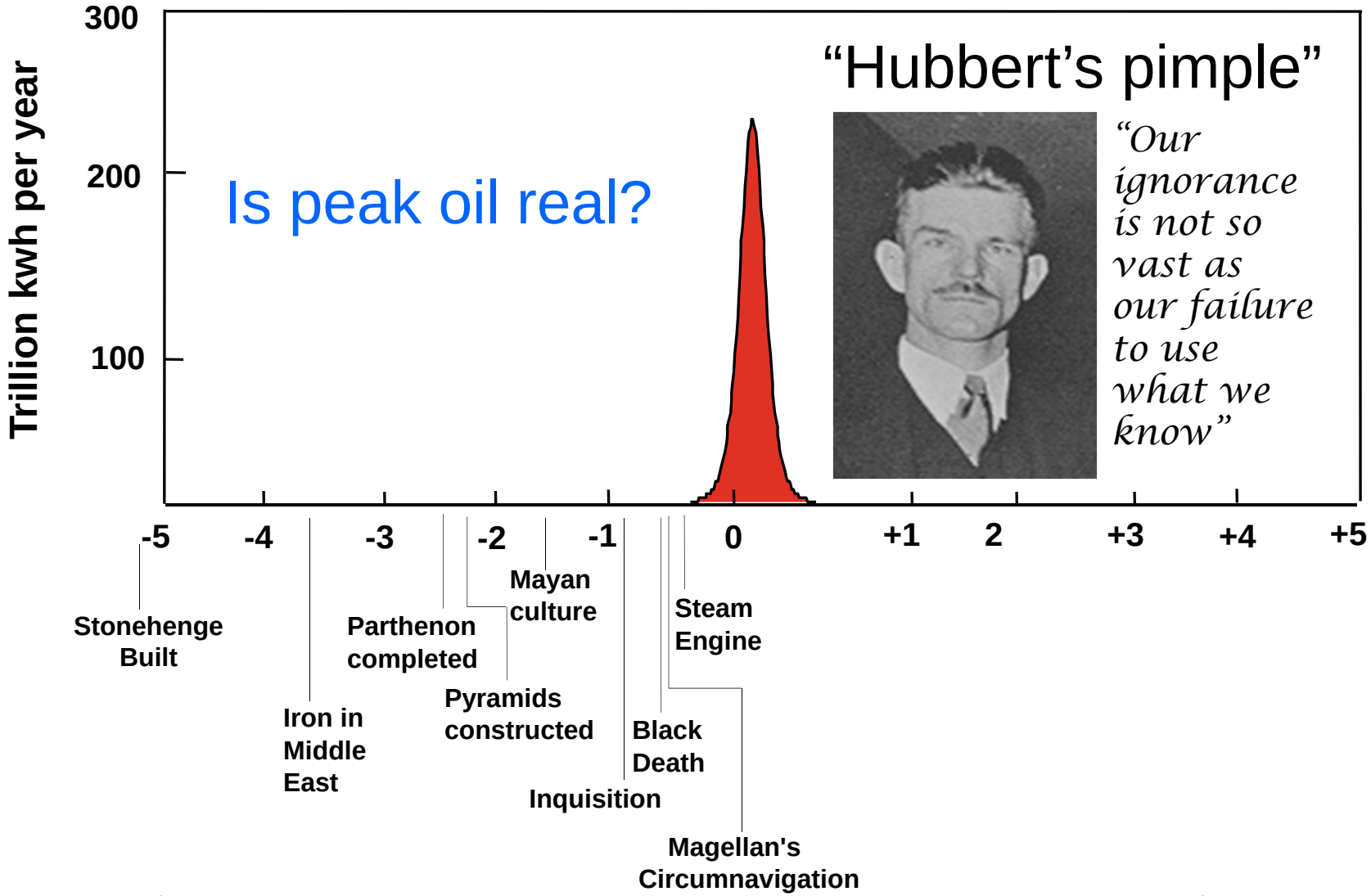


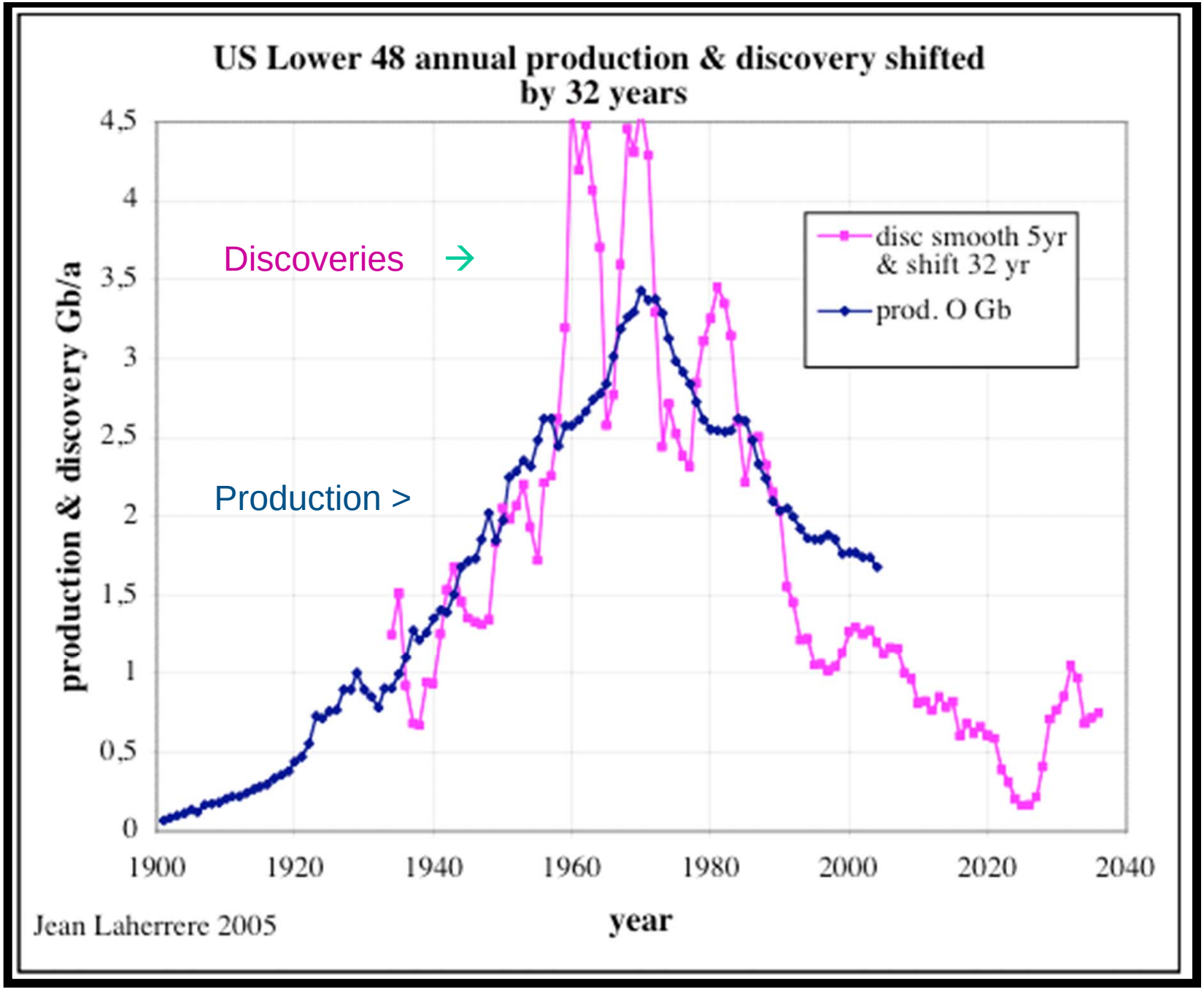
Global energy mix



The Epoch of Fossil Fuel Exploitation

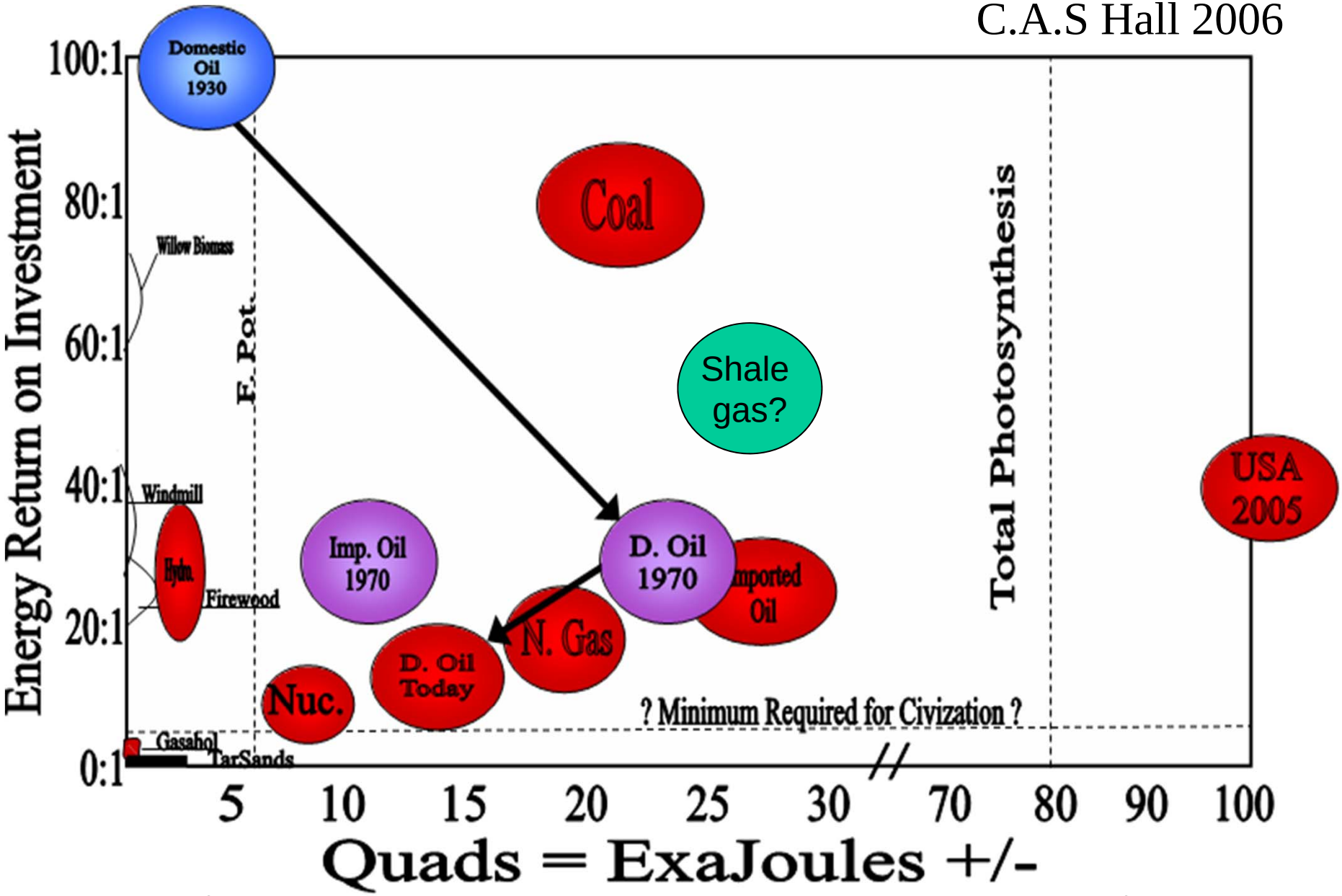
(after Hubbert, 1969)




US Lower 48 annual production & discovery shifted by 32 years
Discoveries →
Production >
disc smooth 5yr & shift 32 yr
prod. O Gb
production & discovery Gb/a
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
1900
1920
1940
1960
1980
2000
2020
2040
year
Jean Laherrere 2005

Fossil fuels are a sweet deal!

C.A.S Hall 2006




The Gas Play IS an important part of Pennsylvania's economy and should be developed in a responsible manner so all can benefit now and into the future.

Endangerment Causes

Urbanization	247
Agriculture	205
Water diversions (e.g., reservoirs)	160
Recreation, tourism development	148
Pollution	143
Domestic livestock, ranching	136

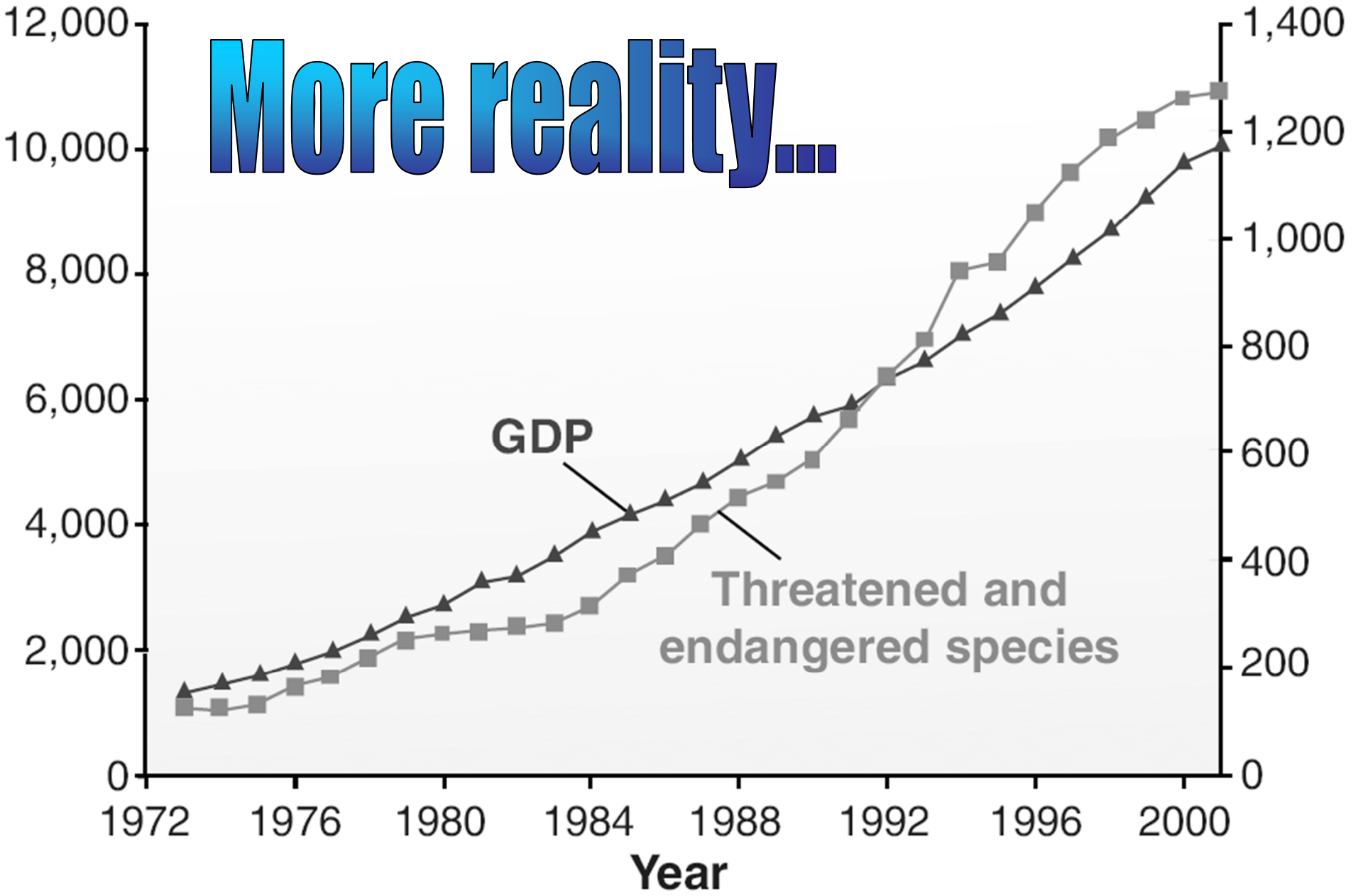
Czech et al. 2000. *Bioscience* 50(7):593-601.

Causes (cont.)

Mineral, gas, oil extraction	134
Non-native species	115
Harvest	101
Modified fire regimes	83
Road construction/maintenance	83
Industrial development	81

Czech et al. 2000. *Bioscience* 50(7):593-601.

More reality...



Potential issues with shale mining

Short Term (construction)

- Water withdrawals
- Flowback disposal
- Light and noise
- Drilling ponds – wildlife
- Air quality
- Seismic activity

Long Term (occupancy)

- Pad on landscape
- GW contamination
- Habitat fragmentation
- Solids disposal on site
- Invasive species
- Edge effects; succession

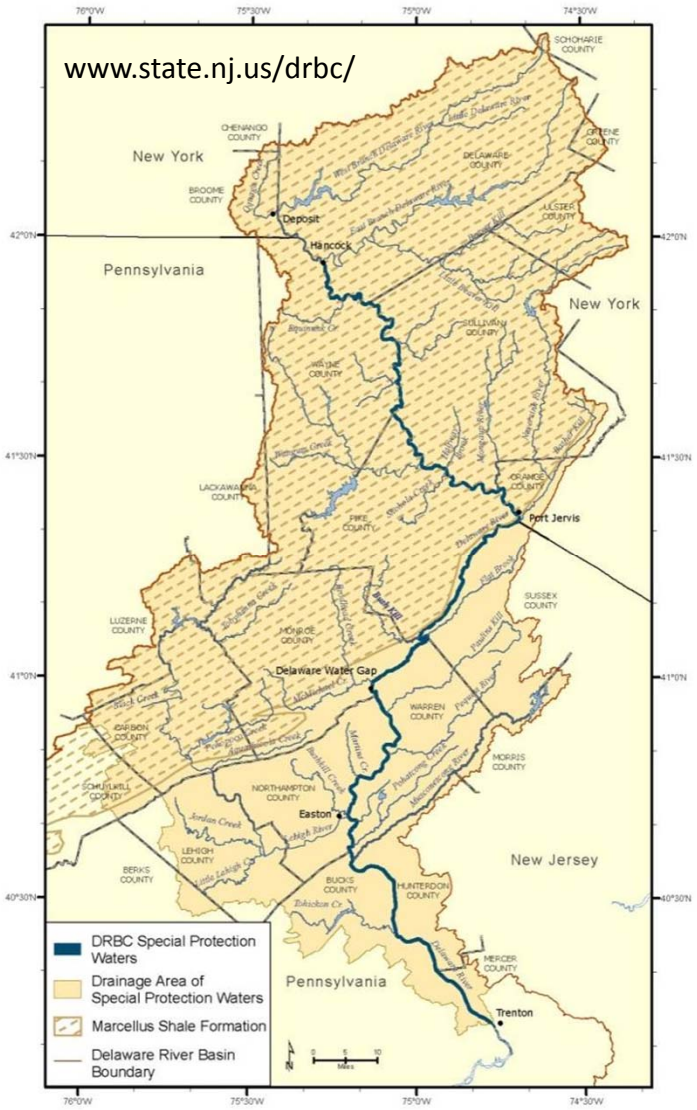
Why is it important to monitor these activities?

• Both loss of forest area and chemical impacts can reduce *Ecosystem Services* of upper Delaware Watershed stream network by:

- reducing nutrient removal,
- impacting recreational fisheries,
- reducing water quality, and
- decreasing recreational use.

>> Very little information is available related to land use changes and the biological impacts of increases in total dissolved solids in smaller streams and watersheds due to drilling activities therefore a study that investigates the **Cumulative Impacts to Aquatic Resources** needs to be undertaken.

What are some of the potential impacts?



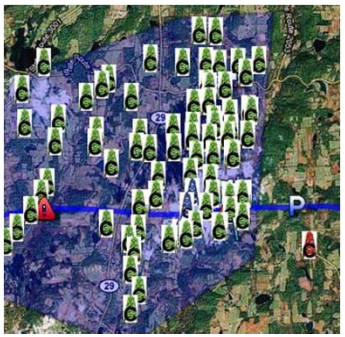
- *Decreased Water Quantity:* Water withdrawals from small streams, rivers and groundwater
- *Decreased Water Quality* (surface and groundwater): High concentrations of dissolved solids (and radioactive material) can impact ground and surface waters and decrease biological diversity and function
- *Land-Habitat Fragmentation:* Reduction of forest and open space, loss of connectivity among habitats

Pilot Study 2010:
What are some of the Ecological Impacts?

- 9 sites
  - 3 picked as High Density (1 with recorded spill event)
  - 3 Low Density
  - 3 reference
- *Watershed Indicators*
  - land cover
  - watershed area
  - riparian cover
  - stream substrate
  - others

- *Chemical Indicators*
  - Conductivity
  - pH
  - Dissolved Oxygen
- *Biological Indicators*
  - macroinvertebrates (to family)
  - algal community
  - salamanders

Study Area



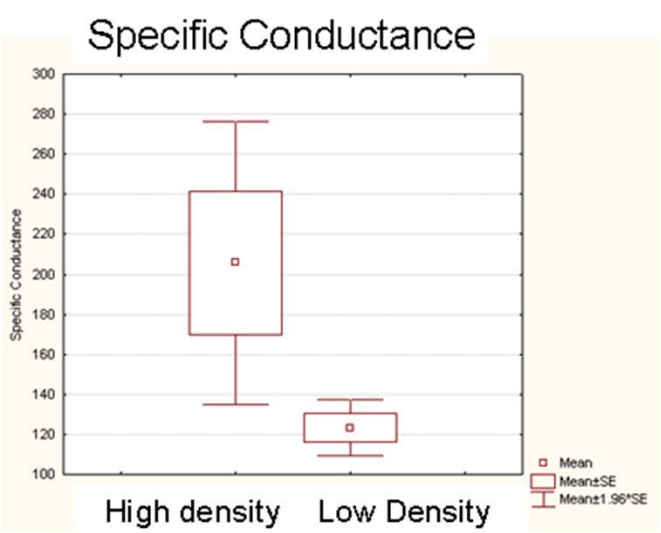
High Density

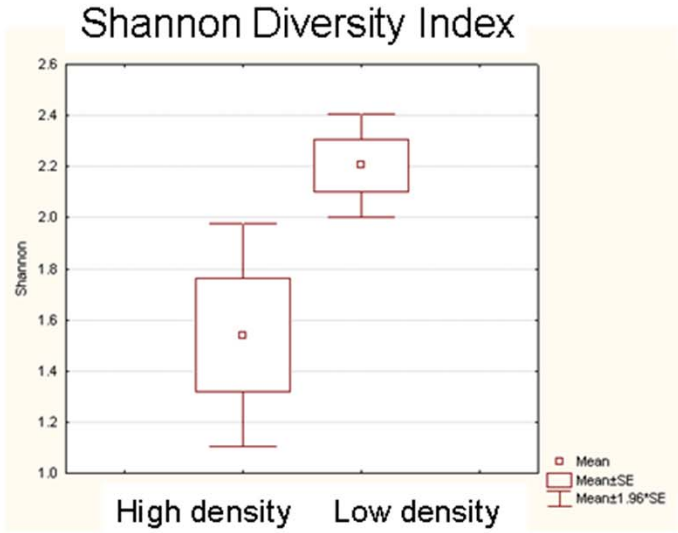
Low Density

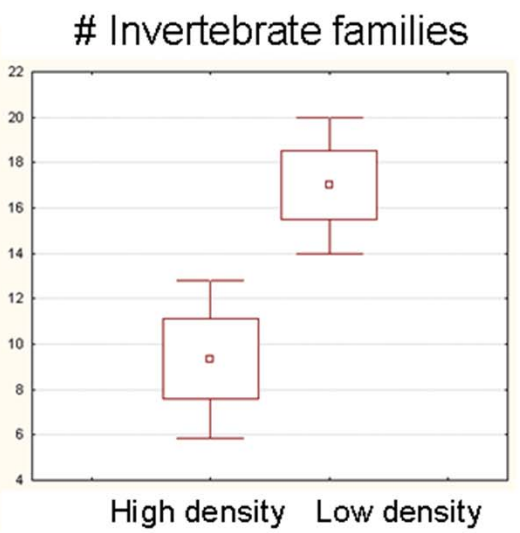
All test sites and all but 1 reference site were located in Southwestern Susquehanna County Pennsylvania, within or nearby the townships of Dimock and Springville.

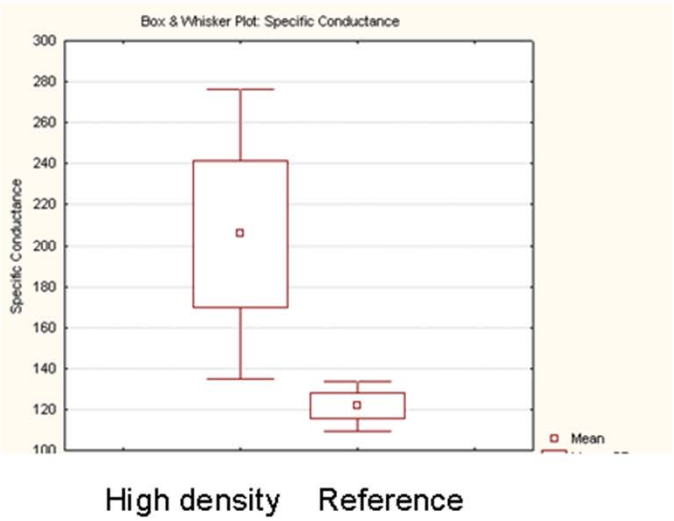
Along with reference locations

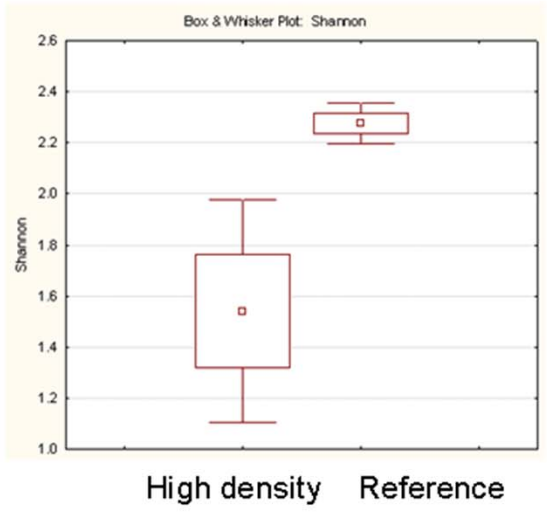
Well density and stream health

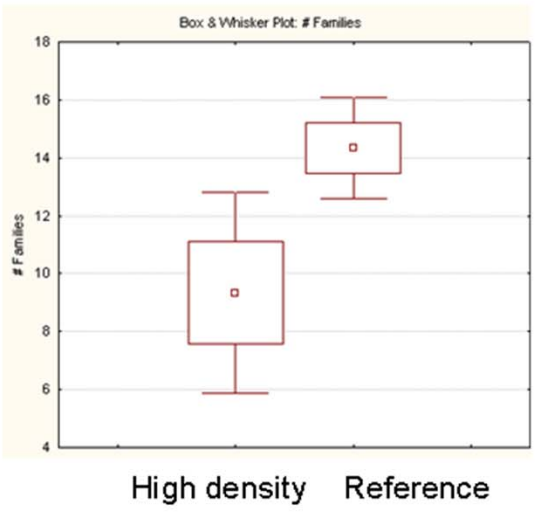












(Anderson et al., In review)

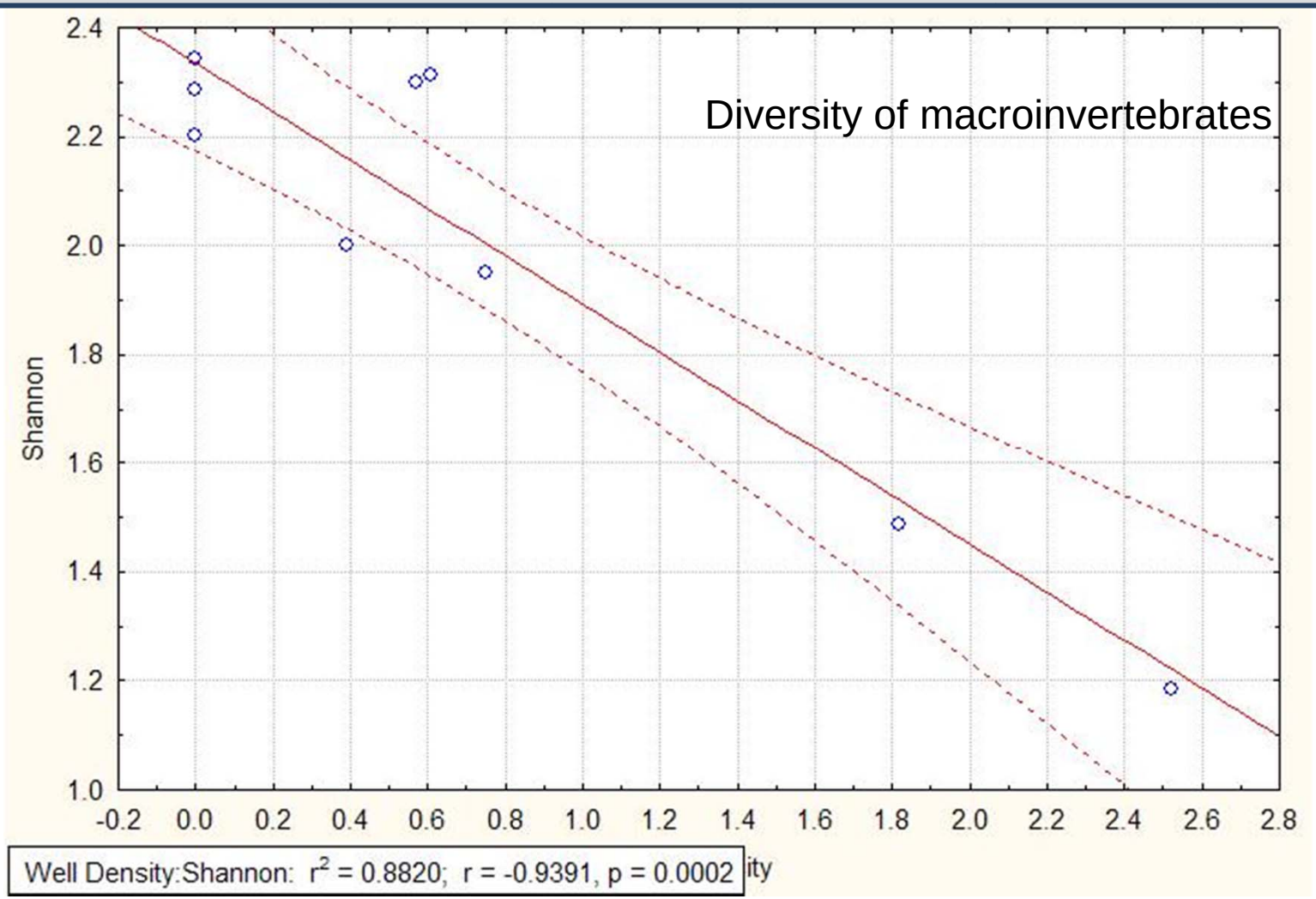
Well density and stream ecosystem: T-tests

Table 4. Paired T-tests comparing High Well Density (HD), Low Well Density (LD) and Reference (R) sites. Significant values are in bold.

	Specific Cond.	TDS	% Algal Presence	% EPT	Shannon Diversity	Family Richness
HD and LD	**205|123†**	**0.134|0.081†**	32|21	30|41	**1.54|2.20†**	**9|17‡**
HD and R	**205|122†**	**0.134|0.084†**	32|23	30|41	**1.54|2.28‡**	**9|14†**
LD and R	123|122	0.081|0.084	21|23	41|41	2.20|2.28	17|14
(Paired data are stream quality indicator means; ‡ = p > 0.05; † p > 0.1)						

Correlation to well density

	uS/cm3	g/l	EPT	Shannon	Families	Amphibians
Well Dens	0.9206	0.9082	-0.8465	-0.9391	-0.7356	-0.7208
	p=.000	p=.001	p=.004	p=.000	p=.024	p=.028



Well density

What to do next?

Cumulative Impact Statement

Developing guidelines and tools for managers to minimize the impacts of Marcellus shale gas mining on stream ecosystems and land use

More sites and indicators to increase statistical power of decision making process

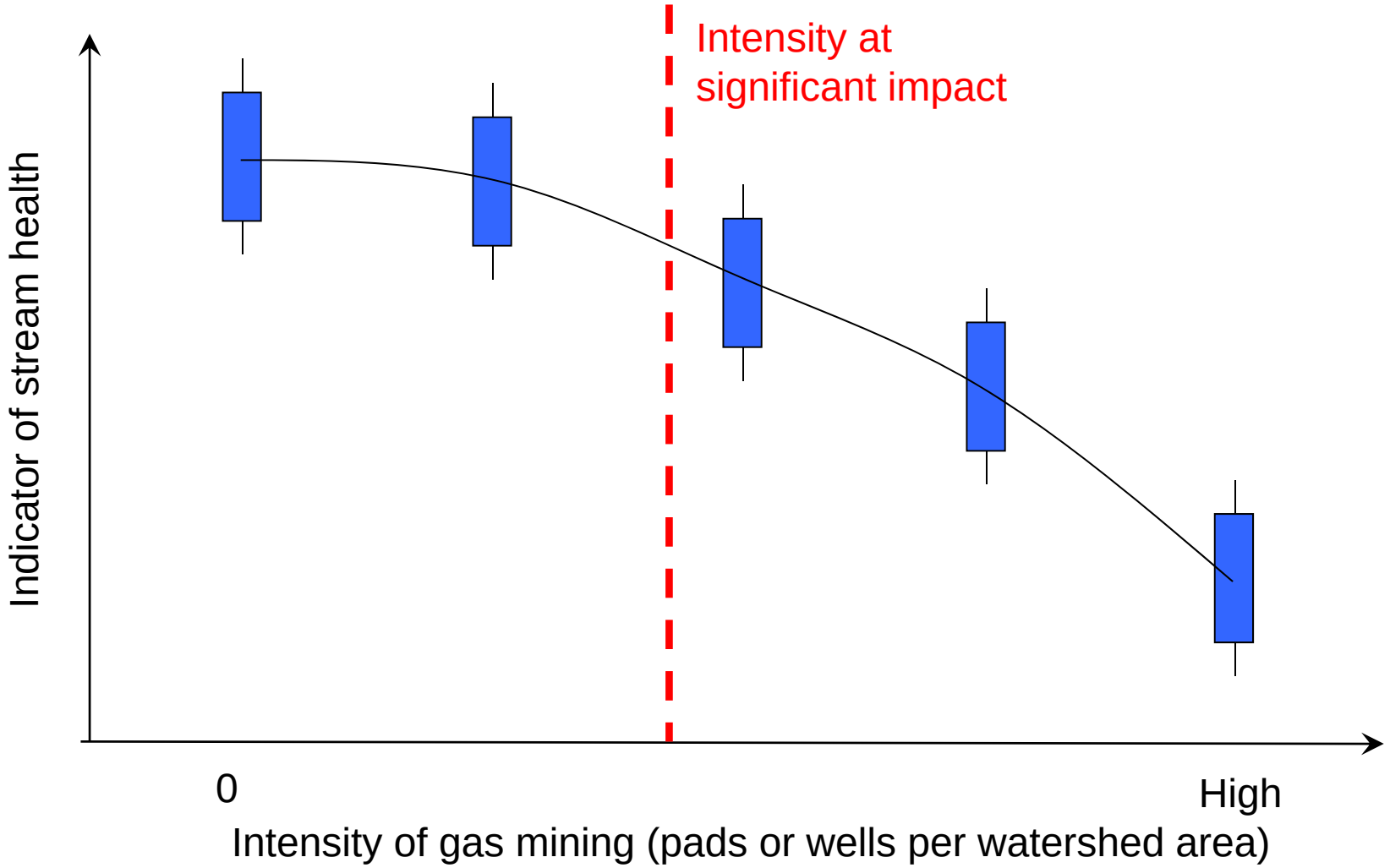
2011 Study at Patrick Center
Project Goals:

- Determine if the density of wells in a watershed influences stream ecosystem health and water quality (following a similar approach as the pilot study)
- Determine the relationships among well density, stream size, stream ecosystem health, and water quality
- Evaluate other metrics of natural gas development intensity (algorithms relating violations, density, distance from streams, operational history, etc).
- Spatially model impacts across the study area

Study Design

- Whole basin assessment of stream reaches (120 meter long reach);
- Study 40 stream reaches with a gradient of well density, but little variation in watershed conditions;
- Assess multiple indicators of water quality including diatoms and metal ions (Ba, Sr, Br – frac fingerprints);
- Relate well density to indices of stream community health.

Main project target



Minimizing risks using a threshold

- Restrict density of wells or well pads;
- Industry could restore ecosystem around a “exhausted” well then move to new location;
- Increase threshold as industry develops new practices (incentive for BMPs).

Thank you!