Ethics of Sustainable Engineering

AIChE Project Background for CWRU Senior Capstone Internship

During Xellia Pharmaceuticals Spring 2020 Semester

AIChE Cleveland Section February 24, 2021 Meeting

Project Concept and Motivation:

Joseph Yurko, P.E.
Project Lead Xellia Pharmaceuticals USA, LLC (Retired)
AIChE Cleveland Section Newsletter Editor & Webmaster
Emeritus Member of AIChE and Fellow

Presentation Overview:

I. Dr. Bakshi's Sustainability Engineering Textbook Topics
   A. Motivation, The Basis of Human Well-Being
   B. Goods and Services
   C. Definitions and Challenges
   D. Economics and the Environment
   E. Business and the Environment
   F. Science, Engineering and the Environment
   G. Society and the Environment

Why Do A Carbon Footprint Analysis?

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Why do we pay Federal Income Taxes?

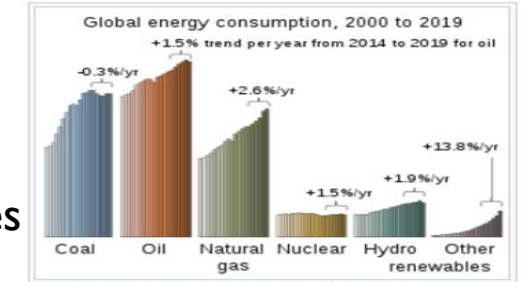
So we do not go to prison?
No, so we can provide funding to the U.S. Federal Government's Programs
And, to benefit from the funding of Federal Services:

- Health and Human Services (FDA)
- Housing and Urban Development
- State Department
- Treasury Department
- Justice Department
- National Intelligence Department
- Environmental Protection Agency
- Economic Advisers Department
- Small Business Administration
- Homeland Security (& Military/Pentagon)
- Labor Department (OSHA)
- Transportation Department (FAA)
- Veteran Affairs Department
- Ambassador to the United Nations
- U.S. Trade Department
- Management & Budget Department
- Science and Technology Policy Department

Ohio State Reformatory, Mansfield, Ohio

Why Do A Carbon Footprint Analysis?

- Carbon Footprint Analysis is done to measure a company's impact on the environment
- This is done by converting the company's activities into carbon dioxide generation
- Carbon Dioxide a greenhouse gas, when released will add to the elevation of global temperatures
- When a company knows its carbon dioxide footprint it can change behavior to reduce it



Coal, oil, and natural gas remain the primary global energy sources even as renewables have begun rapidly increasing.[1]

Capstone Project with CWRU Motivation:

"Sustainable Engineering, Principles and Practices"
Textbook authored by Dr. Bhavik Bakshi,
AIChE Lawrence K. Cecil Award 2019

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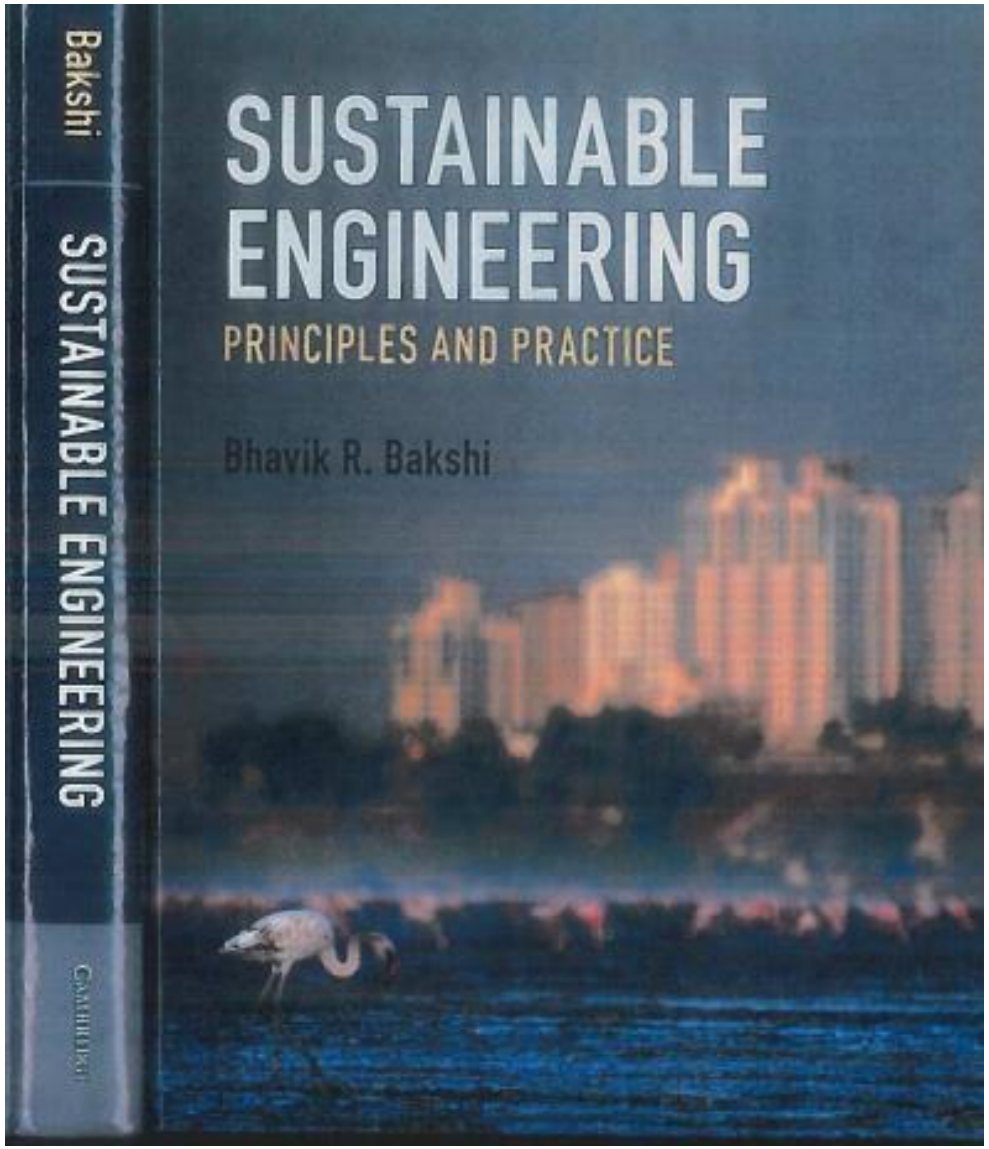
Congratulations to the Lawrence K. Cecil and Early Career Award Winners

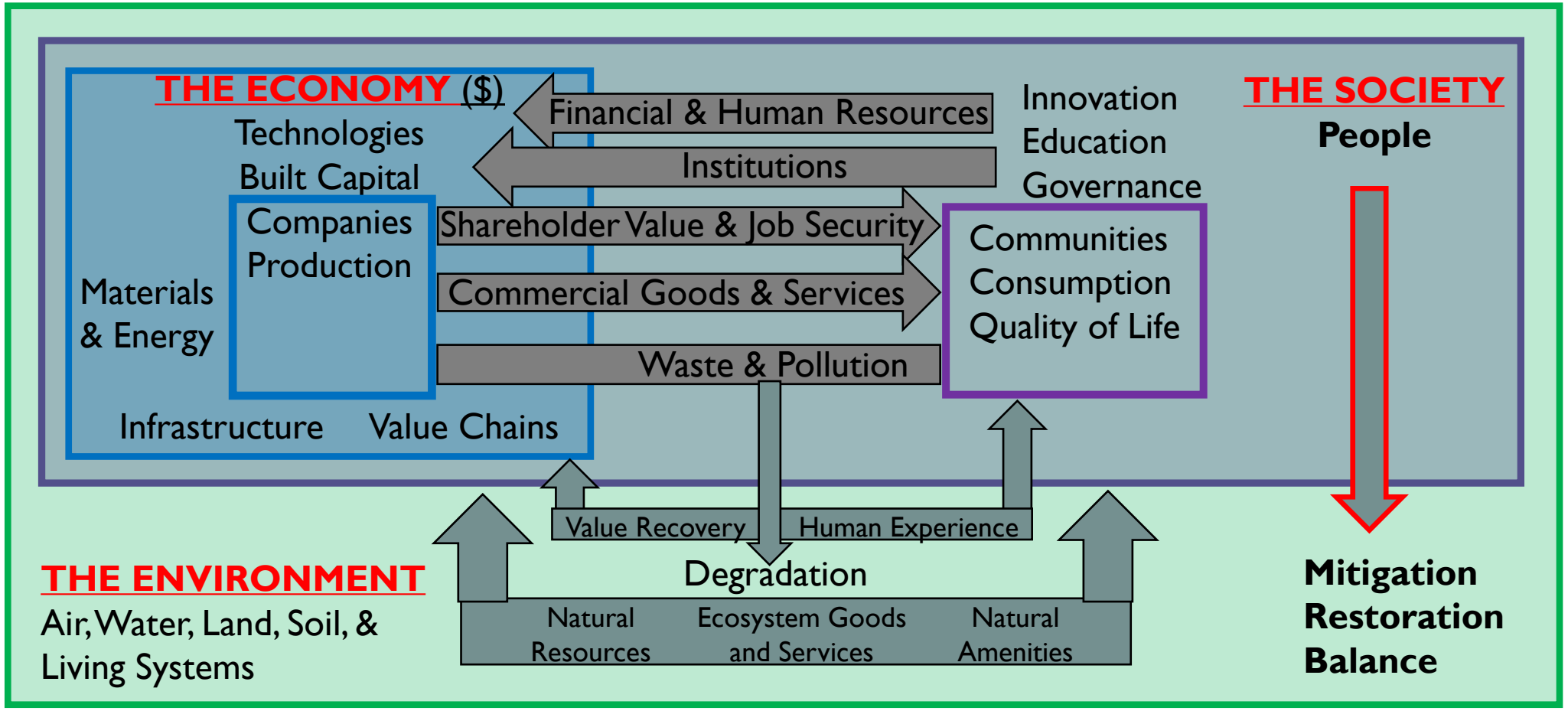
2019 Lawrence K. Cecil Award Winner: Dr. Bhavik R. Bakshi, Richard M. Morrow Professor, Ohio State University

Dr. Bhavik R. Bakshi is the Richard M. Morrow Professor of Chemical and Biomolecular Engineering at The Ohio State University. He received his B.Chem.Eng. degree from the Institute of Chemical Technology in Mumbai, India and his MSCEP and PhD degrees from the Massachusetts Institute of Technology. His research is in the area of Sustainable Engineering which is resulting in systematic methods for developing products and processes that make positive contributions to human well-being while being economically feasible and respecting nature's limits. He has recently authored a textbook on Sustainable Engineering and is on the editorial boards of several multidisciplinary journals.

In addition to university courses, he co-teaches short courses on Sustainable Engineering at several institutions including MIT and IIT-Bombay. His awards include the Ted Peterson student paper award from the CAST division of AIChE, the CAREER award from the National Science Foundation, a Distinguished Alumnus award from ICT, the Research Excellence and Education awards from the Sustainable Engineering Forum of AIChE, and the Lawrence K. Cecil Award from the Environmental division of AIChE.

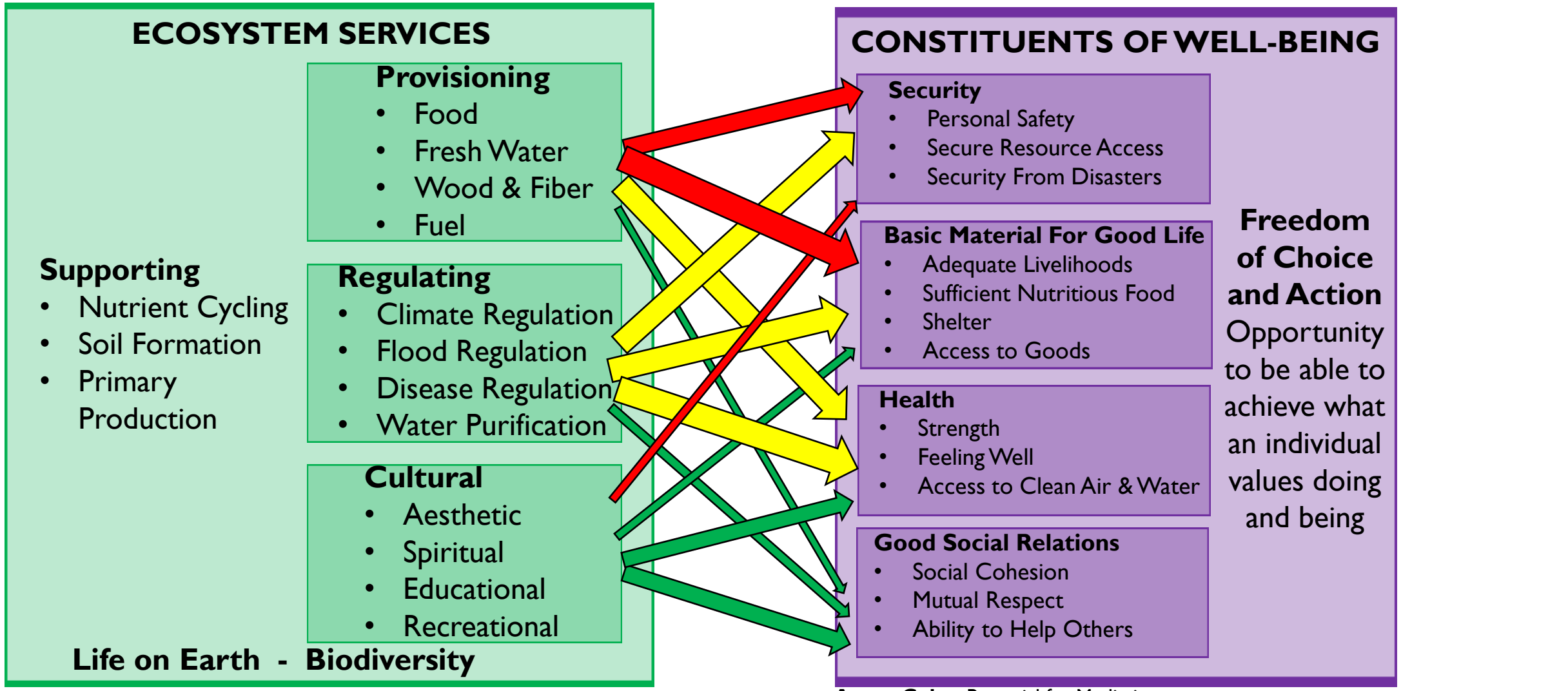


Balance between Ecosystems, Society, and the Economy:



* Bakshi, *Sustainable Engineering Principles and Practice*, Figure 1.7, page 8

Role of Ecosystem Services in Human Well-Being



* Bakshi, *Sustainable Engineering Principles and Practice*, Figure 1.11, page 16

Human Well-Being, Then and Now

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Lessons of Easter Island, <u>THEN</u>:

1. **An island's civilization collapsed** due to the loss of ecosystems
2. **Polynesians arrived there in the fifth century** to discover a volcanic island with limited resources.
3. **Fresh water** was in the volcano's crater & the soil had poor quality
4. **The islander's diet** was of sweet potatoes, fish, and chickens
5. **The 20-30 settlers** grew in population and developed culture and rituals
6. **Complex and elaborate society** developed a construction ritual
7. **They carved stone statues** 20 feet tall and weighing several tons
8. **They built over 600 statues** over time from inland stone quarries
9. **They used trees** to move the statues from the quarry to the coast
10. **The collapse of this civilization** seems to have been due to the massive environmental destruction of trees for logs to move carvings
11. **Deforestation** caused soil erosion that reduced agricultural yields
12. **Boat building and repairs ceased** so no fishing or leaving the island
13. In 1600's the civilization began to collapse from a population of 7,000
14. In 1722 Captain John Cook found 3,000 islanders living in reed huts
15. There was warfare between clans, some resorting to cannibalism

* Bakshi, *Sustainable Engineering Principles and Practice*, page 10

Human Well-Being, Then and Now

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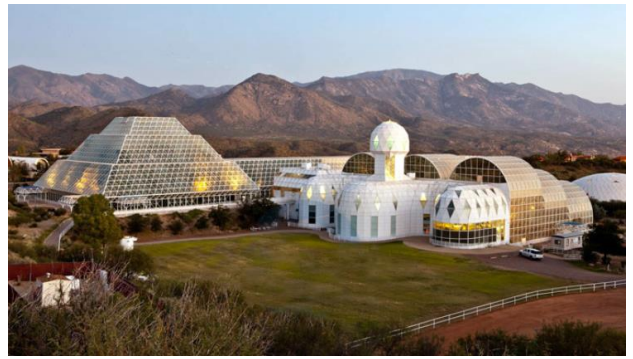
Lessons of Biosphere 2 Project, <u>NOW</u>: (built in 1990s near Tucson, Arizona)

1. **Self-contained site** with rainforest, ocean, and desert ecosystems for agriculture
2. **Structure was designed** to have close to zero exchange with the surroundings
3. **Only sunlight** was to enter the system to provide energy like Biosphere 1, Earth
4. **Eight scientists**, or "biospherians" were to inhabit the Biosphere 2 for two years
5. **They were to study interaction of people** inside closed biomes for space colonization
6. **Many new scientific insights** were obtained from this work
7. **The goal of building an artificial biosphere** was never realized
8. **Among the many problems encountered** during this experiment was the inability to maintain the desired atmospheric composition of the carbon dioxide concentration in the closed atmosphere, and it continued to rise
9. **With the ability to artificially synthesize things** we are still not able to produce the goods and services we get from nature
10. **Ecosystem goods and services** are truly the foundation of all human (and planetary) activities
11. **Without them humanity cannot be sustained!**
12. **Sustainability is about ensuring** the availability of ecosystem goods and services for present and future generations!



* Bakshi, *Sustainable Engineering Principles and Practice*, page 9

Goods and Services

I. **Provisioning Services**
   A. **Products from ecosystems** such as food, fresh water, fuel, ornamental resources, genetic resources, biochemicals, and pharmaceuticals
   B. **Owing to their direct role** in human activities
II. **Regulation and Maintenance Services**
   A. **Are benefits from** the maintenance of ecological processes by the regulation or air quality, water quality, climate, soil fertility, pests, and diseases
III. **Cultural Services**
   A. **Non-material benefits** that people get from nature in the form of spiritual and religious values, cultural diversity, educational values, aesthetic values, sense of place, social relations, and recreation and ecotourism
   B. **Sustainability** is about human beings and our well-being in the short run and the long run.
   C. **Human well-being** is dependent on healthy ecosystems.
   D. Sustaining ourselves does require saving the planet!

* Bakshi, *Sustainable Engineering Principles and Practice*, page 13

Goods and Services

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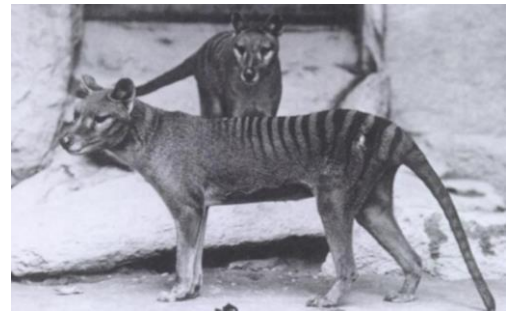
I. Biodiversity

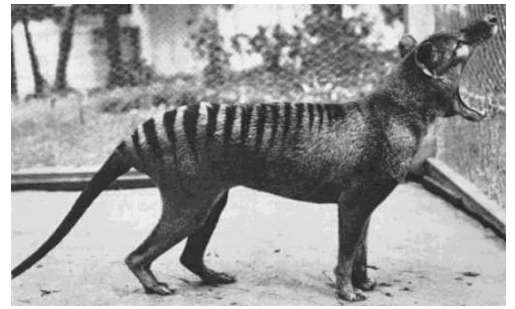
A. The planet has experienced five mass extinctions so far
B. According to biologists we are in the middle of a sixth mass extinction
C. Previous event was the disappearance of dinosaurs 65M years ago
D. Current rate of species extinctions is estimated to be 1,000 times the natural rate
E. It is estimated that half the animal individuals that once lived on the planet are gone
F. Biologists estimate that most the large specimens in the oceans have been fished out
G. Such biological destruction is a precursor to species extinction
H. This is a loss of services that ecosystems can provide for human well-being

II. Millennium Ecosystem Assessment (United Nations 2001-2005 Global Study)

A. Assesses the status of ecosystem goods and services and their role in human well-being
B. There are 24 ecosystem services where 15 are degraded, 5 are mixed, and only 4 enhanced:
   i. Provisioning Services: Food: Crops (+), Livestock (+), Capture fisheries (-), Aquaculture (+), Wild Foods (-); Fiber: Timber (+/-), Cotton, hemp, silk (+/-), Wood fuel (-); Genetic resources (-); Biochemicals, natural medicines, pharmaceuticals (-); Fresh water (-)
   ii. Regulating Services: Air quality regulation (-), Climate regulation global (+) regional and local (-), Water regulation (+/-), Erosion regulation (-), Water purification and waste treatment (-), Disease regulation (+/-), Pest regulation (-), Pollination (-), Natural hazard regulation (-)
   iii. Cultural Services: Spiritual and religious values (-), Aesthetic values (-), Recreation and ecotourism (+/-)

* Bakshi, *Sustainable Engineering Principles and Practice*, page 42





The **thylacine** (*Thylacinus cynocephalus*) is an extinct carnivorous marsupial that was native to the island state of Tasmania, New Guinea and the Australian mainland. The last known Tasmanian Tiger was in the Beaumaris Zoo in 1933. Extinct in 1986 after 50 years with no sighting in the wild.

Goods and Services, Status of Ecosystem

* Bakshi, *Sustainable Engineering Principles and Practice*, page 43

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The Millennium Ecosystem Assessment

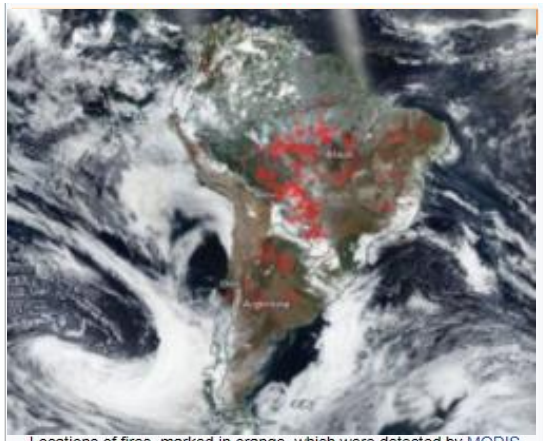
1. **People depend on nature and ecosystem services** to provide the conditions for a decent, healthy, and secure life
2. **Humans made changes to ecosystems** recently to meet growing demands for food, fresh water, fiber, and energy
3. **They helped improve the lives of billions, but weakened nature's ability** to deliver key services like purification of air and water, protection from disasters, and the provision of medicines
4. **Problems by this assessment are:** dire state of the world's fish stocks; intense vulnerability of the 2 billion people living in dry regions to the loss of ecosystem services like water supply; and growing threat to ecosystems from climate change and nutrient pollution
5. **Human activities moved the planet towards massive species extinctions**, threatening our own well-being
6. **Loss of services derived from ecosystems** is a significant barrier to the achievement of the Millennium Development Goals to reduce poverty, huger, and disease
7. **Pressures on ecosystems will increase globally** in coming decades unless human attitudes and actions change
8. **Measures to conserve natural resources** are more likely to succeed if local communities are given ownership of them, share the benefits, and are involved in decisions
9. **Today's technology and knowledge** can reduce our impact on ecosystems. Our understanding of ecosystems services must be perceived as not being free and limitless
10. **Better protection of natural assets** will require coordinated efforts across all sections of governments, businesses, and international institutions. The productivity of ecosystems depends on policy choices on investment, trade, subsidy, taxation, and regulation.

* Millennium Ecosystem Assessment. *Living Beyond our Means: Natural Assets and Human Well-Being*. Island Press, 2005

Goods and Services, Deforestation of Amazon Rainforest

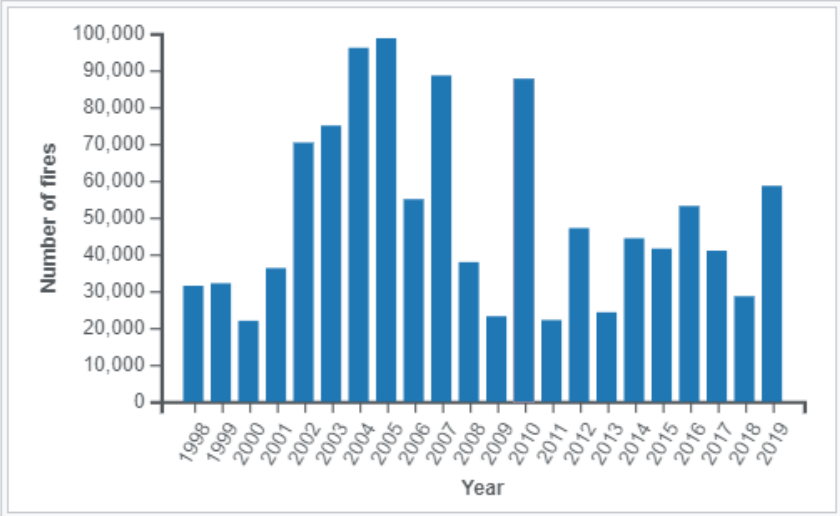
- The Amazon Rainforest is the world's largest terrestrial carbon dioxide sink, and it plays a significant role in mitigating global warming.
- It is threatened by intentional forest fires and land clearing for agriculture.

Guardian graphic. Satellite fire alerts data taken from NASA's VIIRS sensor between 1 January and 1 September 2020

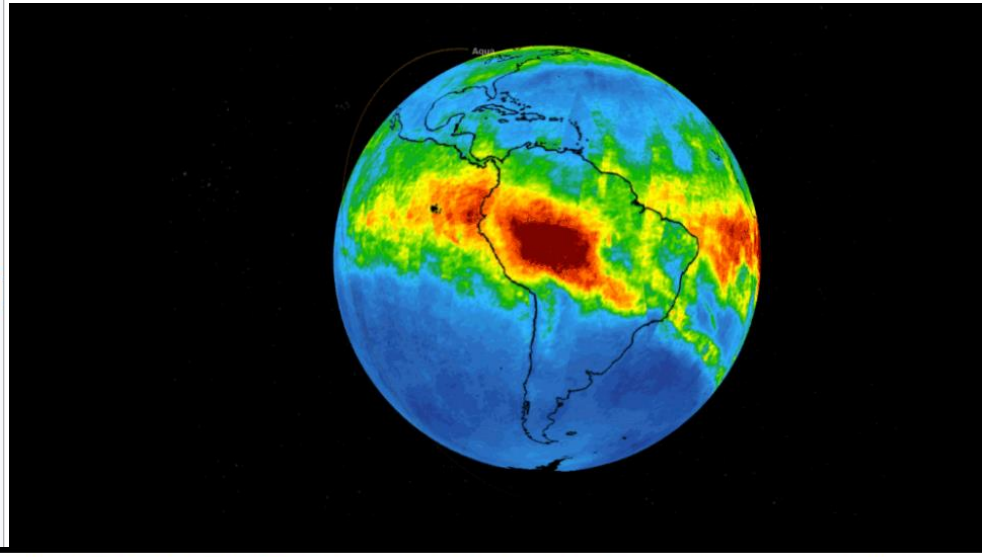


Locations of fires, marked in orange, which were detected by MODIS from August 15 to August 22, 2019

Location	Brazil, Bolivia, Peru, Paraguay, Colombia
Statistics	
Total fires	>40,000[1]
Cost	>$957 billion (2019 USD)[2][3]
Date(s)	January–October 2019
Burned area	906,000 hectares (2,240,000 acres; 9,060 km^2; 3,500 sq mi)[4]
Cause	Slash-and-burn approach to deforest land for agriculture and effects of climate change and global warming due to unusually longer dry season and above average temperatures around worldwide throughout 2019



Number of fires in Brazil's Amazônia Legal between January 1 and August 26 by year, reported by INPE[49]



Images created by the Atmospheric Infrared Sounder which depict carbon monoxide caused by fires in the Amazon region of Brazil from Aug. 8-22, 2019.[161]

NASA/JPL-Caltech - https://www.nasa.gov/sites/default/files/thumbnails/image/brazil-fires-16.gif

Reasons for Unsustainability

I. The IPAT Equation
   A. Simple but insightful way of understanding the causes of environmental impact of human activities is provided by this basic equation: **I = P x A x T**
   B. Where:
      a. **I** is the Environmental Impact
      b. **P** is the Population
      c. **A** is the Affluence of the population
      d. **T** is the Technology
   C. Equation conveys the relevance of diverse cross-disciplinary factors in determining environmental impact
   D. Engineering is captured by the T term
   E. The A and P terms are influenced by economics, business, and social sciences
II. Economics and the Environment
III. Business and the Environment
IV. Science, Engineering, and the Environment
V. Society and the Environment

* Bakshi, *Sustainable Engineering Principles and Practice*, page 73

Economics and the Environment Cause and Effect, Then and Now:

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I. Lake Erie and Harmful Algal Blooms (CyanoHABs), NOW:
   A. Caused by runoff pollution
   B. Rainfall washes fertilizer and manure spread from farm fields into streams that flow into Lake Erie
   C. Algae blooms ae preventable per scientific reports that recommend reducing the amount of runoff pollution
   D. Unfortunately, few rules are in place to limit runoff pollution from big farms.
   E. Mandatory regulations to reduce the amount of runoff pollution allowed to flow into Lake Erie are needed.
   F. Filtration Systems for water runoff is needed to reduce HABs
   G. New regulations will reduce Lake Erie's blooms, restore the lake, and ensure safe, clean drinking water for our families.
   H. Join to learn how you can help protect our region's most precious resource: Alliance for the Great Lakes
      http://greatlakes.org

* Bakshi, *Sustainable Engineering Principles and Practice*, page 83

** Ortiz, AIChE Presentation, *Climate Change Threatens Drinking Water Across the Great Lakes*, 11Jun2020

Economics and the Environment
Cause and Effect, Then and Now

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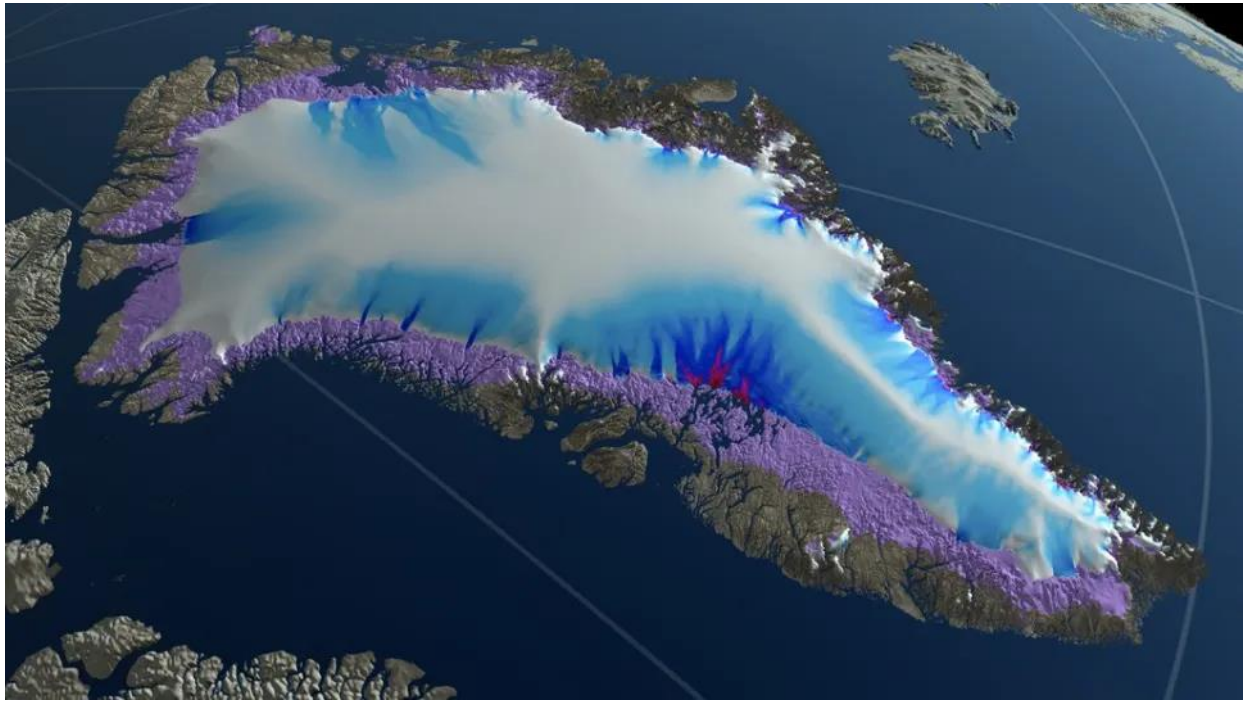
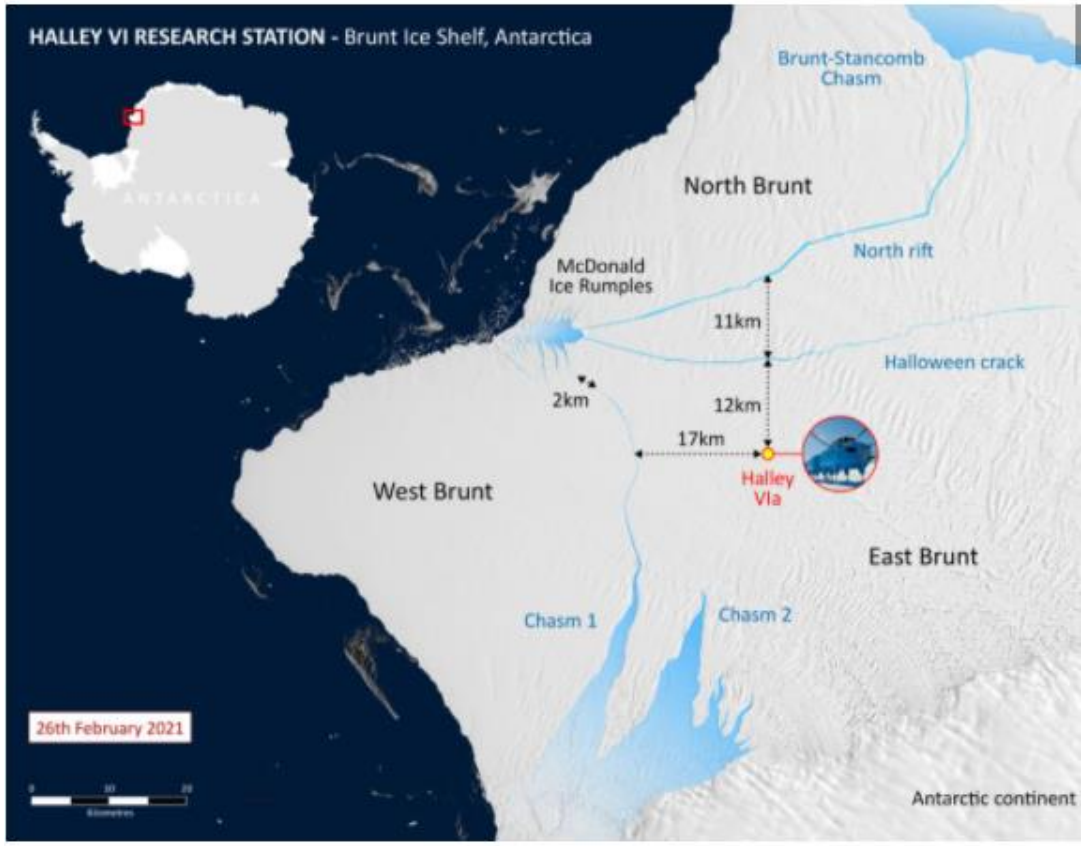
Cracks in the Arctic and Antarctic Ice Sheets from Human Behavior with Global Warming, NOW:

- Greenland Ice Sheet cracks future with high carbon emissions shown below
  - Regions shown in violet are exposed bedrock that was ice covered in 2008
  - Greenland is now losing ice six times faster than it was in 1980
- Antarctic Ice Sheet cracks shown to the right
  - Iceberg 20 times size of Manhattan broke off Brunt Ice Shelf
  - Photo of North Rift crack to right from January 2021



Greenland Ice Sheet projected into year 2300 under high C emissions



Antarctic Ice Sheet cracks North Brunt shown as it is today

Economics and the Environment, Cause and Effect, Then and Now

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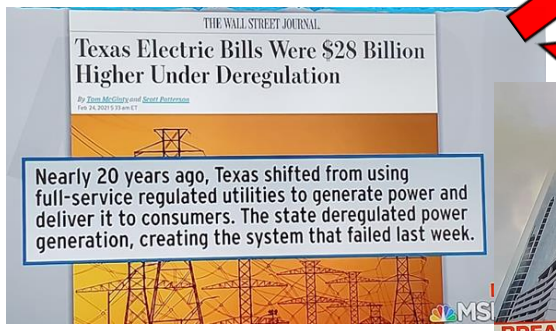
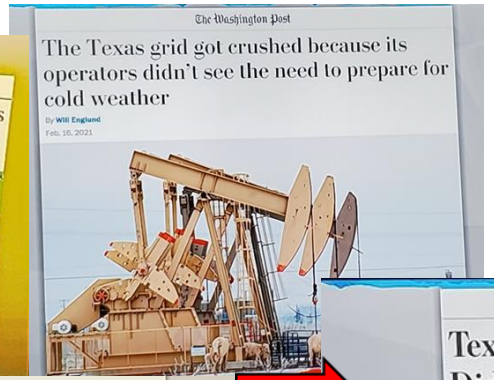
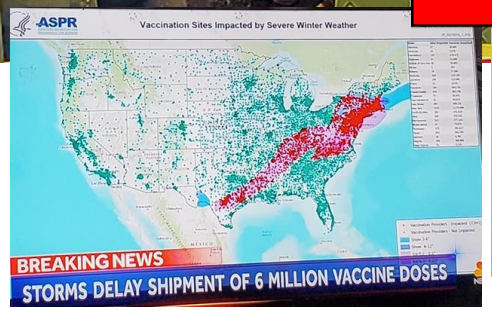
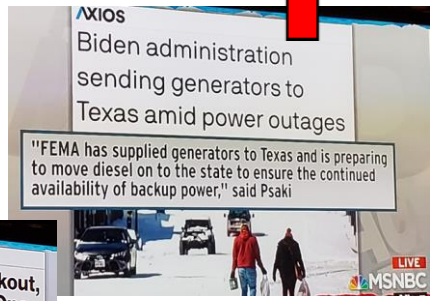
The Houston Winter Storm of 2021, NOW:

- Houstonians woke up to blankets of snow, sleet, record low temperatures and energy blackouts on Monday (February 15) morning thanks to a historic winter storm making its way across the region.
- Houston has not seen weather this frigid for more than 30 years.
- Cold weather caused losses of electrical power to homes and industry
- Electrical Power and Natural Gas losses caused water lines to freeze
- Frozen water lines in slab homes are located in ceilings in Texas
- Burst water lines destroys dry wall in ceilings and walls damaging flooring
- This will result in millions of homes









Business and the Environment, Cause and Effect, Then and Now

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Cleveland, Ohio's Cuyahoga River Catching Fire, <u>THEN:</u>

- Back in 1952 Time magazine published an article on the river fire
- National Geographic featured the river in their December 1970 cover story "Our Ecological Crisis"
- Congress established the Environmental Protection Agency (EPA) in January 1970
- The first Earth Day was celebrated on April 22, 1970
- The nation was aware of the realities of industrial pollution
- The Cuyahoga River was the symbol of this environmental calamity that spawned a national movement

CLEVELAND PLAIN DEALER

CLEVELAND, SUNDAY MORNING, NOVEMBER 2, 1952

OIL SLICK FIRE RUINS FLATS SHIPYARD

Surly Ohio Pen Rebels Fed at Gunpoint

PRISON GETS FIRST QUIET AFTER RIOTS

1948 CASTS A VEIL OVER 'IKE TO WIN'

FLAMES HIT DRY DOCKS, THREE TUGS

Business and the Environment, Cause and Effect, Then and Now

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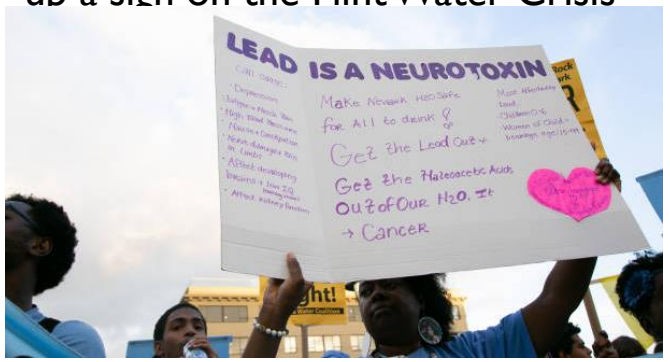
City of Flint, Michigan City Water Quality Failure from Poor Economic Decision, <u>NOW</u>:

- **Flint Water Crisis** was a public health crisis. It went from April 2014 to February 2019
- Due to a city **financial emergency** and to save city funds, Flint's water source changed from Detroit water from Lake Huron (clean) to the Flint River water (not clean)
- City Officials **failed to apply corrosion inhibitors** to the river water treatment and the water leached lead out of the water supply piping lines
- Over 100,000 residents were **exposed to elevated lead levels**
- Between 6,000 to 12,000 children were exposed to elevated levels of lead
- Scientific studies proved that **lead contamination was present** in the city water supply
- Rick Snyder, MI Governor, declared **a state of emergency** on January 5, 2016
- Barack Obama, US President, declared **a federal state of emergency** authorizing help from the Federal Emergency Management Agency (FEMA) shortly afterwards
- Resulted in **79 lawsuits** where 15 people face criminal indictments
- As of October 2020 the City of Flint **replaced about 10,000 lead lines**
- As of November 2020 the victims of the water crisis were awarded a combined **settlement of $640 million** with 80% going to families of children affected by the crisis
- **Court investigations from this crisis continue** into 2021

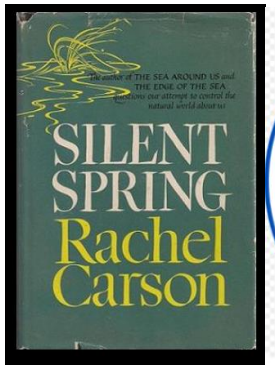
2017 Climate March protestor holds up a sign on the Flint Water Crisis

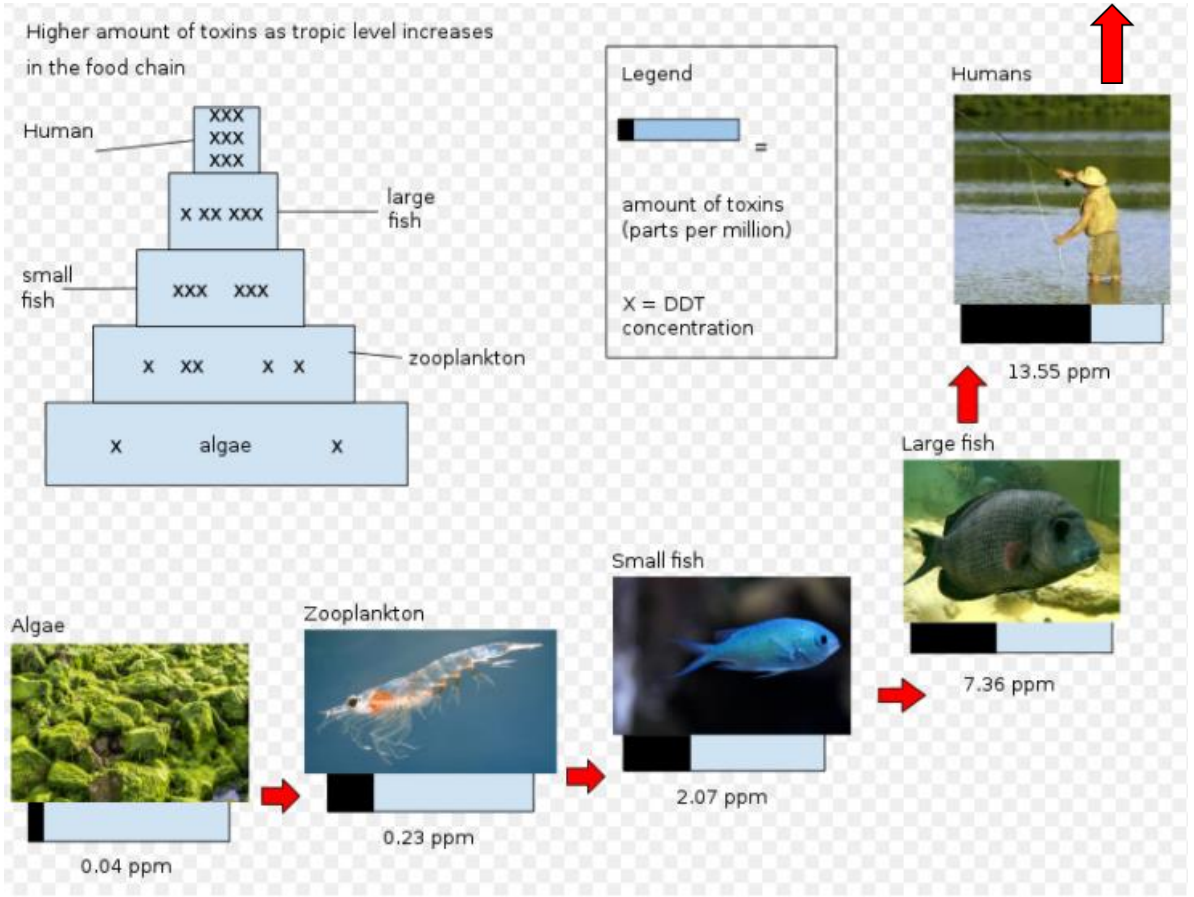


Science, Engineering & Environment Cause and Effect, Then and Now

DDT Pesticide uses, THEN:

- **DDT or Dichlorodiphenyltrichloroethane** was first synthesized in 1874 by Austrian chemist Othmar Zeidler
- **DDT's use as an insecticide** was discovered by Swiss chemist Paul Hermann Muller in 1939
- **DDT was used during World War II** to limit the spread of insect born diseases malaria and typhus
- **Muller was awarded the Nobel Prize** in Physiology or Medicine in 1948 for his work
- **In October 1945 DDT was available** as an agricultural and household pesticide in United States
- **Opposition to DDT was done by Rachel Carson's book *Silent Spring*.** Awareness of environmental impact of DDT.
- ***Silent Spring's*** studies claimed DDT caused cancer and was a threat to wildlife, particularly birds
- ***Silent Spring*** led the way for the environmental movement and resulted in the 1972 ban on DDT's use in U.S.
- **A worldwide ban on DDT** use was formalized by the Stockholm Convention on Persistent Organic Pollutants in 2004
- **With the Endangered Species Act** the United States ban on DDT was a major factor in the comeback of the bald eagle and the peregrine falcon from near extinction in the contiguous United States





Biomagnification is the build up of toxins in a food chain. The DDT concentration is in parts per million. As the trophic level increases in a food chain, the amount of toxic build up also increases. The X's represent the amount of toxic build up accumulating as the trophic level increases. Toxins build up in organism's tissues and fat. Predators accumulate higher toxins than the prey.

Science, Engineering & Environment, Cause and Effect, Then and Now

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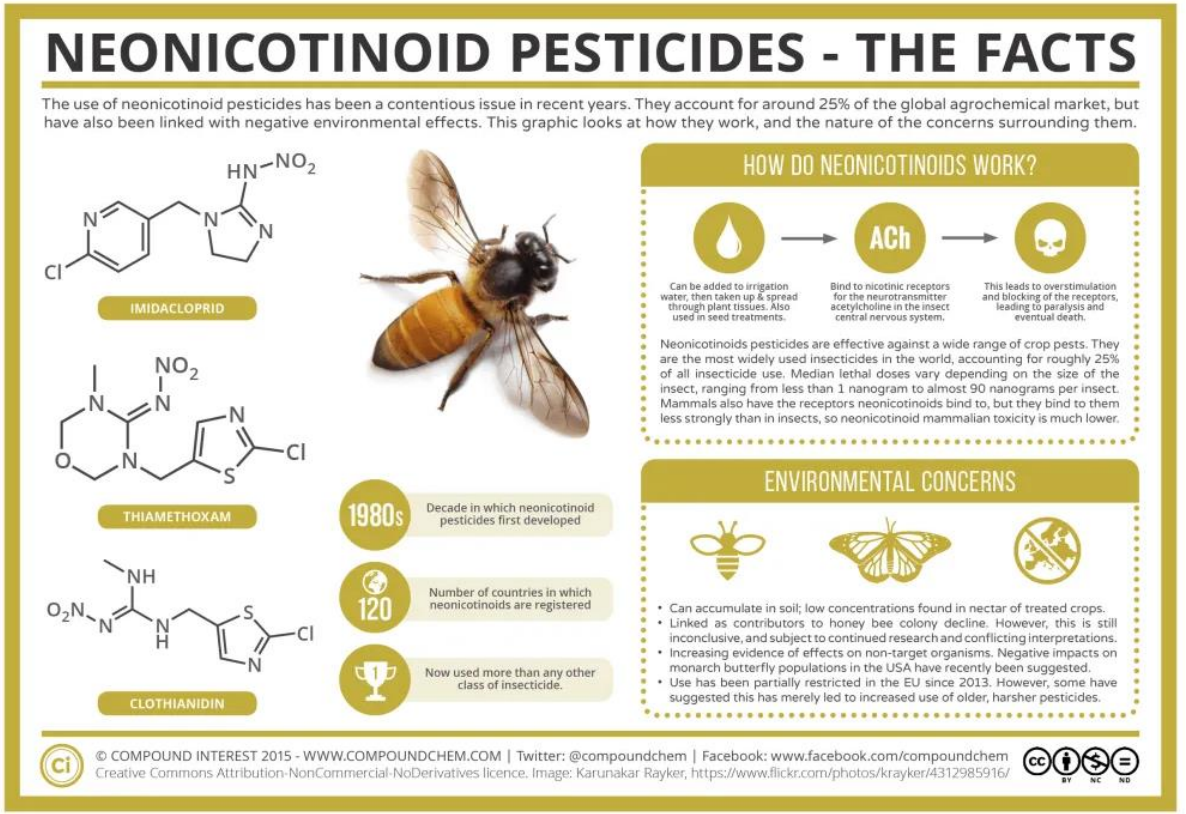
Neonicotinoid Pesticides uses, NOW:

- Pesticides are used to protect crops from insect damage
- Fewer insects means better crops
- Pesticides are destroying bee populations
- Bees pollinate many fruits, vegetables & flowers people need
- Fewer bees means far fewer fruits vegetables and flowers

* Bakshi, *Sustainable Engineering Principles and Practice*, page 39



Society and the Environment

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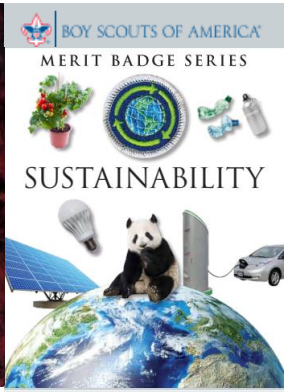
I. **Native Americans** hold a deep reverence for nature
   A. American Indian life is centered on nature with religion, daily rituals, mythology, writings, food, medicine, art, and much more
   B. Their way of life goes hand in hand with the land and environment
   C. American Indian culture respects nature above all else
   D. Native Americans operate under the conviction that all objects and elements of the earth – both living and nonliving – have an individual spirit that is part of the greater soul of the universe.
   E. This principle adheres to a religion called Animism
   F. Native American culture is fiercely devoted to respecting and honoring the spirit of the land and everything with which it provides them.

II. **Boy Scouts of America**
   A. Merit Badge for Environmental Science, Fish & Wildlife Management, Forestry, Nature, Oceanography, Soil and Water Conservation, and Sustainability
   B. Many values in scouting are based on Native American Indian culture

III. **Girl Scouts of America**
   A. Multiple Merit Badges for Environmental Stewardship
   B. Many values in scouting are based on Native American Indian culture

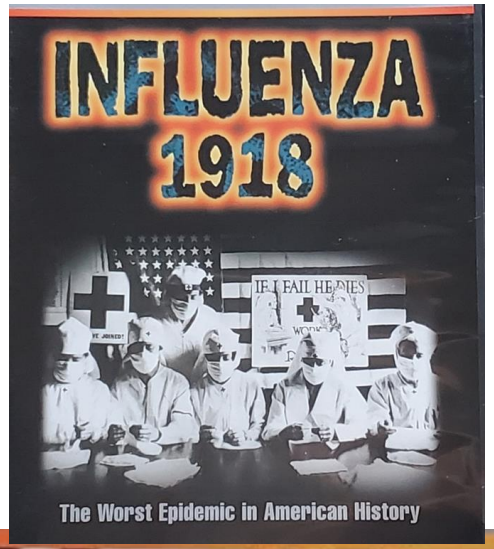
IV. **Cleveland Metroparks**
   A. Managing urban watersheds to Lake Erie (Park Ranger's Public Outreach Programs)
   B. Stormwater, pollution, algal blooms, invasive species and loss of wetlands are addressed
   C. Received national attention for watershed stewardship through education, scientific monitoring and environmental restoration.



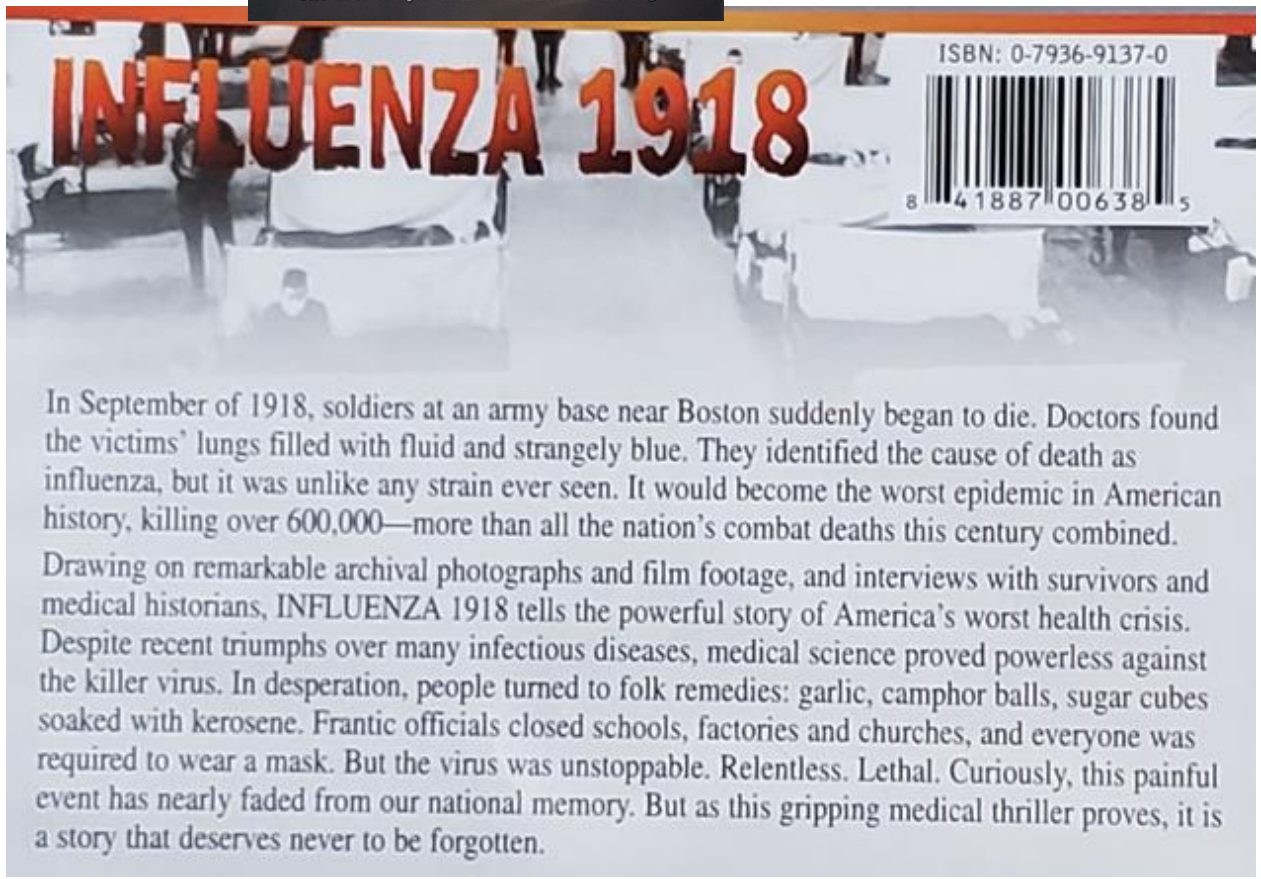
Society and the Environment, Cause and Effect, Then and Now

The Influenza Global Pandemic of 1918, THEN:

- The worst epidemic in American history
- More than 600,000 Americans were lost to the virus
- America's worst health crisis despite recent medical triumphs over many infectious diseases
- Medical science proved powerless against the killer virus
- Frantic officials closed schools, factories and churches
- Everyone was required to wear a mask
- The virus was unstoppable, relentless and lethal
- This painful event has nearly faded from our memory
- This gripping medical thriller proves, it is a story that deserves never to be forgotten



AIChE
The Global Home of Chemical Engineers

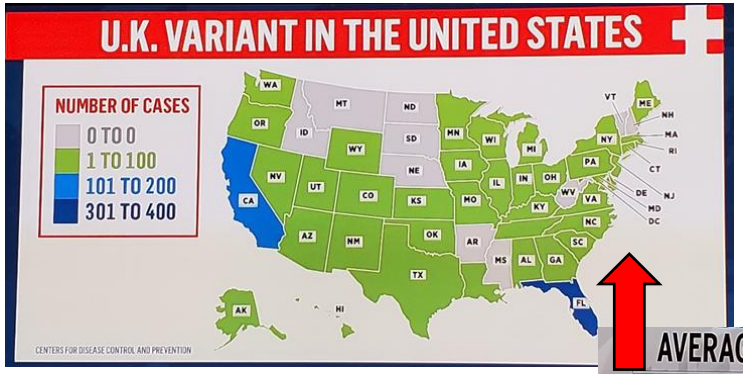


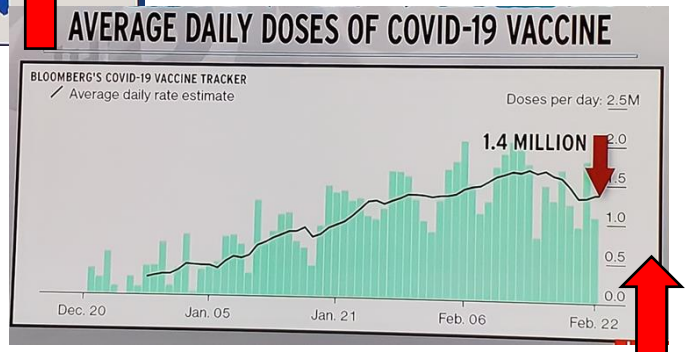
Society and the Environment, Cause and Effect, Then and Now

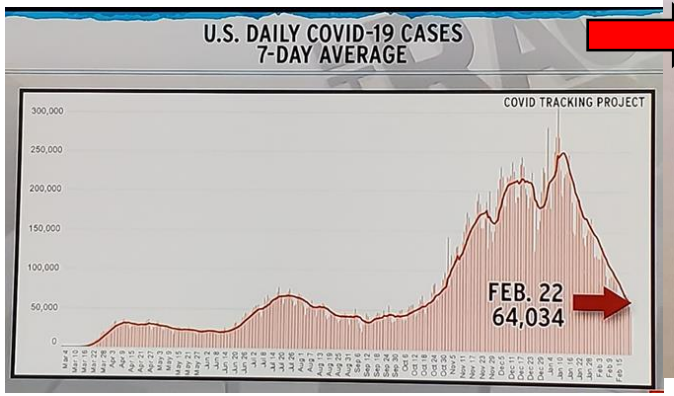
AIChE
The Global Home of Chemical Engineers

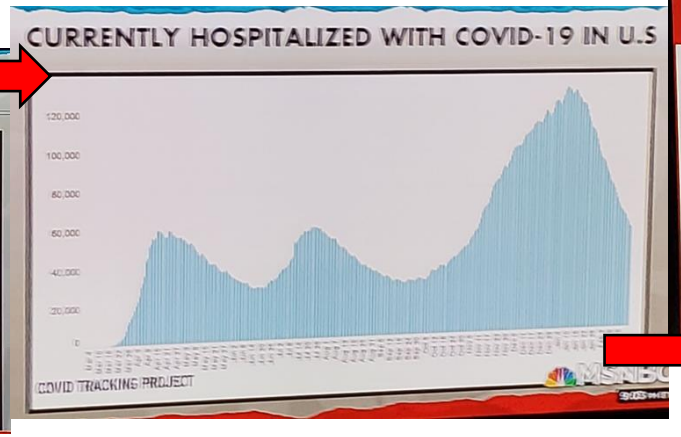
The COVID-19 Global Pandemic of 2020, NOW:

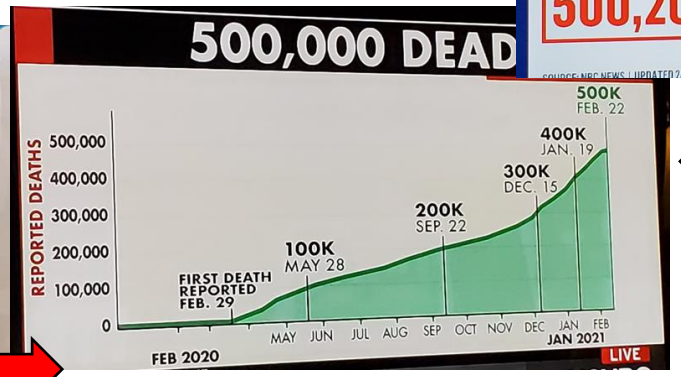
- The worst epidemic in American history
- More than 500,000 Americans were lost to the virus
- America's worst health crisis despite recent medical triumphs over many infectious diseases
- Medical science proved powerless against the killer virus (vaccine)
- Frantic officials closed schools, factories and churches
- Everyone was required to wear a mask, but only half did
- The virus was unstoppable, relentless and lethal
- Vaccine development followed COVID-19 Chinese RNA sequence
- After one year three vaccines were developed and approved
- Pfizer (2 injections, ultra cold), Moderna (2 injections, cold), and J&J (1 injection, normal)

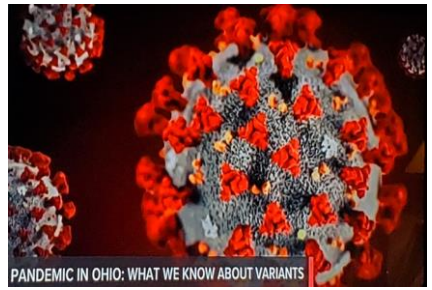












Society and the Environment

Other reading recommendation:

Bill Gates, *How To Avoid A Climate Disaster*, 2021

- Why Zero?
- This Will Be Hard
- Five Questions to Ask in Every Climate Conversation
- How We Plug In
- How We Make Things
- How We Grow Things
- How We Get Around
- How We Keep Cool and Stay Warm
- Adapting to a Warmer World
- Why Government Policies Matter
- A Plan for Getting to Zero
- What Each of Us Can Do
- Climate Change and COVID-19
  - "Many of our lessons from the pandemic - and the values and principles that guide our approach to it - apply just as well to Climate Change"