Title: Energy and the Environment - What Physicists Can Do

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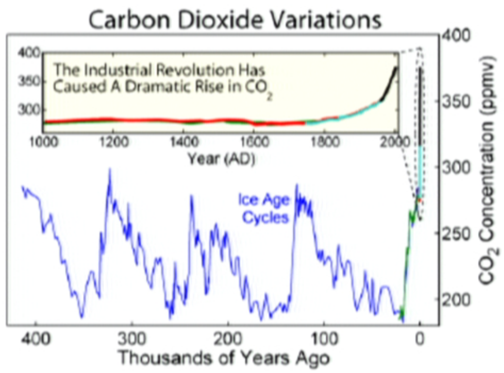
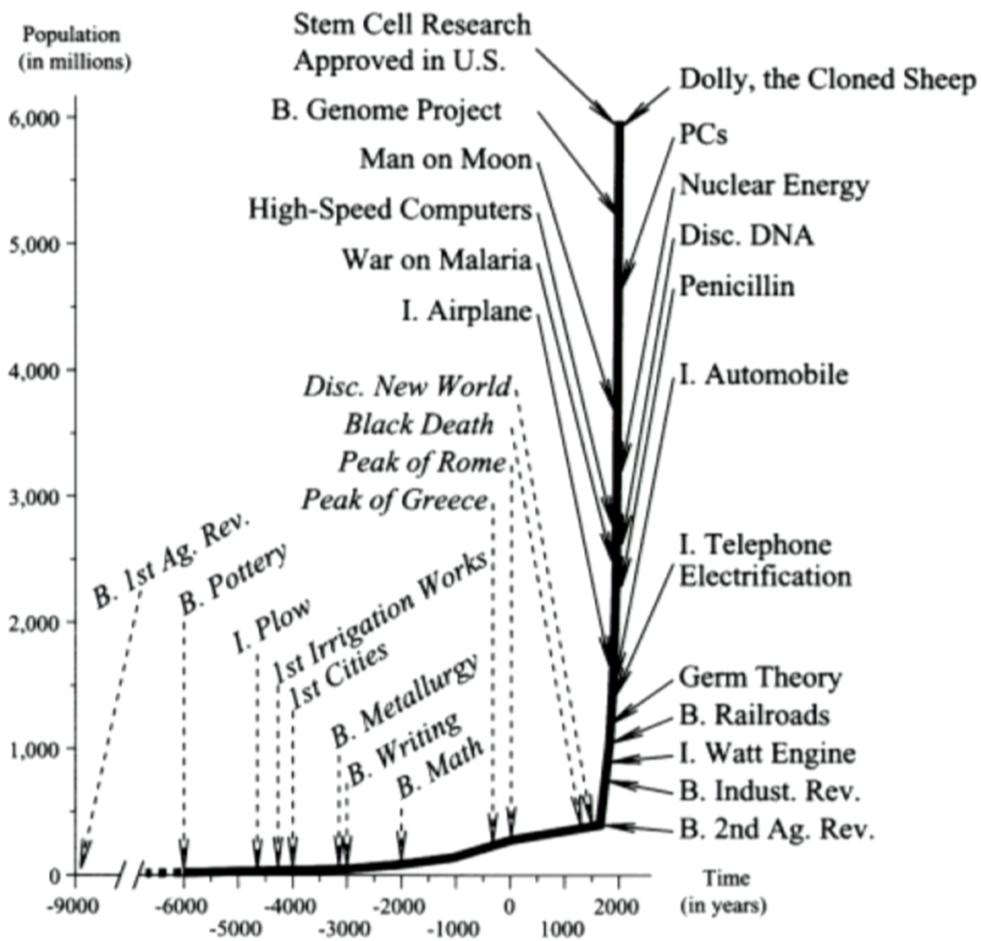
Abstract: The global warming crisis is part of a bigger transformation in which humanity realizes that the Earth is a finite system and that our population, energy usage, and the like cannot continue to grow exponentially. While politics and economics pose the biggest challenges, physicists are in a good position to help make this transition a bit easier. After a quick review of the problems, we discuss a few ways physicists can help.

ENERGY, THE ENVIRONMENT, AND WHAT PHYSICISTS CAN DO

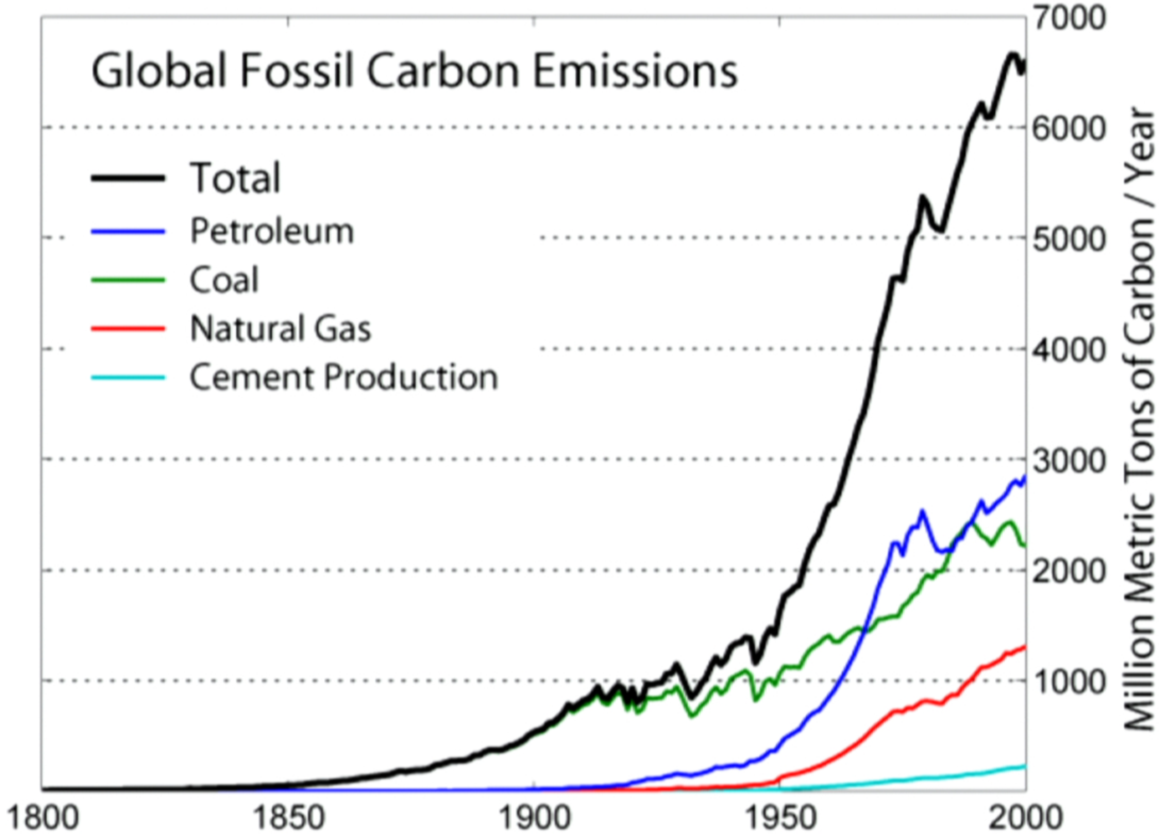


John Baez
Perimeter Institute

17 April 2013



Robert Fogel - *The Escape from Hunger and Premature Death, 1700-2100*


Global Fossil Carbon Emissions
Total
Petroleum
Coal
Natural Gas
Cement Production
7000
6000
5000
4000
3000
2000
1000
Million Metric Tons of Carbon / Year
1800
1850
1900
1950
2000

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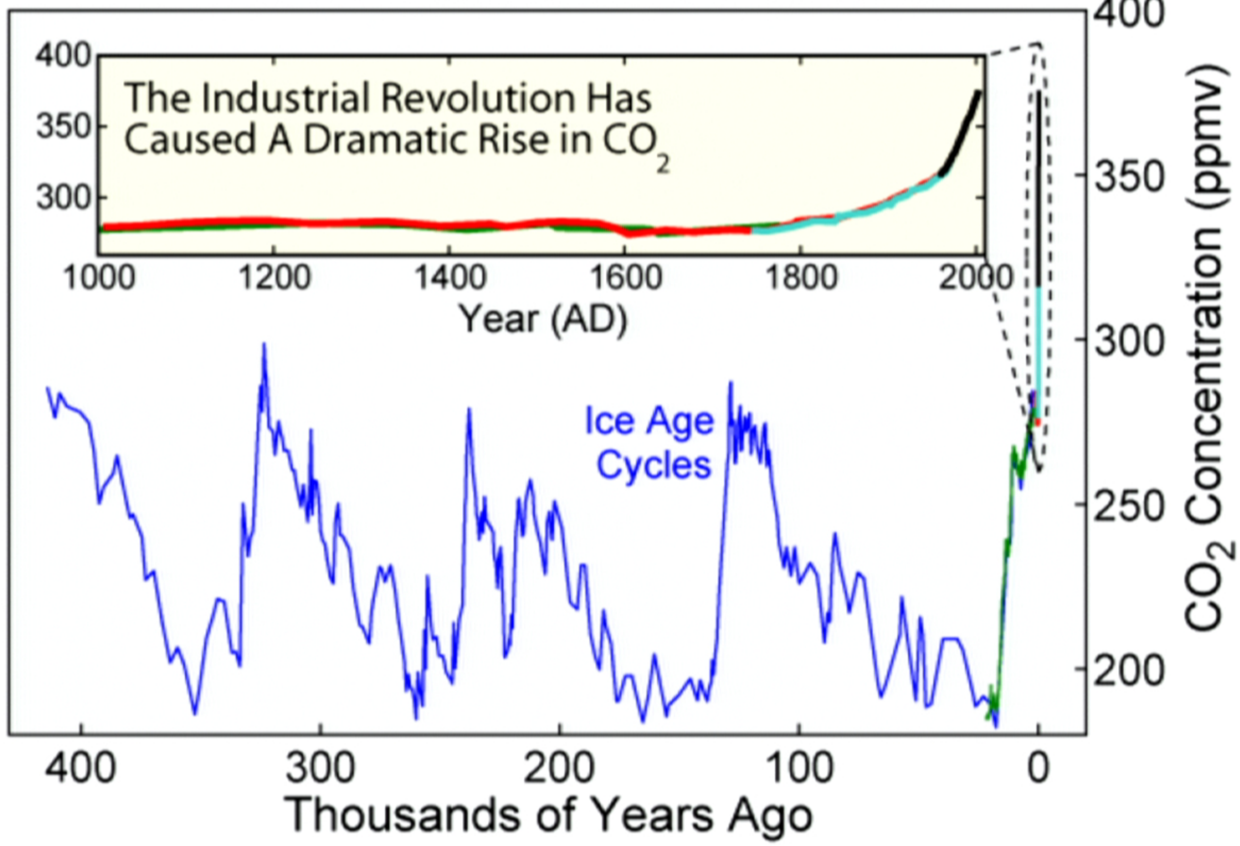
The average Canadian put out 4.4 tonnes.

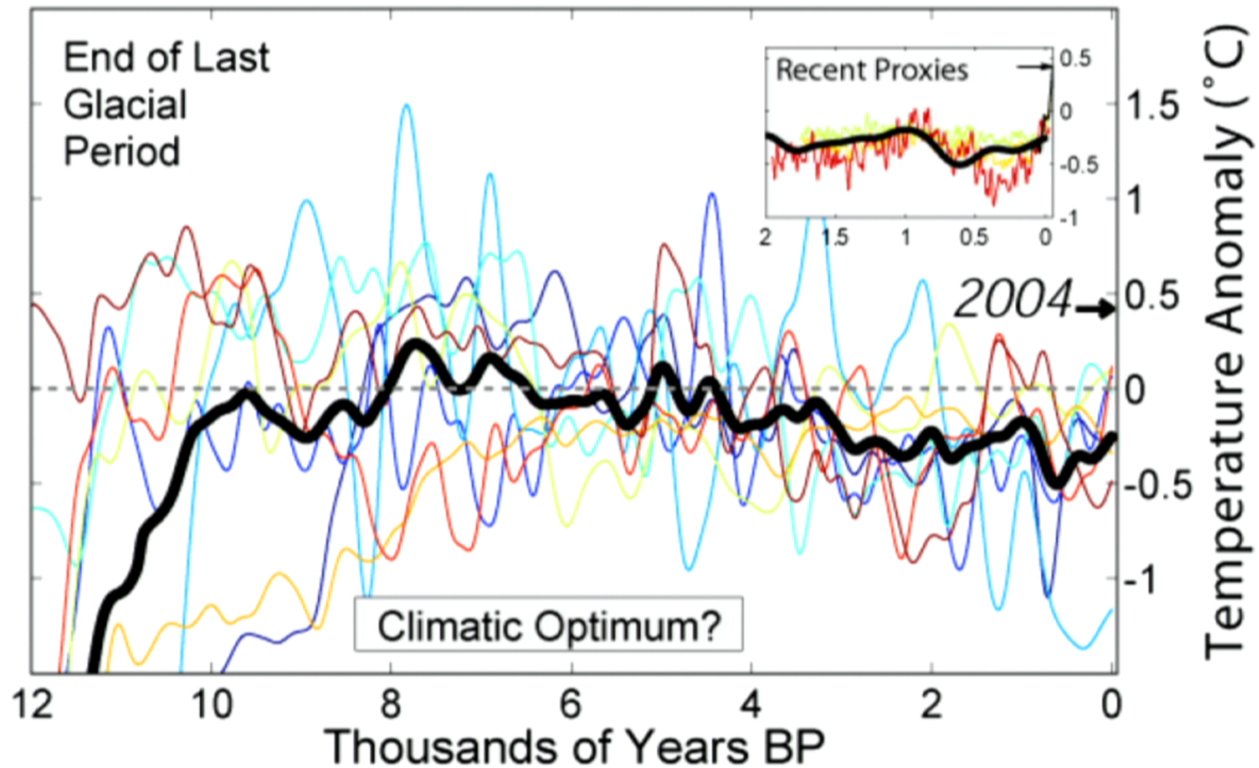
Worldwide, we put 10.4 gigatonnes of carbon into the air in 2011.

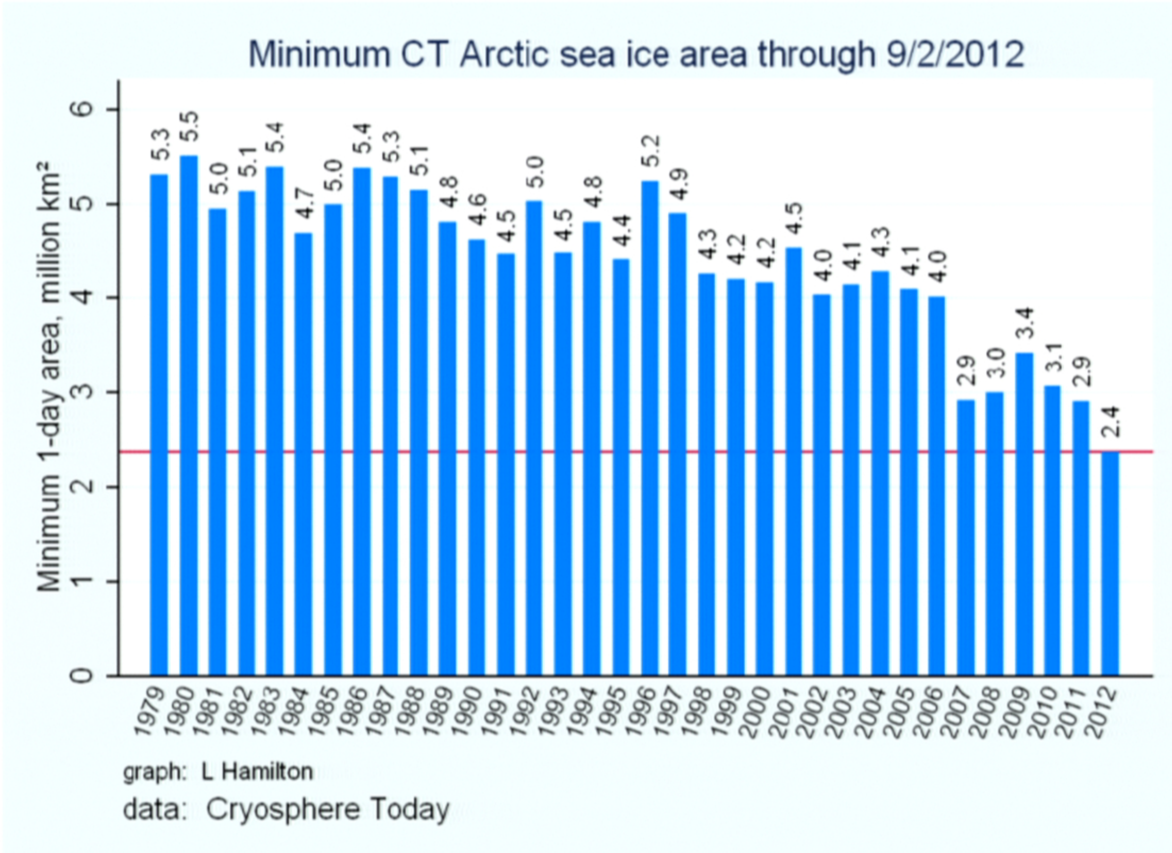
The total amount of carbon in the atmosphere is just 3000 gigatonnes. So, we're dramatically affecting the biosphere.

Carbon Dioxide Variations



Holocene Temperature Variations




Minimum CT Arctic sea ice area through 9/2/2012
Minimum 1-day area, million km²
0
1
2
3
4
5
6
5.3
5.5
5.0
5.1
5.4
4.7
5.0
5.4
5.3
5.1
4.8
4.6
4.5
5.0
4.5
4.8
4.4
5.2
4.9
4.3
4.2
4.2
4.5
4.0
4.1
4.3
4.1
4.0
2.9
3.0
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1999
2000
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2007
2008
2009
2010
2011
2012
graph: L Hamilton
data: Cryosphere Today

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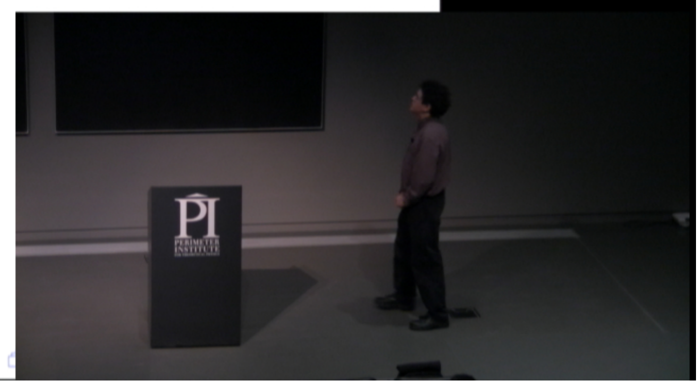

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Acting as if these are true inevitably brings us to a point where they stop being true.

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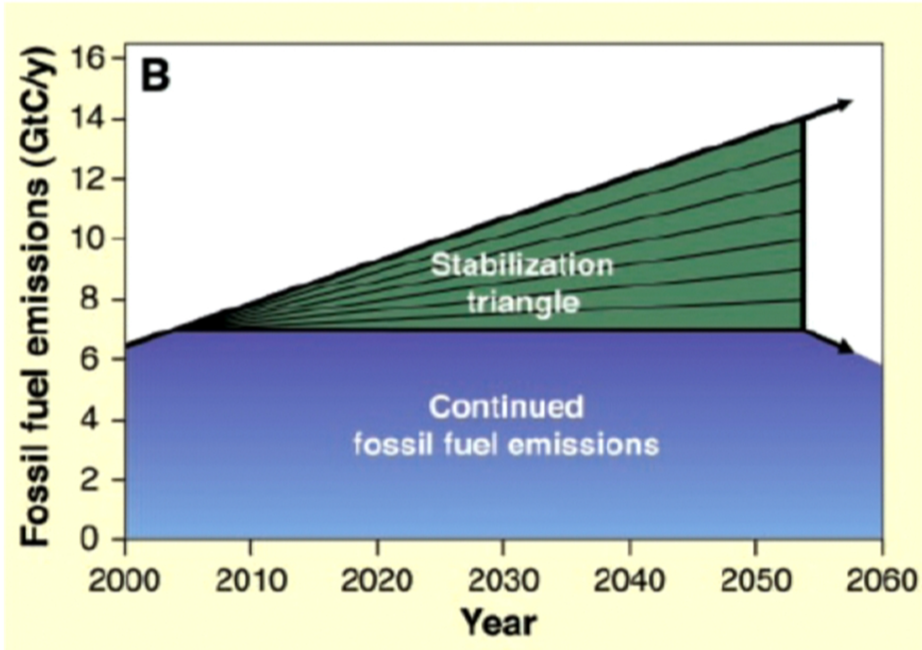
If we do not muster the will to change our habits *before* things get significantly worse, we will do so later. Either way, a transformation is inevitable.

In 2004, Pacala and Socolow looked for ways to hold carbon emissions constant until 2054 — *not a solution, just a start!*



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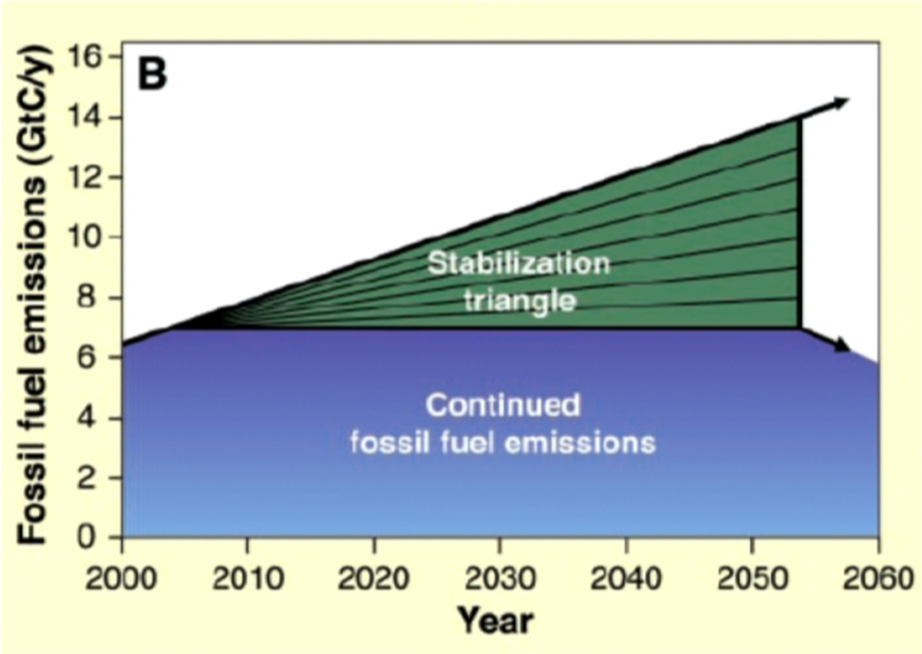

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Some examples of wedges:

Solar: Replace 700 gigawatts of coal power by solar power. Starting now, this requires *multiplying solar power by a factor of 30!* But this is just an 8% average annual growth rate. The rate is now 75%.

Wind: Replace 700 gigawatts of coal-fired power plants by wind power.

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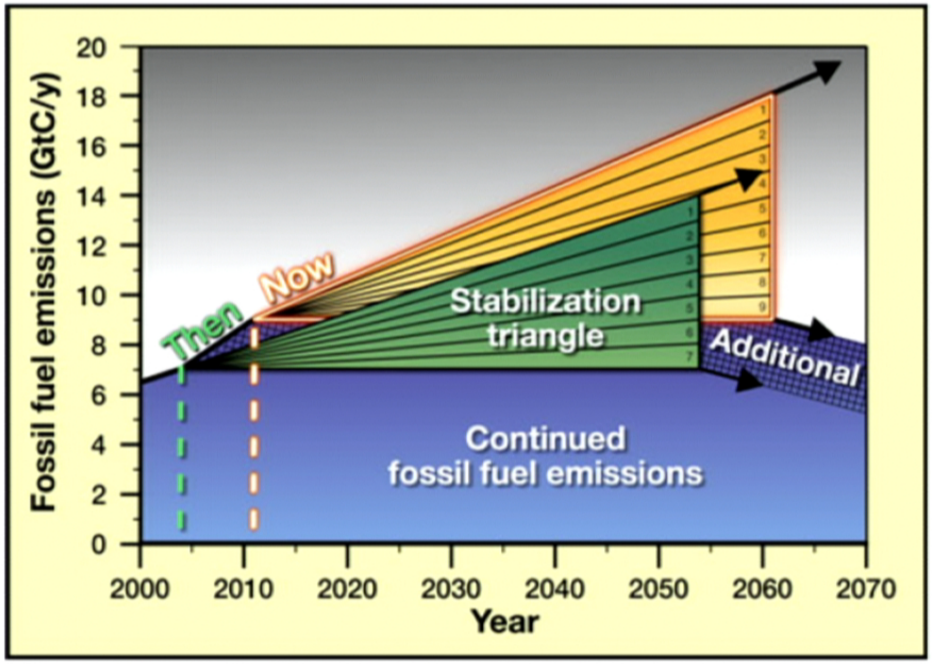
Nuclear: Replace 700 gigawatts of coal power by nuclear power. This requires annual growth rate of just 1.6%.

Conservation: Assuming the number of cars goes up from 500 million to 4 times that, *make everyone in the world drive half as much!*

Efficiency: Under the same assumptions, make all cars twice as efficient *without people driving more!*

Conservation/efficiency: Cut carbon emissions by 25% in buildings and appliances.

It's a race against time. In 2004 we needed 7 wedges to hold carbon emissions constant for 50 years. In 2011 we needed 9:



And this is just a stopgap. We really need to *stop burning carbon* or *actively remove it from the air*.

What can physicists do?

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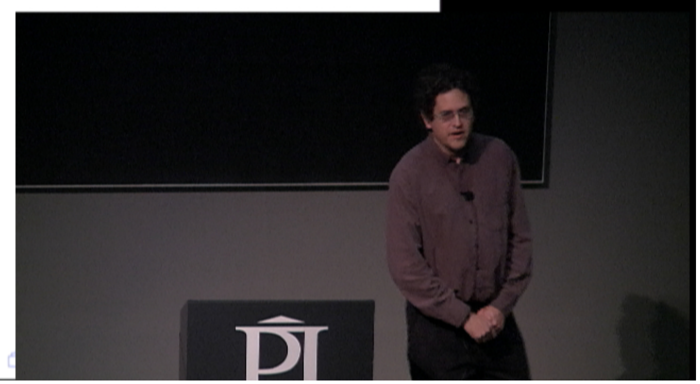

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We should get smart about conferences: *transfer more bits, fewer bodies.*

2. Teach physics better.

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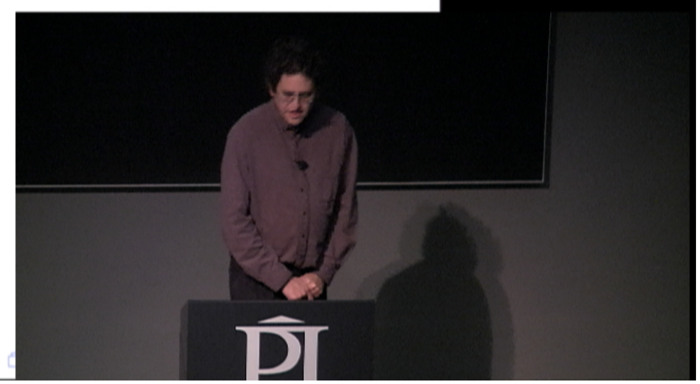
- Student's initial common-sense intuitions are their main roadblock to learning physics.
- Physics lectures don't change those intuitions much.
- Giving better lectures doesn't help much.
- But: classes that include students working with their neighbors to solve simple problems helps **a lot!**

For help, get Eric Mazur's Peer Instruction materials.

One reason this matters. Ordinary folks have trouble with the difference between *stocks* and *flows*:

$$X(t) \text{ vs. } \frac{dX(t)}{dt}$$

For example: whether force creates *velocity*, or *acceleration*.



What does this have to do with global warming?

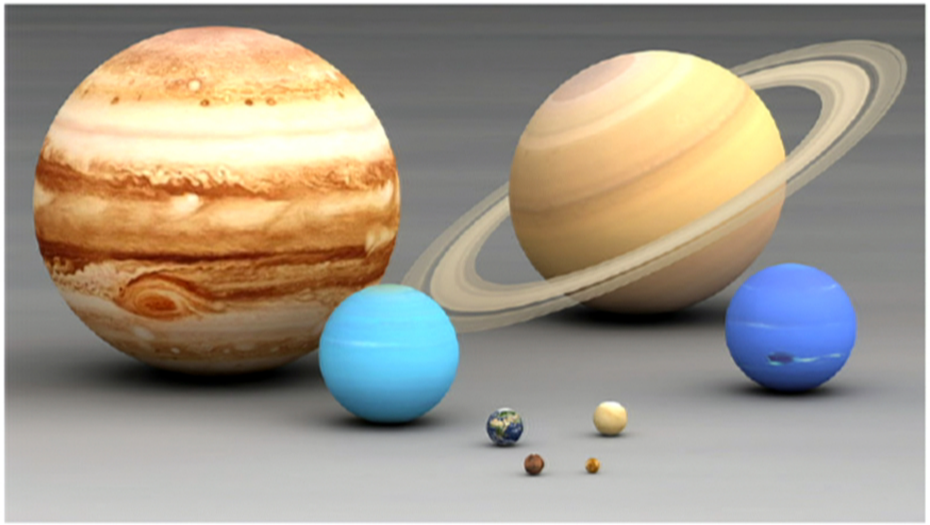
For most practical purposes, *carbon dioxide stays in the air forever.* 1/3 to 1/2 will stay there for over 1,000 years!

So, to a good approximation, to stop rising CO_2 concentrations:

- Holding emissions constant is not good enough.
- Cutting them by 80% is not good enough.
- **Stopping them entirely** is good enough.

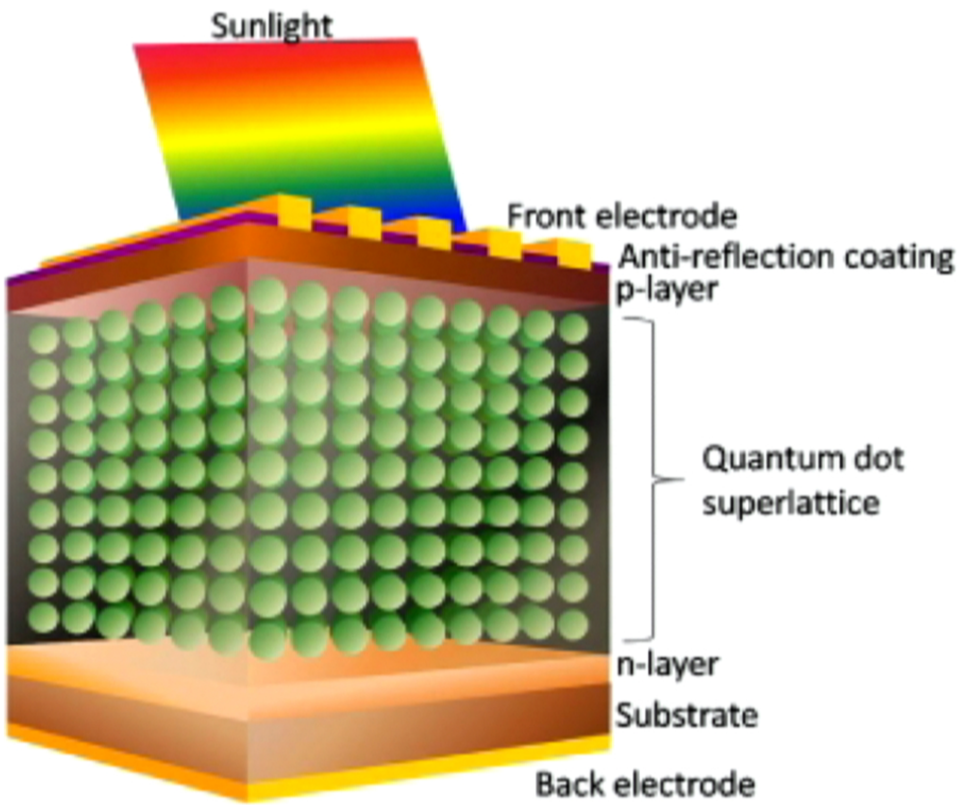
In 2007, most MIT grad students didn't know this. Better physics teaching could help.

3. Create the physics we need for life on a finite-sized planet.

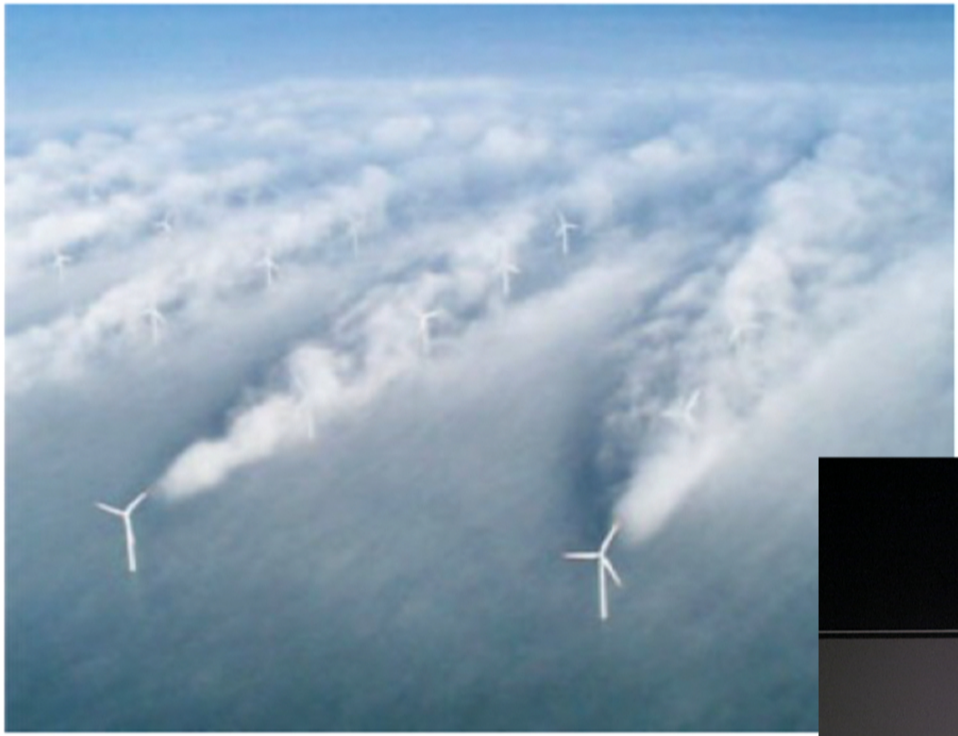


There are many *fun* things to do here! I'll say just a few.

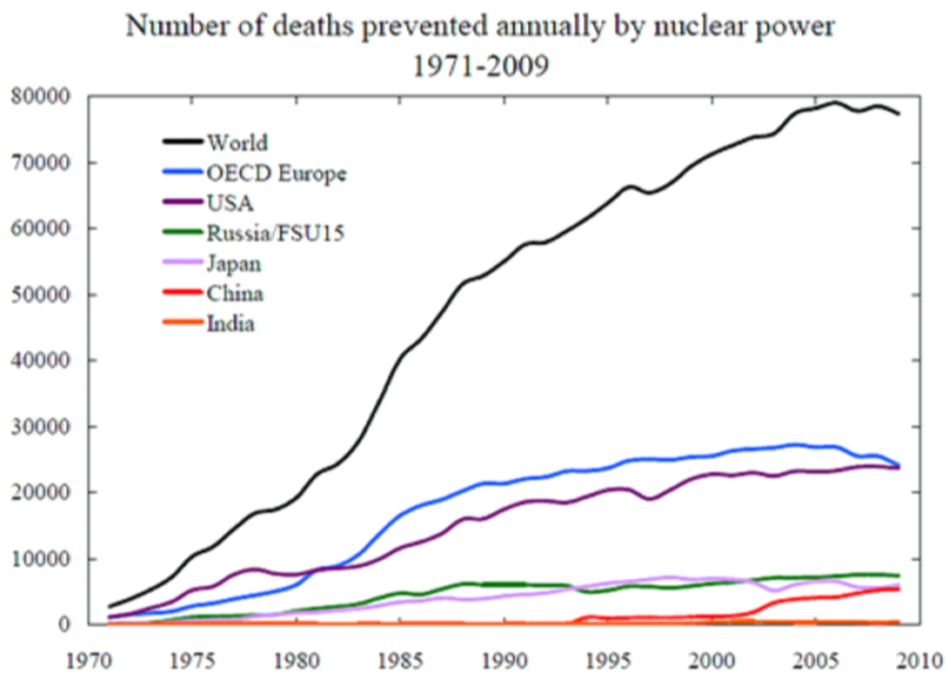
- Make solar power cheaper than fossil fuels. For example: quantum dot solar cells have efficiency 65% instead of just 31% for ordinary silicon cells.



- Make wind power cheaper than fossil fuels. For example: understanding multi-scale turbulence is important. In the US, if a wind farm's predicted power generation is off by 1%, it can cost them millions of dollars!

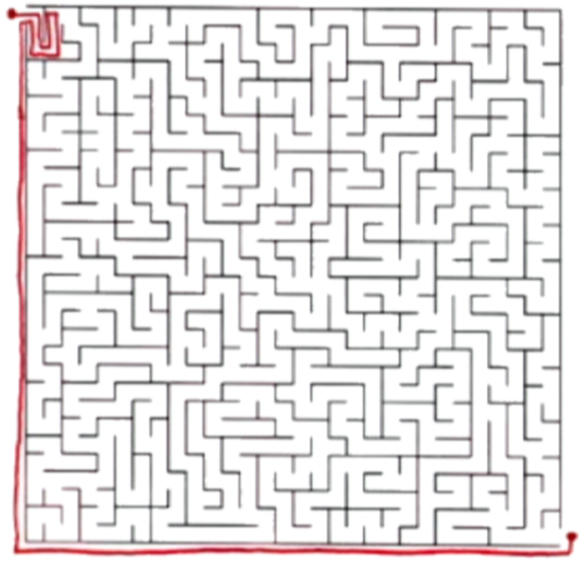


- Make nuclear power cheaper and safer. According to James Hansen it's already saved 1.8 million lives: coal is what kills!



But there's a lot to be done on passive safety, thorium reactors and more. And for the ambitious, don't forget fusion!

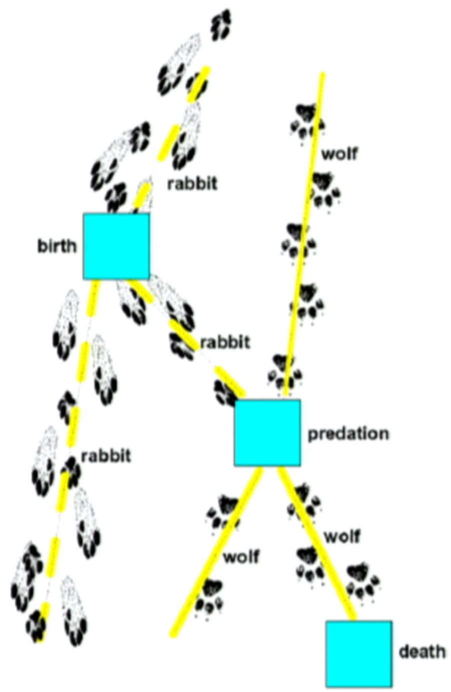
- Think outside the box.



Physicists are famous for doing this.

There's lots of room for everyone.

Since I'm very mathematical, I've been working on *networks*.



To understand ecosystems, ultimately will be to understand networks. — B. C. Patten and M. Witkamp

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If we do not muster the will to change our habits *before* things get significantly worse, we will do so later. Either way, a transformation is inevitable.

For better or worse, we *will* adapt to life on a finite-sized planet. The challenge is to do it gracefully.