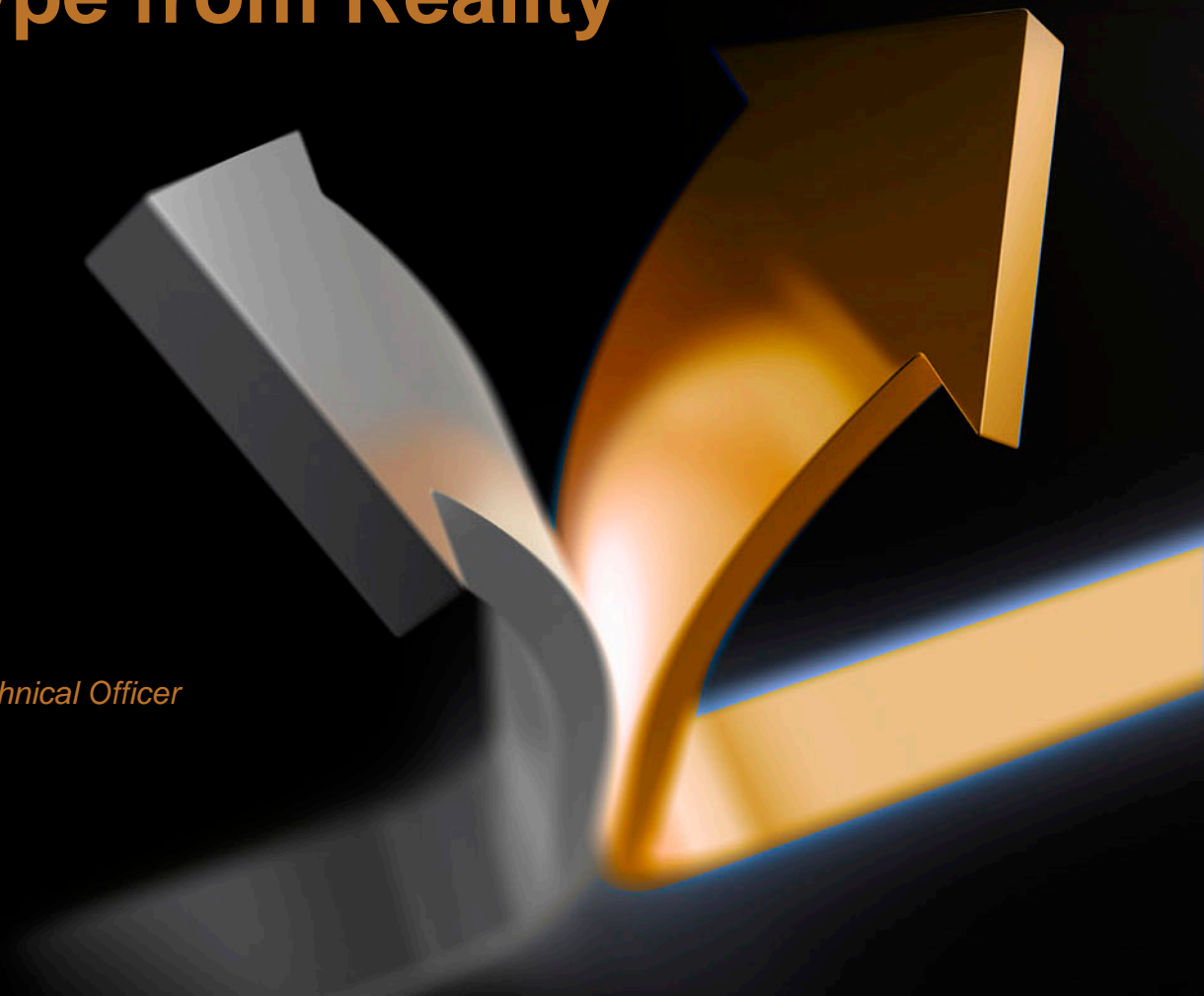




# Materials Solving Energy Issues: Separating Hype from Reality

William F. Banholzer  
*Executive Vice President and Chief Technical Officer*  
The Dow Chemical Company



# Call to Scientists and Engineers

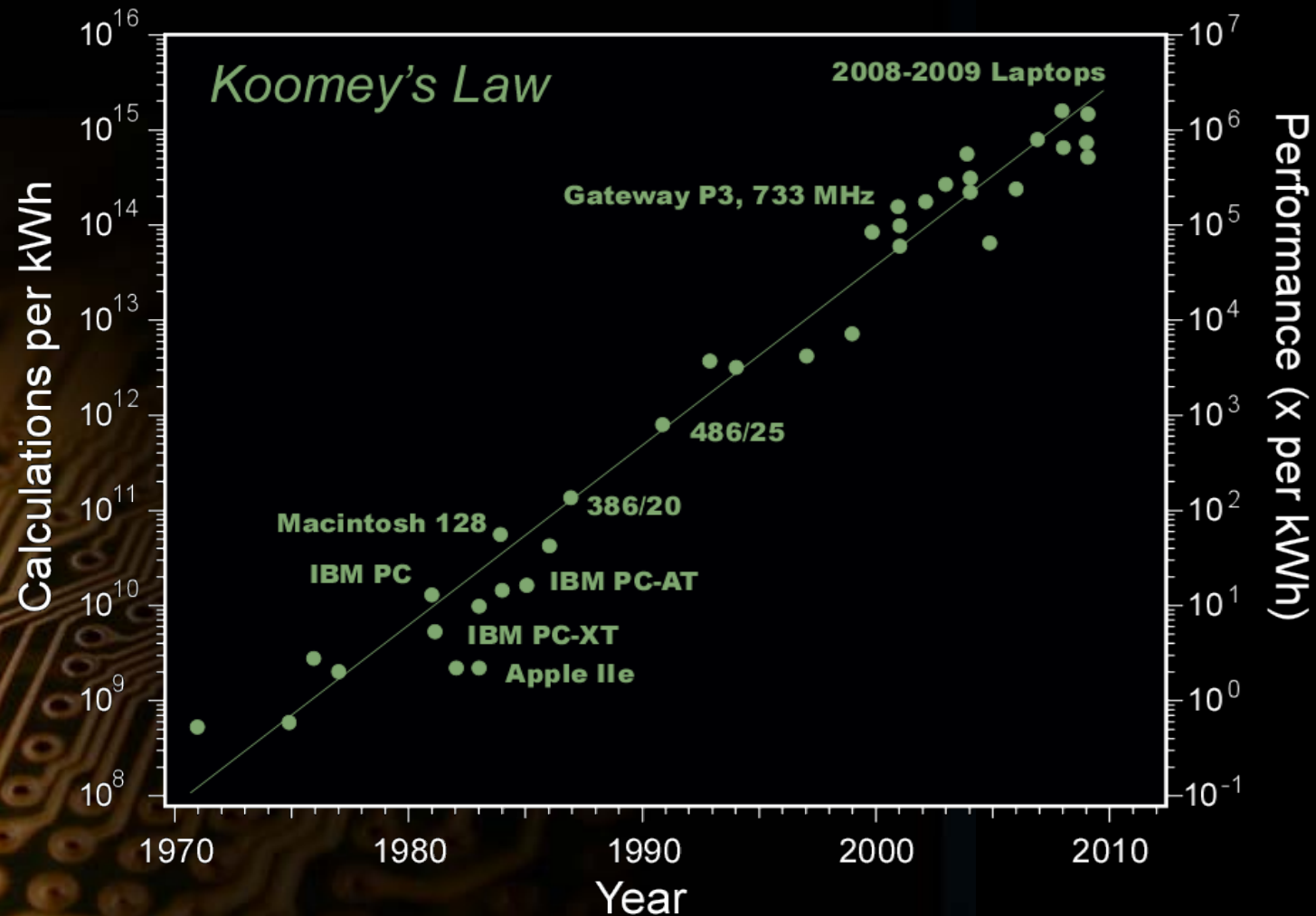


“Too much hype for the possible and  
not enough on focus on the practical.

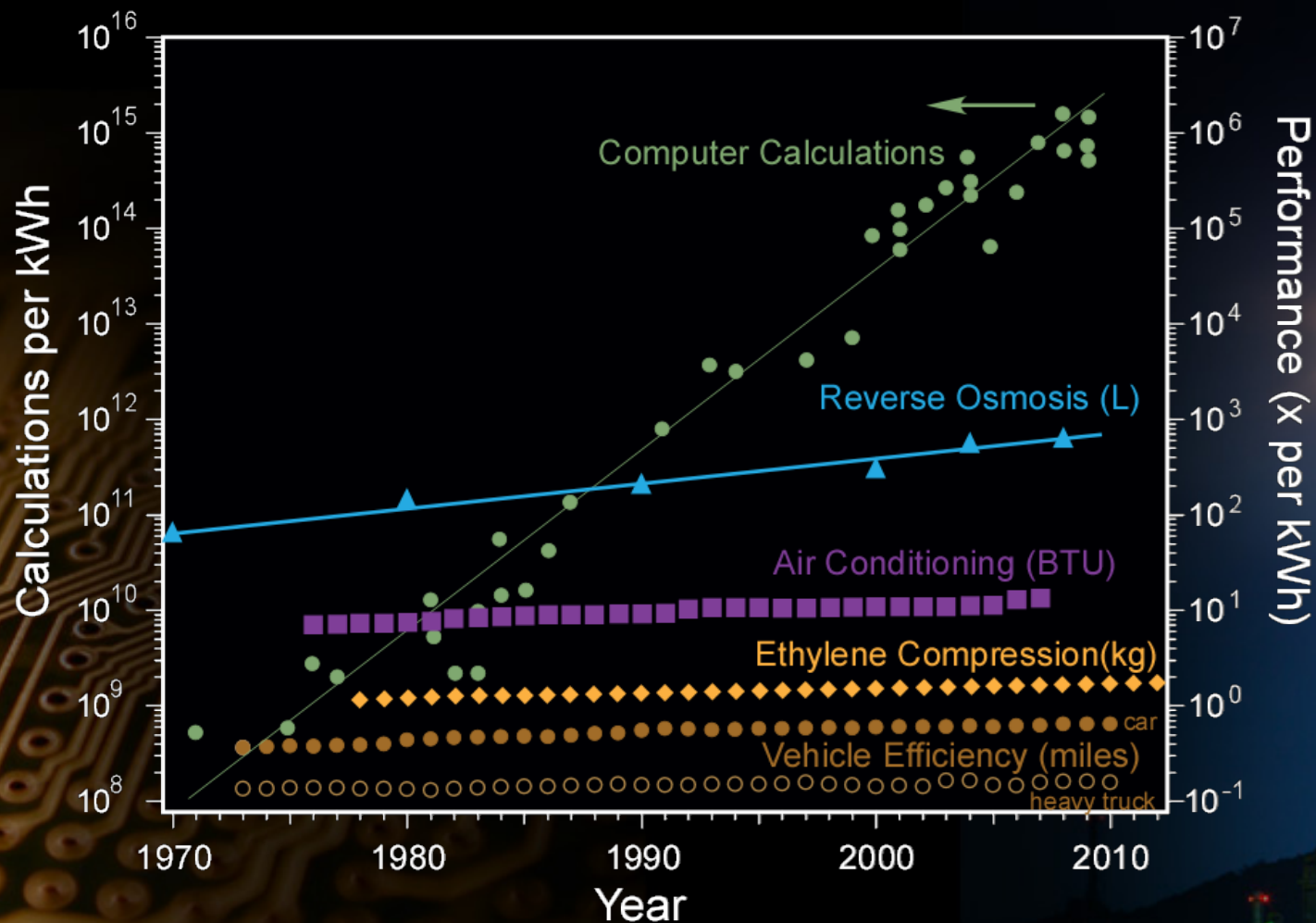
We are letting society down!”



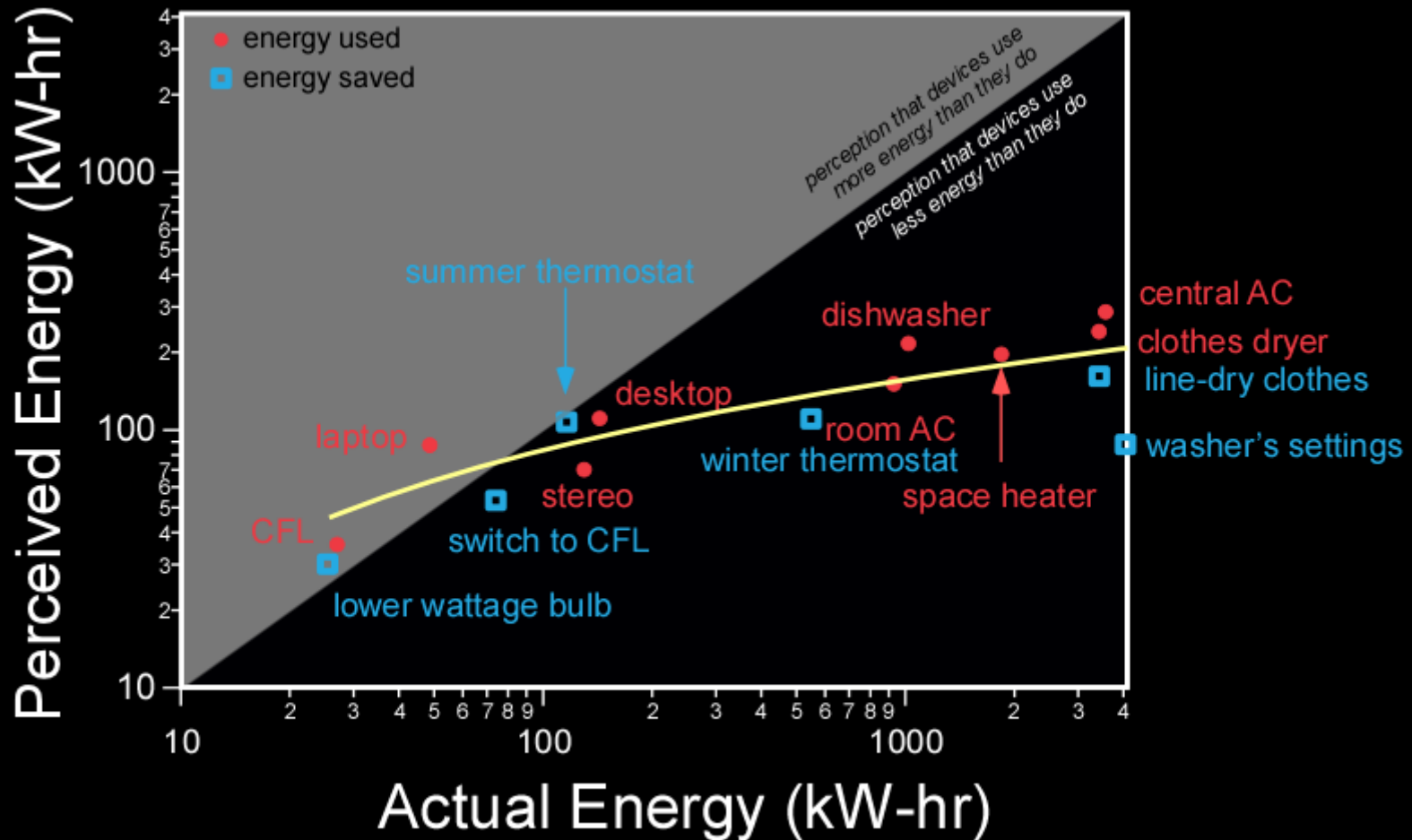
# Engineering Triumph



# Moore's Law Sets Unrealistic Expectations

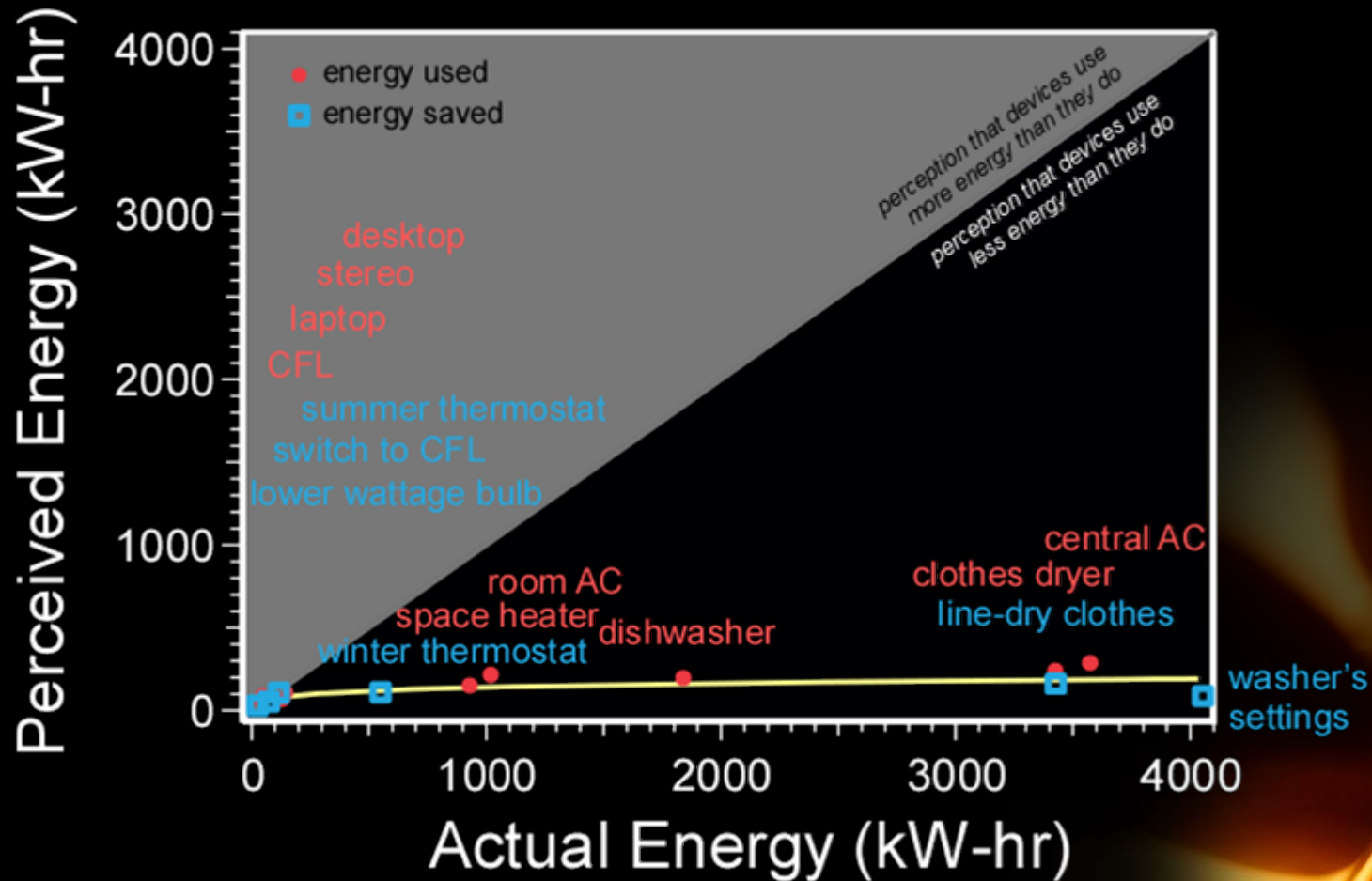


# We Are Poor Judges of the Energy We Use



We are poor judges of how much energy everyday devices consume.

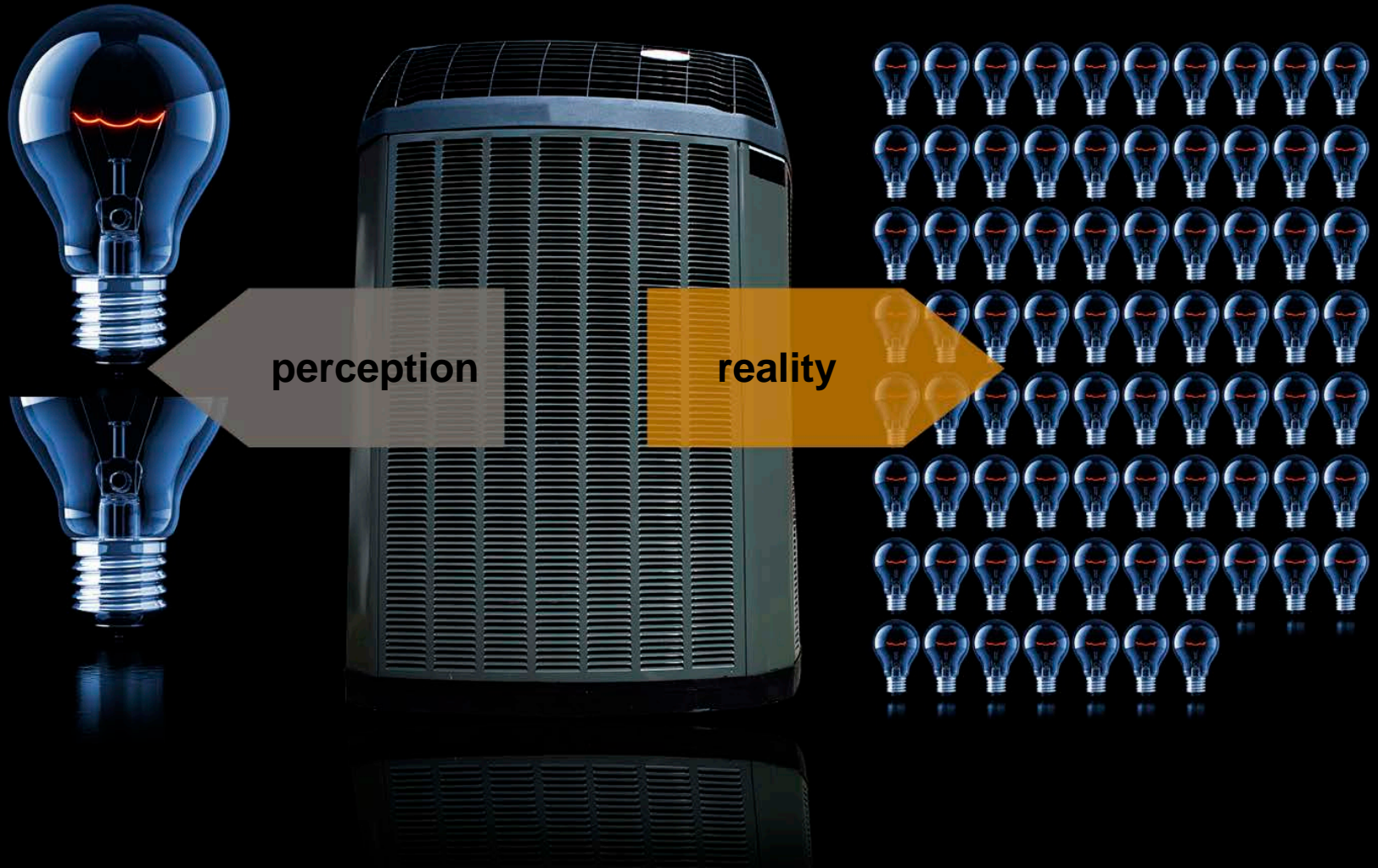
# We Are Poor Judges of the Energy We Use



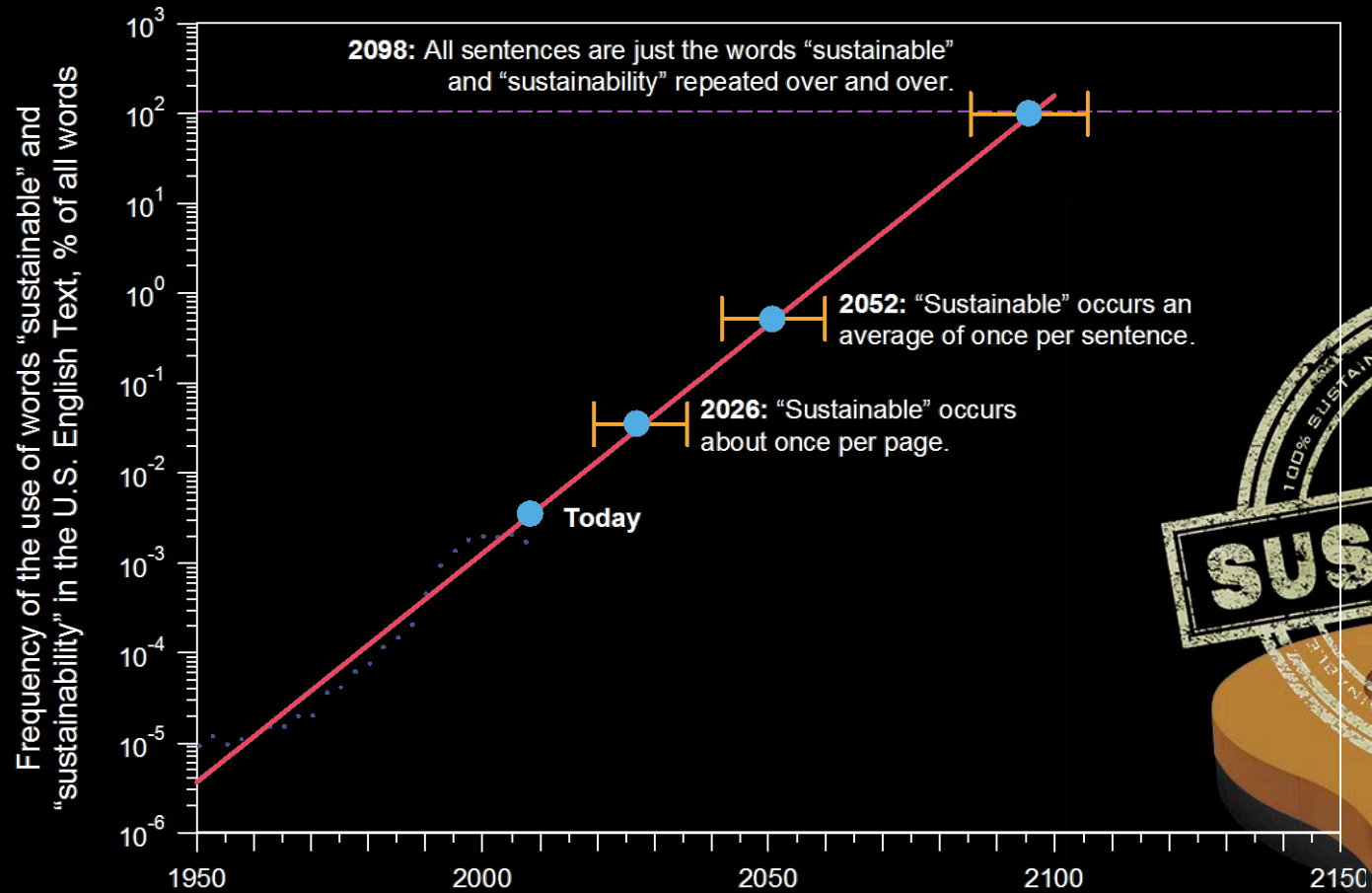
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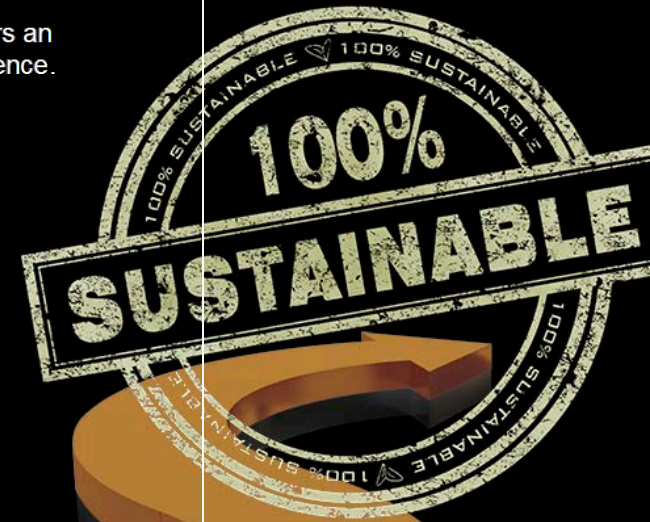
# Energy Perception and Reality



# Ripe for Hype



Source: Google Ngrams





# Gross Mismatch

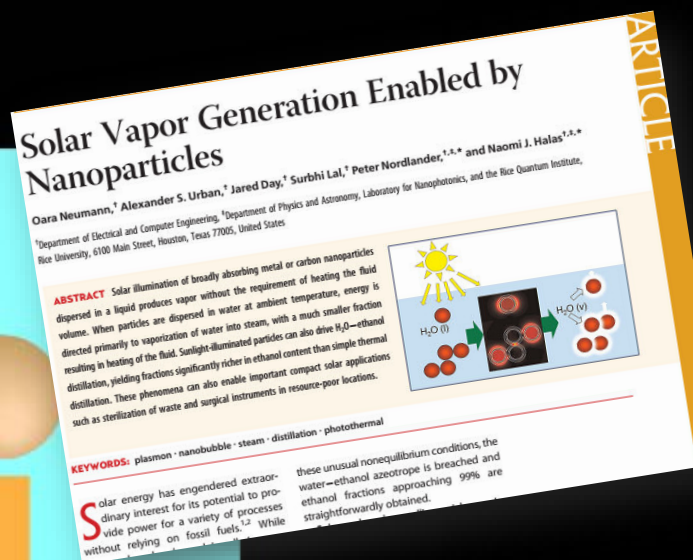
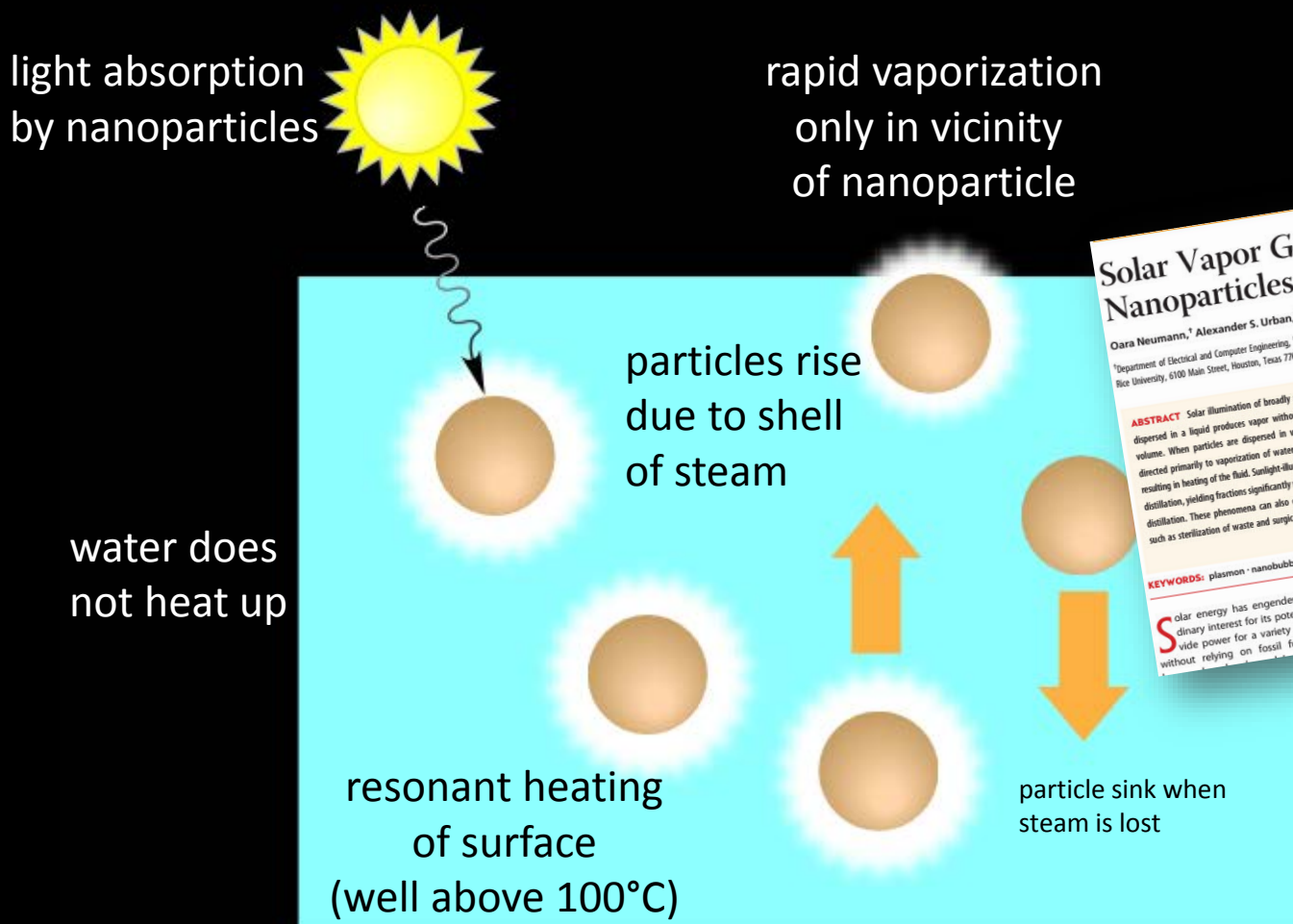


Expectations are sky high.

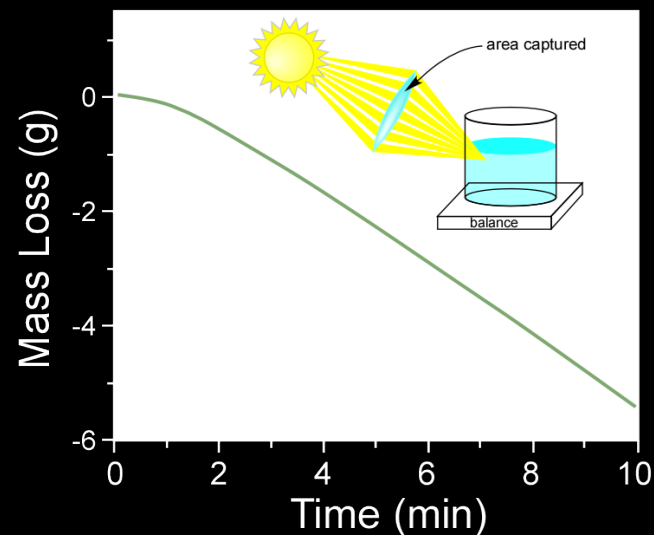
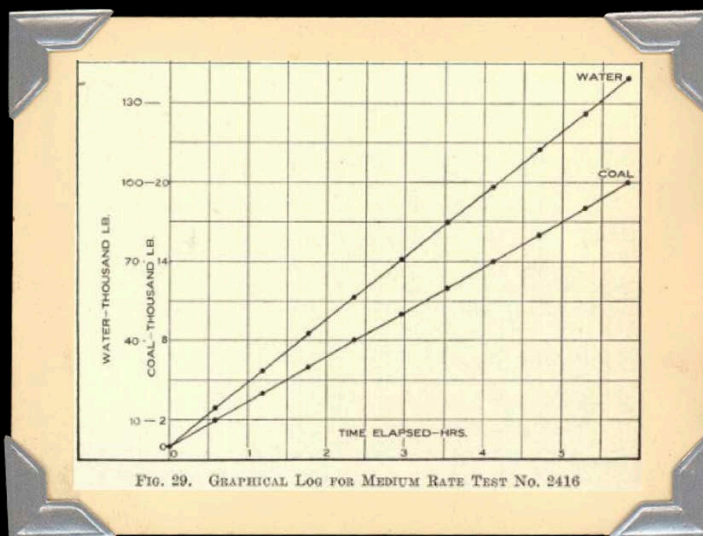


Understanding is low.

# Possible



# Not Possible



# Solar Energy Quiz



?

=

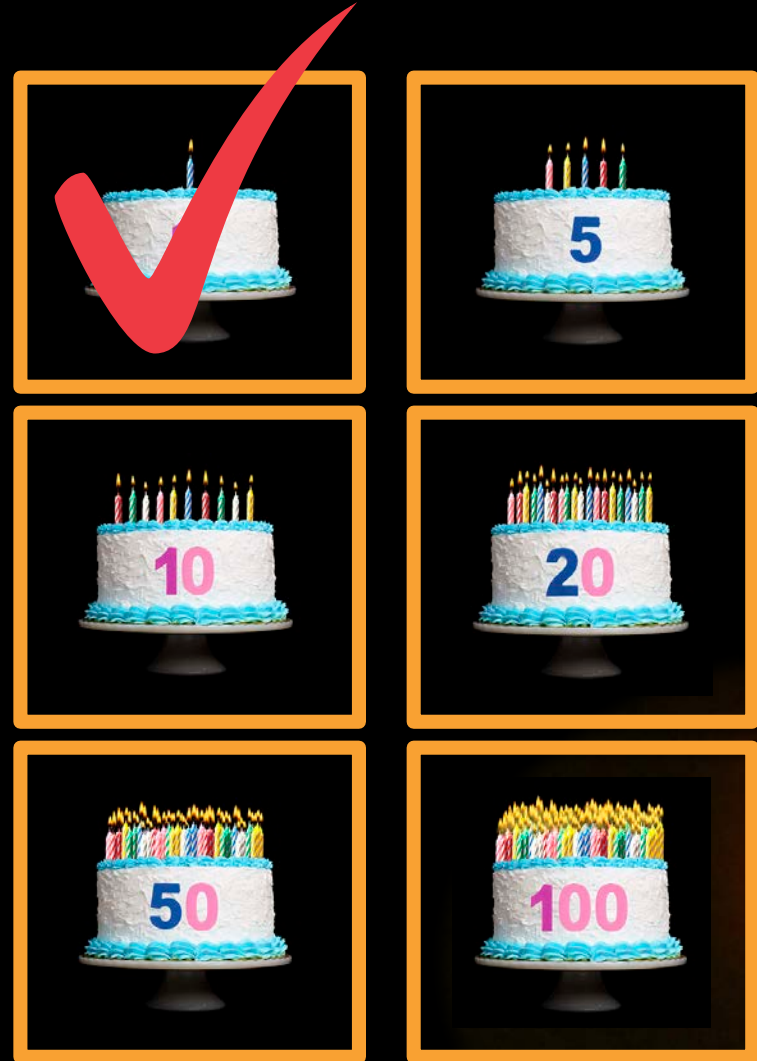


# Solar Energy Quiz



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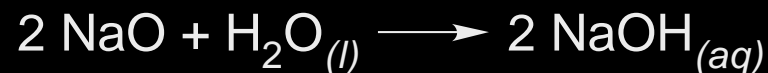
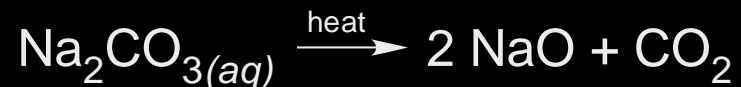




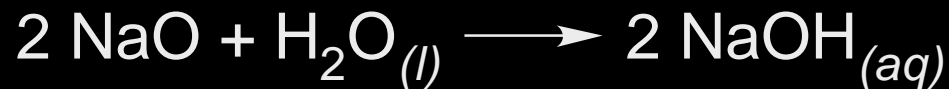
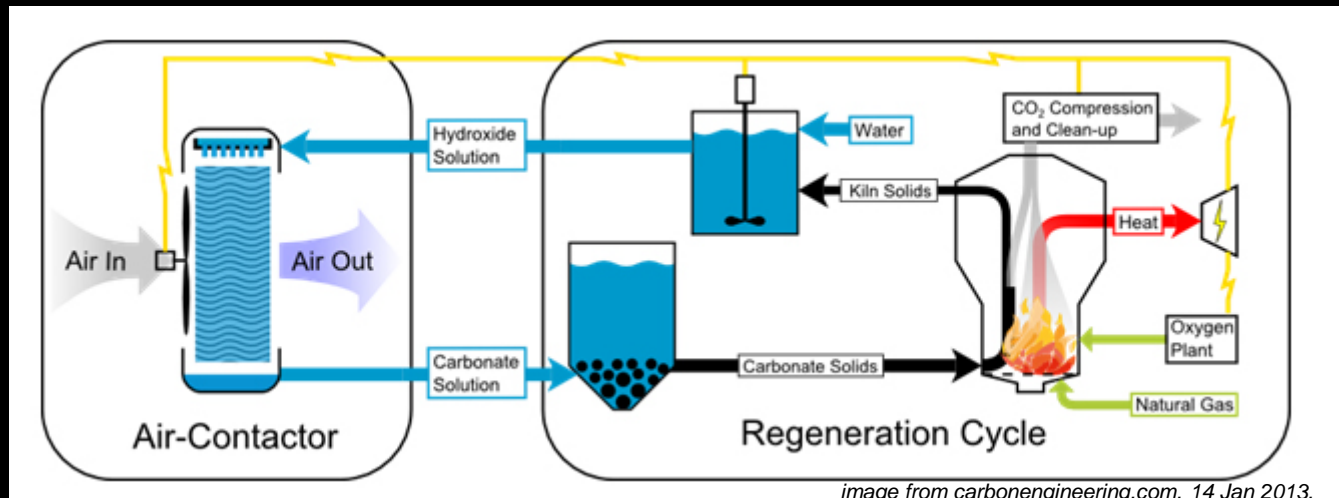
# Possible, Not Economical



Carbon Engineering seeks to scrub atmospheric CO<sub>2</sub> by using alkaline solutions that are dried and thermally regenerated.



# Possible, Not Economical



*Problem: fuel use makes >50% of the CO<sub>2</sub> the system can scrub*

*Problem: CO<sub>2</sub> has no value (this is an added COST)*

# Rules for Business



What people  
can afford

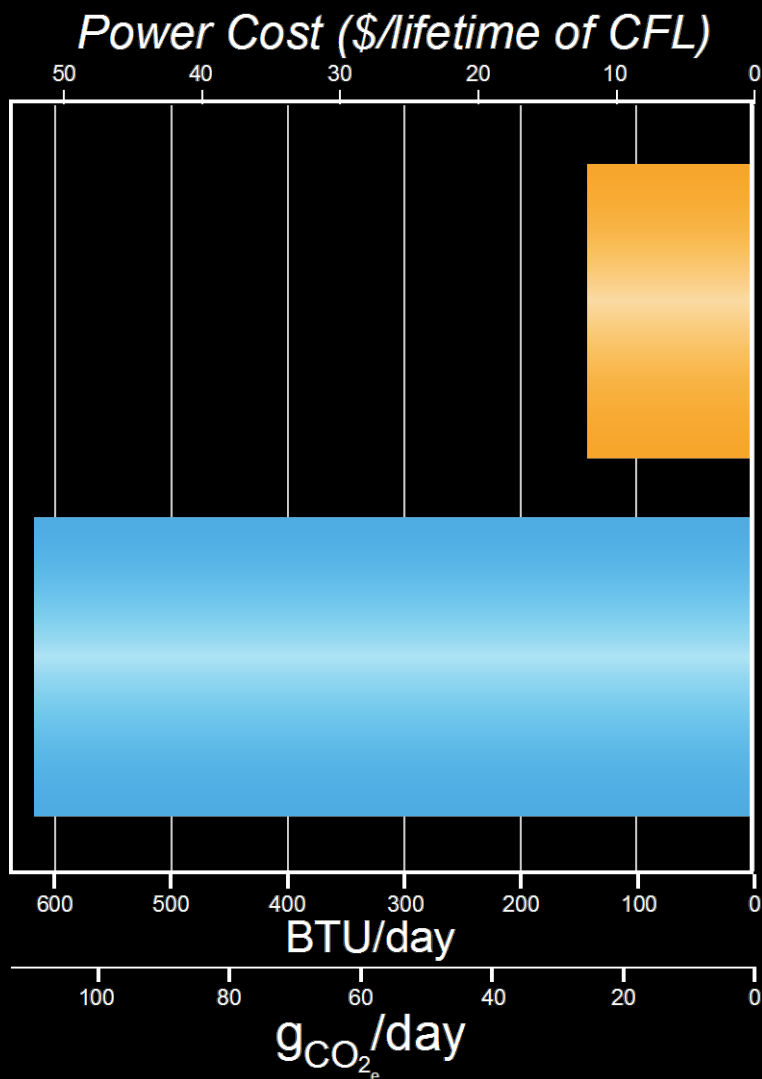
What people  
will pay for

What people  
want

**BUSINESS  
SUCCESS**



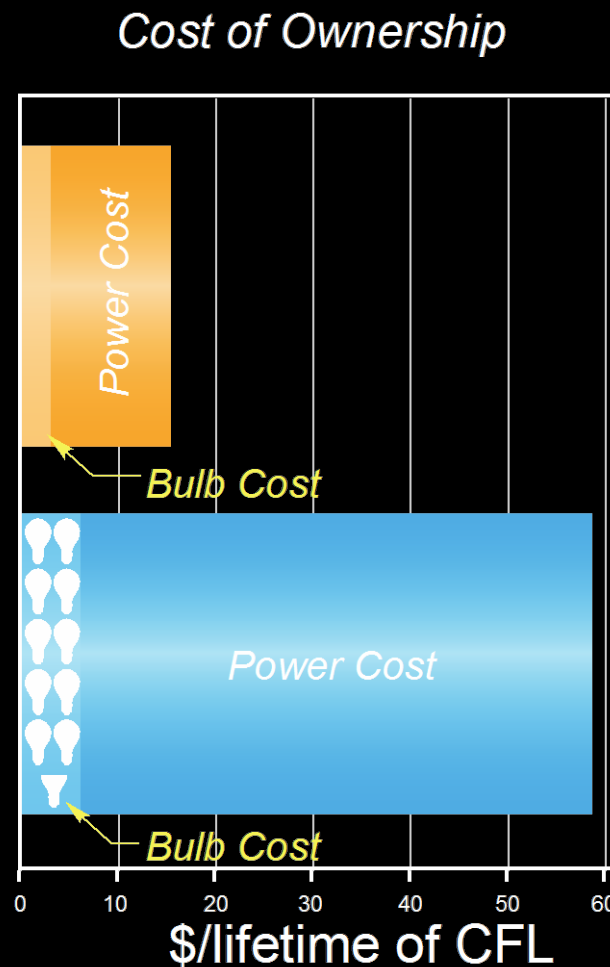
# People Don't Always Make Smart Choices



\$3.40



\$0.60





# What Consumers Invest In





# Which Uses Less Total Energy to Go a Mile?



**2011 Compressed  
Natural Gas Civic**



**U.S. Average Gas**

**2011 Leaf  
Electric  
Vehicle**



**U.S. Average Power**

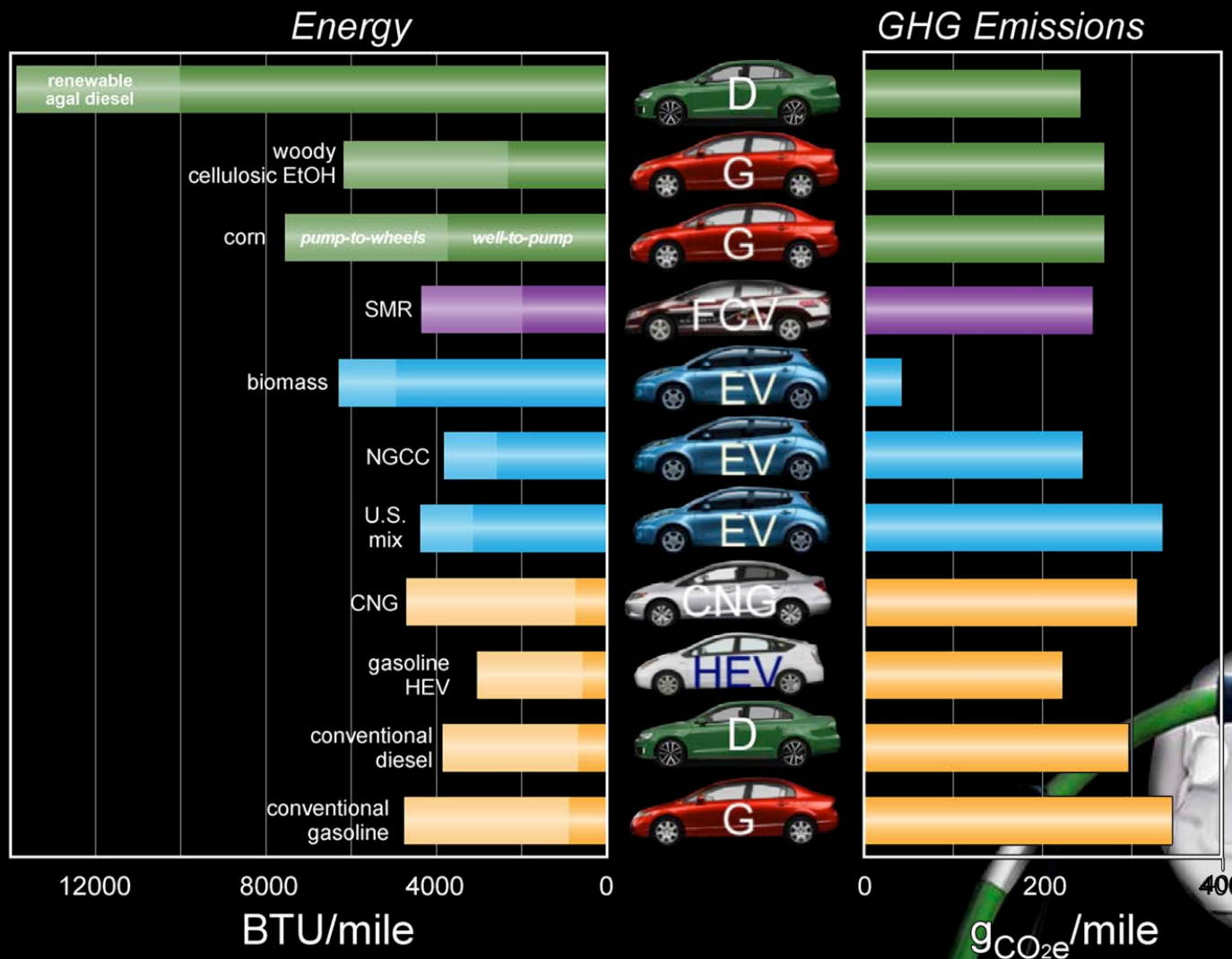
**Natural Gas  
Combined Cycle**

**2011 Civic  
Using E-85**

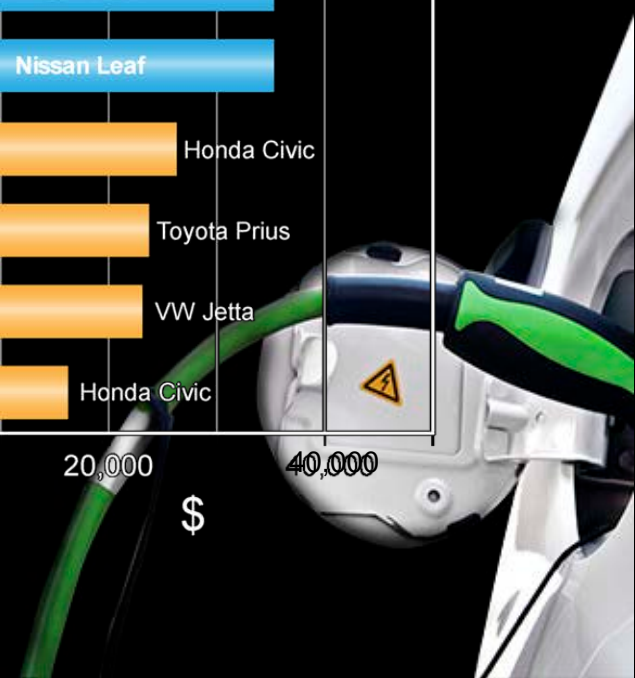
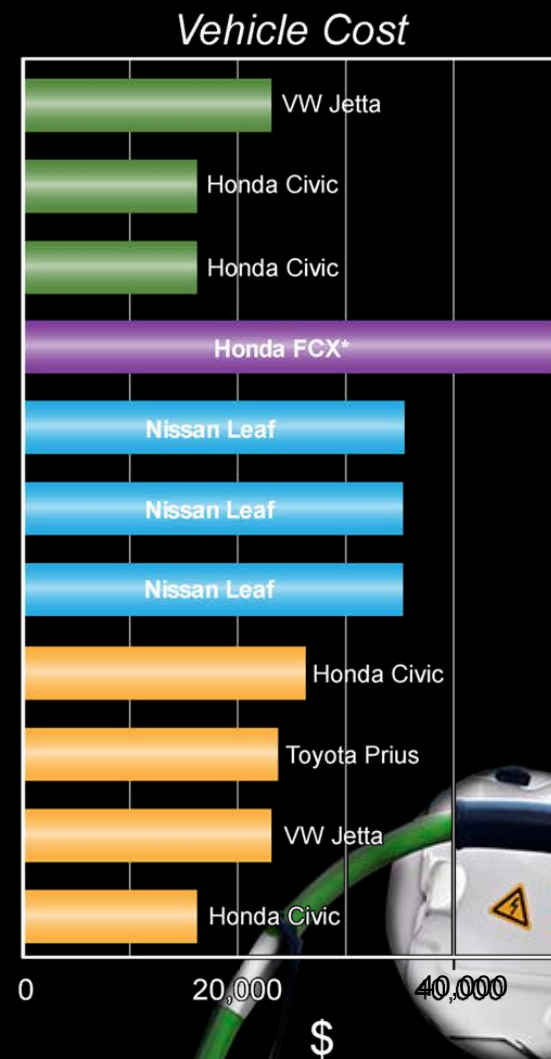
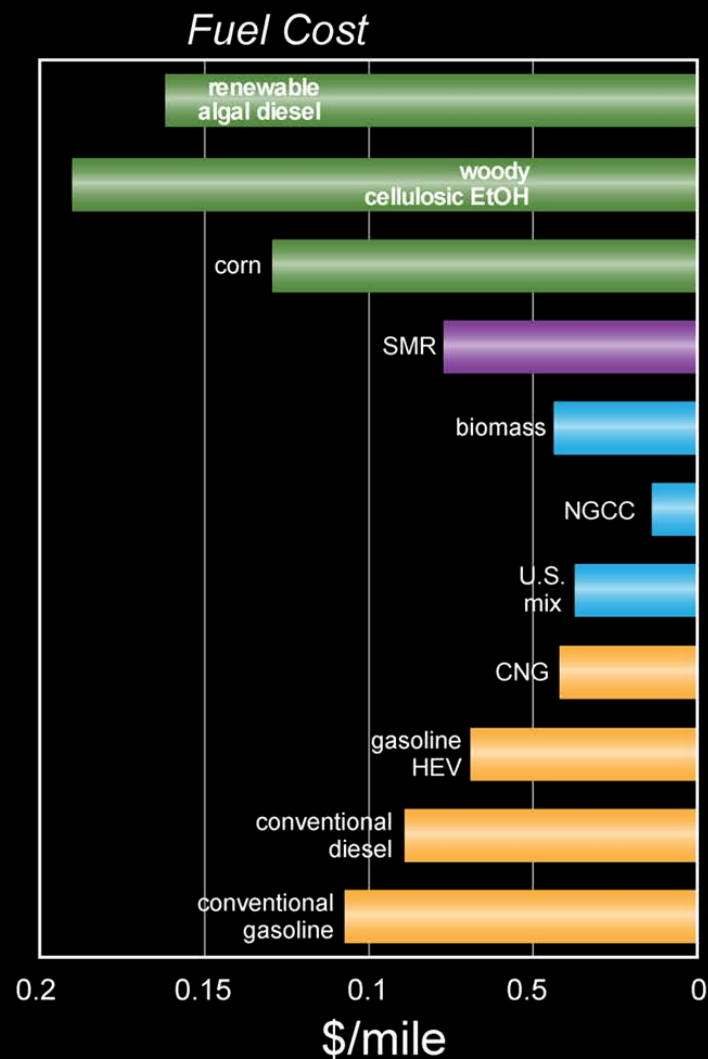


**Current Corn Ethanol**

# Electrification Beats Biofuels (Impact)




# Electrification Beats Biofuels (Costs)



# A Look at Biofuels



## BIOMASS FUELS PROGRAM

Four classical columns, likely Corinthian, are shown against a black background. Each column has a label written vertically on its shaft. The columns are light-colored, possibly marble or limestone, and have ornate capitals with acanthus leaves.

REDUCE PETROLEUM

ENERGY SECURITY

JOB CREATION

IMPROVE THE ENVIRONMENT

# Consider the Biofuels Challenges



- How much biomass is available?  
Not enough to replace fossil fuels
- How much will biomass costs?  
It is not cheap
- How much will biofuels cost?  
More than fossil
- How much more are we willing to pay?  
No premium



CELLULOSIC  
ETHANOL



# Particularly Problematic in Biofuels



Hype

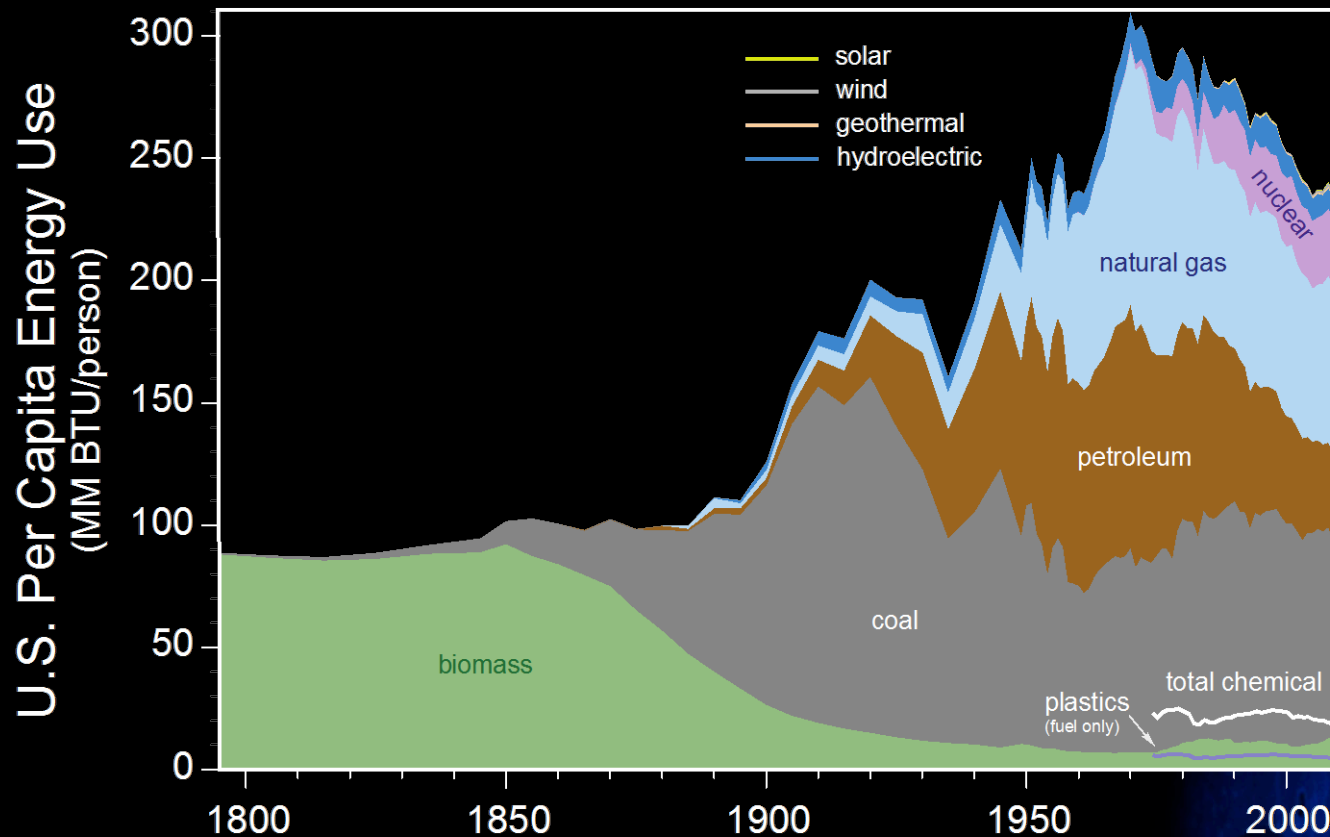


Practical Application

ENERGY DENSITY

LIMITATIONS OF BIOLOGY

# Energy Sources Always Change



What's changed?

- Oil price rise
- CO<sub>2</sub> awareness



Will this reverse the trend?

# Pivot to Biomaterials



## BIOMASS FUELS PROGRAM

REDUCE PETROLEUM

ENERGY SECURITY

JOB CREATION

IMPROVE THE ENVIRONMENT



AMYRIS



## BIOMATERIALS PROGRAM

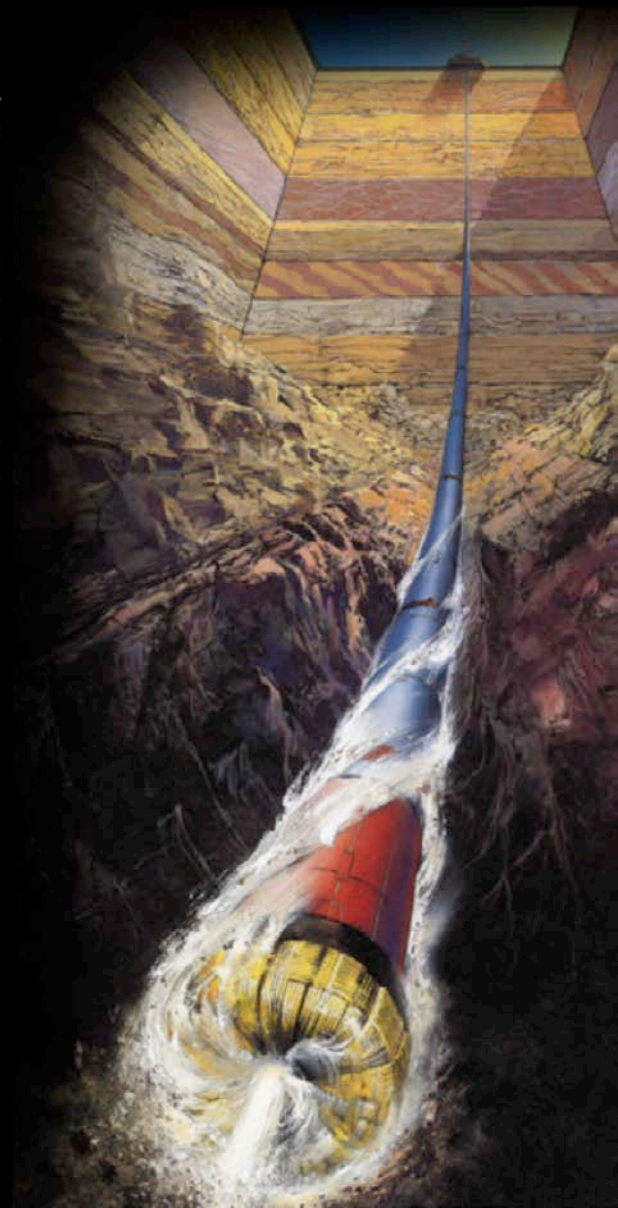
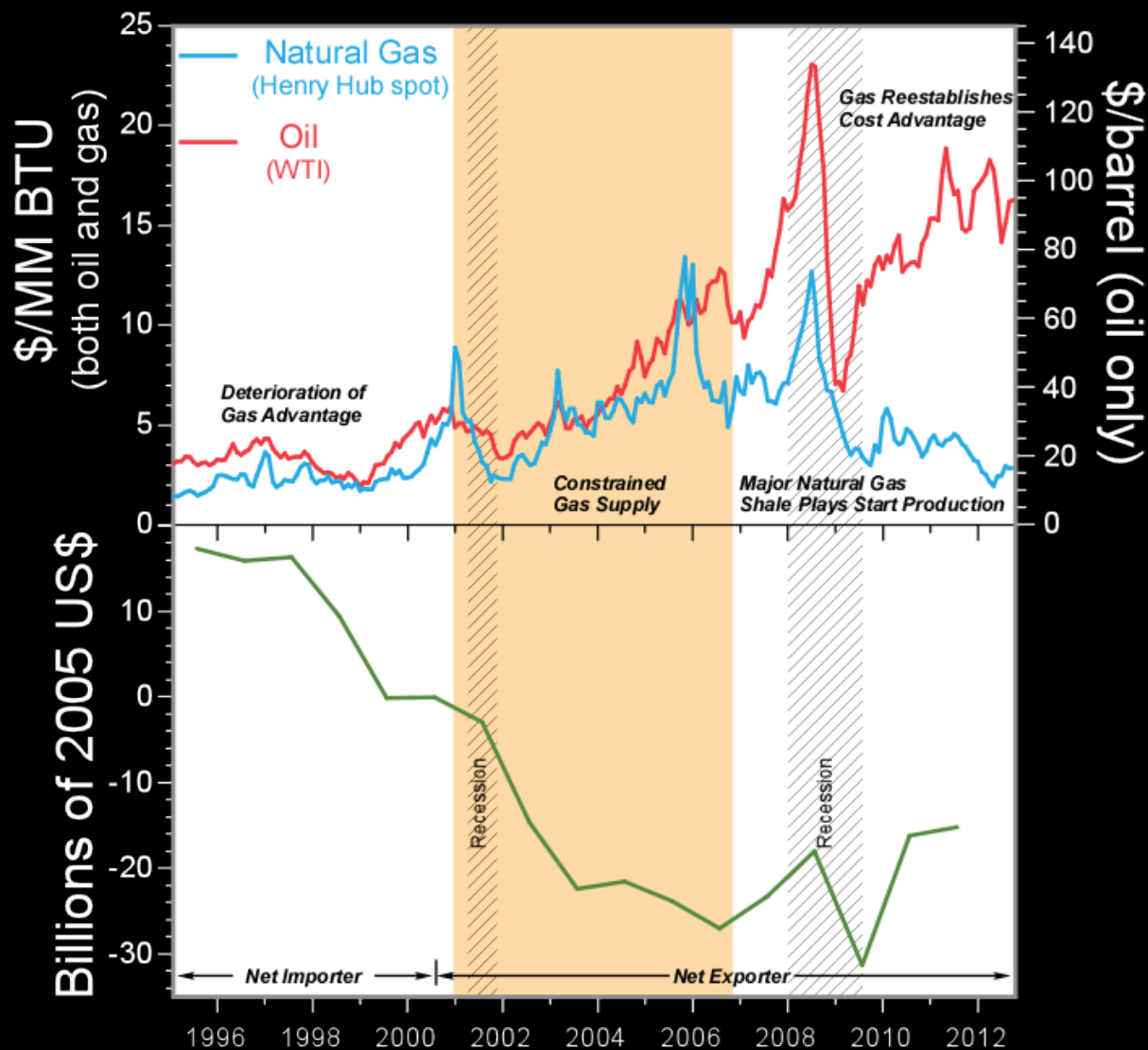
REDUCE PETROLEUM

ENERGY SECURITY

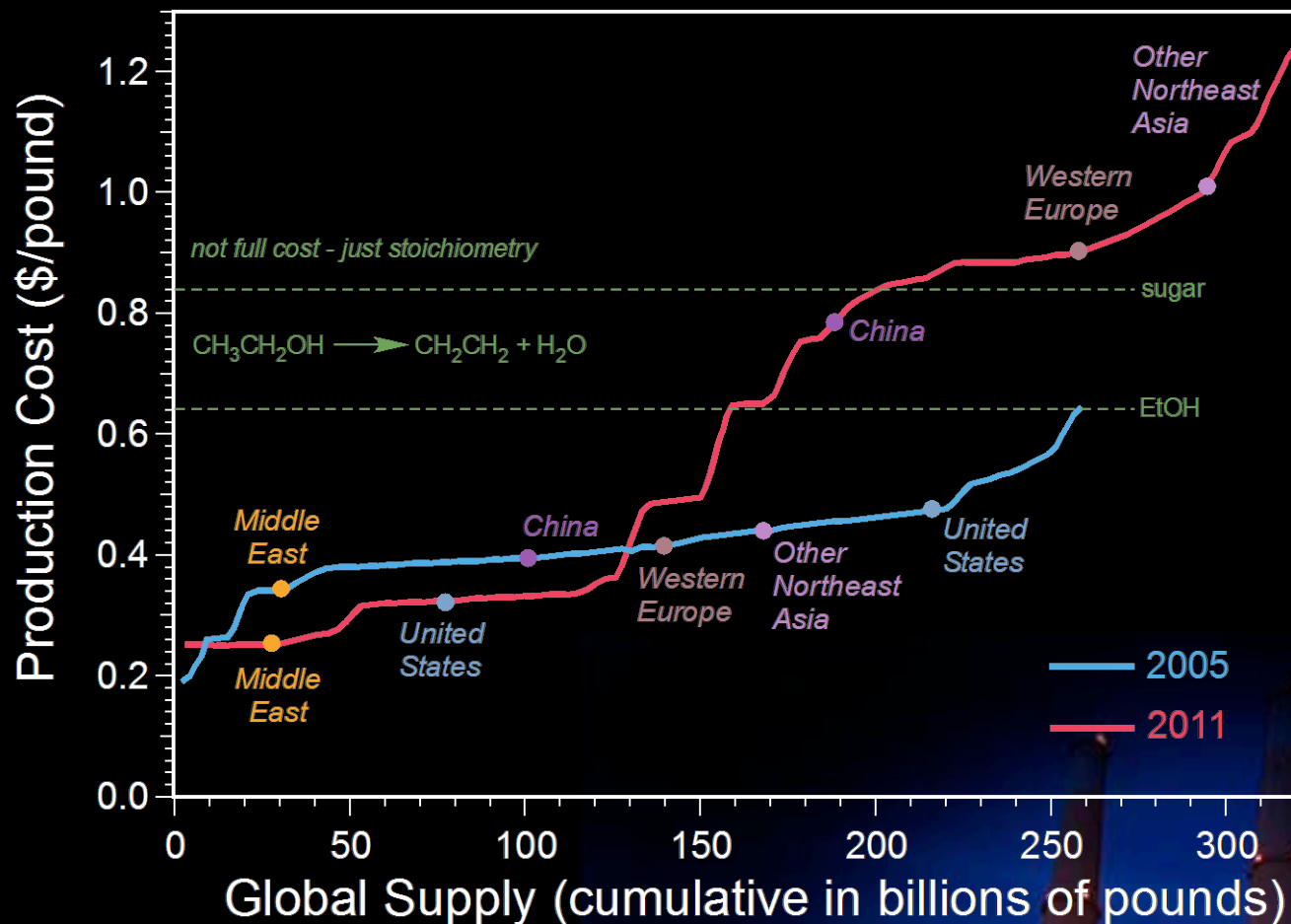
JOB CREATION

IMPROVE THE ENVIRONMENT

# Chemical Industry is Rejuvenated



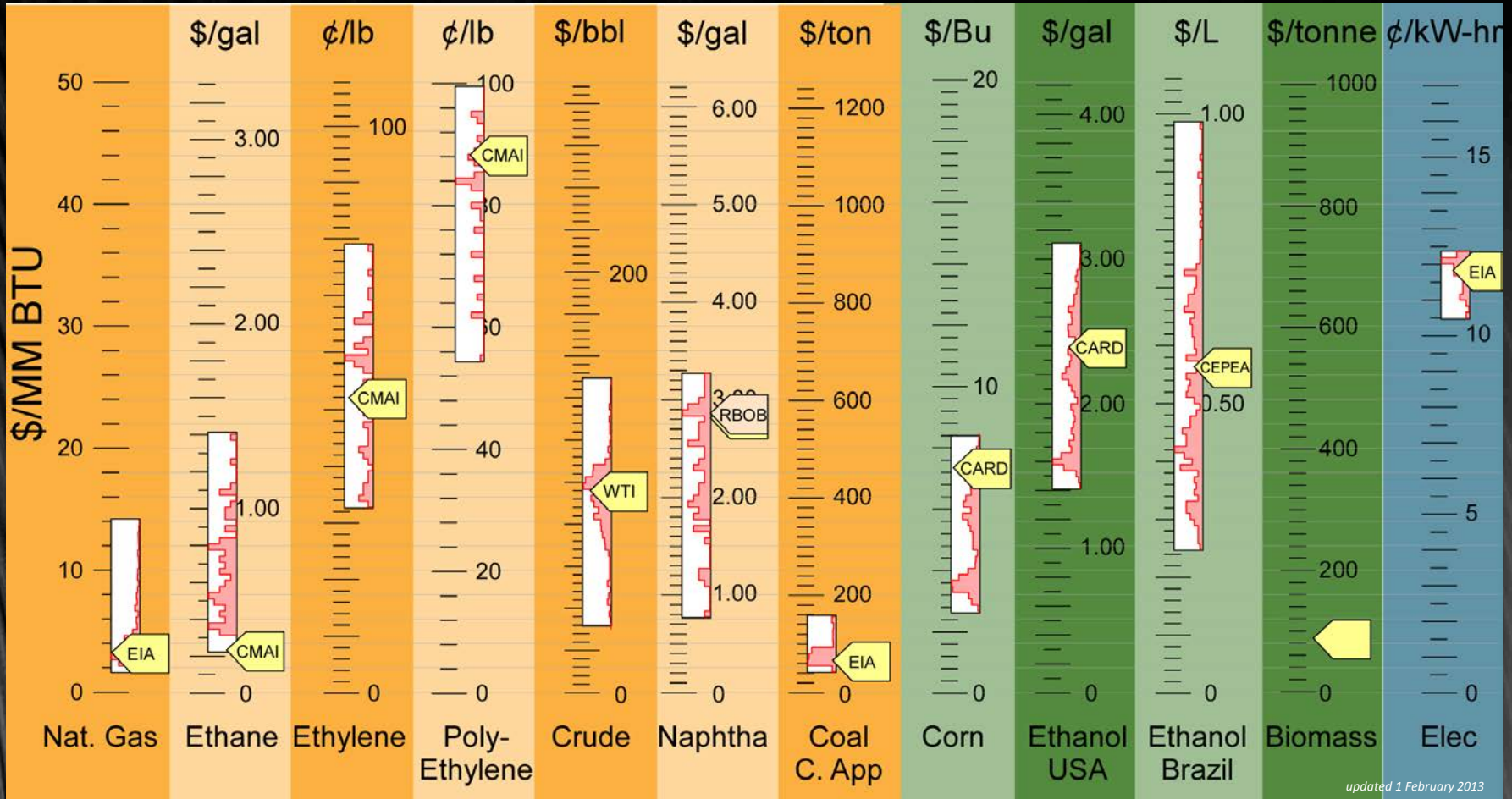
# Impact of Low Gas Prices



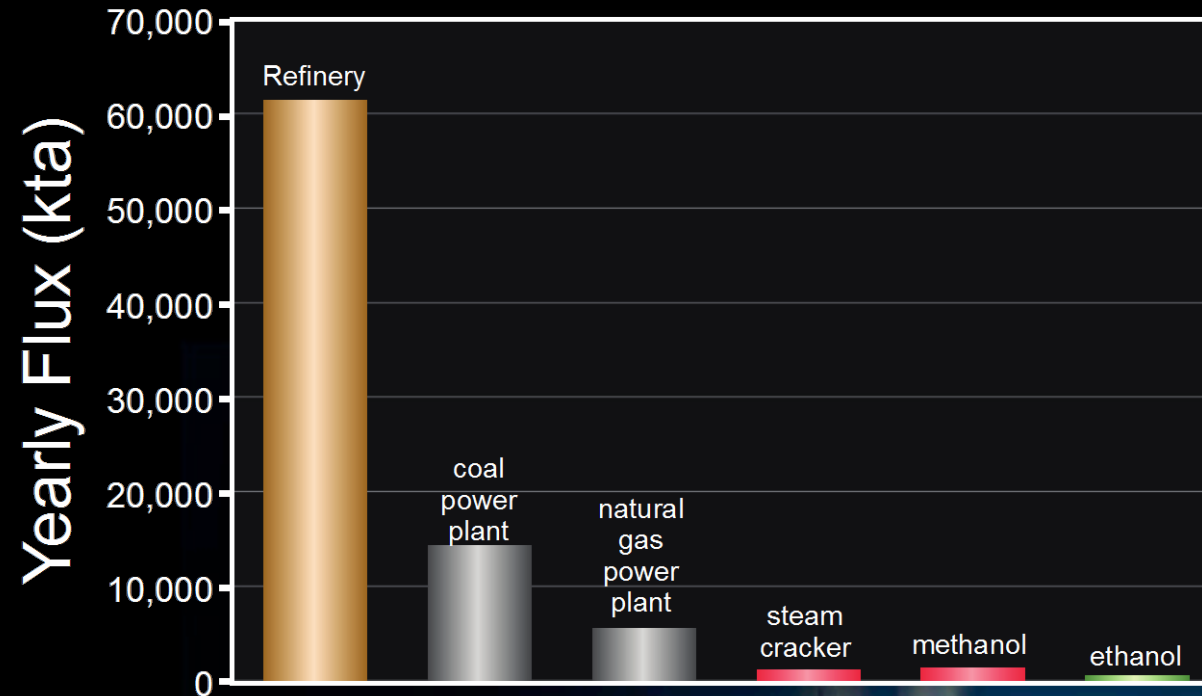
Owen Kean and T.K. Swift, American Chemistry Council, "Industry-Transforming Natural Gas into Products", National Academy Forum on Unconventional Gas, 11 September 2012.  
Ethanol and Sugar from 10 Jan 2013 prices sugar is average of monthly close for 2011; EtOH is average of daily close for 2011.



# An Honest Look at Energy Content



# Energy Happens at Large Scale



# The Importance of Scale



Scale reduces the cost of production when materials are consumed or produced.



# Green Design and LCA Rankings Don't Match Up

*Biopolymers rank in the middle of LCA rankings*



Polymer	Material	Green Design Rank	LCA Rank
Polypropylene	Fossil fuels	9	1
HD Polyethylene	Petroleum	5	2
LD Polyethylene	Petroleum	7	3
Polyhydroxyalkanoate-Stover	Cornstalks	2	4
General Purpose Polystyrene	Petroleum	10	5
Polylactic Acid – NatureWorks	Sugar/cornstarch	1	6
PVC	Chlorine/petroleum	11	7
Polyhydroxyalkanoate-General	Corn kernels	2	8
Polylactic Acid-General	Sugar/cornstarch	4	9
PET	Petroleum	6	10
Polycarbonate	Petroleum	12	11
Bio-PET	Petroleum/plants	8	12

Tabone, MD; Cregg, JJ; Beckman, EJ; Landis, AE. Environ. Sci. Technol. 2010, 44, 8264-9.

# BIOMATERIALS ≠ BIOFUELS



## BIOMATERIALS PROGRAM

REDUCE  
PETROLEUM

ENERGY SECURITY

JOB CREATION

IMPROVE THE ENVIRONMENT



# Materials Science Success: DOW POWERHOUSE™ Solar Shingles



POWERHOUSE™  
 SOLAR



# FILMTEC™ Modules for Water



Energy savings on water purification

Process	Operating Energy Consumption (Kwh/m <sup>3</sup> )	Customer Energy Savings 2005-2015 (Barrels of Oil-eq)
Multi Stage Flash (MSF)	13.5 - 25.5	242 million
Multi Effect Distillation (MED)	6.5 – 11	82 million
Reverse Osmosis	3 - 3.5	

# Biofuels and Clean Tech Conclusions



- Too much hype for the possible, not enough focus on the practical
  - Incumbent fossil sources set the standard for competition
  - It takes decades to deploy a new technology
  - Biomass availability limits biofuels scale
- Move to bioproducts needs scrutiny
- Fundamental engineering judgment is crucial to long-term innovation
- Materials solutions will enable viable energy options

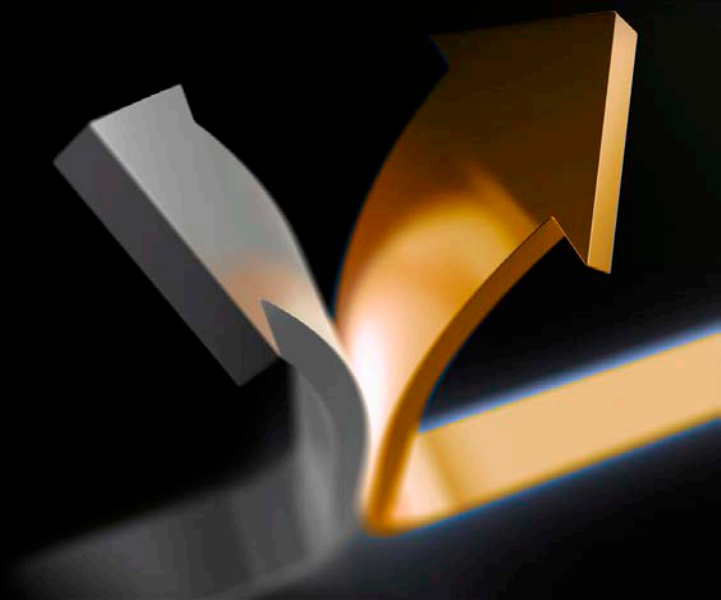
"Facts are the air of scientists.  
Without them you can never fly."

Linus Pauling



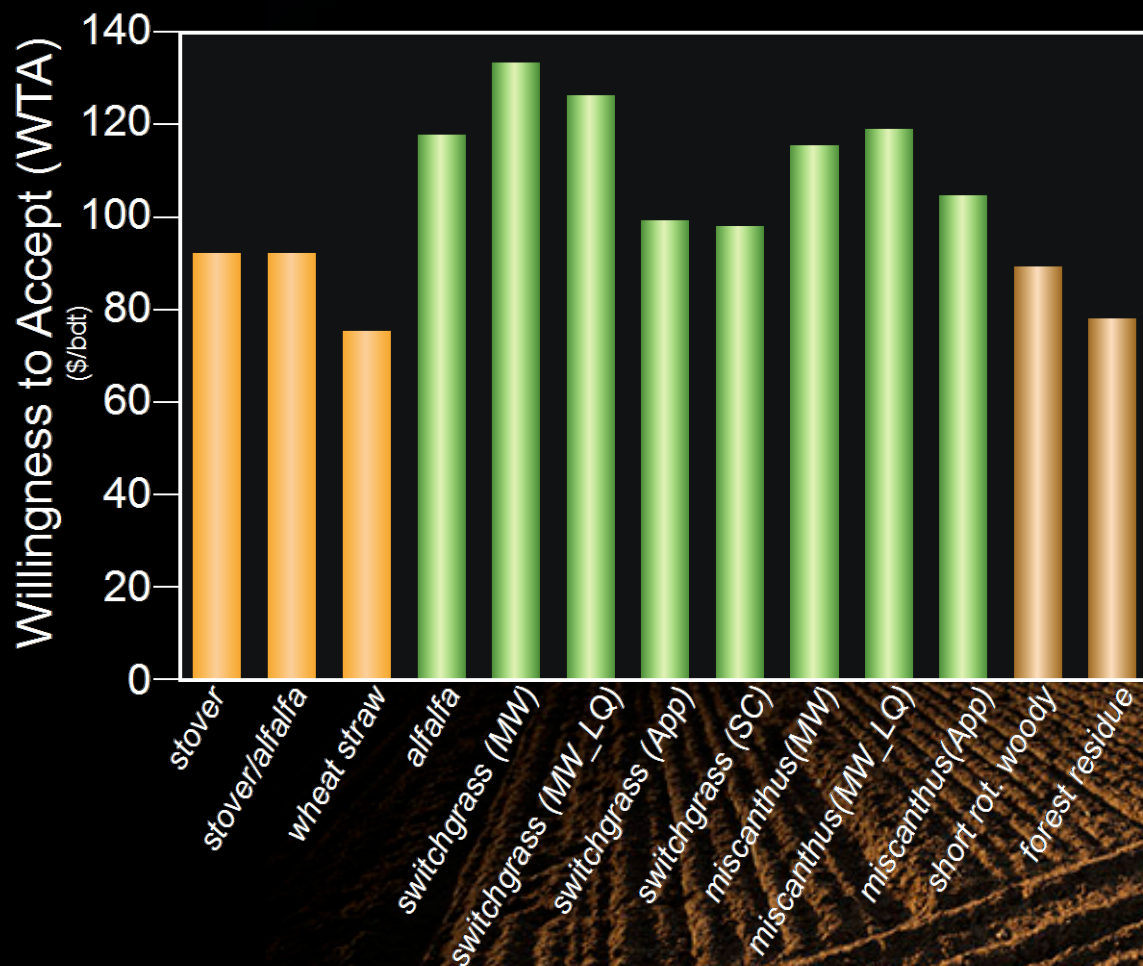


**Thank You**





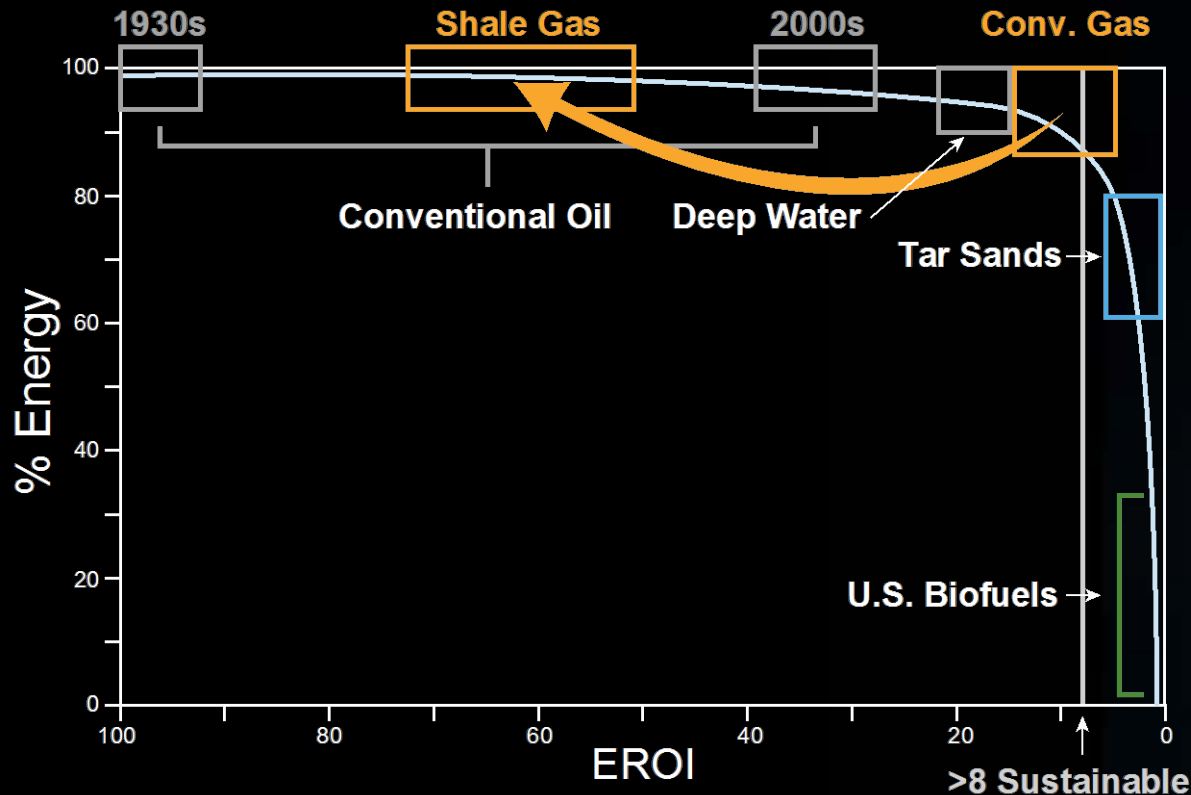
# Biomass Cost: Farmers Are Practical, Too



Landowners/farmers have finite land and time. They will not plant lower value crops and sacrifice return off the land.



# Thermodynamic Entitlement



Energy return is a key parameter when the products are fuels.

Shale goes against recent trends.

# Bio Fads

“The art of being wise is the art of knowing what to overlook.” – *William James*



## Hydrogen Car



"We asked ourselves, 'Is it likely in the next 10, 15, or 20 years that we will convert to a hydrogen car economy?' The answer, we felt, was 'no.'"

*Steve Chu, Energy Secretary, May 2009*

## Corn Ethanol



"...Using land to grow fuel leads to the destruction of forests, wetlands and grasslands that store enormous amounts of carbon."

*Michael Grunwald, TIME, April 2007*

## Biodiesel

**"Biofuels are contributing to higher prices and tighter markets."**

*Timothy Searchinger, Princeton University, April 2011*



## Cellulosic Ethanol

"...the need for trucks, machinery and manpower would come during harvest, already the busiest time of the year on the farm. And that's where a massive federal initiative into cellulosic ethanol may find its biggest bottleneck – on the farm."

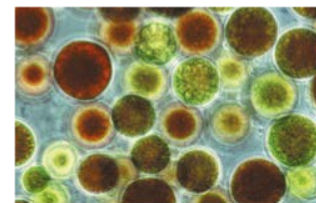
*Robert Rapier*



## Algae

"...microalgae can be raised on cheap, sun-splashed land that is unsuitable for crops or much of anything else."

*Paul Voosen, New York Times, 29 March 2011.*



## Bio Plastics

Dow launched the JV with Cargill in 1997 to develop and market PLA from corn; we exited the JV in 2004.



## THE WALL STREET JOURNAL.

**"Sun Chips Bag to Lose Its Crunch"**



Photo: Associated Press

Bio-based packaging launched in 2009 was discontinued by late 2010, due to performance perception issues.

## Glycerin to Epi

Dow postponed in 2009 due to uncertain supply.



## Natural Oil Polyols

**RENUVA™**

Dow launched in 2007, exited in 2010.



## ADM-Metabolix

ADM has given notice of termination of the Telles, LLC joint venture for PHA bioplastics.



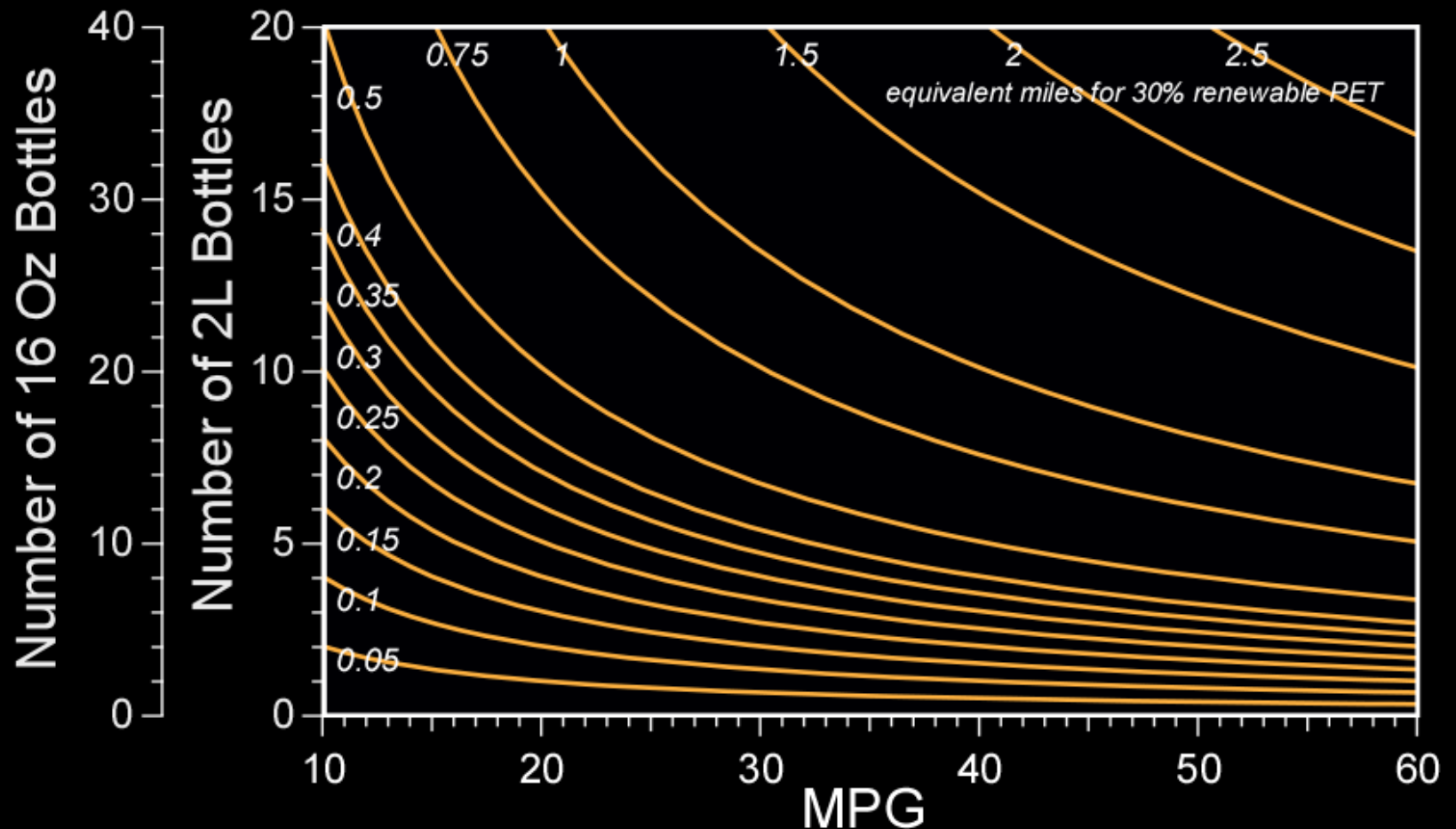
# What Impact?



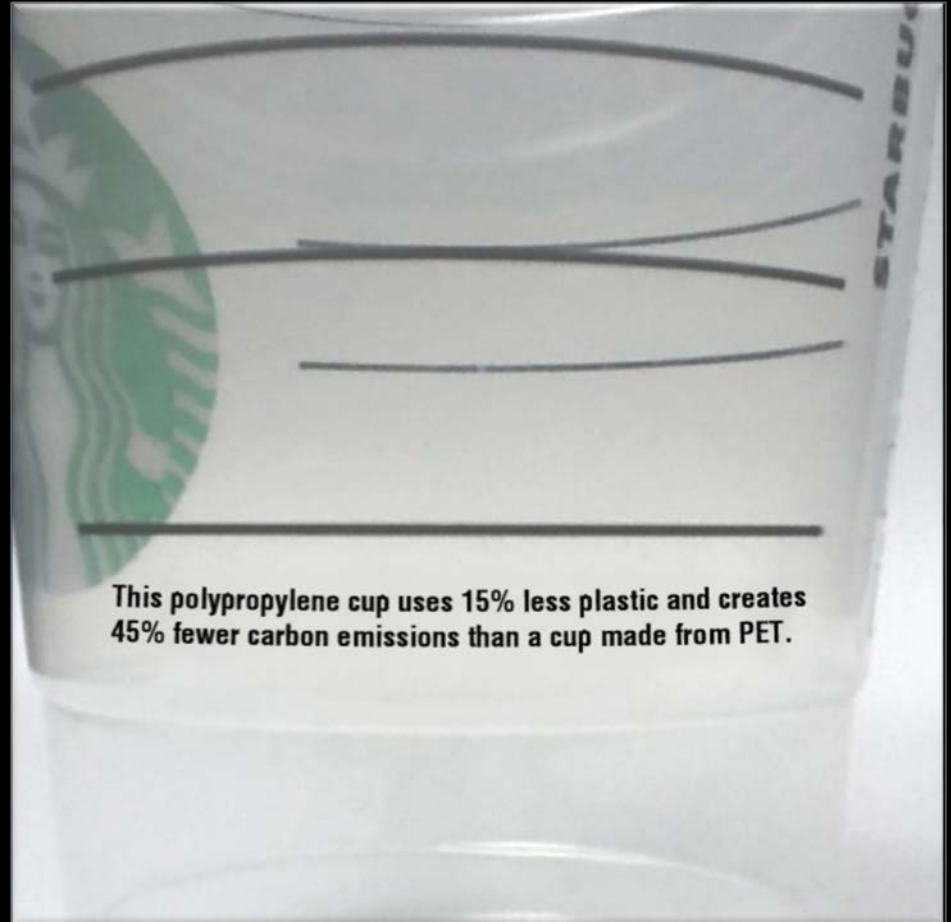
100% renewable PET (not yet available) would required ~80 2 L bottles to offset burning 1 gallon of gasoline or about 400 at today's 30%

material	per capita consumption (lb/yr)
PET packaging	17
petroleum	6619
natural gas	8037
coal	6439
gasoline	2495
sand and gravel	13923
cement	512
iron ore	340
salt	403
beef	54.3
chicken	55.7

# PET Comparison

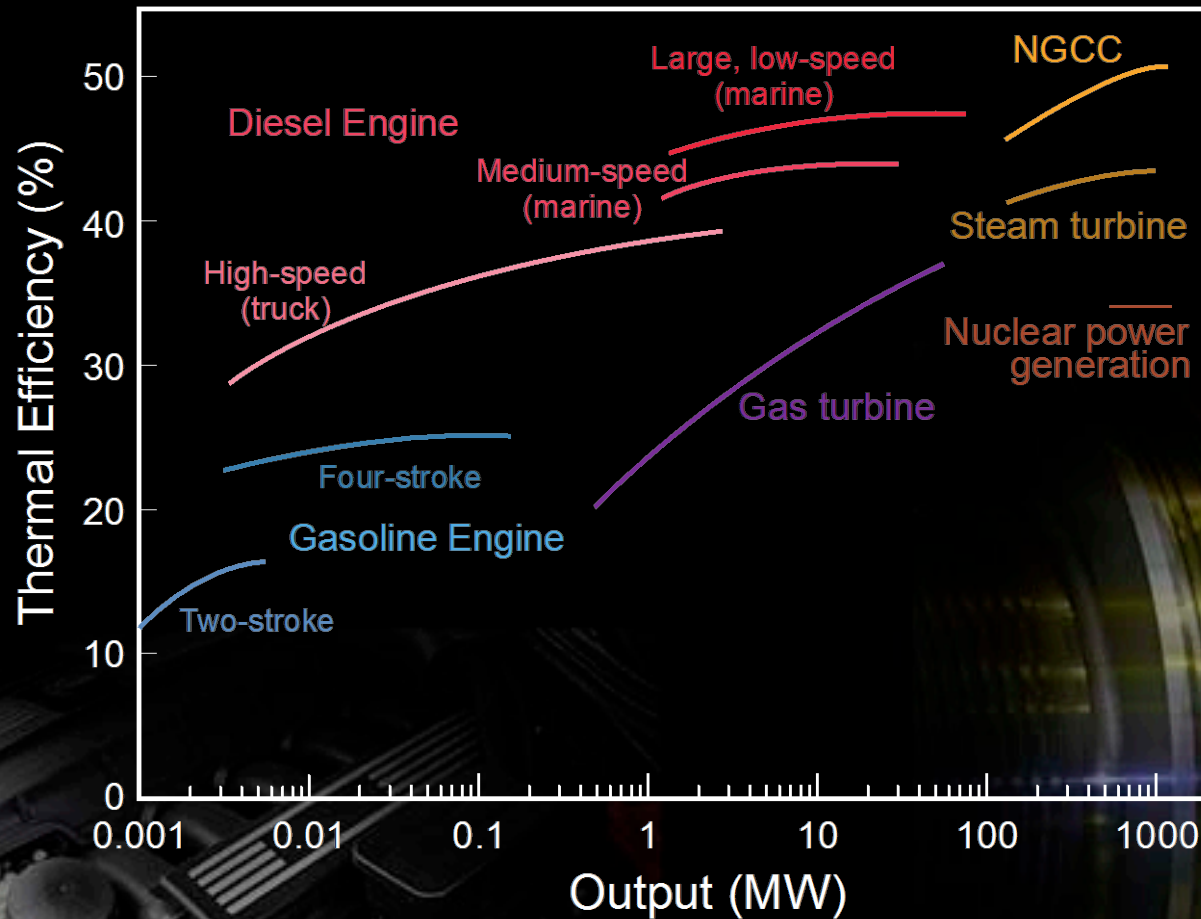


# Signs of Hope

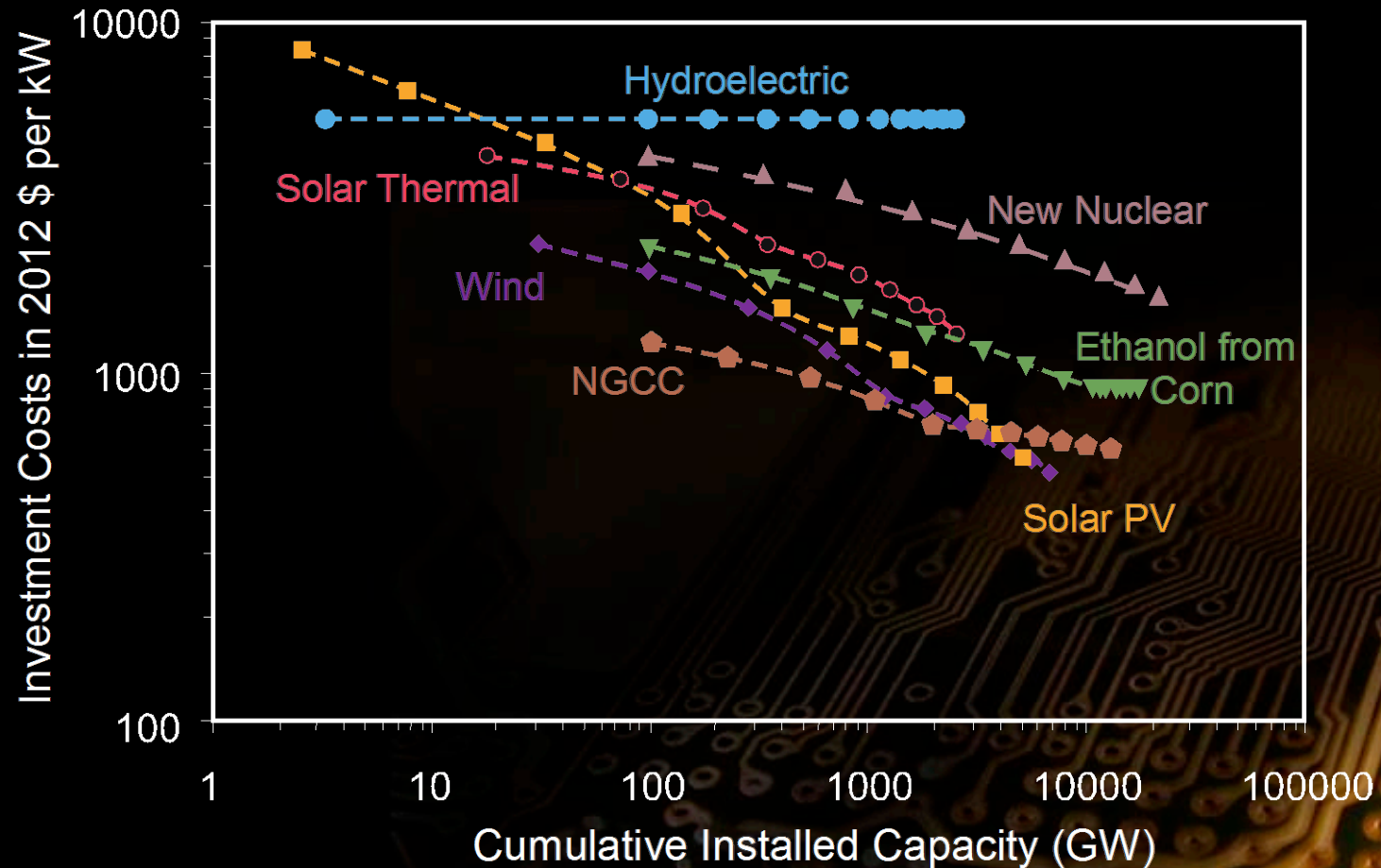




# Scale Improves Efficiency



# Experience Curves



# Chemical Industry is Rejuvenated

