Human Population
2018
Lecture 9
Climate change
Our extended forecast includes global warming & the catastrophic end of the human race. But for the weekend, it's looking like sunny skies, mild temperatures, & a general apathy toward environmental concerns.

Back to you, Jim.
Some of this outgoing infrared radiation is trapped by the earth’s atmosphere and warms it. Some energy is radiated back into space by the earth in the form of infrared waves. Most of this radiation is absorbed by the Earth and warms it.
The Biggest Sources of Greenhouse Gases

- Thawing Permafrost
- Coal mining
- Coal plants
- Crop burning
- Oil production
- Forest burning
- Industrial processes
- Industrial agriculture
- Fertilization
- Land transportation
- Landfills
- Air transport
In 1972 + 1.5 ppm/yr

In 2015 + 3.05 ppm/yr
Global Carbon Emissions from Fossil Fuels

Billion Metric Tons of Carbon

Data: U.S. Department of Energy/CDIAC
The energy trapped by man-made global warming pollution is now “... equivalent to exploding 400,000 Hiroshima atomic bombs per day 365 days per year.”

James Hansen
Former Director, NASA Goddard Institute for Space Studies
Summer Temperatures Have Shifted
1951 – 1980

1983 – 1993

Cooler than average
Average
Warmer than average
Extremely hot

The “extreme” temperature events used to cover 0.1% of the Earth. Now they cover 14.5%.

Global Surface Temperature – Departure from Average

January – October 1880 – 2015

Data: NOAA
Nov 2012 through Dec 2013
2259 peer-reviewed climate articles from 9136 authors
1 author rejected anthropogenic global warming
The Hottest Year Ever Measured…

16 of the 17 Hottest Years on Record Have Occurred Since the Year 2001

Data: NASA/GISS
The heat index in Bandar Mahshahr, Iran reached 165° F (74° C) on July 31, 2015.
The tiny nation of Kiribati will soon be underwater

At least 2,330 people died in the 2015 India heat wave.
93% of the extra Heat trapped by manmade global warming pollution goes into the Ocean
Half of the increase has occurred since 1997.

Adapted by permission from Macmillan Publishers Ltd: Nature Climate Change, Industrial-era global ocean heat uptake doubles in recent decades, Figure 4, copyright 2016.
So the downpours get bigger
Phoenix, Arizona
July 18, 2016
Thailand is experiencing its worst drought in 60 years.
Over 400 farmers in Maharashtra committed suicide in the first four months of 2016, due mainly to pressures from the ongoing regional drought.

Snowpack has declined at 90% of Colorado’s monitoring sites.

Each line represents a separate monitoring site.

Data: U.S. Environmental Protection Agency
Pine-borer beetle damage
Over the last 25 years, Arctic ice has receded significantly and continues to recede. An ice-free arctic in September is predicted within 5 years.
Positive feedback effects of arctic ice decline.

Ice albedo effect. Ice reflects more light than the open ocean.
Heat of fusion of water is 79.72 cal/g. Heat capacity of liquid water is 1.0 cal/deg/g. Therefore the amount of heat that it took to melt one g of ice will heat the meltwater from 0°C to 80°C.

Positive feedback effects of arctic ice decline.
Methane (CH$_4$) is stored in permafrost under the ocean as caged gas, or clathrate. As the ocean warms, the clathrates melt, releasing the CH$_4$ gas, which bubbles up to the surface. CH$_4$ has a much higher (150x) greenhouse gas potential than CO$_2$, and has a half-life in the atmosphere of decades.

The East Siberian Sea sediments contain 100 to 1000x more carbon than all of the methane currently in the atmosphere.


https://youtu.be/FPdc75epOEw
Arctic Methane Emergency: Methane released by the Gigaton!

https://youtu.be/FPdc75epOEw?t=42m46s
Positive feedback effects of arctic ice decline.

- Methane release
- Ocean temperature
- Warming
- Greenhouse effect

(+)

Diagram shows a feedback loop where an increase in ocean temperature leads to warming, which in turn leads to an increase in methane release, further warming the ocean, and ultimately a positive feedback effect.
Isa there any good news? Yes!

Projection 2017: 36.8 Gt CO₂
△2.0% (0.8%-3.0%)

2016: 36.2 Gt CO₂

Exponential decline model is selected because fossil fuels will be forced downward "externally" (i.e. not due to declining availability). Exponential decline is appropriate when the growth of an alternative (i.e. solar) is exponential. Decline will be even faster if population also declines.
In 2016, solar + wind reached approx. 2% of global energy production.

10-fold increase in 9 years means, if maintained, 20% of global energy production by 2027. 100%+ of global energy production before 2036.
“Wind turbine service technician” is forecast to be the fastest-growing job category in the U.S. through 2024.

Colorado Highlands Wind Farm, Fleming, Colorado
Some utilities in Texas are offering free electricity at night because wind energy is so abundant.
The U.S. now has 75 gigawatts of wind power installed, enough to power 20 million homes.

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Akron Township, Michigan
Globally, wind could supply worldwide electricity consumption 40 times over.
Large Lithium Ion Battery Cost Trend

$ US per kWh

Source: Navigant and Bernstein estimates and analysis
Green Energy Progress
How Do Projections Compare With Reality?

**2002 Projection**
The solar energy market will grow 1 GW per year by 2010

**Reality**
The reality is that goal was exceeded by 77 x

Data: Fresh-Energy; Bloomberg
World Solar PV Installations
1980 – 2016

Fort Carson Army Base, Colorado

Source: U.S. Army
The rise of renewables!

In 2016, solar + wind reached approx. 2% of global energy production. 10-fold increase in 9 years means, if maintained, 20% of global energy production by 2027 and 100%+ of global energy production before 2036.

https://www.greentechmedia.com/articles/read/iea-global-installed-pv-capacity-leaps-to-303-gw#gs.oEbQcfY
Exponential decline model is selected because fossil fuels will be forced downward "externally" (i.e. not due to declining availability). Exponential decline is appropriate when the growth of an alternative (i.e. solar) is exponential. Decline will be even faster if population also declines.

In 2016, solar + wind reached approx. 2% of global energy production. Growing exponentially.

(revised: Hypothetical model for emissions goal of zero in 2050)

(This is an informal, back-of-the-envelope, model!)
Excess power could be used to sequester carbon!
Carbon capture

• https://youtu.be/5GBui1FRK78
Carbon capture!
I endorse these videos:

Anything by Paul Beckwith
paulbeckwith.net

Anything by James Hansen
http://www.columbia.edu/~jeh1/

Anything by Michael E Mann
http://www.realclimate.org/

More here: follow!
https://www.facebook.com/bio4961/

I do NOT endorse these videos:

It's Too Late To Stop Climate Change, WE ARE DEAD, Guy McPherson 18Nov2013
or anything by Guy MacPherson
https://www.youtube.com/watch?v=SQxYmVrSrl

Arctic Death Spiral and the Methane Time Bomb
https://youtu.be/m6pFDu7ILV4?t=54m25s
A model for tree growth.

A tree growing in the open collects an amount of radiant energy roughly proportional to its leaf area. The JABOWA growth rate equation for a tree growing under optimum conditions has the form:

\[ \delta(D^2H) = R \cdot LA \cdot \left(1 - \frac{DH}{D_{max}H_{max}}\right) \]  

(1)

in which \( D \) is the dbh of the tree, \( H \) its height, with \( D_{max} \) and \( H_{max} \) being maximum values of these quantities for a given species, \( LA \) is the leaf area, and \( R \) is a constant. The equation states that the change in volume \( (D^2H) \) of a tree over a period of 1 year is proportional to the amount of sunlight which the tree receives, derated by a factor \( (1 - DH/D_{max}H_{max}) \) which takes some account of the energy required to maintain the living tissue. The right-hand side of eqn (1) is later multiplied by additional factors to take shading, climate, etc. into account. Values used in JABOWA version 1 for \( D_{max}, H_{max} \) and other parameters are given in Table 1.