Lec #3: Energy Implications of Growth

LAST TIME:

- Bartlett Video, Part 1: Mathematics of Growth
- Introduction to Course

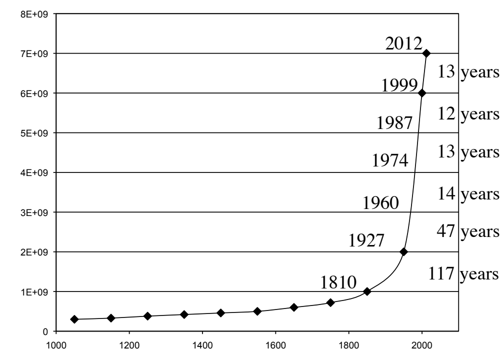
TODAY:

- Discussion of Population Growth and its Implications for Resource Consumption

NEXT WEEK: (finish reading Chapter 1)

- Estimating the Remaining Lifetime of Fossil Fuels
- What causes an “energy crisis”?
- Can it be avoided?

Exponential Growth of World Population



Semi-log Plot of World Population
(straight line = exponential growth)

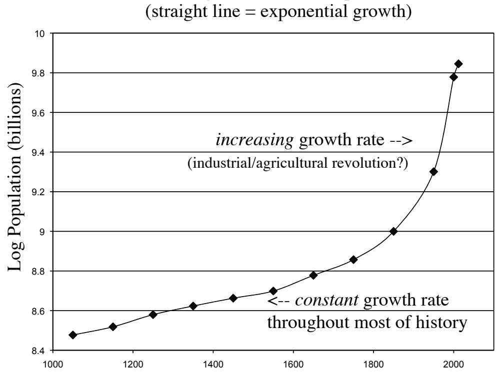
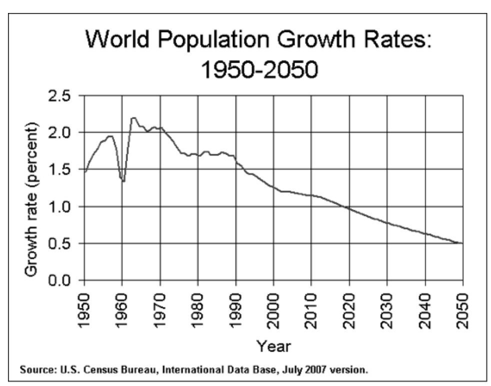
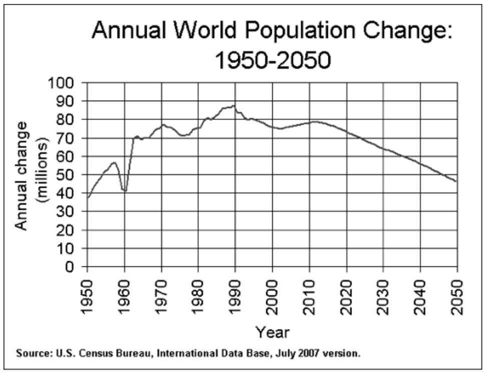


photo of an exhibit at the Smithsonian

Assuming constant growth rate of about 2% per year (doubling time = 35 years)

	Year	Total Number of people	Population Density ($1/m^2$)
current	1998	$5x10^9$	$4x10^{-5}$
mass_people=mass_earth	3540	$7.5x10^{22}$	$1.5x10^8$
using 100% of solar energy	2600	$8.5x10^{14}$	1.6
using 100% incident on land w/ clouds	2500	$1.1x10^{14}$	0.2
using 10% through consumption	2345	$6.7x10^{11}$	$1.2x10^{-3}$
1/4 land arable; 50% food to animals	2140	$8.4x10^{10}$	$6.3x10^{-4}$
typical city			$6.2x10^{-4}$
Club of Rome - maximum		15-20 billion	$1.3x10^{-4}$
UN - maximum		11.5 billion	$8.6x10^{-5}$





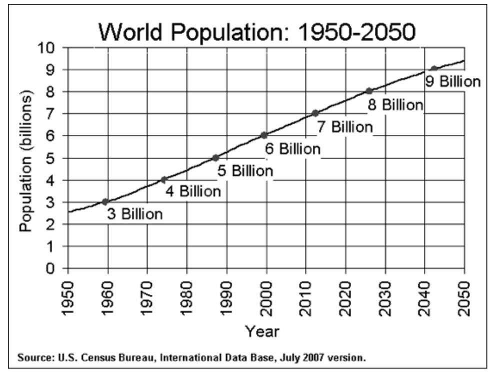


Table of Options

<u>Increase Populations</u>	<u>Decrease Populations</u>
Procreation	Abstention
Motherhood	Contraception/Abortion
Large Families	Small Families
Immigration	Stopping Immigration
Medicine	Disease
Public Health	
Sanitation	
Peace	War
Law & Order	Murder & Violence
Scientific Agriculture	Famine
Accident Prevention	Accidents
Clean Air	Pollution
Ignorance of the Problem	

What Causes Exponential Growth?

change proportional to current amount

- <u>Example #1: Compound Interest</u>
  - interest earned in 1 compounding period = fixed fraction of current amount (interest rate, I)
  - e.g. $1000 at 10%/year
  - $1000*.10=$100 total = $1100
    - = $1000*1.1 = $1000*(1+.1)^1
  - $1100*.10=$110 total = $1210
    - = $1000*1.1*1.1 = $1000*(1+.1)^2
  - general formula for compound interest....

$$N(t)=N_0(1+I)^t$$

(t=# of times compounded)

- <u>Example #2: Population Growth (continuous exponential)</u>
  - # of babies born proportional to # of potential parents
  - k is constant of proportionality (e.g. fraction having offspring each year)
  - dN(t)/dt = k*N(t) (differential equation)
  - solve by integrating... $\int(1/N)\, dN = \int k\, dt$
  - so ln(N) = kt; undo natural log with exponential
  - so general formula for exponential growth is ....

$$N(t)=N_0e^{kt}$$

t=time (continuously varies)

Doubling Time

- $N(t)=N_0\, e^{kt}$
  - $2N_0/N_0 = 2 = e^{kt_D}$ [undo exponent with log]
  - $t_D = \ln(2)/k = 100*\ln(2)/100*k$
  - $t_D \approx 70/k$ [where k is in percent per time period]
- $N(t)=N_0*(1+I)^t$
  - $2N_0/N_0 = 2 = (1+I)^{t_D}$ [undo exponent with log]
  - $\ln(2) = t_D \ln(1+I)$
  - $t_D = \ln(2)/\ln(1+I) \approx \ln(2)/I$
  - $\ln(2)=0.693$; $\ln(2)/I = 100*\ln(2)/100*I$
  - $t_D \approx 70/I$ [where I is in percent per time period]