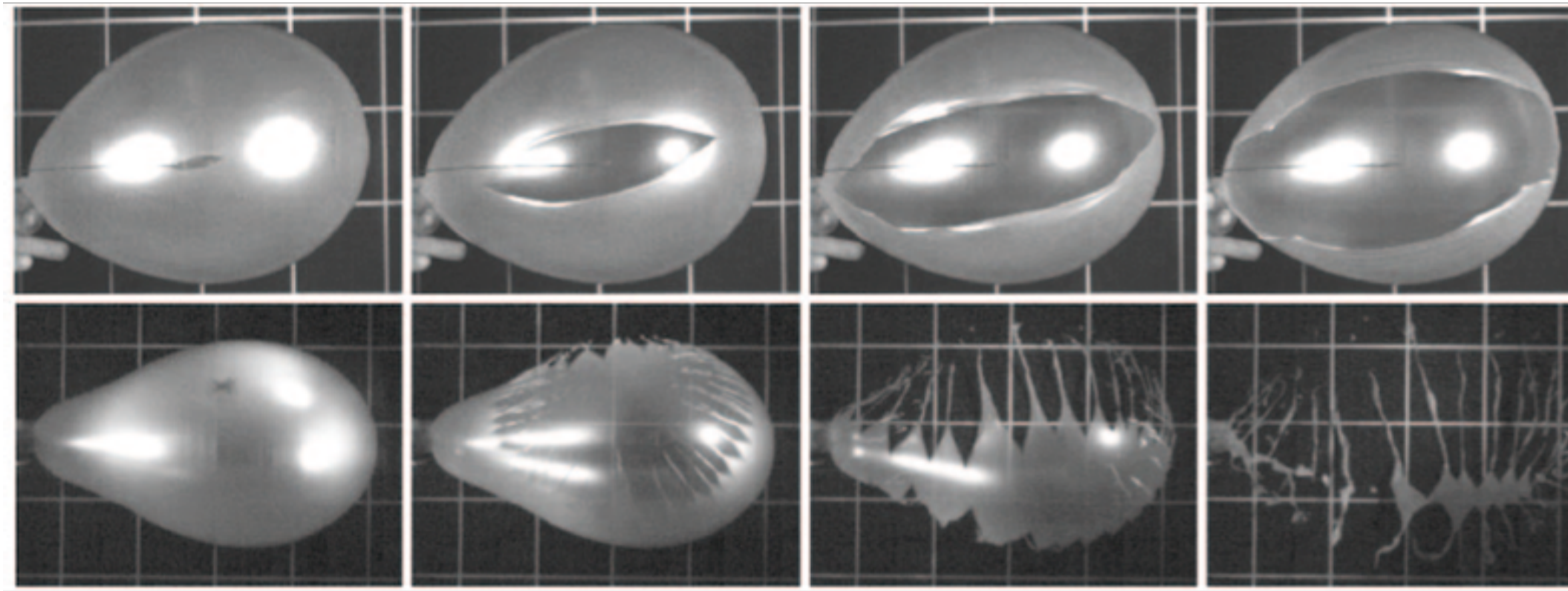
Human Population 2017

2,626.57

Lecture 20
predictions, adaptations

Popping a balloon or letting it pop.



Things we have learned so far

- Exponential growth is unsustainable.
- Earth is finite.
- Biocapacity is autoregenerating, like an endowment.
- Overusing biocapacity leads to collapse.
- Responding to limits quickly avoids collapse.
- Delayed reponse time leads to overshoot.

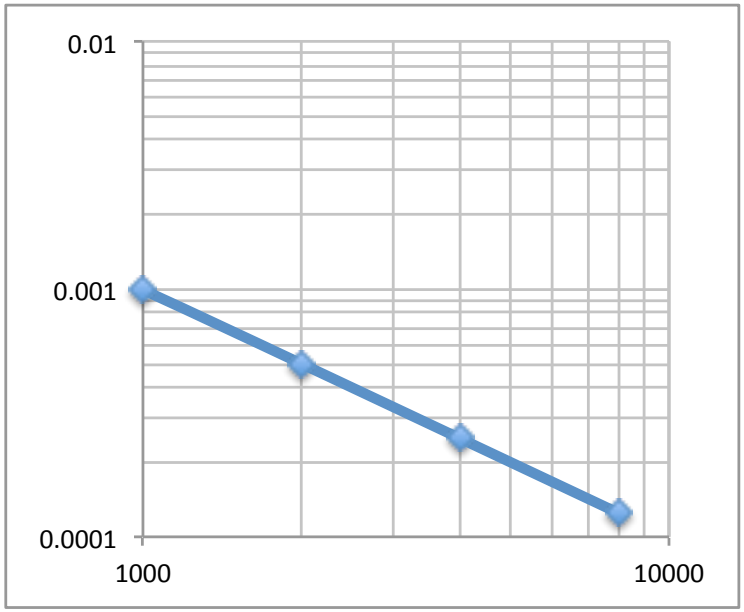
Concepts we have covered so far

- Overshoot leads to collapse.
- Increasing efficiency only buys time.
- As we hit more and more limits, we run out of ability to cope.
- Bigger overshoot leads to bigger collapse.
- Increased inequality leads to ...

Running out of "the ability to cope"

- LtG p223

emmissions level required to keep the same air quality

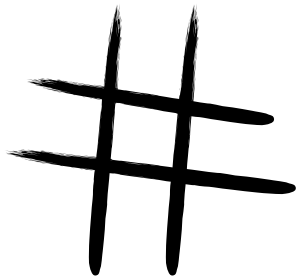


cars on the road

Imagine doing all you can to adapt to ("cope with") and maintain exponential growth.
The adaptation rate will have to scale with population.

New ideas

- If the rules of the game make the game unwinnable, **change the rules**.
- What are the new rules?
    - Can we remove:
        - Limits?
        - Delays?
        - Growth?



Conclusions from Limits to Growth Ch 7

Changing numbers

Numerical adjustments of the **World3** model.

World3 scenarios 2 (more non-renewables), 3 (more nonrenewables and pollution control), 4 (+land yield enhancement), 5 (+ erosion protection), 6 (+ resource efficiency).

Result: failure to cope. Population collapse.

Conclusions from Limits to Growth Ch 7

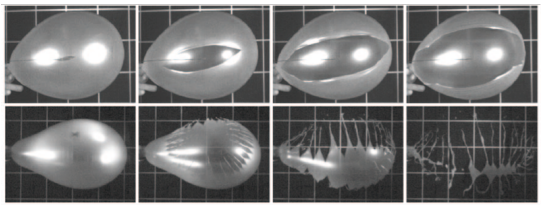
Changing structure

Structural adjustments of the World 3 model. Scenario 7 (pop. control), 8 (+affluence control), 9 (+circular economy).

Result: Success. Sustainable high population. But is it realistic?

What about *non-linear* changes?

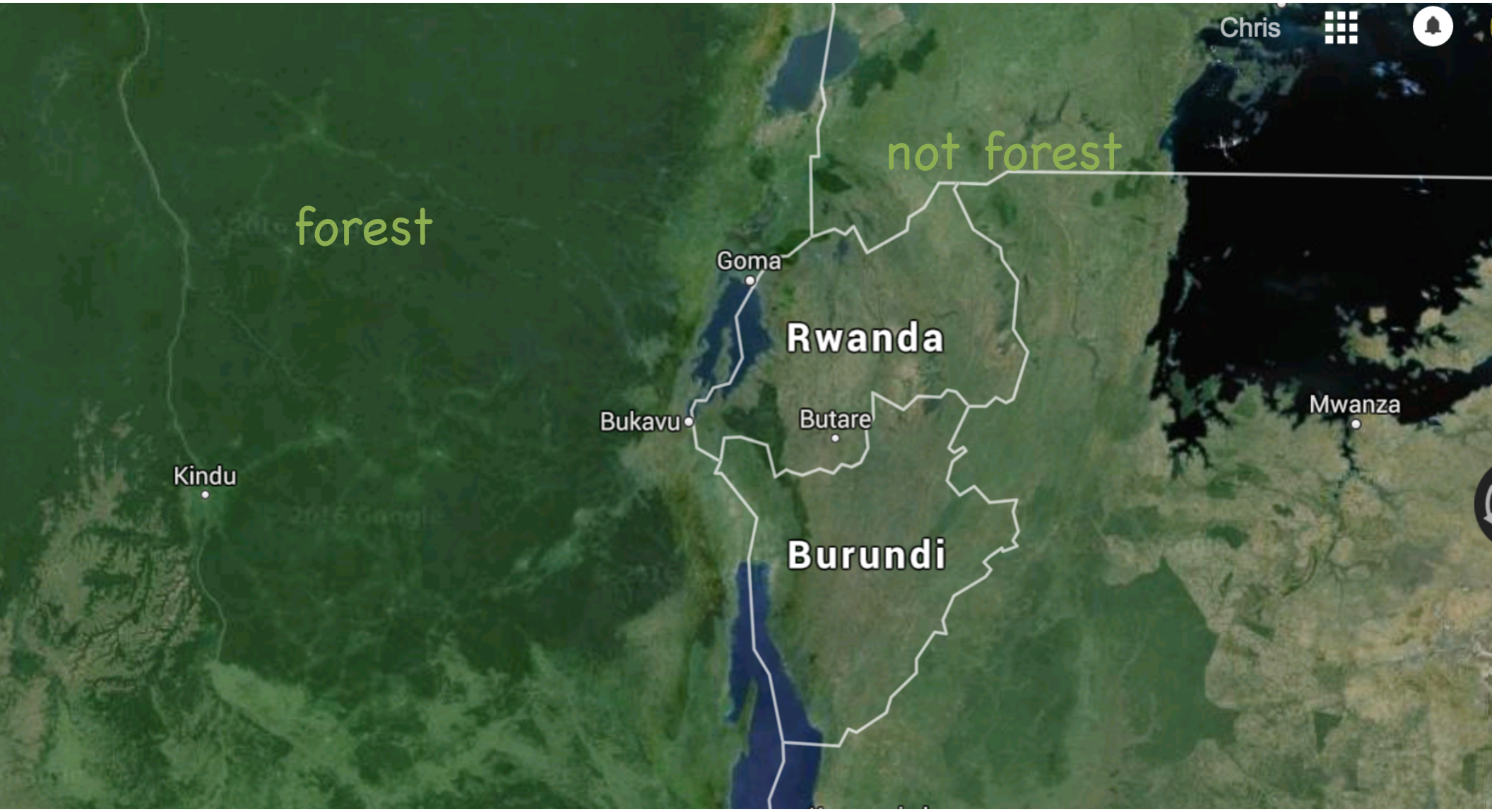
- World3 does not model violence/unrest, inequality.
- In the model, hunger leads to decreased LEB.
- But what also happens with hunger?
  - Venezuela
  - Rwanda



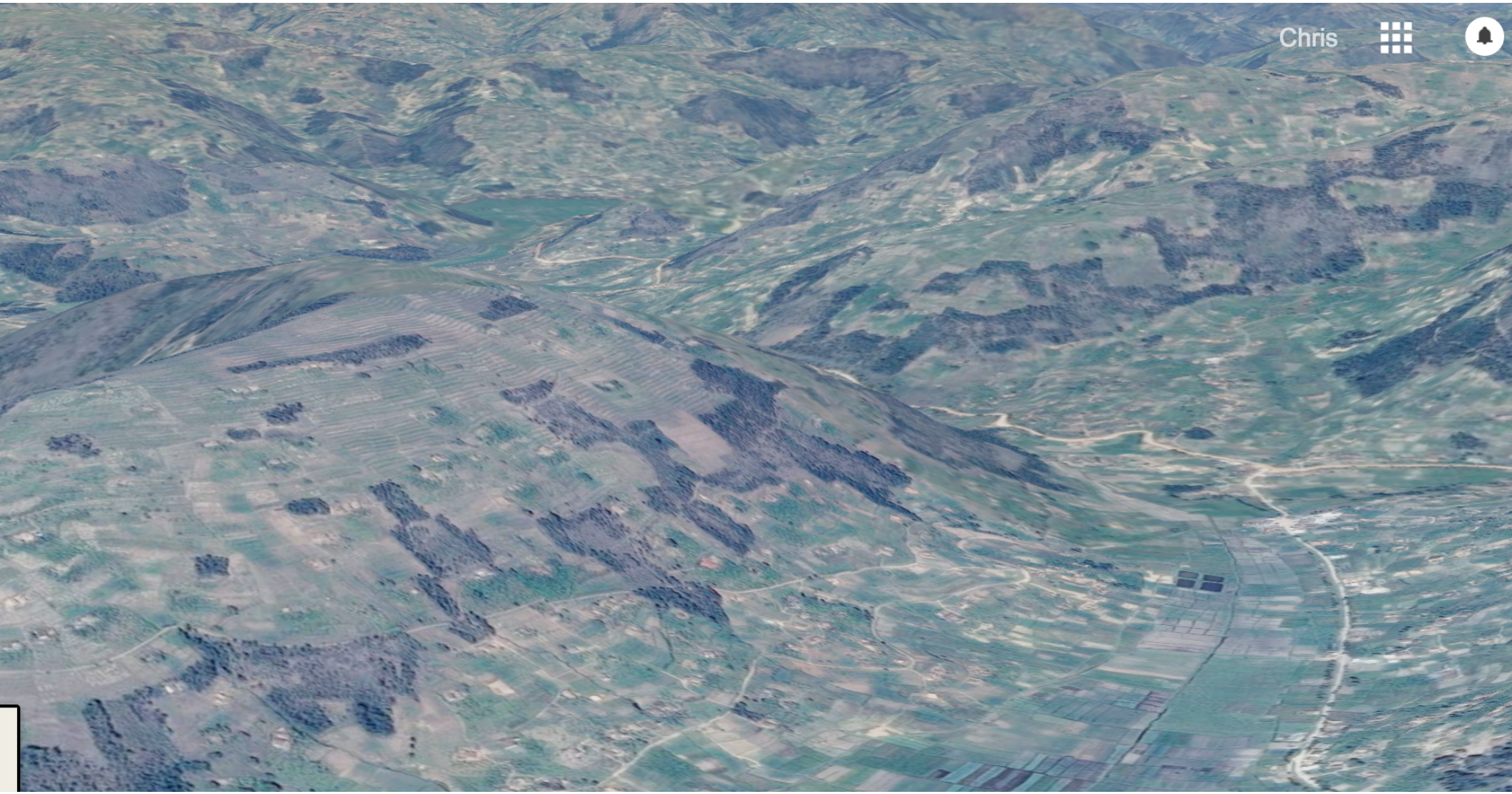
Rwanda 1994

- **Population pressure**
  - 760 people / sq mi in 1990
  - unmechanized, unmodernized agriculture
  - A "sea of children"
  - forests cleared, wetlands filled. slopes farmed.
  - drop in coffee prices, 1989.

High population density



Farming on slopes.



Northern Rwanda farms occupy valleys, hilltops, slopes, except for the steepest.

www.google.com/maps 2016

Juvénal Habyarimana, alias "kinani" (invincible). Re-elected with 98.9% (1978), 99.97% (1983) and 99.98% (1988) of the vote.

https://en.wikipedia.org/wiki/Juvenal_Habyarimana

Killed Apr 6, 1994 sparking genocide.

"get out of the way and let us work". [i.e. killing Tutsis]

--Prov Pres. Théodore Sindikubwabo.
Radio address April 19, 1994.

https://en.wikipedia.org/wiki/Theodore_Sindikubwabo

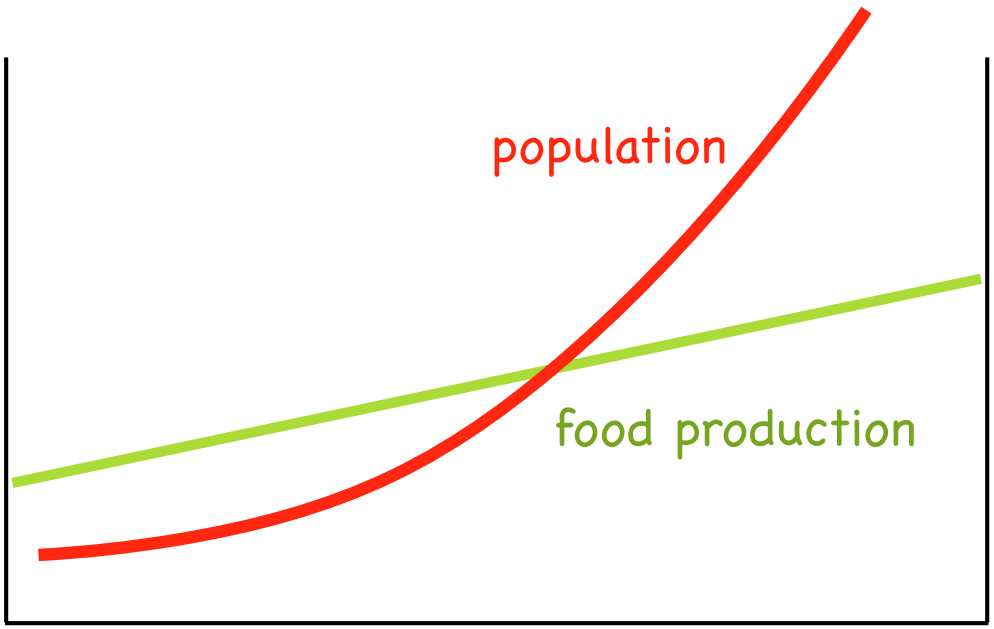
- April-July 1994:
  - International groups stand aside.
  - As much as 1/3 of civilian population involved in killings.

Paul Kagame, current President of Rwanda. Previously commanded the rebel force (RPF) that ended the 1994 Rwandan Genocide

Malthusian dilemma?

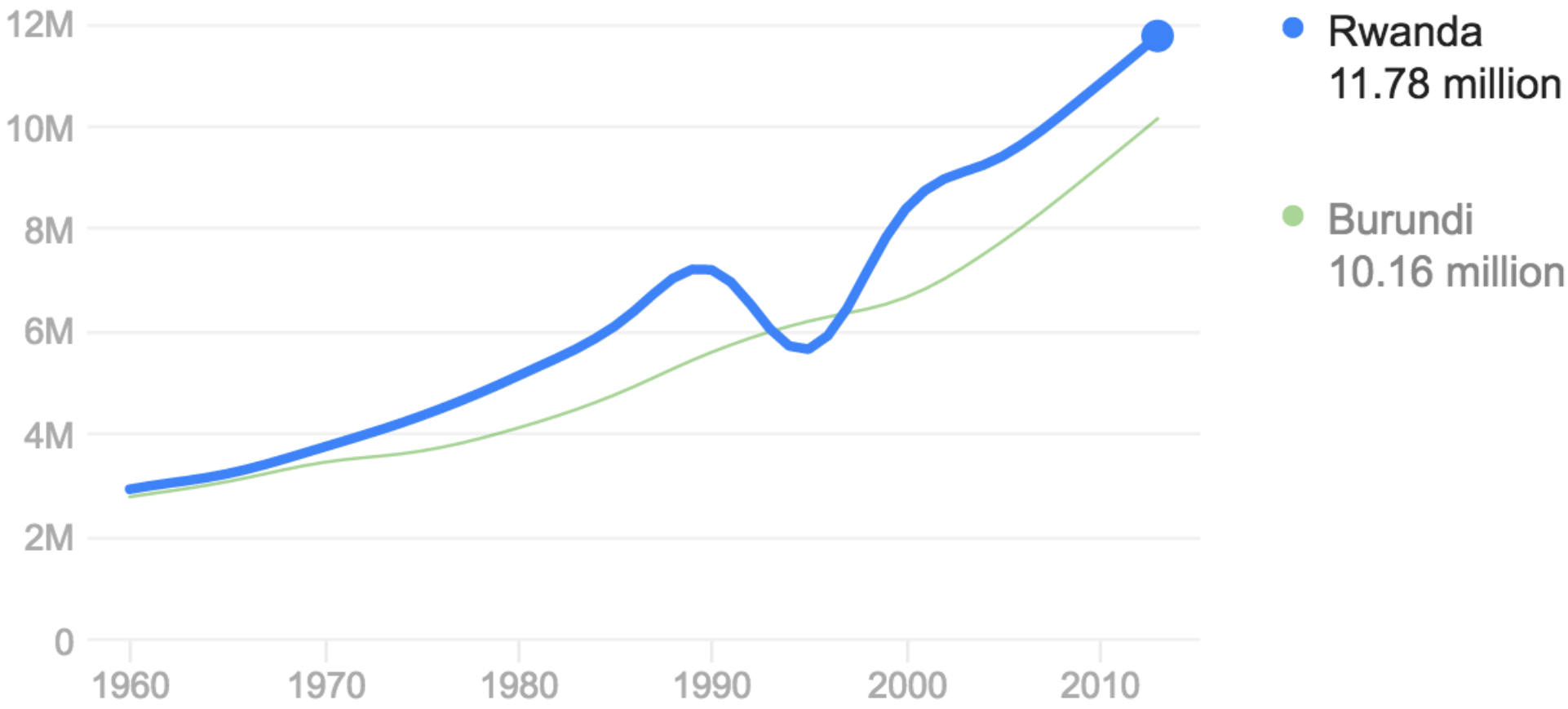
"The decision to kill was of course made by politicians, for political reasons. But at least part of the reason it was carried out so thoroughly by the ordinary rank-and-file peasants in their ingo was feeling that there were too many people on too little land, and that with the reduction of their numbers there would be more for the survivors."

Gerard Prunier, a French scolar of East Africa.
in J. Diamond "Collapse" p.326



"...It is not rare, even today, to hear Rwandans argue that a war is necessary to wipe out an excess population and to bring numbers into line with available land resources."

C. Andre and JP Platteau "Land relations under unbearable stress: Rwandans caught in a Malthusian trap." J. of Econ. Behaviour and Organization 34:1-47 (1998)


12M
10M
8M
6M
4M
2M
0
1960
1970
1980
1990
2000
2010
Rwanda
11.78 million
Burundi
10.16 million

Rwanda 20 years later

http://www.voanews.com/content/years-after-genocide-rwanda-prospers-but-political-freedom-remains-elusive/1889977.html

"the sustainability revolution"

Genocide?

New rule: arbitrary killing to increase death rate and counter-balance growth.

- Eliminates growth.
- But at expense of ... rule of law, justice, peace, concern for other species and the planet, etc etc.

"the sustainability revolution"

Circular economy?

New rule: No waste.

- Eliminates the **Impact** of Growth.
- But, does it enable **unending** growth? (No. Because of the "coping" problem.")

Sci-Fi Story

Anticipating the coming of the Great Celebration, when humanity would surely collapse and become extinct on Earth, a space ship was launched to colonize an Earth-like planet 8 light-years away. They arrived and studied the planet, but it contained too much arsenic, and the ship was forced to return to Earth, unsuccessful in its mission. When they arrived and woke from their long cryo-sleep, one thousand years had passed on Earth.

To their surprise, humanity was alive and well. The forests and oceans were healthy and the climate was mild. Collapse had happened as expected, but it was incomplete. And in the years since the collapse, the global population had not increased at all. Nor had it decreased.

The ship's captain, Joniqua Williams-Williams, demanded to be brought to the world's supreme leader. She was directed to an ancient cyborg called "The Accountant."

"If you want to know why we survived, you must read the Selection for the Constitution of Earth." said the cyborg.

"Where can I find this 'Selection'?" the Captain asked.

"It's on the next slide." Said the Accountant.

Intentional selection for the human

Constitution of the Earth

...

Article 3. On Human Continuance.)

Section 1.

a. Continuance shall be defined as the inheritence of the right to live. b. Each Continuance represents a single life. c. To live an entire life of more the eighteen (18) years without Continuance is a violation of the Selection, punishable by Celebration. d. Continuance must be maintained in symbolic form capable of ownership and trade.

Section 2.

a. Continuance may be gifted on or after the death of the previous carrier. b. Continuance may be received by anyone regardless of age. c. A Continuance gifted to a woman may be designated to the unborn child of that woman. In the event that no child is born, it may be re-gifted without restriction. d. Persons who die while carrying an un-gifted Continuance pass it to a designated family member regardless of the previous carrier, or in the event that no family member is designated, to the State. e. Persons may carry any number of Continuances. f. Persons carrying no Continuance are subject to Choosing by the Accountant, his or her agents, or local delegates.

Section 3.

a. Continuance may be denied only by the Public Servant upon recommendation by the Judicial Body. b. Continuance may not be denied on the basis of political views, ideology, health or race. c. Continuance may be awarded by the State at the descretion of the Public Servant. d. The Accountant must establish the count upon submissions and has the sole authority to mint new Continuances.

Sci-Fi Story

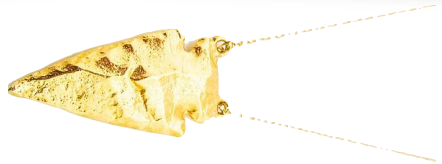
But alas, the document was darkly stained, and the script was curvy and small. The Captain asked for a synopsis.

"It is easy." Said the cyborg as it reached into a compartment where its heart should have been. "Everyone alive today has one of these."

The Accountant showed the Captain a small arrowhead made of gold. On it were engraved many names in tiny letters.

"Each person must have one, and must pass it on to a pregnant woman before passing away. The baby is called the 'continuance' of the life of the owner of this arrow. And the baby, when it is old, passes on the arrow in a similar manner, to their own child or to another. So you see, we can only have as many people as we have these golden arrows."

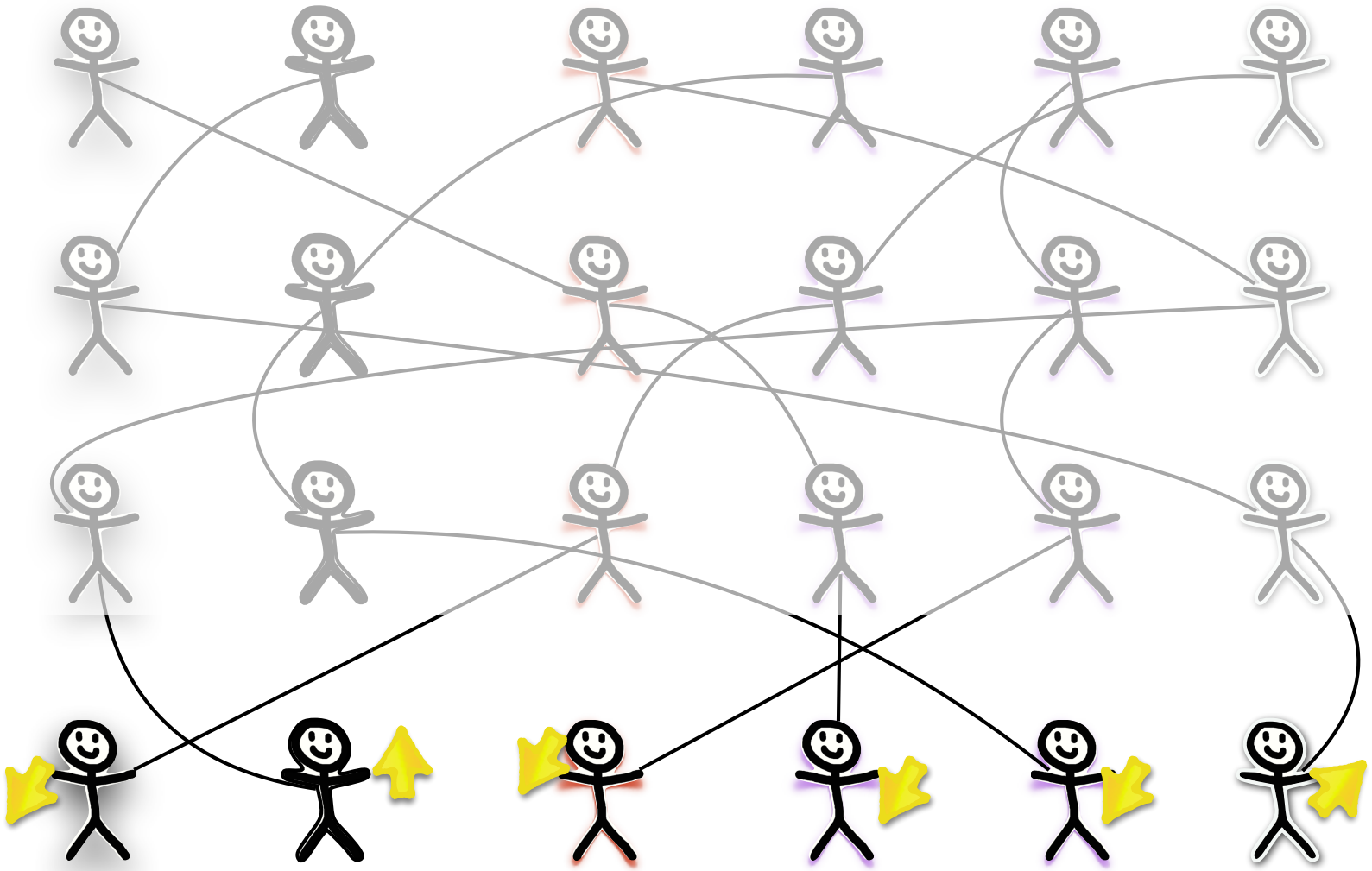
With that, and without another word, the cyborg reached behind its neck and flipped a switch. It fell immediately into sleep, oblivious to the Captain's questioning stare. The Captain let herself out.



"the sustainability revolution"

New rule: one-for-one

gener-
ations



Numbers

Term Projects

Model one of these, or come up with your own idea.

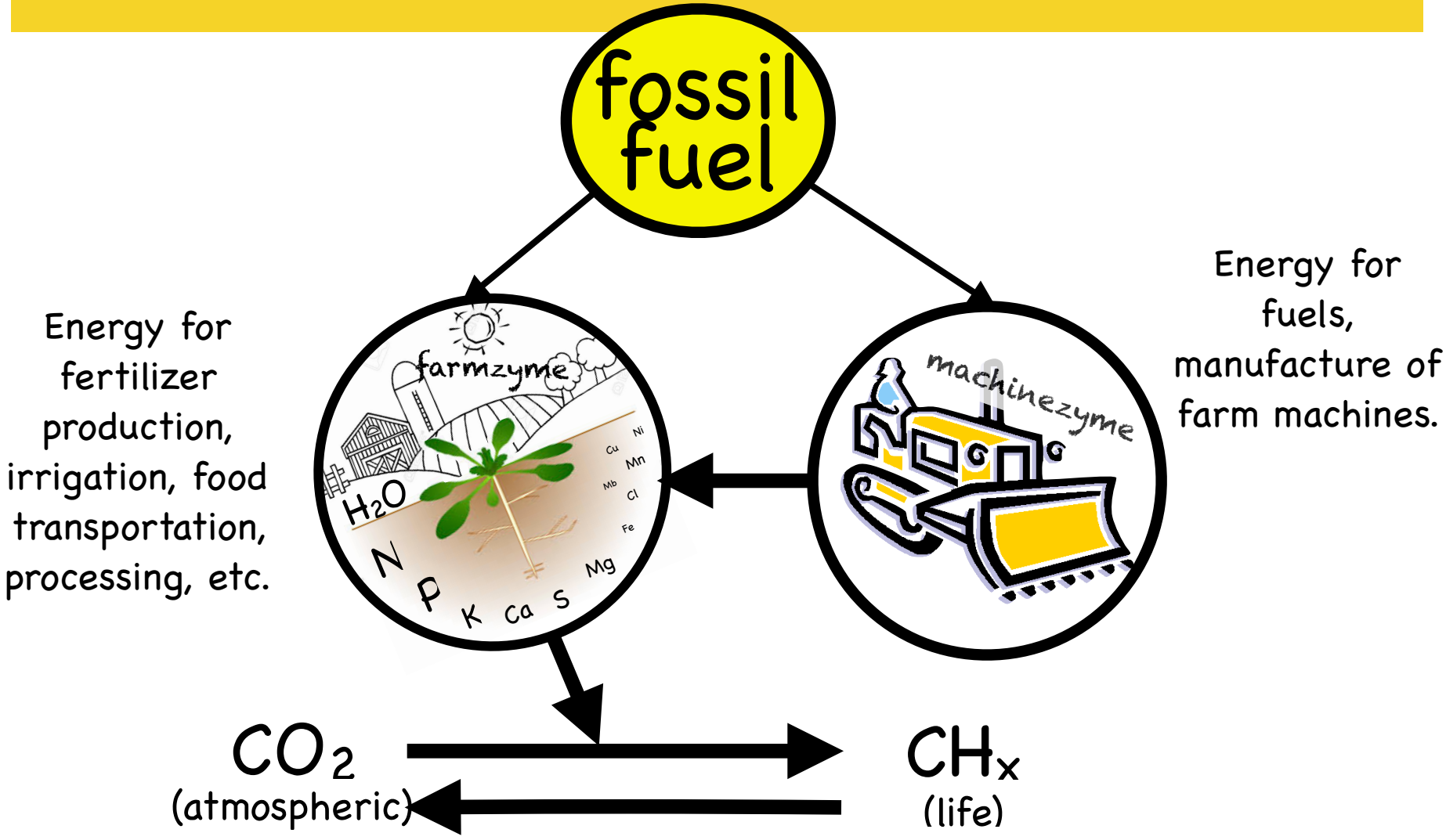
1. climate change.
2. contraceptive technology and usage.
3. female empowerment.
4. renewable energy.
5. fresh water availability.
6. food supply.
7. unrest and violence.
8. species extinctions.
9. inequality.

What is the thought process for modeling?

- Pick a thing to model. Ask if it is already in the model, if not...
- Is it a stock or a variable?
- What goes into it? What comes out?

Adding non-renewables to the model

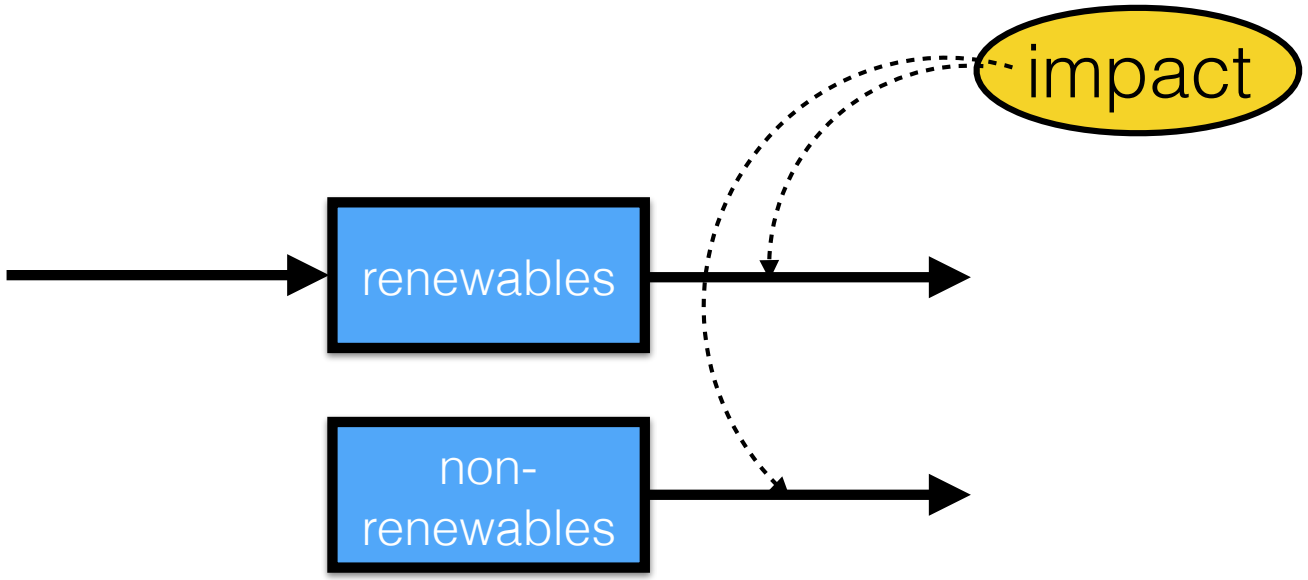
Non-renewables fuel the catalysts



Catalysis of "life" may be energy limited!!

Links and FLows

- renewables and non-renewables are both resources.
- renewables regenerate.
- non-renewables don't.
- Both are consumed.
- Consumption (impact) is split between renewables and non-renewables. (how is not important, yet)



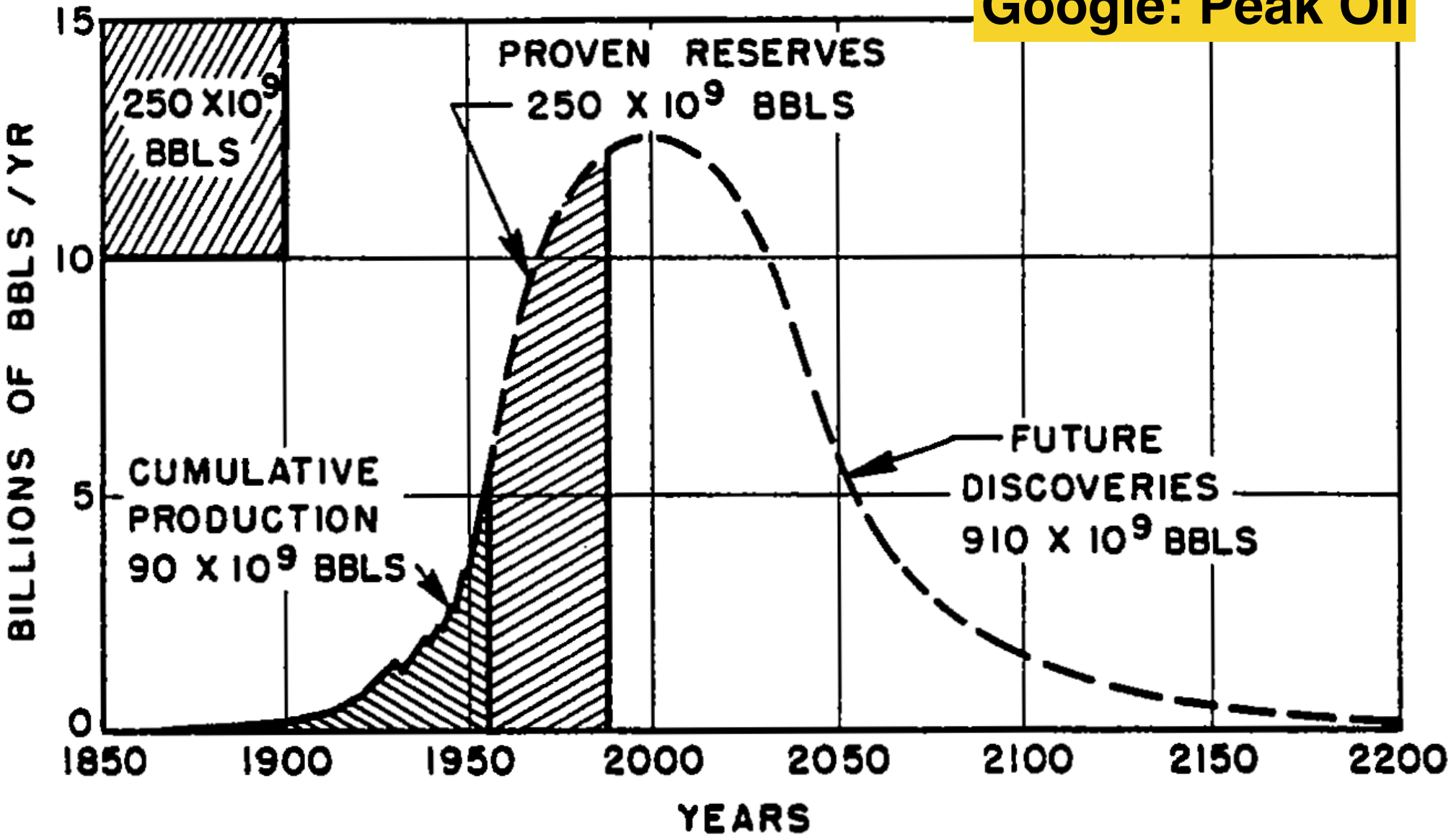
Data , Equations

- Once the model has the right links, we need to think about the equations.
  - How is consumption [Impact] split between renewables and non-renewables?
  - How does the flow relate to [Impact]? That is, what is the efficiency?
- Find the data! (this might be the hard part!)
- Fit the equations to the data.

Data , Equations

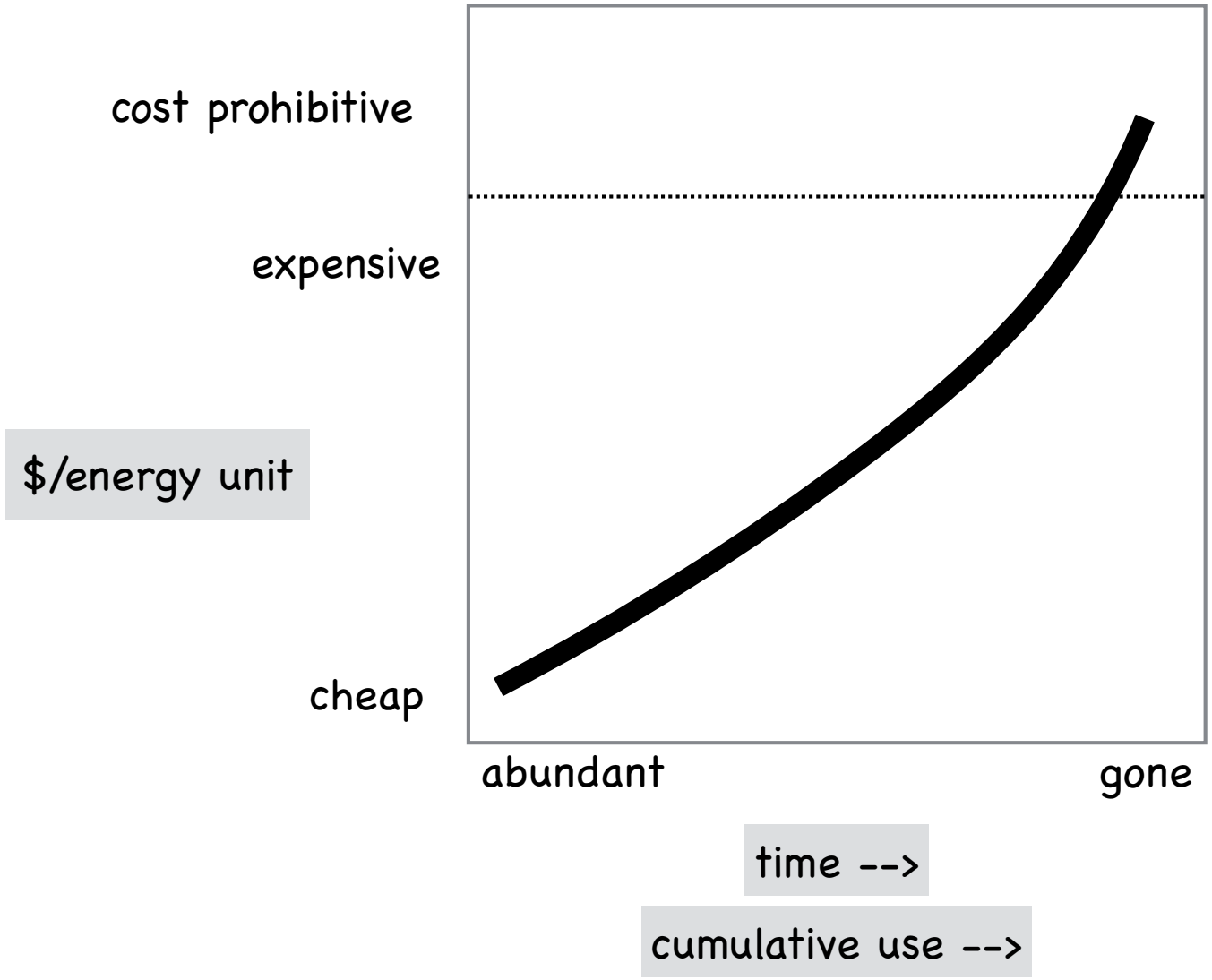
Hubbert's Curve

Google: Peak Oil

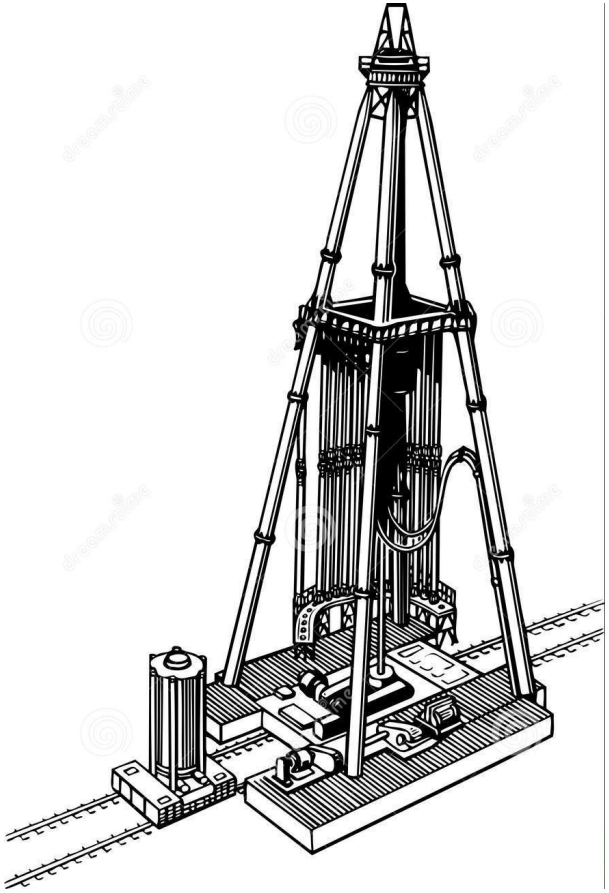


Estimating the total amount of oil on Earth.

Plot of depletion vs time with increasing consumption and increasing extraction costs



In the early days of oil exploration, costs were relatively low.



Drillers could afford to be wasteful...

Cost of extraction: "MENA" oil

- You pay  0.1 barrels
- You get 

1 barrel

Net: 0.9 barrels

not counting cost of clean-up!!

Cost of extraction: tar sands

- You pay

3 barrels

- You get

5 barrels

not counting cost of clean-up!!

Scenes from the Alberta tar sands

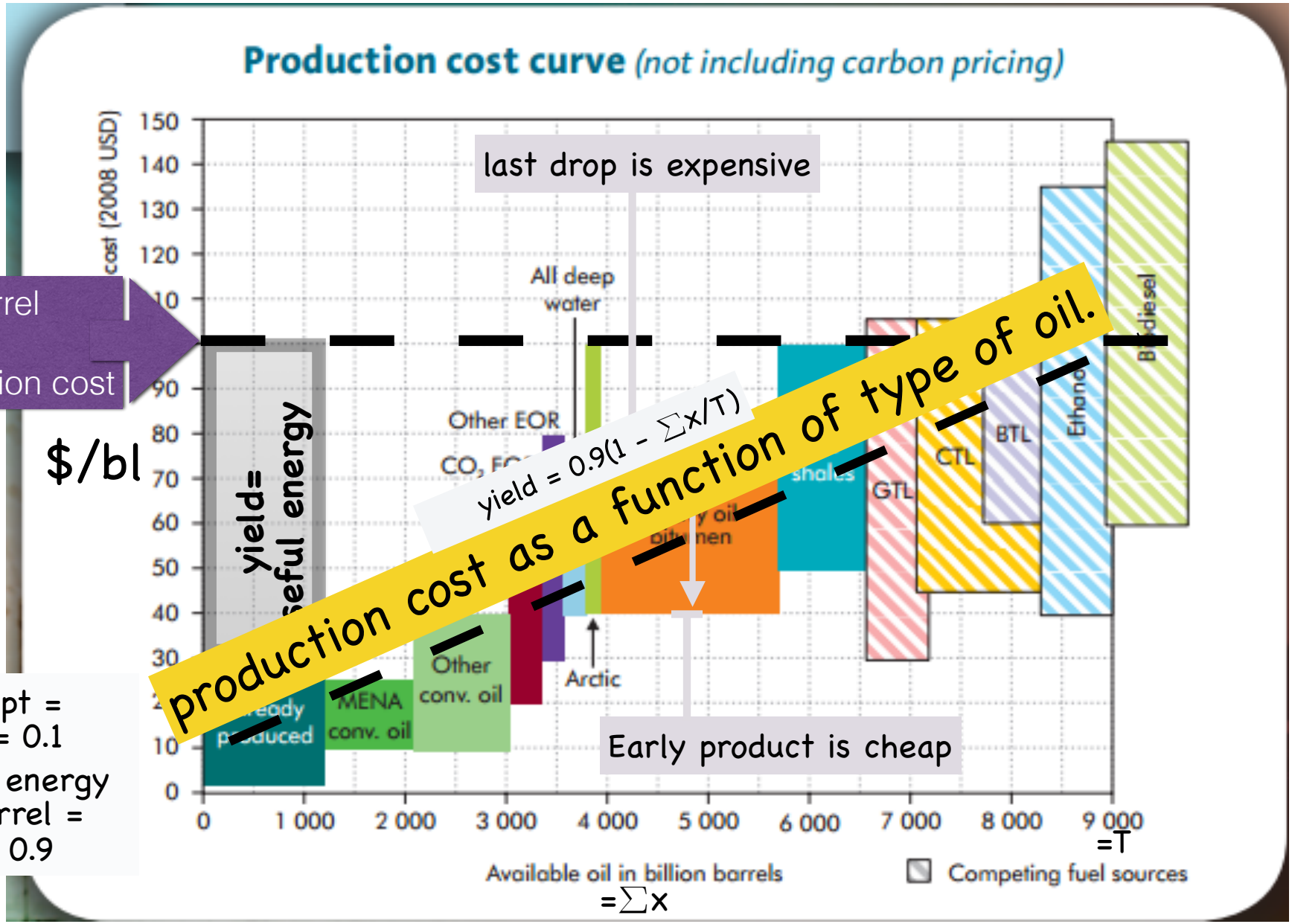
now...

we have to dig deeper

spend more fuel to make fuel

pollute more

Cost of extraction as a fraction of the useful energy produced.



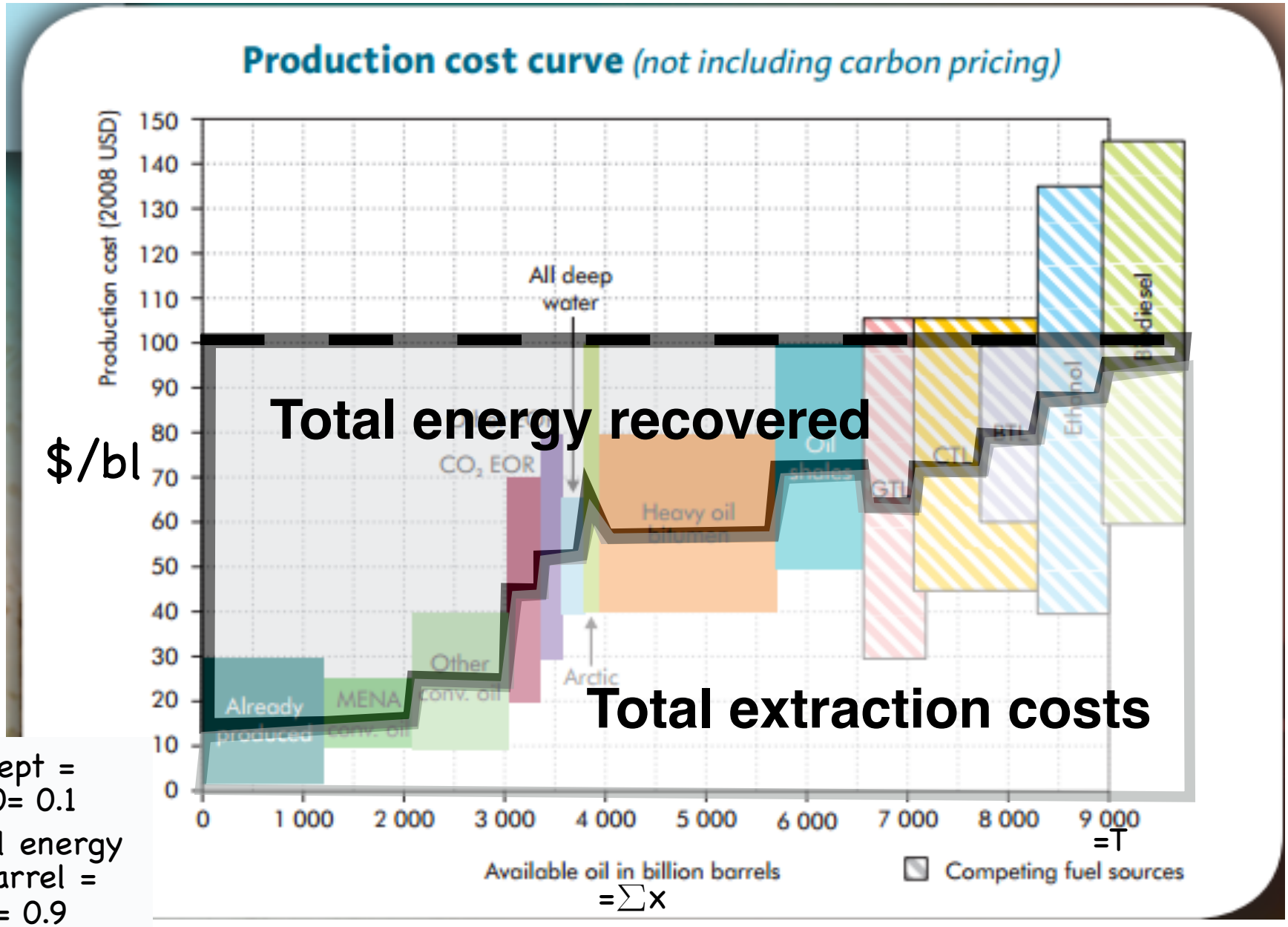
One barrel worth of production cost

$/bl

intercept = 10/100= 0.1

Useful energy per barrel = 1-0.1 = 0.9

Cost of extraction as a fraction of the useful energy produced.



intercept = 10/100= 0.1

Useful energy per barrel = 1-0.1 = 0.9

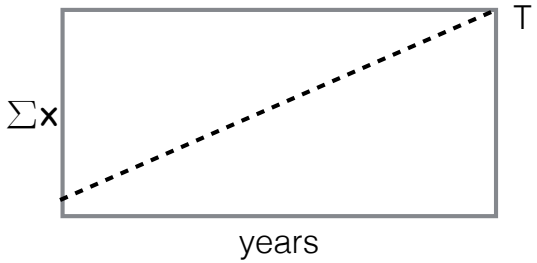
At a constant rate of consumption

Oil consumption accelerates as extraction costs go up.

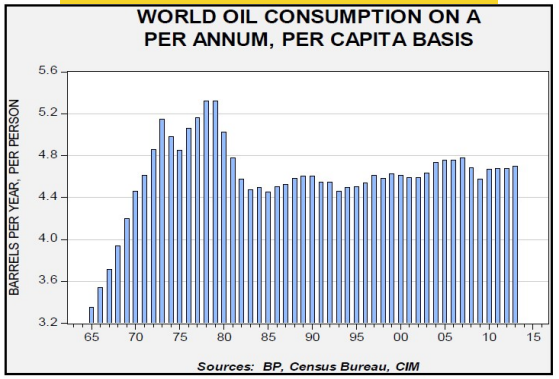
- T = total barrels of oil available at break-even price or better = 9000 bbl
- x = barrels of oil consumed, each year.
- $\sum x$ = cumulative sum of barrels of oil consumed
- y = yield = (useful energy produced) / (energy used)
  = $0.9(1 - \sum x/T)$, where $\sum x < T$
- z = useful energy produced, each year.
- $z = x*y = x*0.9(1 - \sum x/T)$
- Solving for x, barrels of oil consumed…
  $x = z / y = z/(0.9*(1-\sum x/T))$

denominator goes to zero!

Extraction cost ∝ cummulative oil consumption



4.5 bl/year/person



Flow out of [nonrenewables] as a function of [Impact].

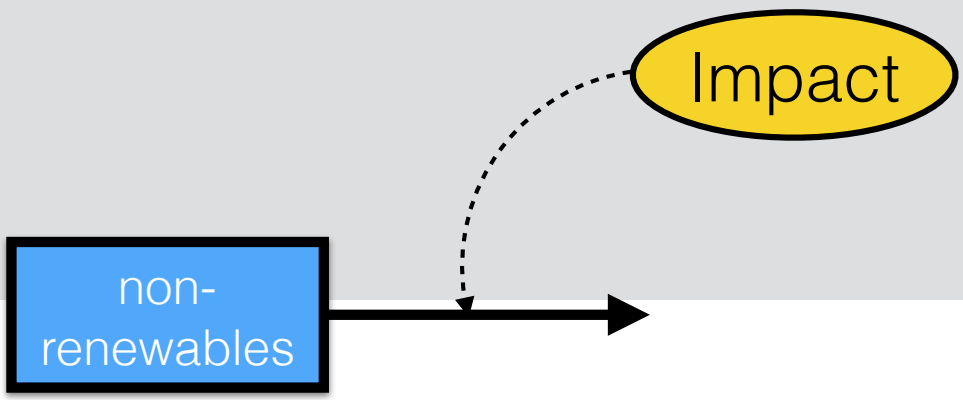
T <- starting value of [nonrenewables]. Total non-renewables on the planet, used or not, found or not. (in barrels or tons, converted to common unit for resources, gha)

z <- [Impact]

y <- 0.9*[nonrenewables]/T

x <- z/y

return x



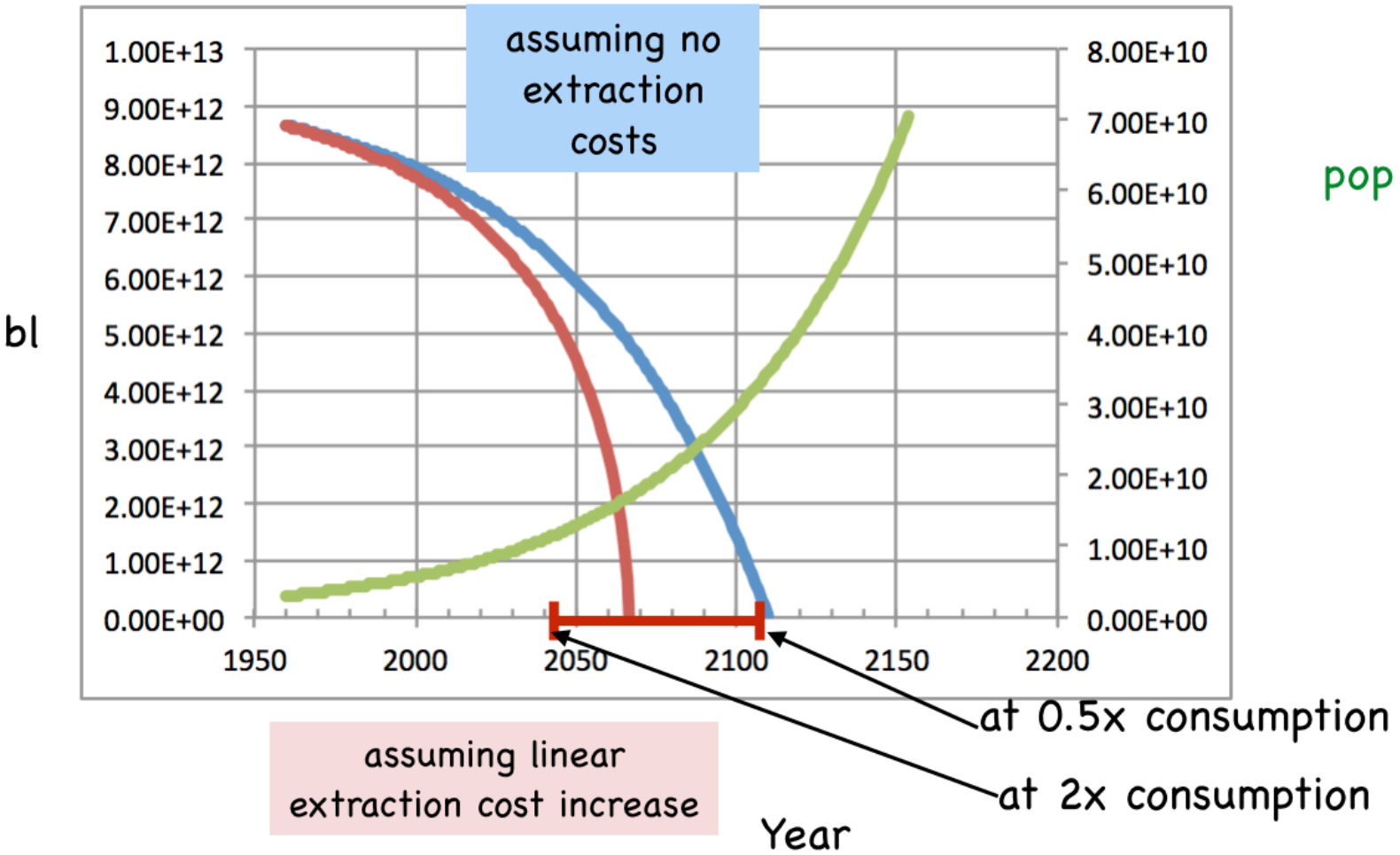
Prediction

- Once you have finished modifying the model, predict the future!
  - How long with non-renewables last under a business-as-usual scenario/
  - How long will they last given a more hopeful scenario?
  - Do sensitivity analysis. What if we double something? What if we cut it in half?

Assuming exponential growth of the population based on 1960-2014 growth rate (=0.0164)

Business as usual. We will run out of all liquid fuels by 2068±30 years

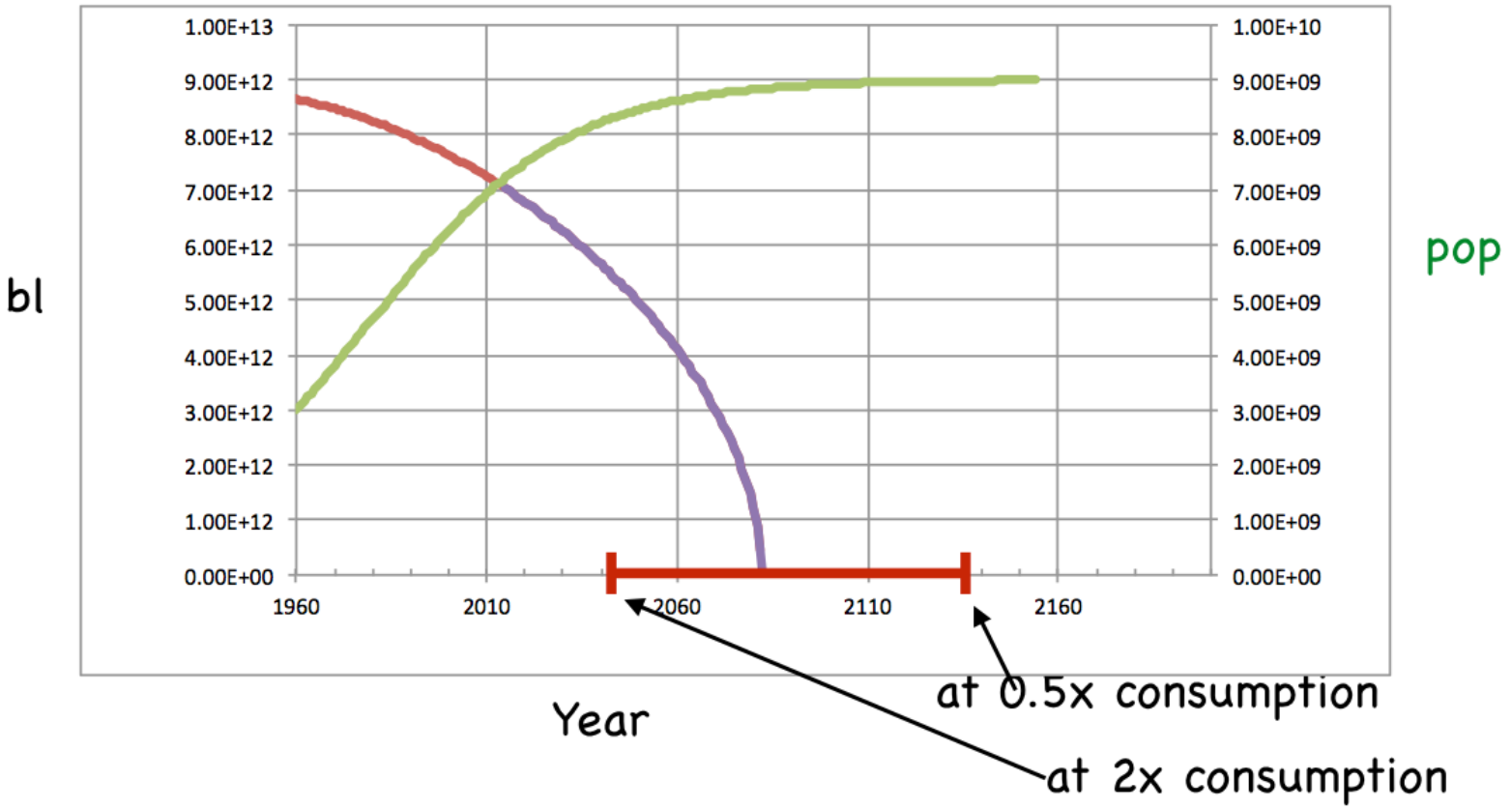
Error bars are based on 2-fold decrease or increase in consumption



Assuming logistic growth of the population based on 1960-2014 growth rate (α_0=0.038,α_1=4.22e-12)

We will run out of all liquid fuels by 2072±40-50 years

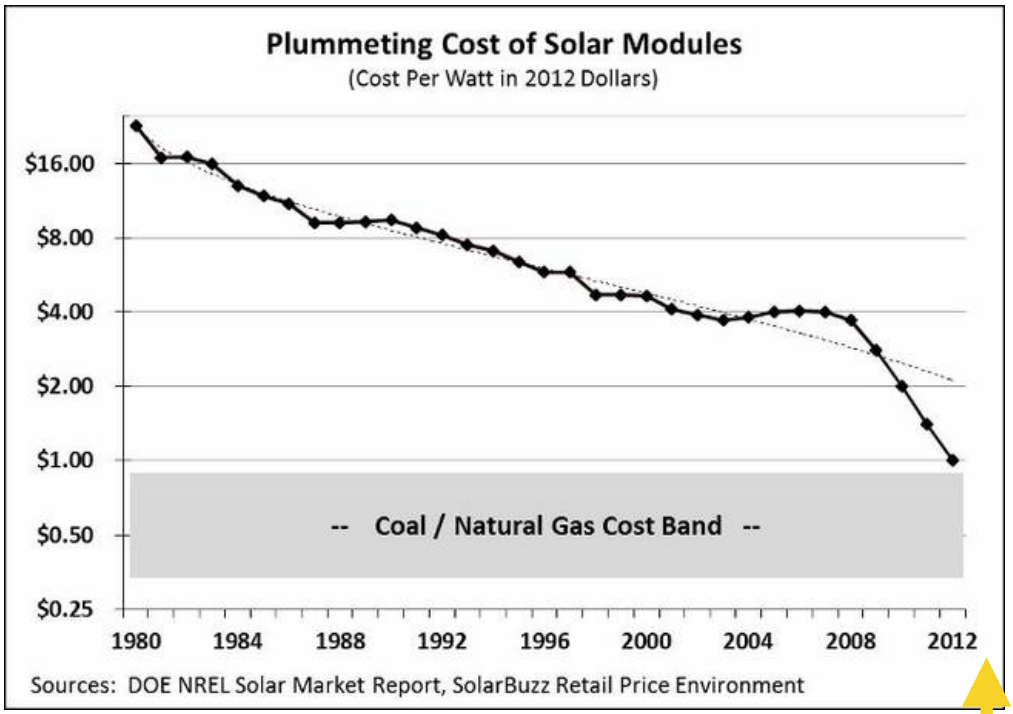
Error bars are based on 2-fold decrease or increase in consumption



"the sustainability revolution"

Solar! energy output/energy input ≈ 10

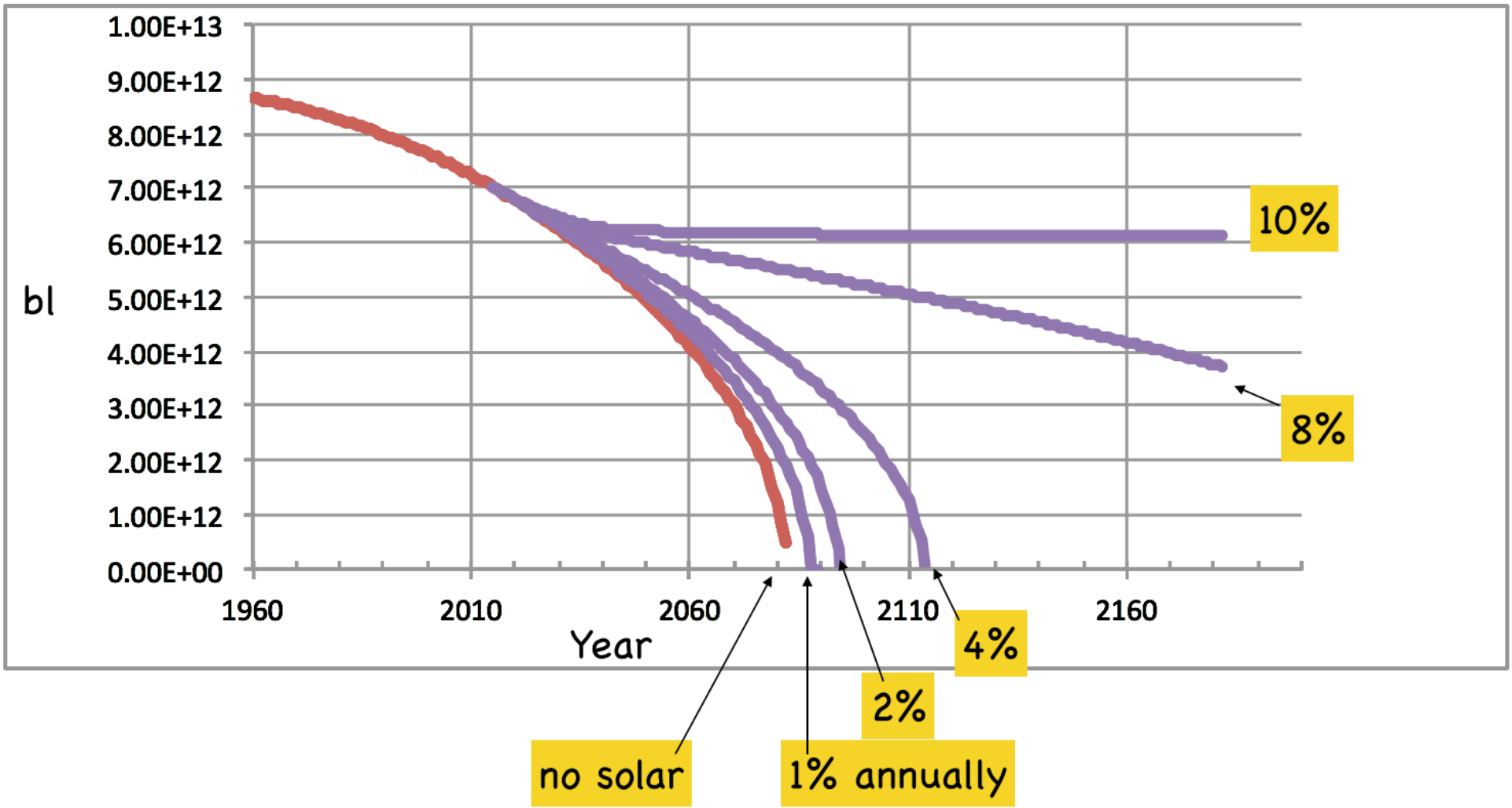
- 1-4 years of the lifetime of a solar panel is the amount of energy required to melt silicon and fabricate the panel.
- Panel lifetimes are 25-50 years.
- Energy payback is roughly 10 kWh out for 1 kWh in.



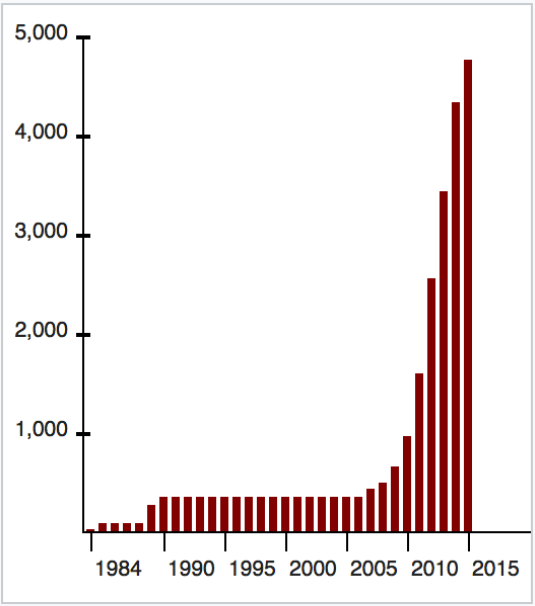
Cost/watt just went below fossil.

Liquid fuel reserves saved after **investment in solar** as a percentage of energy need (bl)

Solar calculated in barrel equivalents/year. Panels assumed to have 30 y lifetime. Cost of making panels set to 0.10 of energy output.



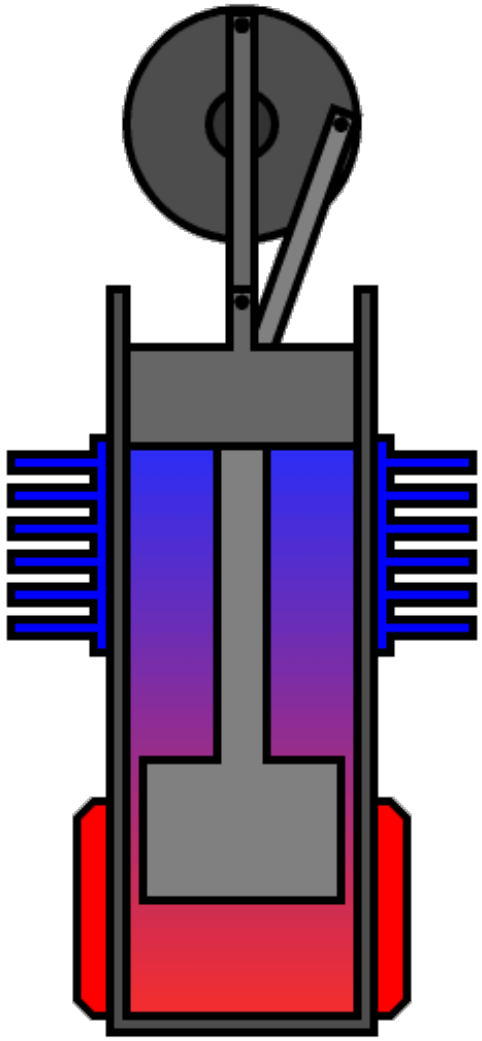
Other types of solar power



Worldwide CSP capacity since 1984 in MW_p

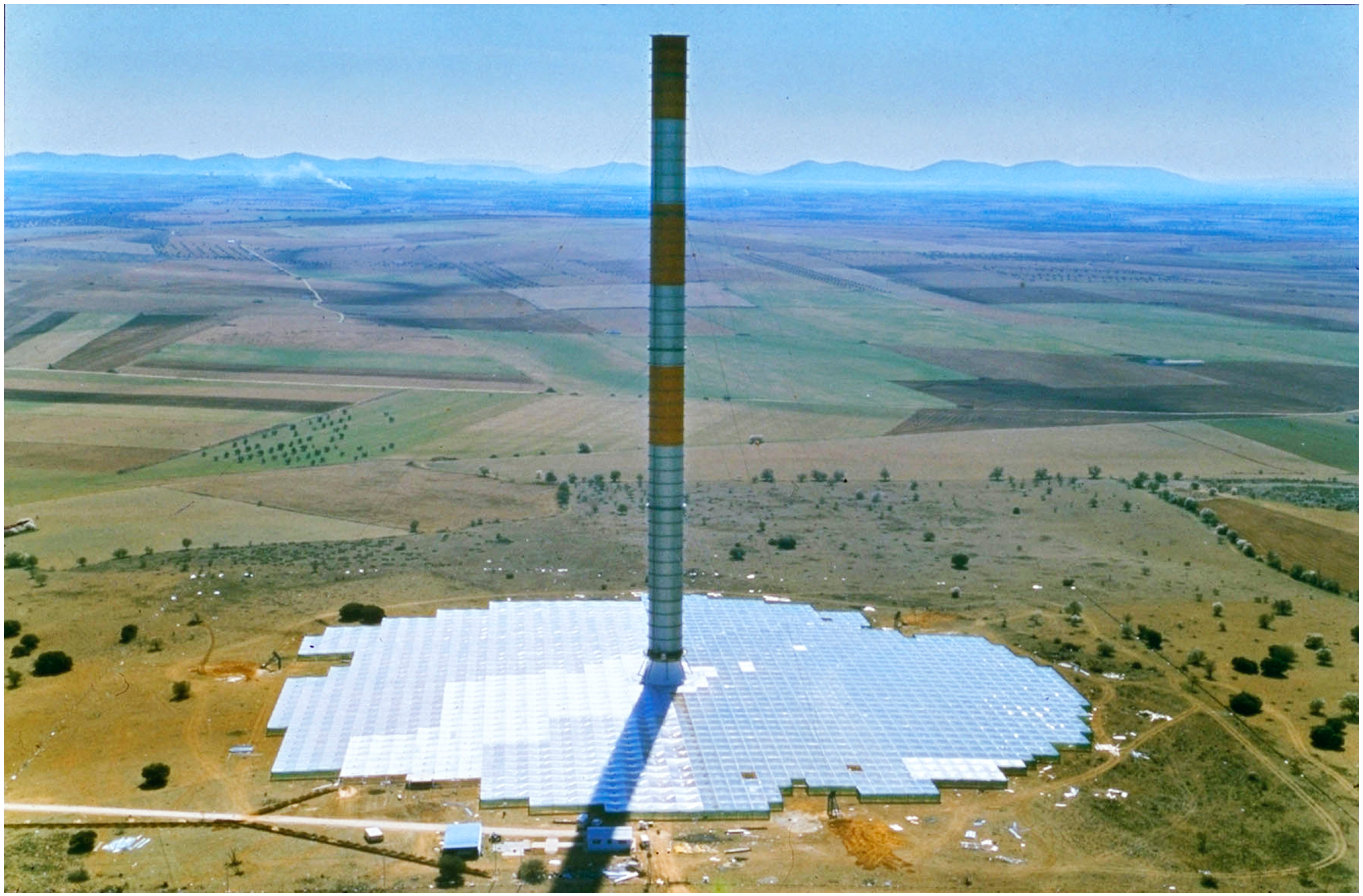
Concentrating Solar Thermal Power (CSP)

Other types of solar power
Dish Sterling



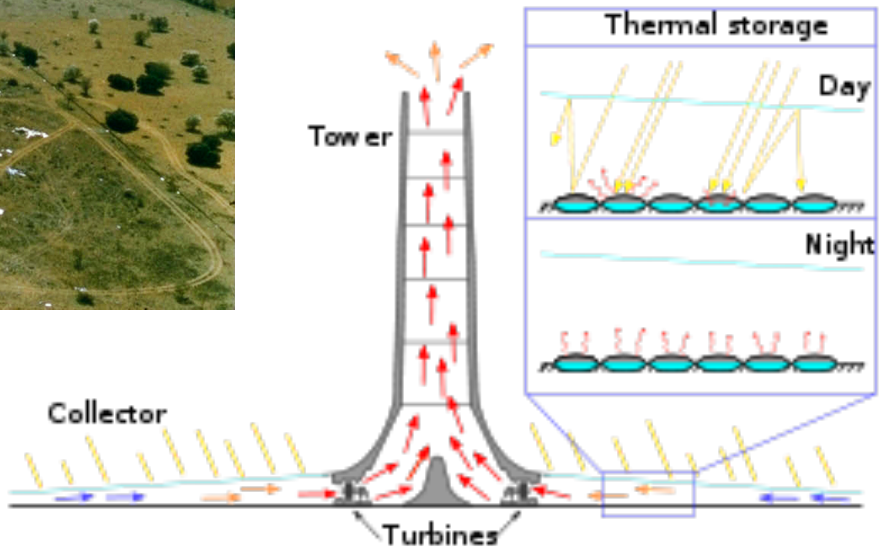
Sterling heat engine

Other types of solar power
Solar updraft



A test solar updraft tower in Manzanares, Spain, ran successfully for several years in the 1980s before toppling in a windstorm.

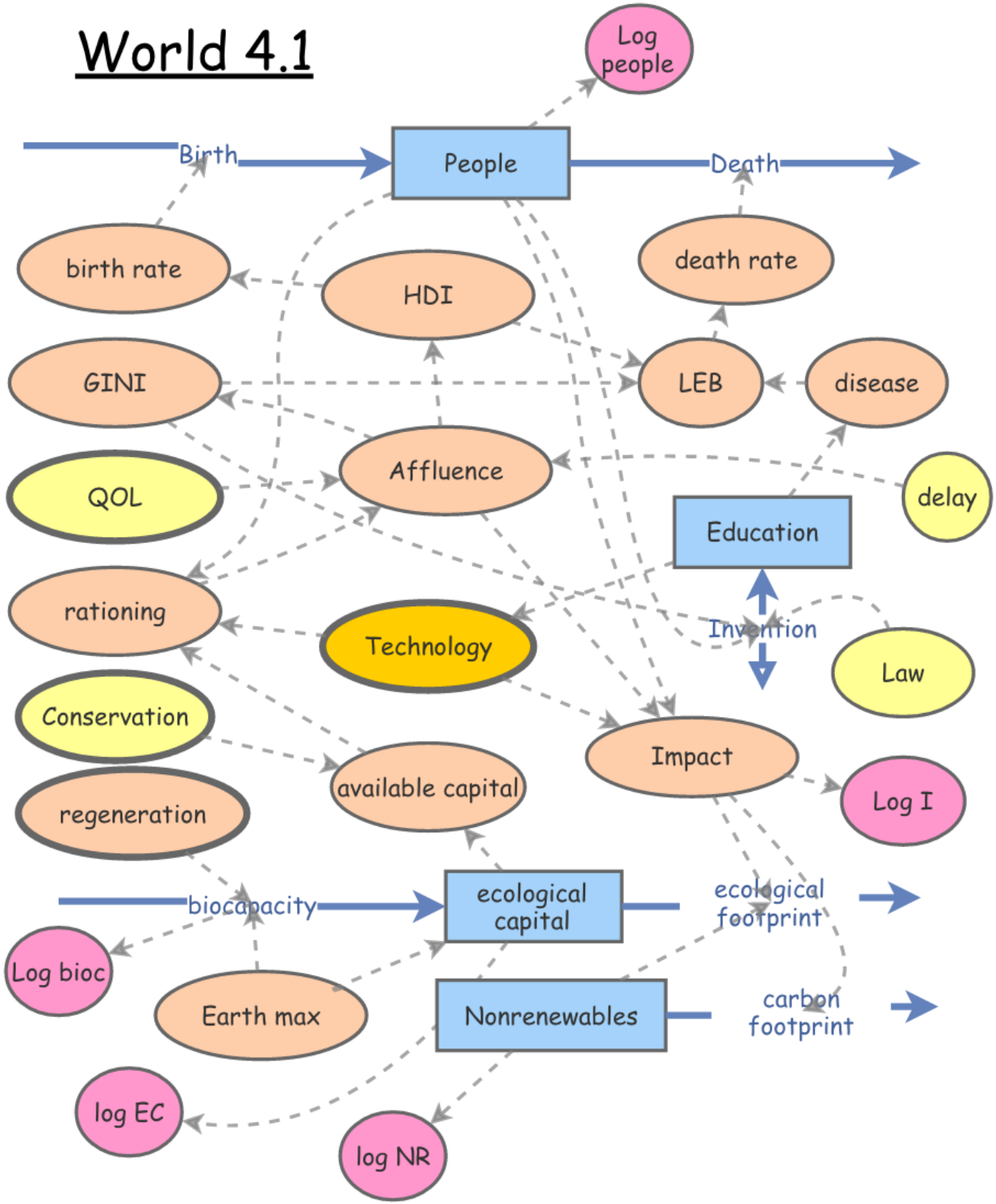
Dual usage greenhouse/ power plant



community solar

Screen shot of web page promoting community solar in Troy. Buyers own a piece of the solar array.

World 4.1


Log people
Birth
People
Death
birth rate
HDI
death rate
GINI
LEB
disease
QOL
Affluence
delay
Education
rationing
Technology
Invention
Law
Conservation
Impact
available capital
Log I
regeneration
biocapacity
ecological capital
ecological footprint
Log bioc
Earth max
Nonrenewables
carbon footprint
log EC
log NR

Start your term project today.

- By the end of class, decide which trend to model

1. climate change.
2. contraceptive technology and usage.
3. female empowerment.
4. renewable energy.
5. fresh water availability.
6. food supply.
7. unrest and violence.
8. species extinctions.
9. inequality.