



*University of California – Berkeley
29 October 2012*

Biomaterials and Biofuels: *Path to Perdition or the Promised Land?*

Mark Jones

Executive External Strategy and Communications Fellow

The Dow Chemical Company

Last Week Was A Big Week

THE NATIONAL
DIVISION ON EARTH AND LIFE STUDIES

Sustainable Development of Algal Biofuels in the United States

Jennie C. Hunter-Cevera
Committee Chair

Mark E. Jones
Committee member

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council



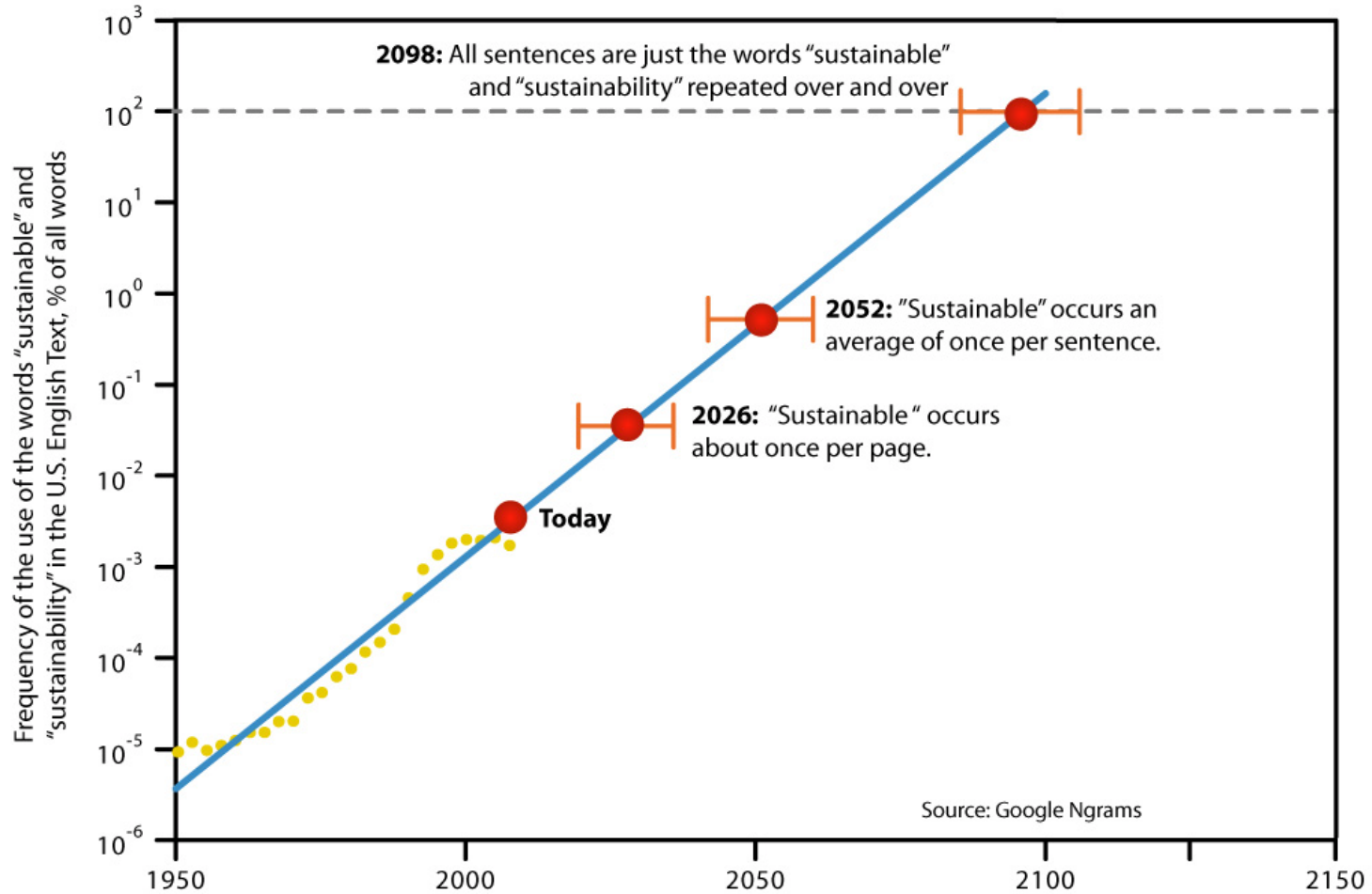
Which is environmentally better?

A meat-eater in a Prius



A vegan in a Hummer

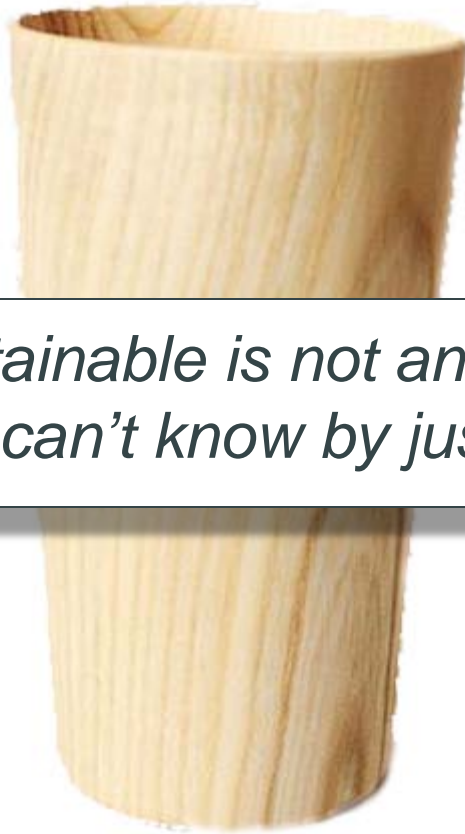
Sustainability is Unsustainable?



<http://imgs.xkcd.com/comics/sustainable.png>



Is this Cup Sustainable?



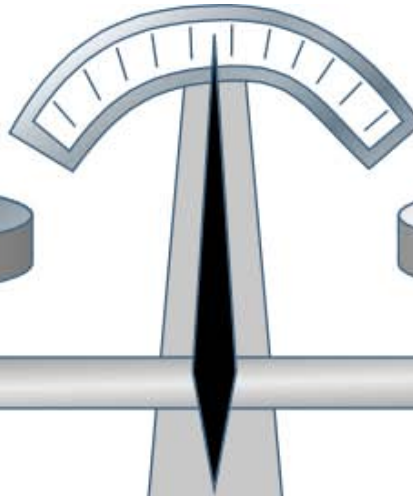
*Sustainable is not an intrinsic property of a material!
You can't know by just looking.*

How about this one?

Sustainability Is A Balance

Sustainable development is the ability to meet present needs without compromising the needs of future generations. World Commission on Environment and Development's

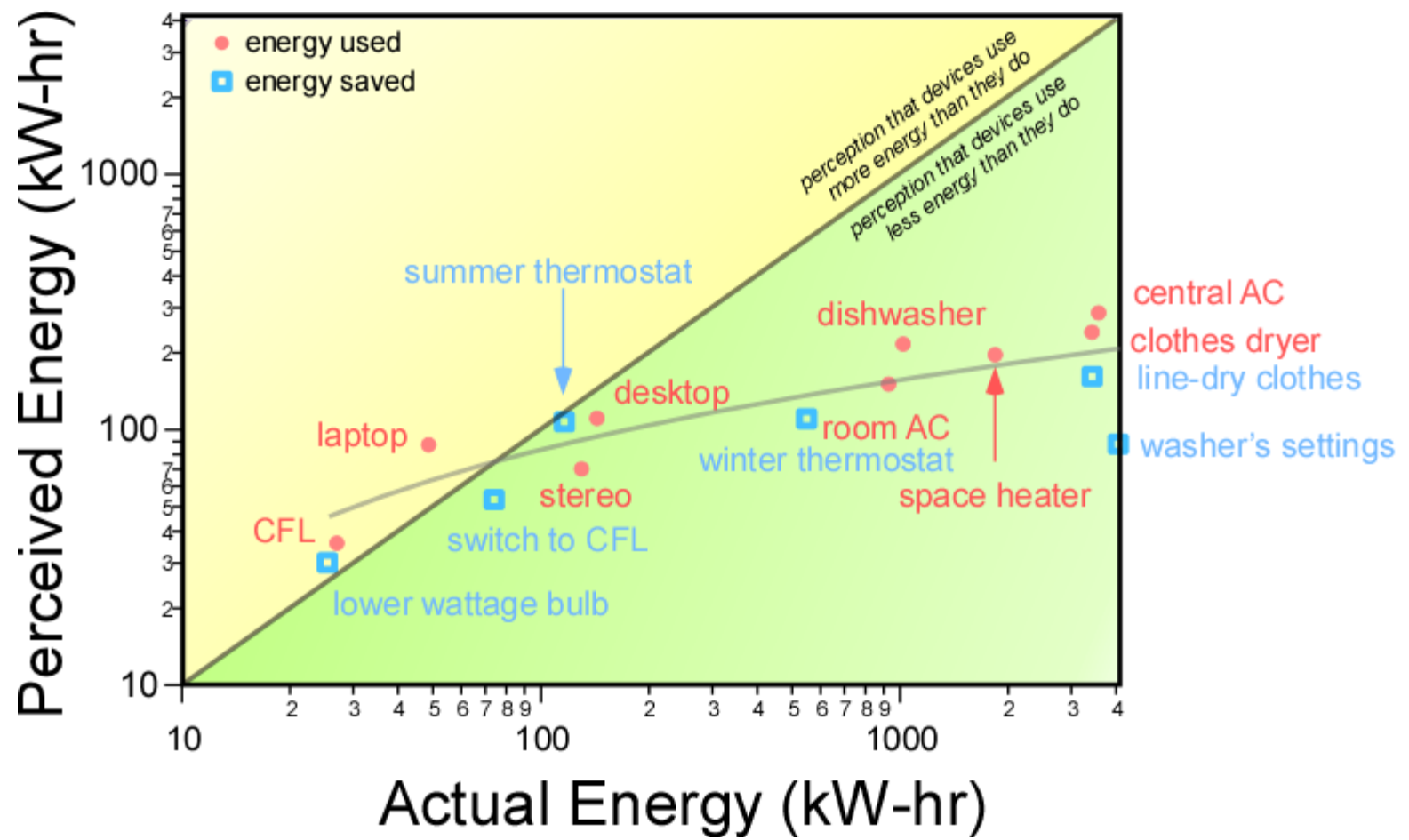
meeting needs



impact in
the future



We Are Poor Judges of the Energy We Use

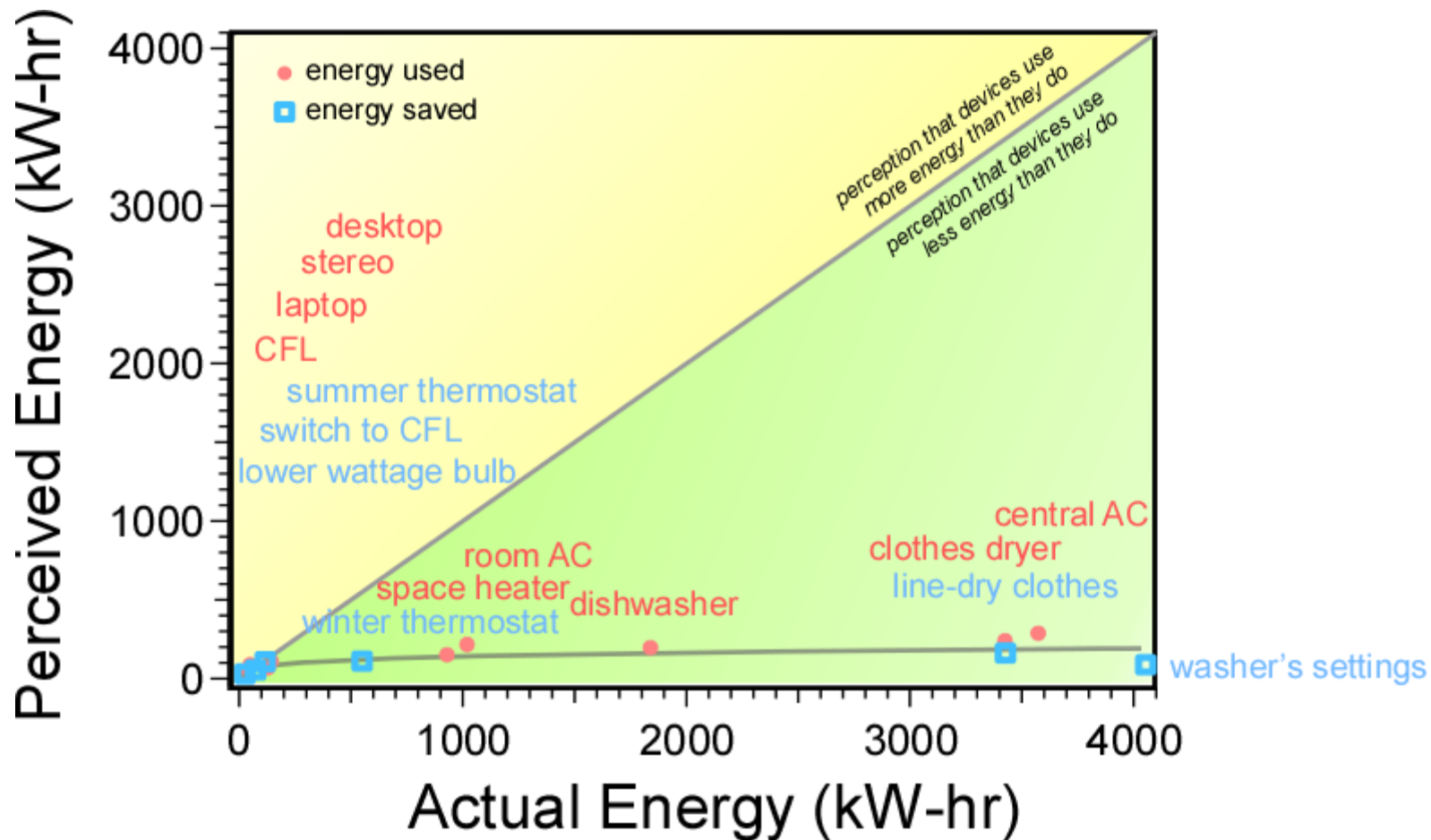


Attari, Sjazzeem Z.; DeKay, Michael L.; Davidson, Cliff I.; de Bruin Wandt Bruine; "Public Perceptions of energy consumption and savings", PNAS doi 10.1073/pnas.1001509107





Same Data – Linear Plot



Attari, Sjaizeem Z.; DeKay, Michael L.; Davidson, Cliff I.; de Bruin Wandi Bruine; "Public Perceptions of energy consumption and savings", PNAS doi 10.1073/pnas.1001509107

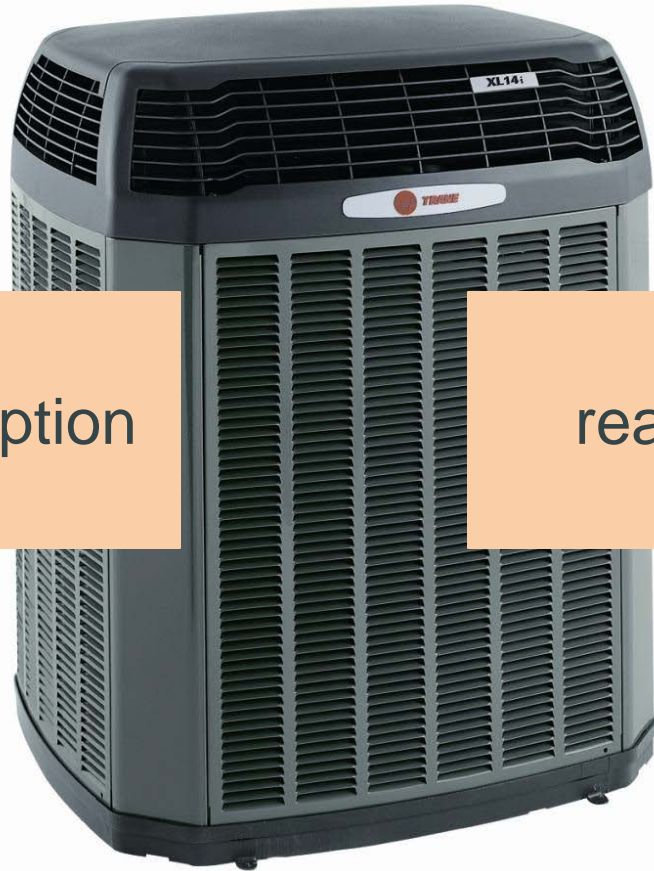




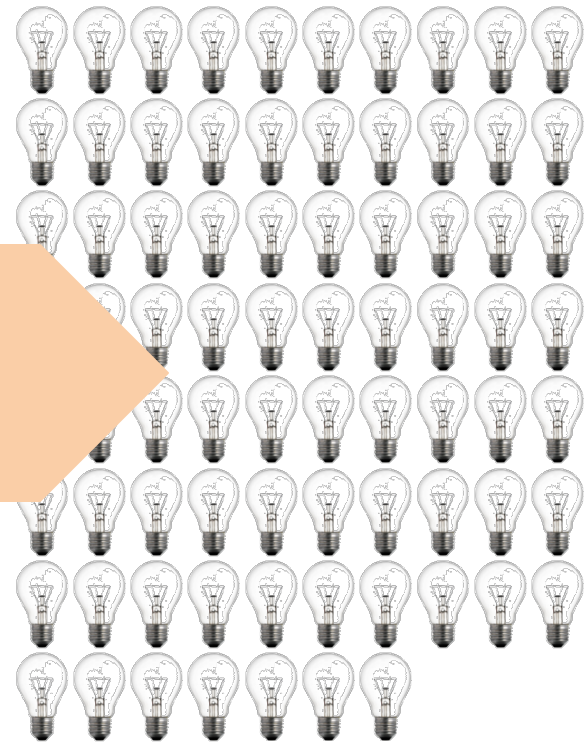
Energy Perception and Reality



perception

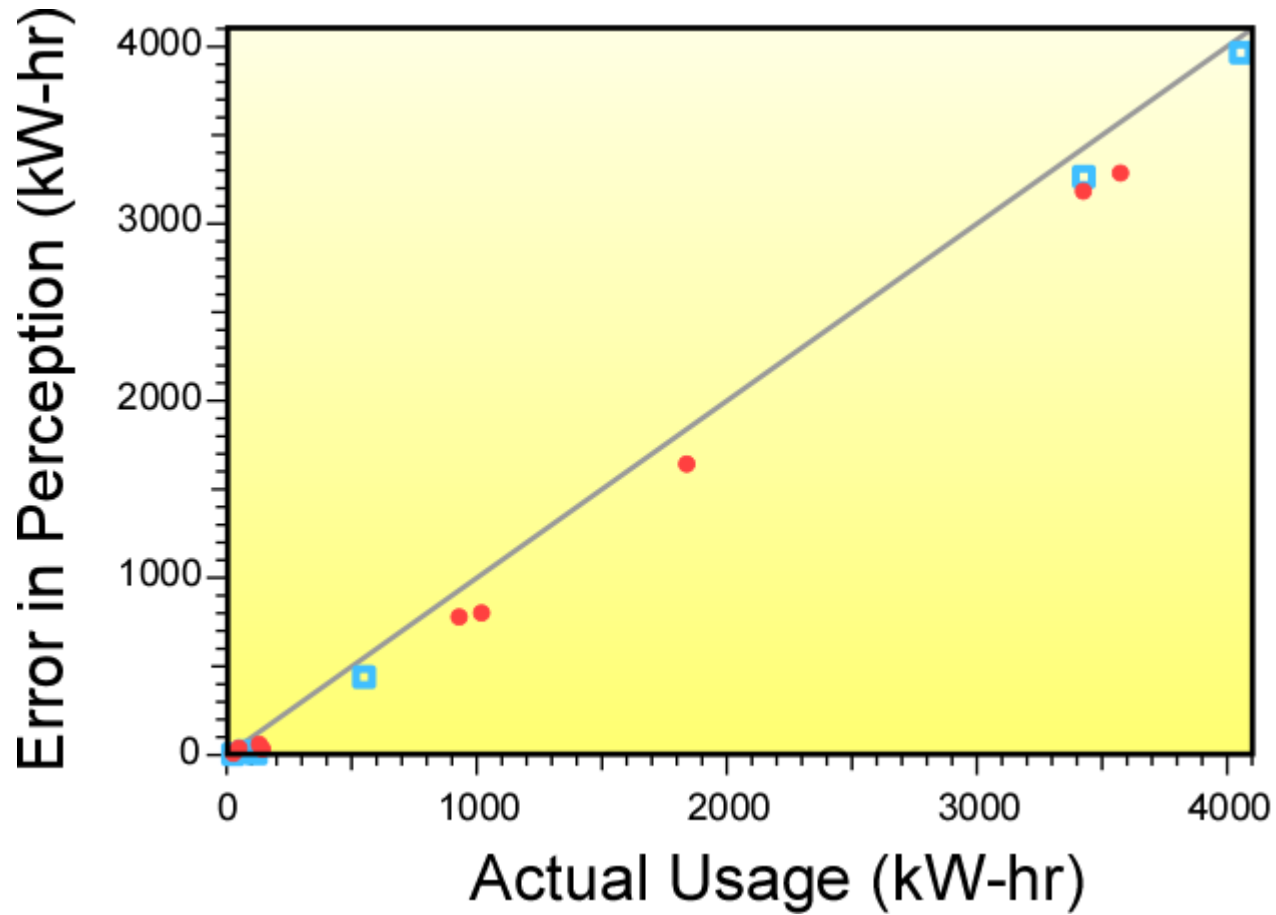


reality





Same Data – Absolute Error



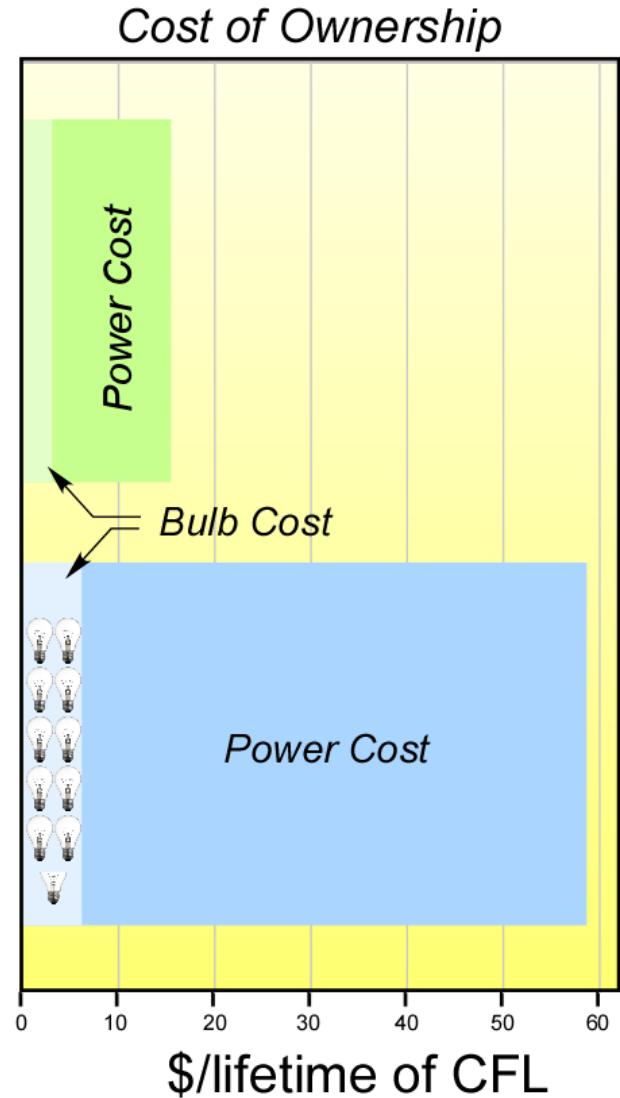
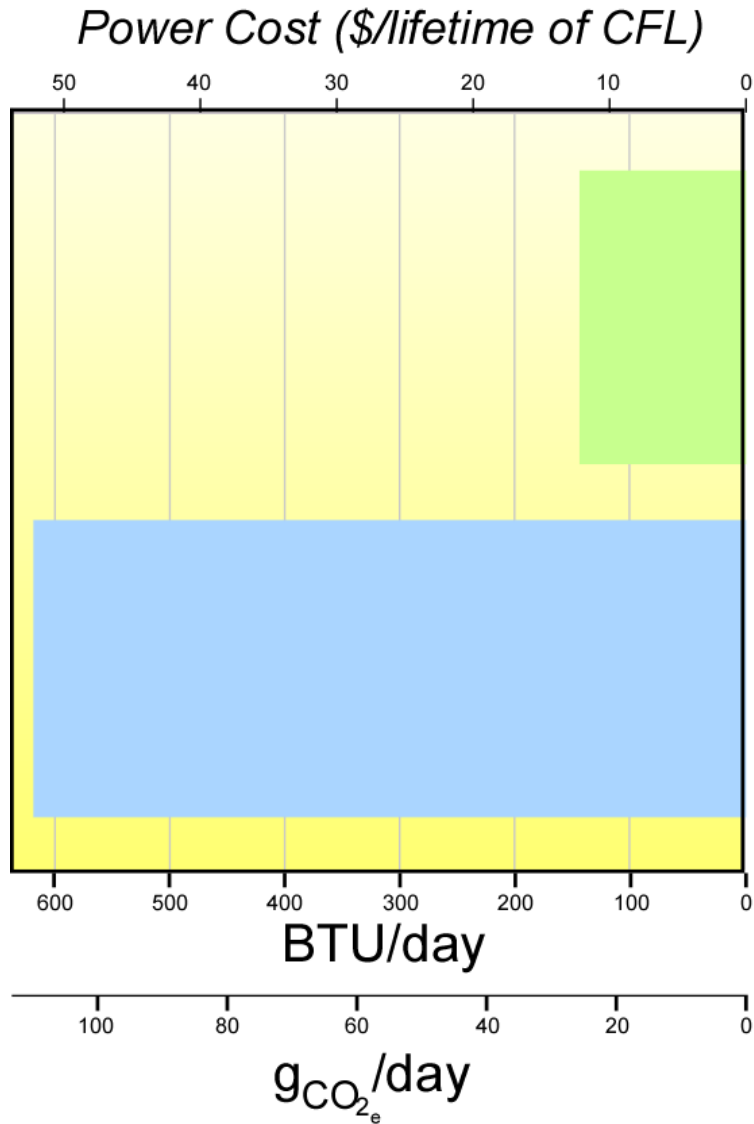
Attari, Sjazzeem Z.; DeKay, Michael L.; Davidson, Cliff I.; de Bruin Wandí Bruine; "Public Perceptions of energy consumption and savings", PNAS doi 10.1073/pnas.1001509107





Lighting Comparison

3 hours per day



Biomass Fuels Program



***Reduce
Petroleum***



***Energy
Security***



***Job
Creation***



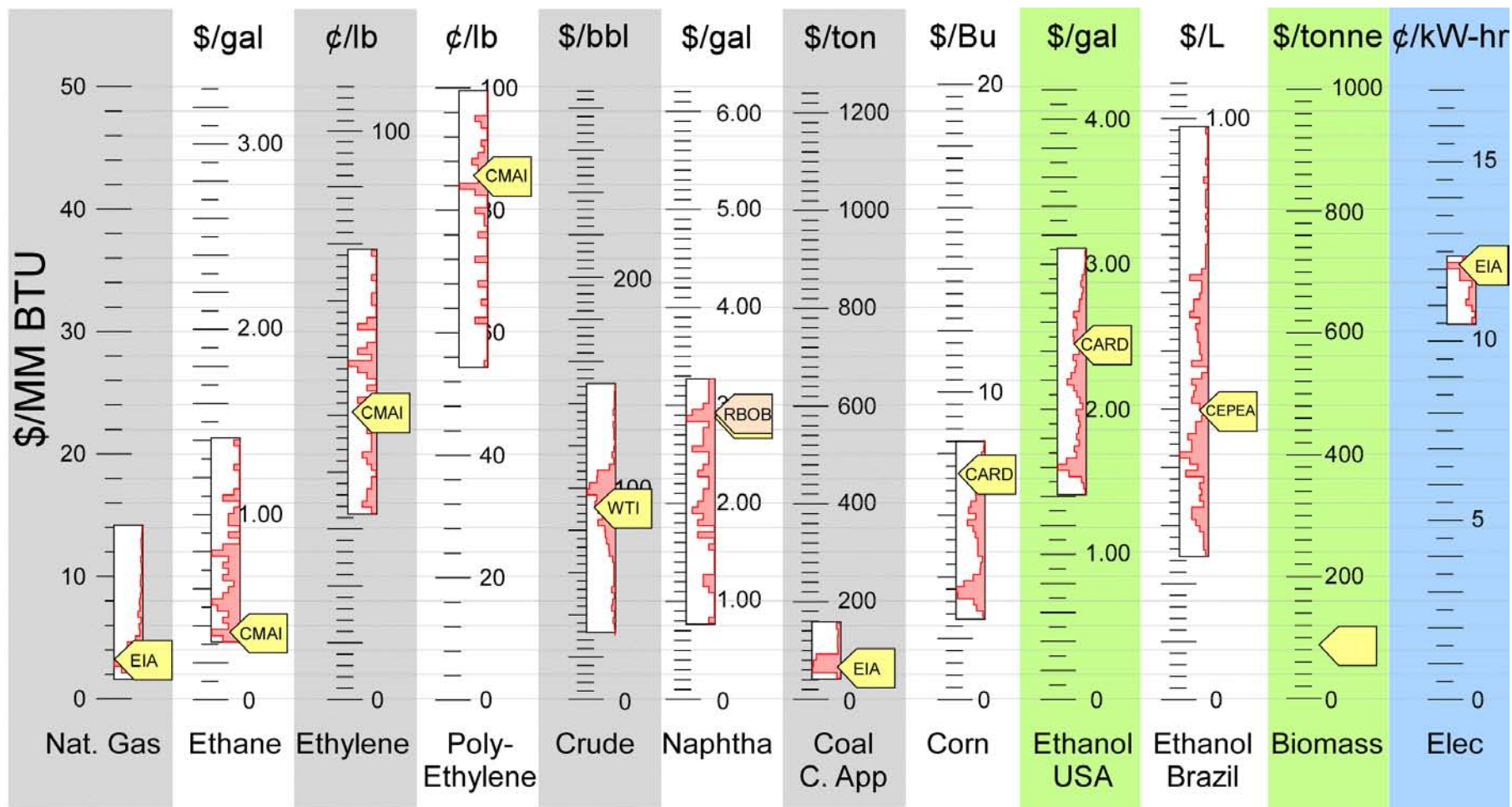
***Improve the
Environment***

Cellulosic Biofuels: Key Issues



- How much *biomass is available?*
not enough to replace fossil fuels
- How much *will the biomass cost?*
it is not cheap!
- How much *will biofuels cost?* *more than fossil*
- How much *more are we willing to pay?*
no premium

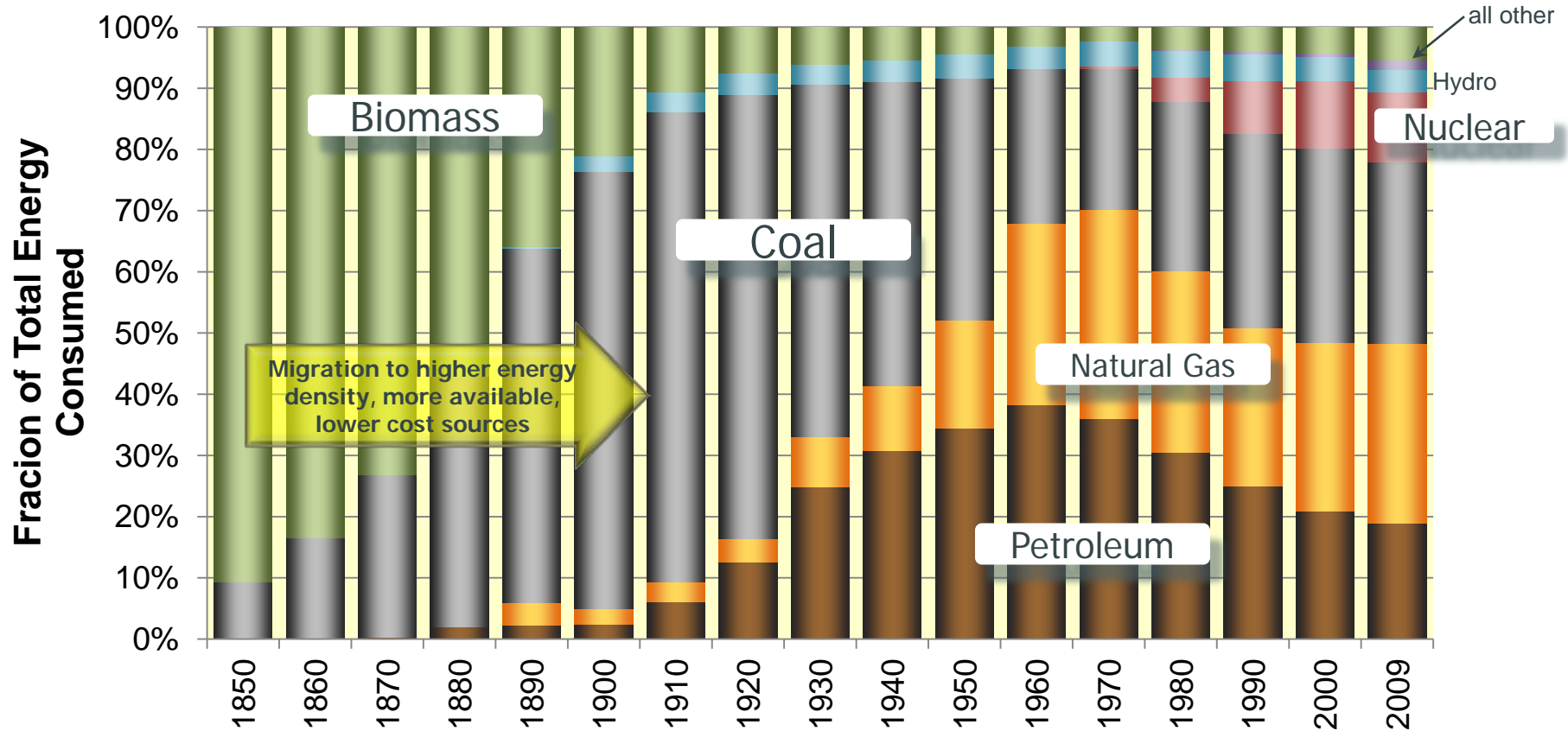
Energy Content



EIA is DOE Energy Information Agency, CMAI is an IHS affiliate, CARD is Iowa State Center for Agricultural and Rural Development, CEPEA is Centro de Estudos Avancado em Economia Aplicada – data for 3-5 years depending on source. updated 18 October 2012



Energy Sources Always Change



What's Changed?

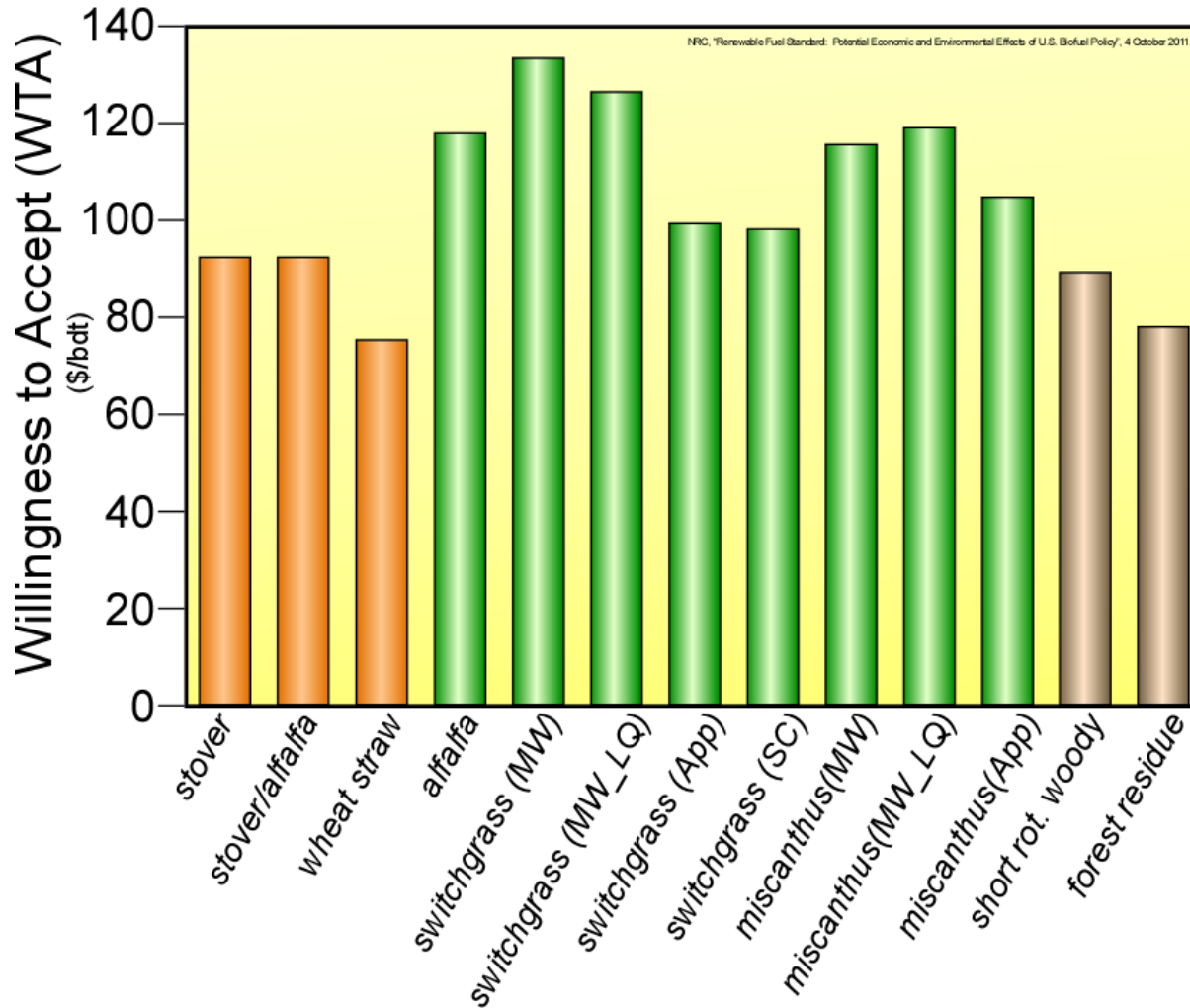
- Oil Price Rise
- CO₂ awareness



Will this reverse the trend?

Source: IEA, EIA; US Primary Energy

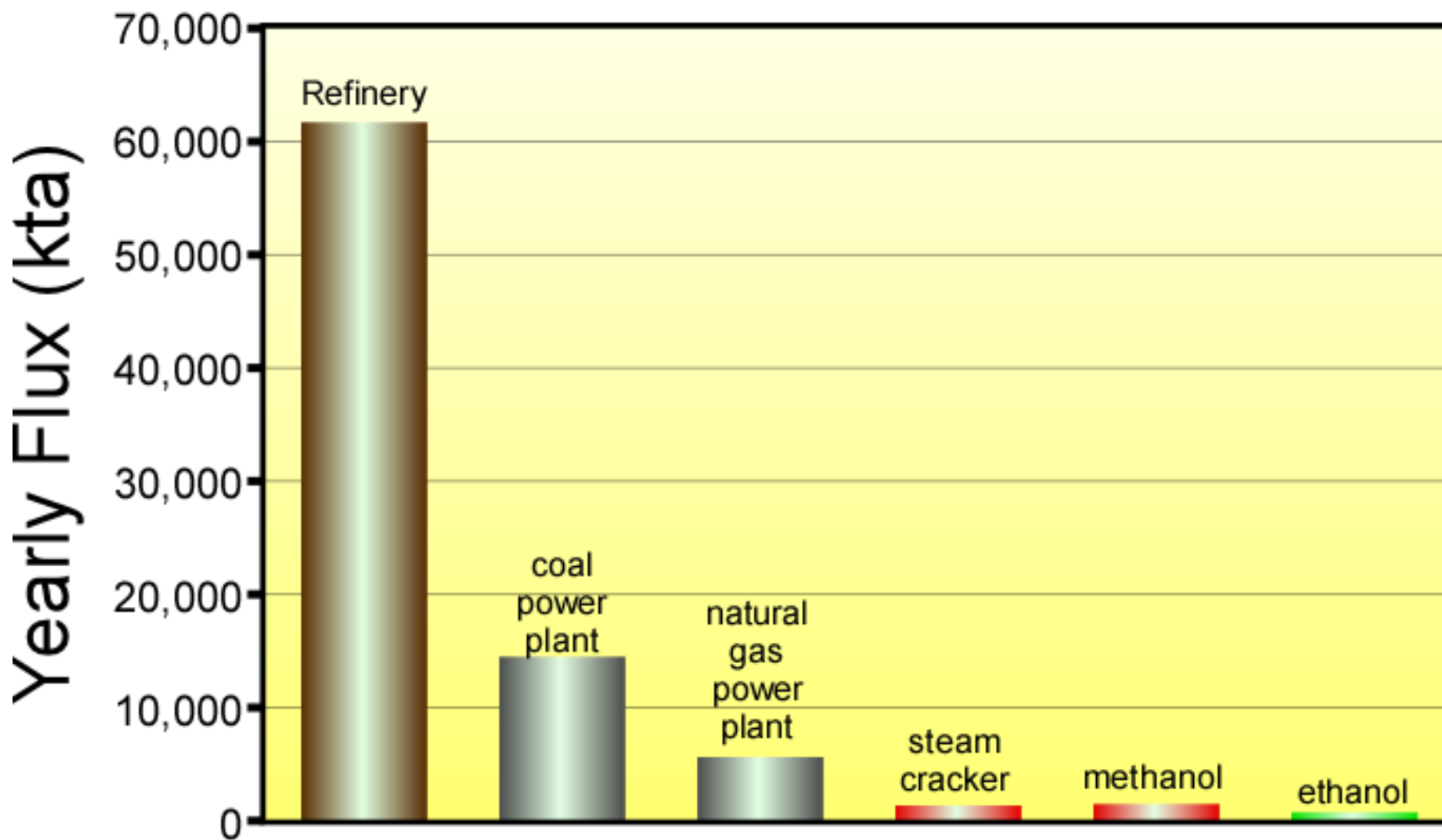
Biomass Cost



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

NRC, "Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy", 4 October 2011.

Energy Happens at Large Scale

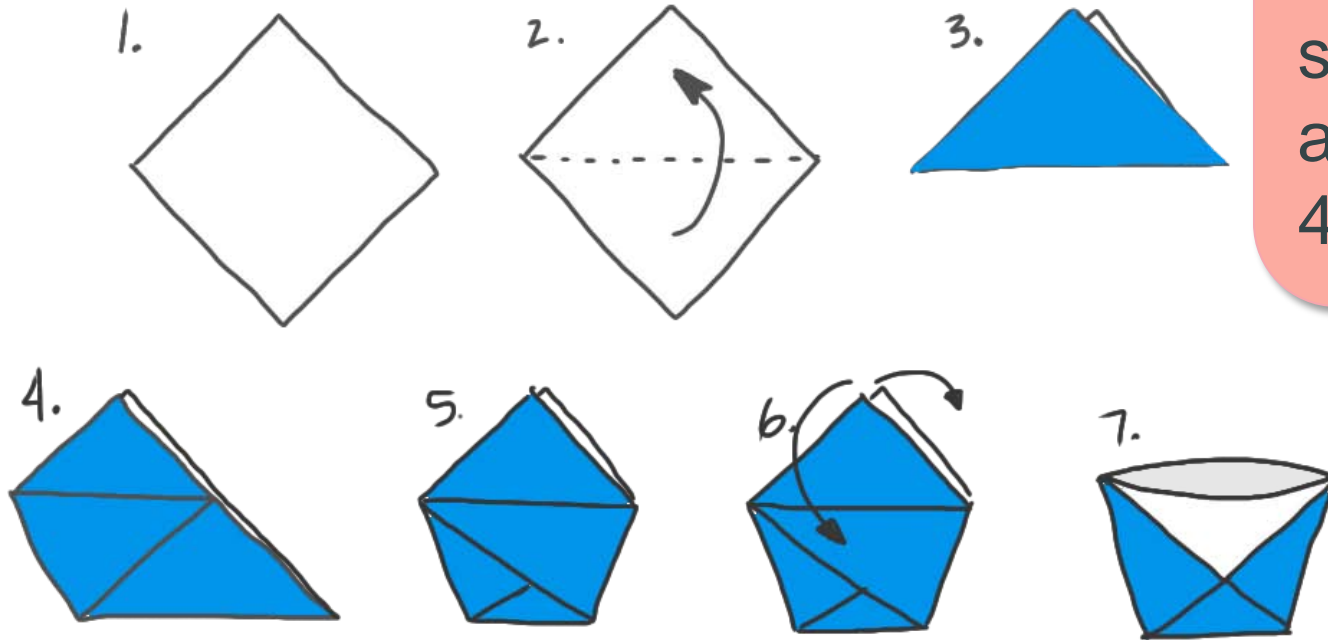


Scale



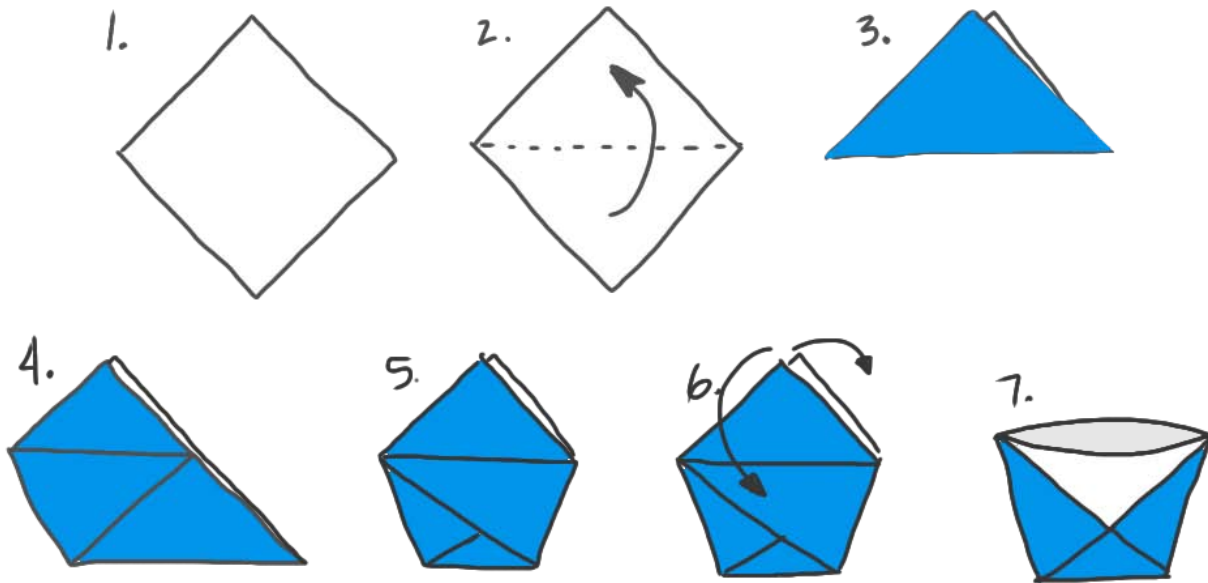
Scale reduces the cost of production when materials are consumed or produced.

Scale is Important – An Example



Make a cup
with an $8\frac{1}{2}$ "
square and
another with a
 $4\frac{1}{4}$ " square

Scale is Important – An Example



Make a cup with an $8\frac{1}{2}$ " square and another with a $4\frac{1}{4}$ " square

The bigger cup holds about a cup. The smaller only about $\frac{1}{8}$ of a cup. The amount of paper required increases by the volume to the $\frac{2}{3}$ power.

Description of the Geometry

MJPHD.NET

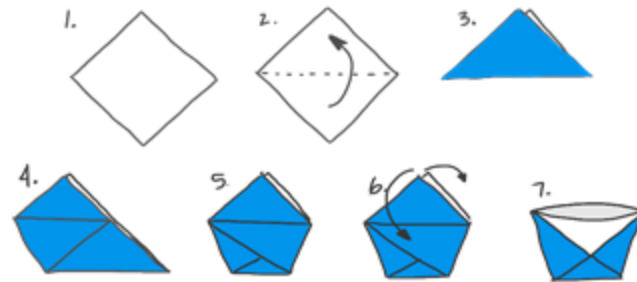
Technical Illustrations

Illustrations by Mark Jones

Technology Related



The Importance of Scale [pdf](#)



Demonstration Layout [pdf](#)

Biofuels Are Like a Jetpack

HYPE

H I P E



**ENERGY
DENSITY**

E N E R G Y
D E N S I T Y

**LIMITATIONS
OF BIOLOGY**

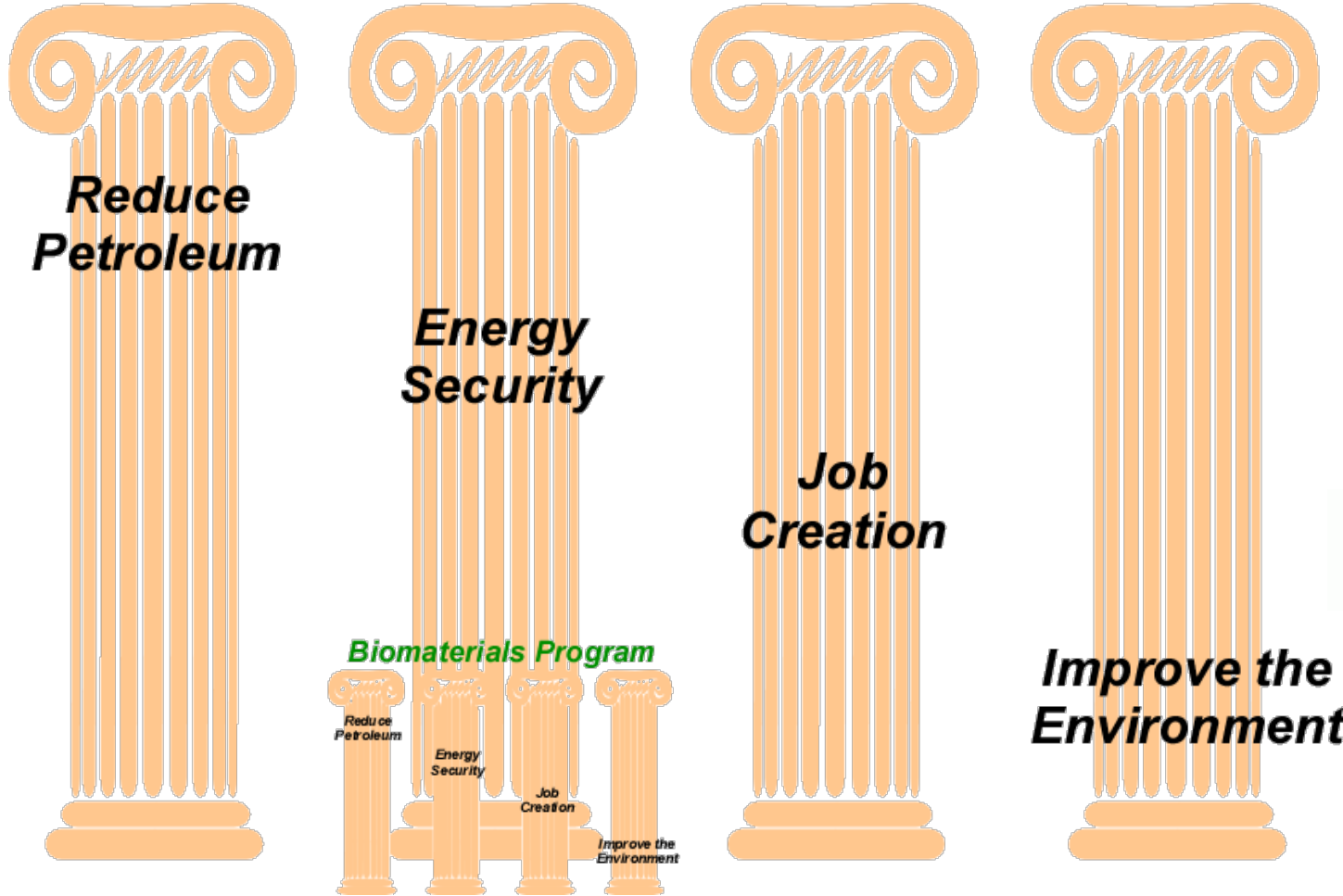
L I M I T A T I O N S
O F B I O L O G Y

**PRACTICAL
APPLICATION**

P R A C T I C A L
A P P L I C A T I O N

Pivot to Biomaterials

Biomass Fuels Program



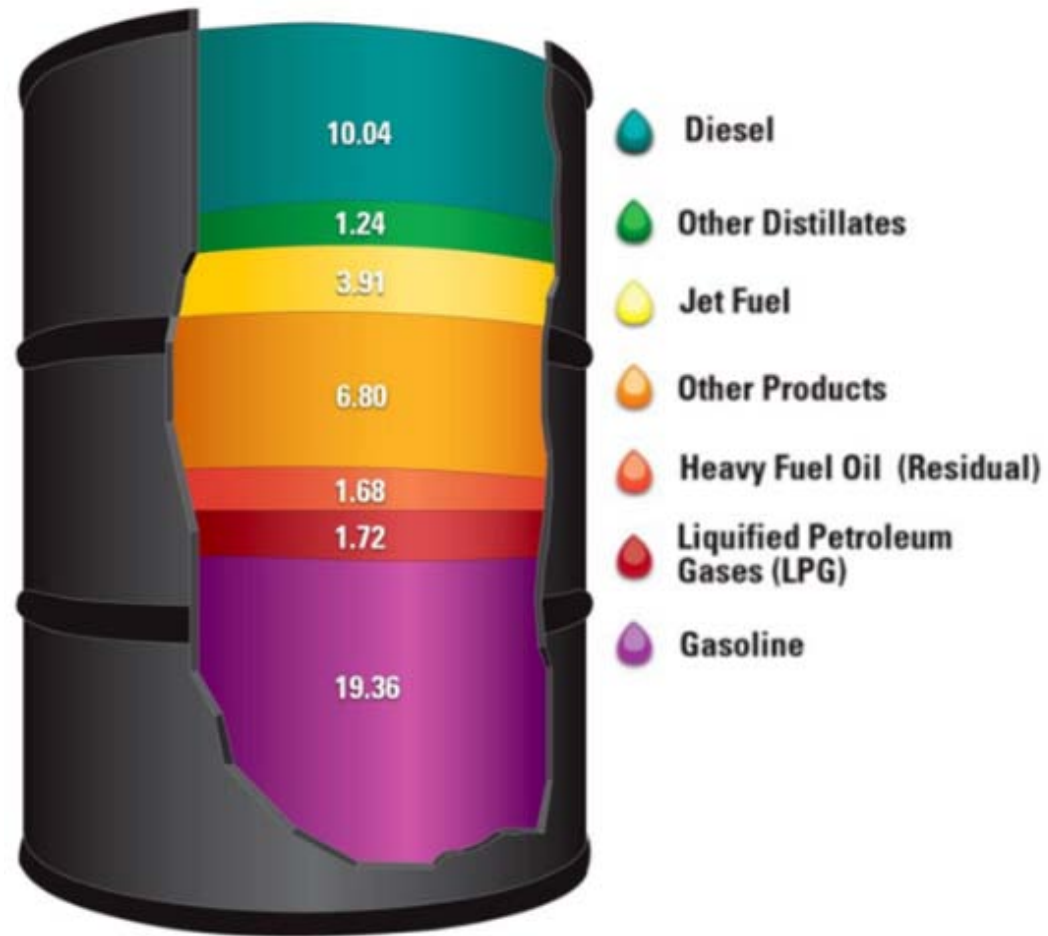
Changing Emphasis

Biomass 2011: Replace the Whole Barrel,
Supply the Whole Market
The New Horizons of Bioenergy

July 26–27, 2011



“sugar is the new crude”





What Unhealthy Looks Like

Healthy

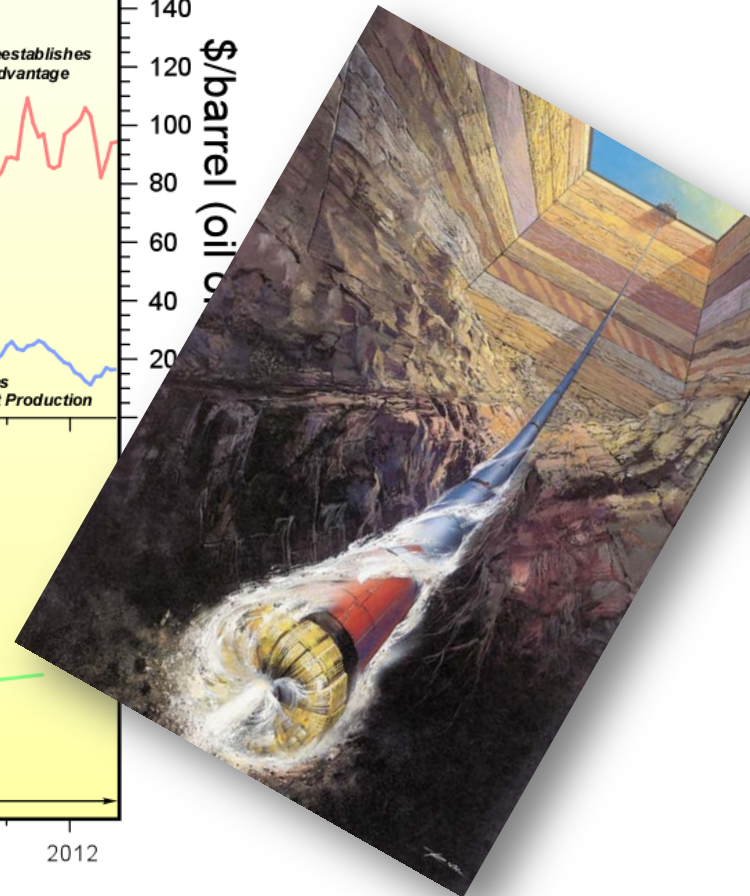
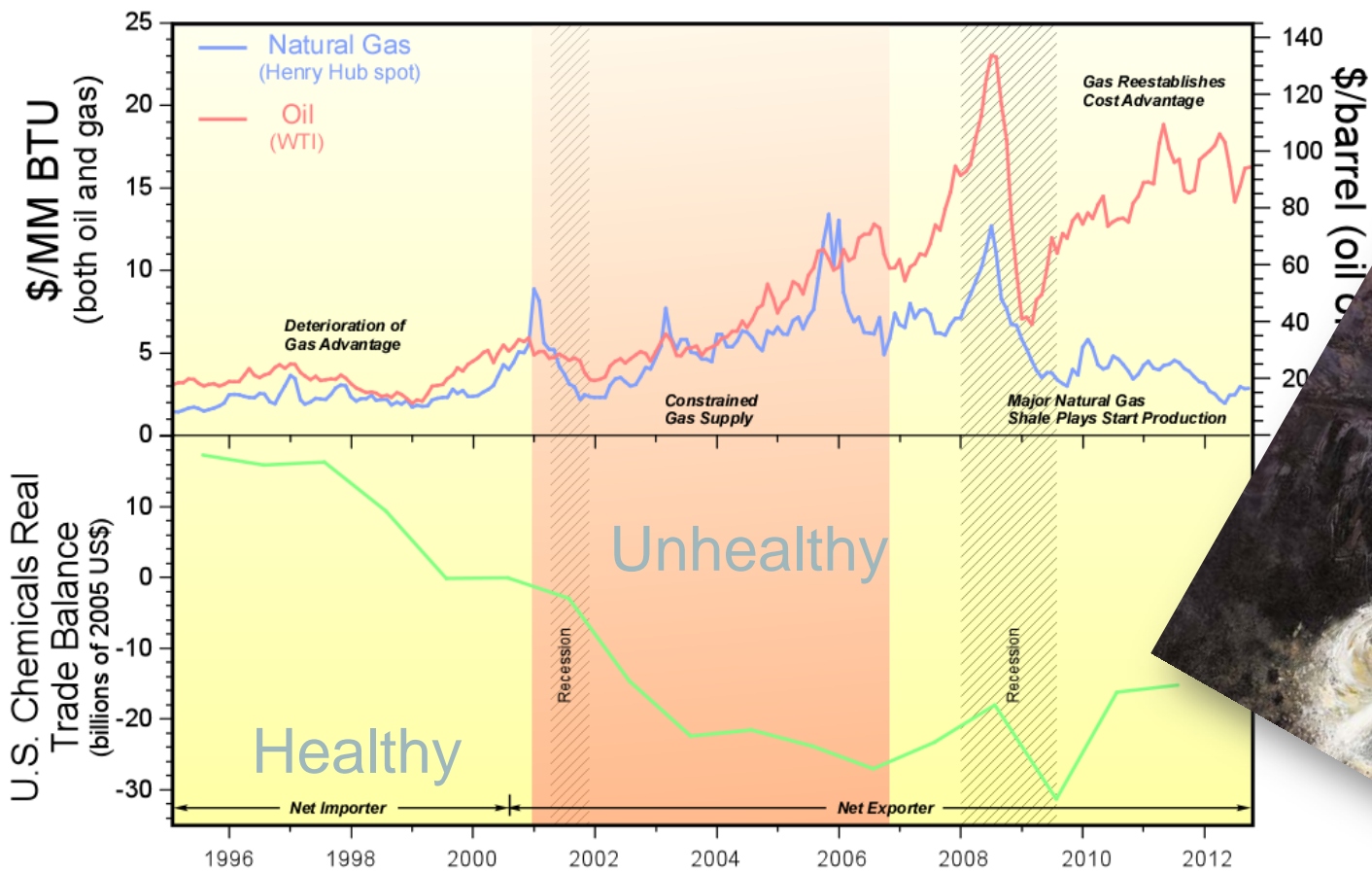


Unhealthy





What Unhealthy Looks Like



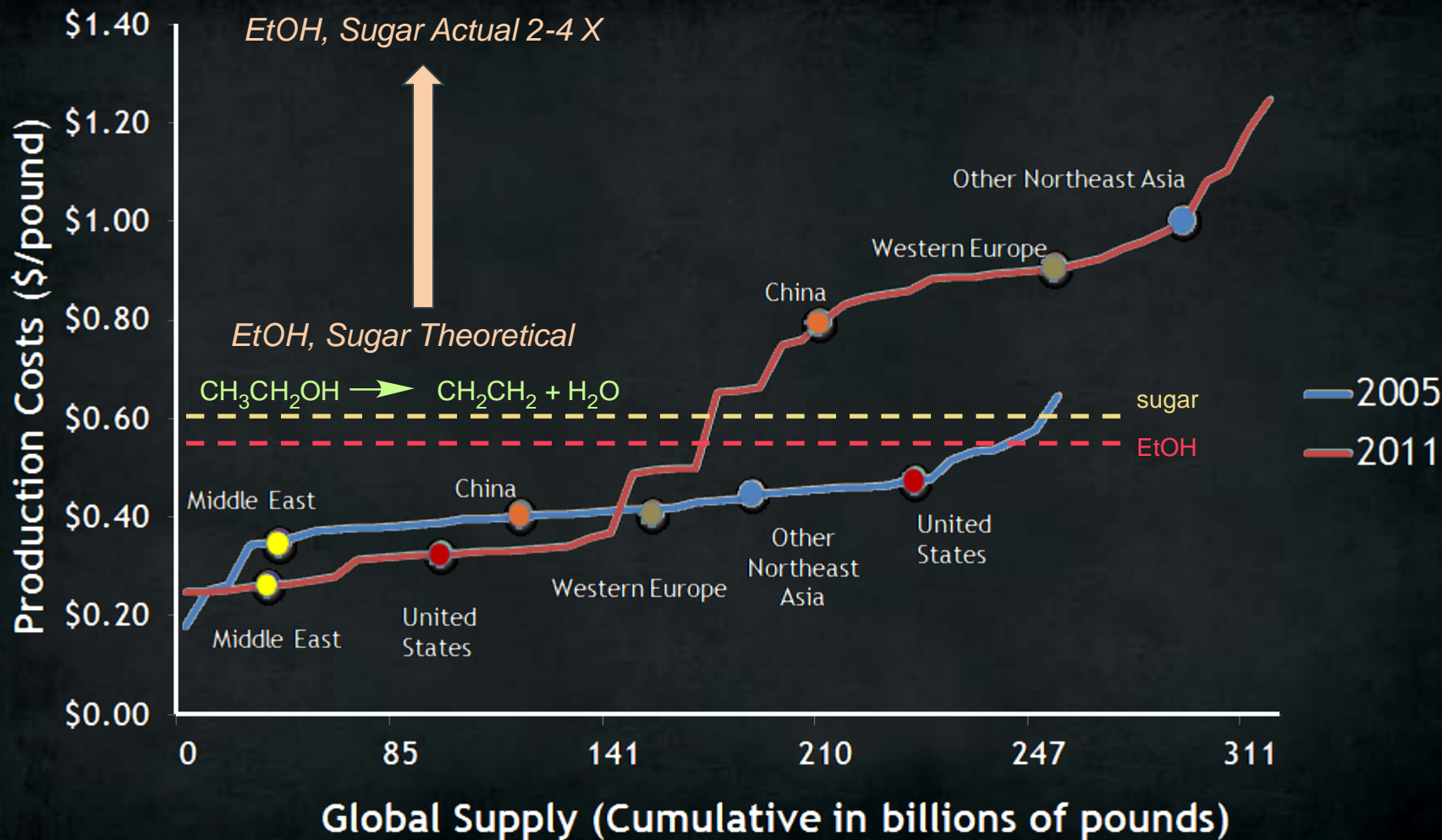
IHS Global Insight, "The Economic and Employment Contributions of Shale Gas in the US", prepared for America's Natural Gas Alliance, December 2011.

US Chemical Industry Rejuvenated



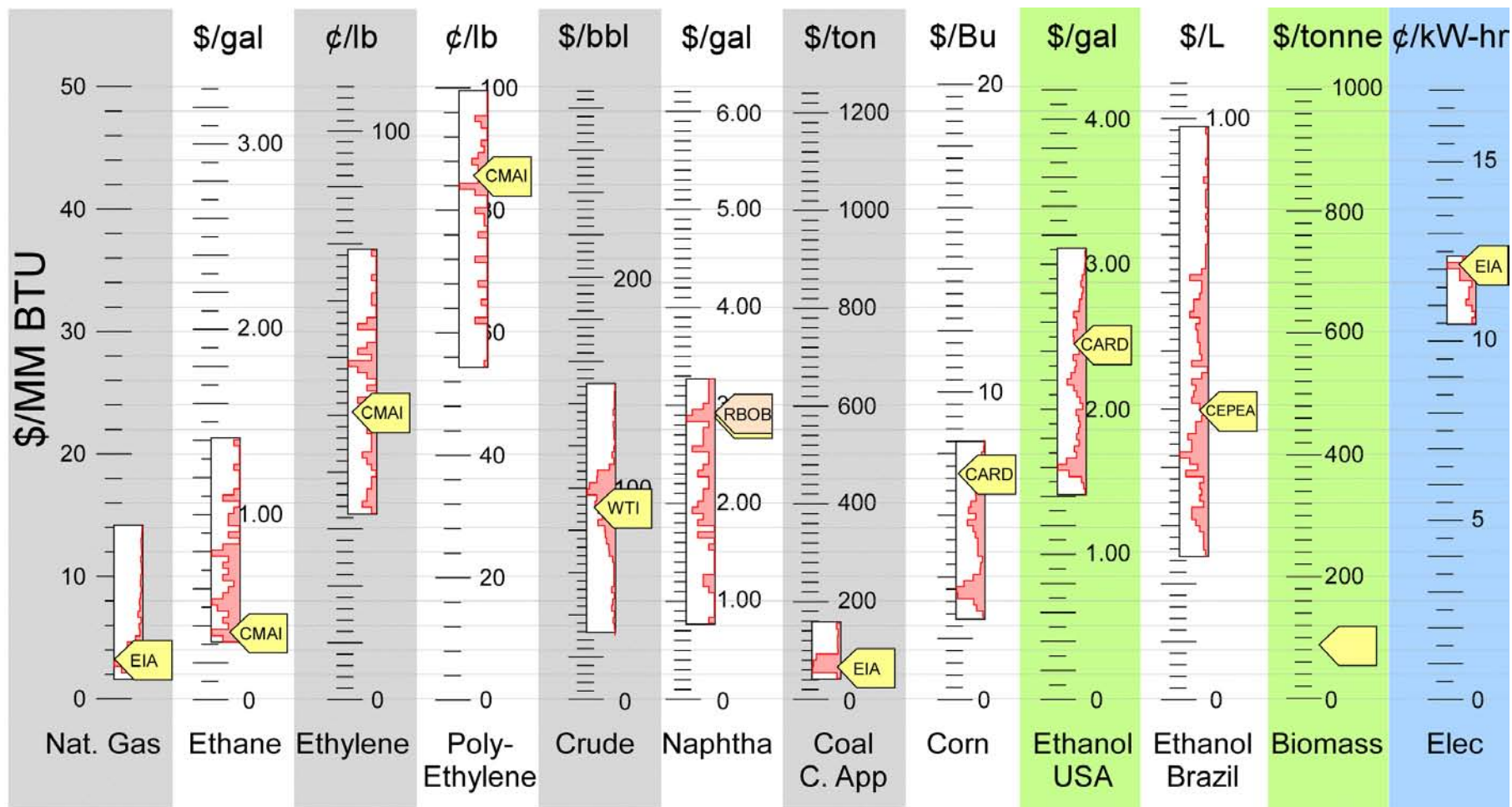


Impact of Low Gas Prices



Owen Kean and T.K. Swift, American Chemistry Council, "Industry-Transforming Natural Gas into Products", National Academy Forum on Unconventional Gas, 11 September 2012.

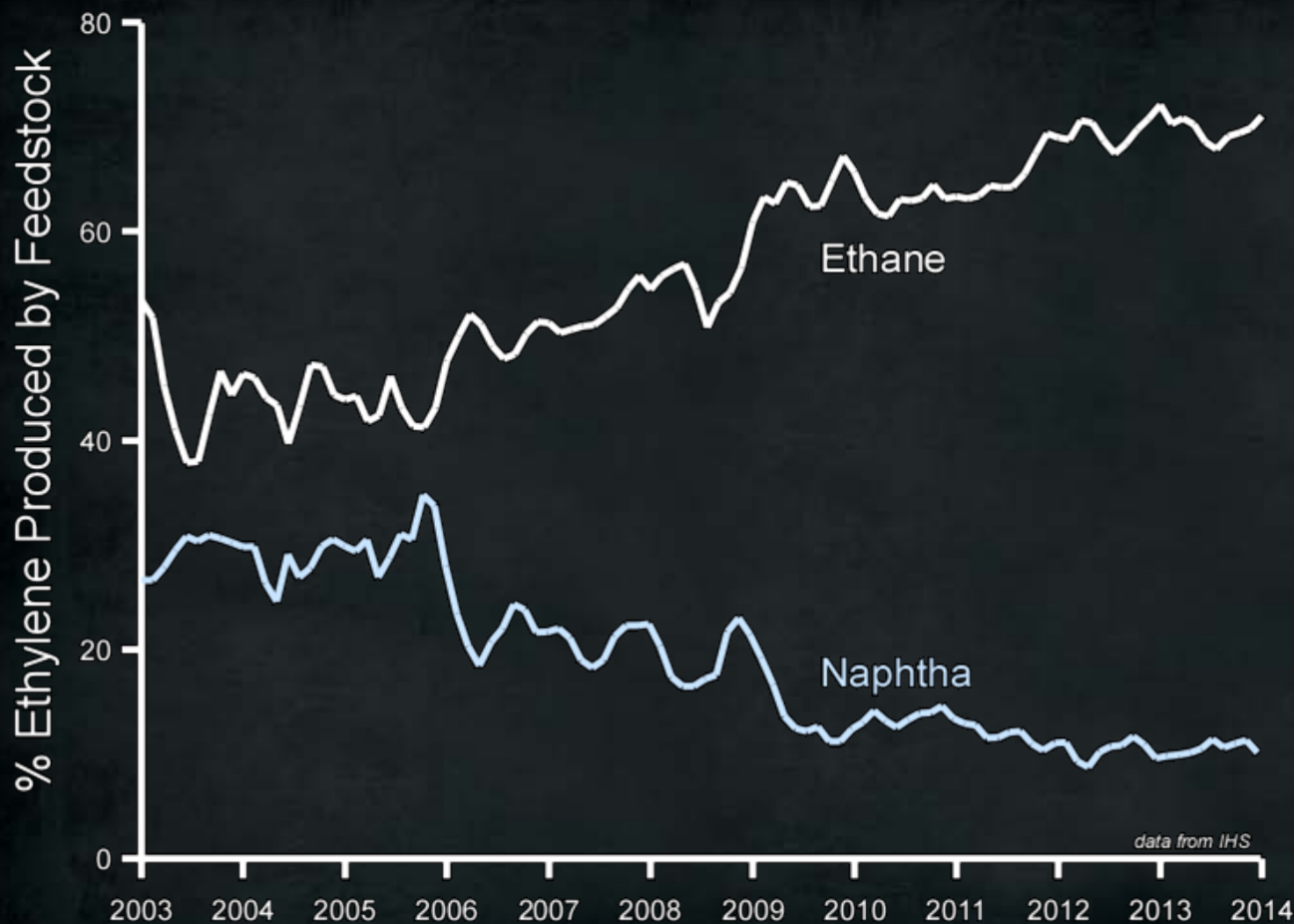
Energy Content



EIA is DOE Energy Information Agency, CMAI is an IHS affiliate, CARD is Iowa State Center for Agricultural and Rural Development, CEPEA is Centro de Estudos Avancado em Economia Aplicada – data for 3-5 years depending on source. updated 18 October 2012



US Trend

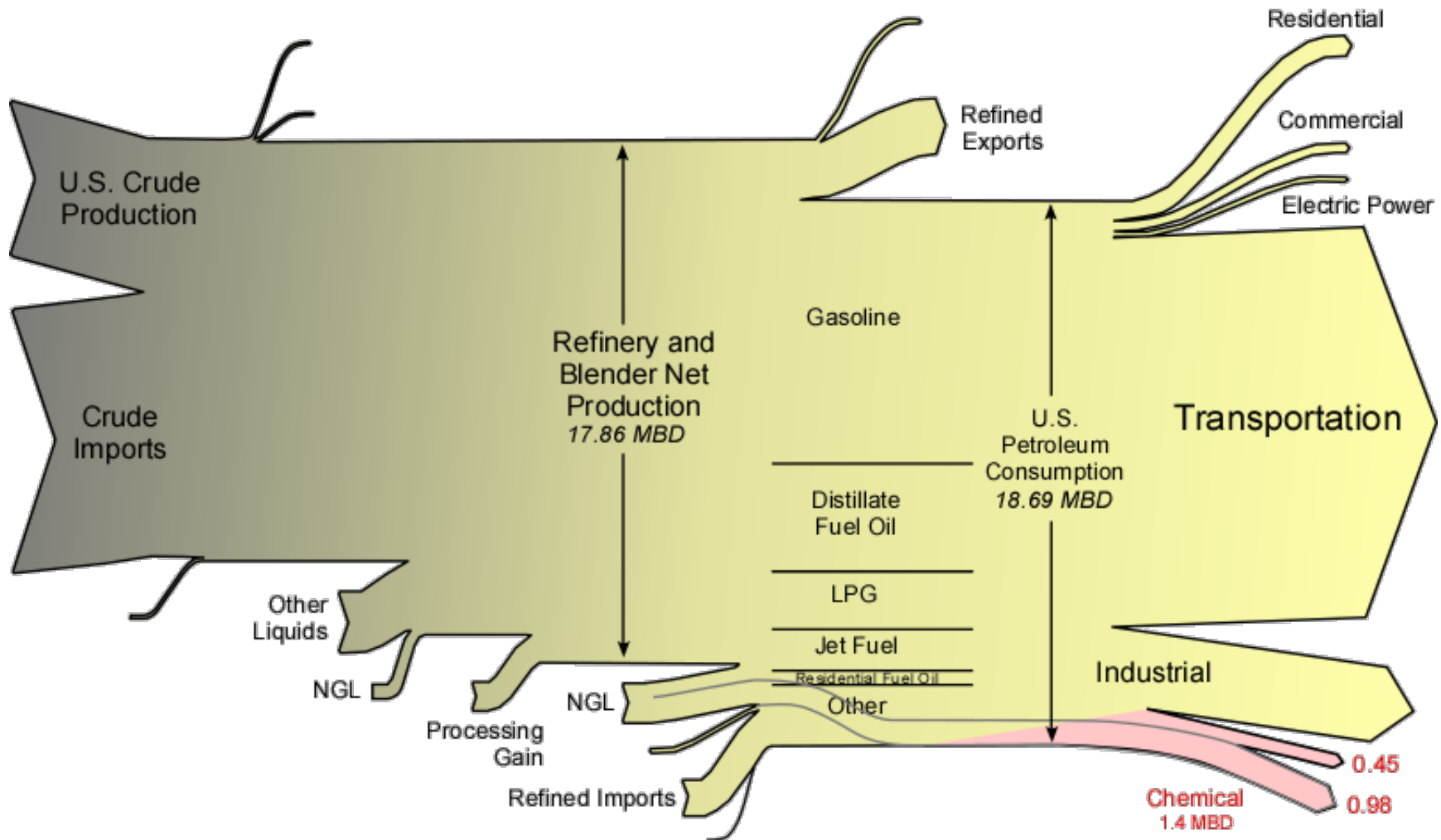


U.S. trend is toward lighter gas cracking and it is an old trend

Implications:

- less propylene
- less butadiene
- less benzene

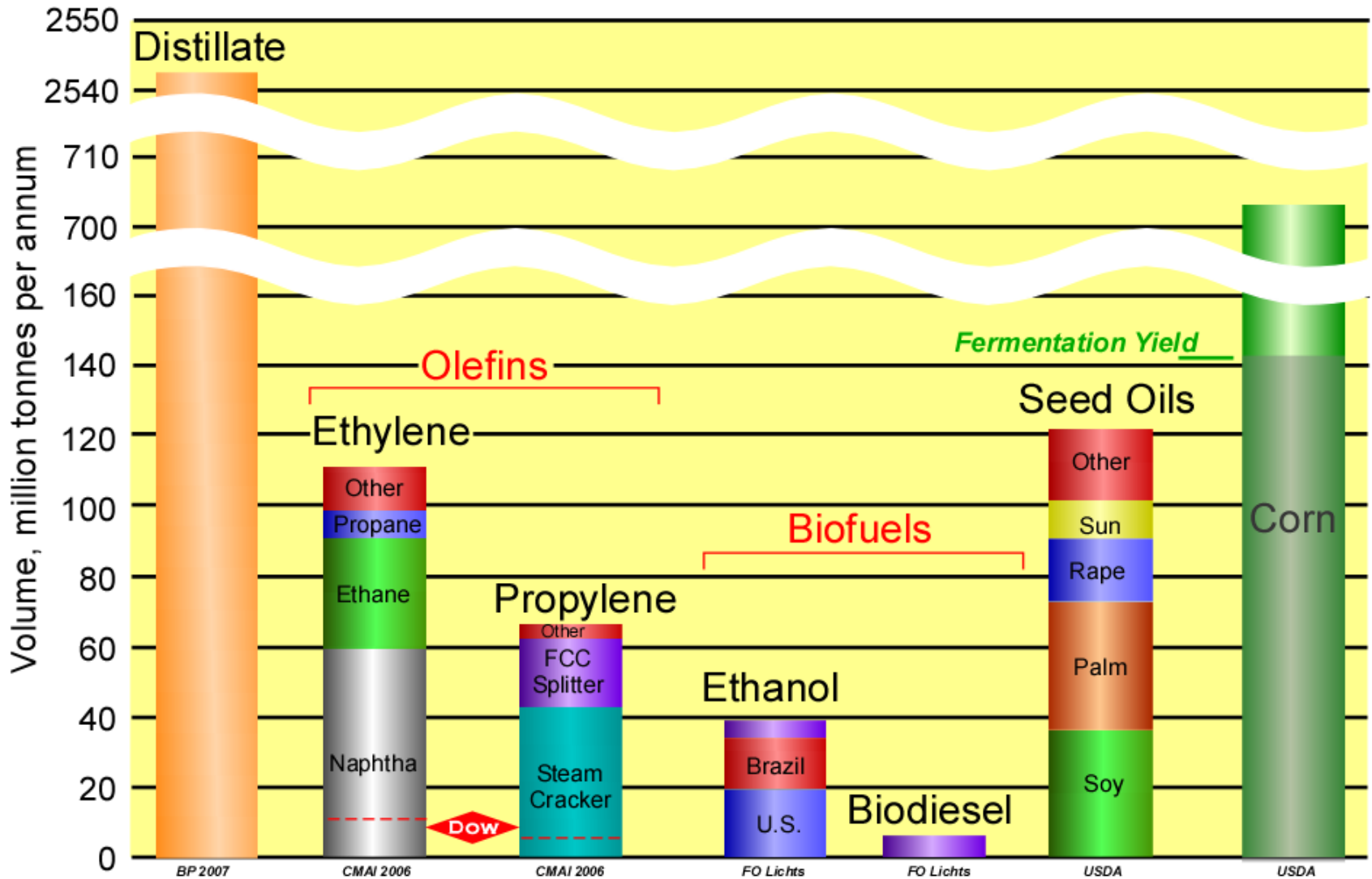
Petroleum Flow 2009



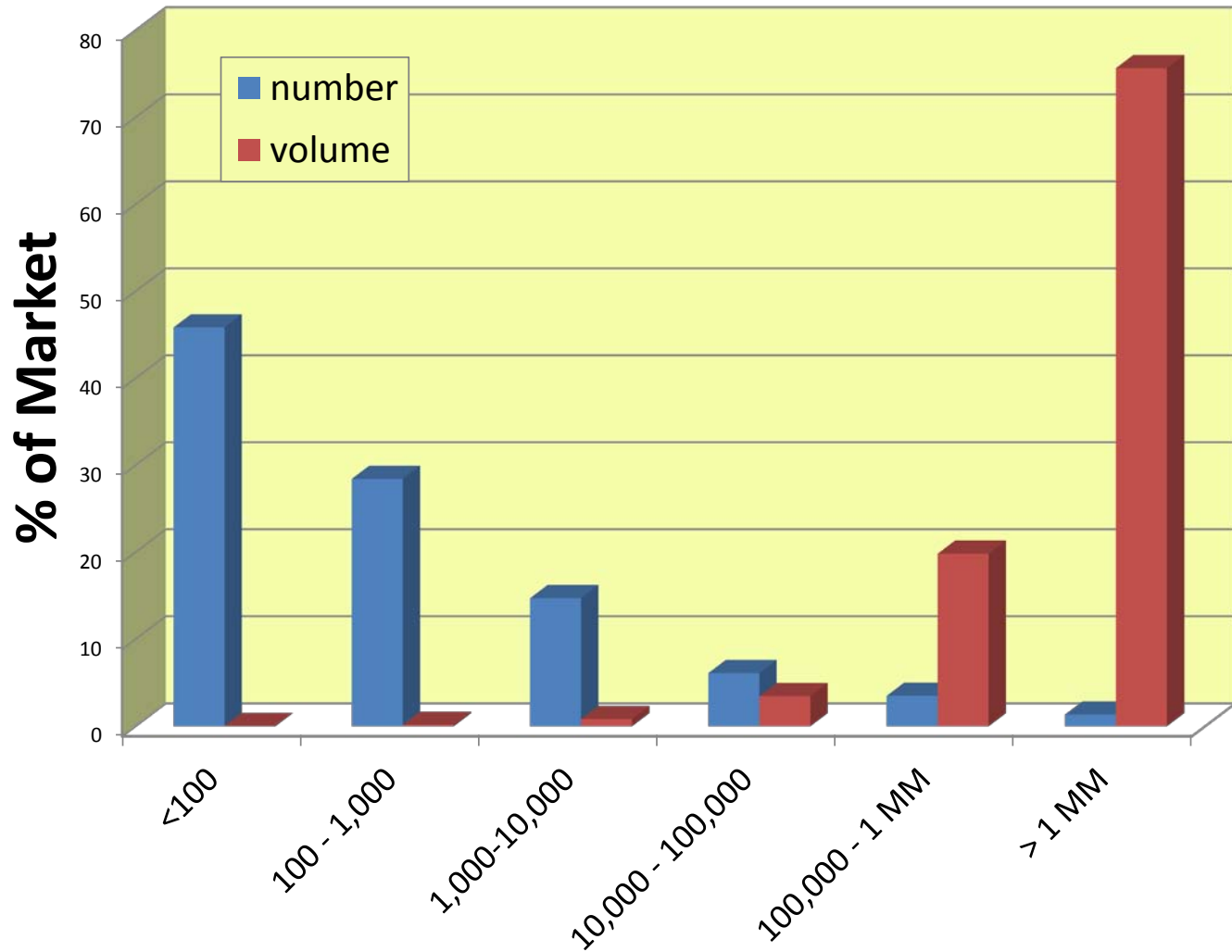
EIA, "Annual Energy Review 2009", August 2010, DOE/EIA-0384(2009) and Sean Davis, "SRI Petroleum Liquid Feedstocks", June 2010



Global Commodity Production

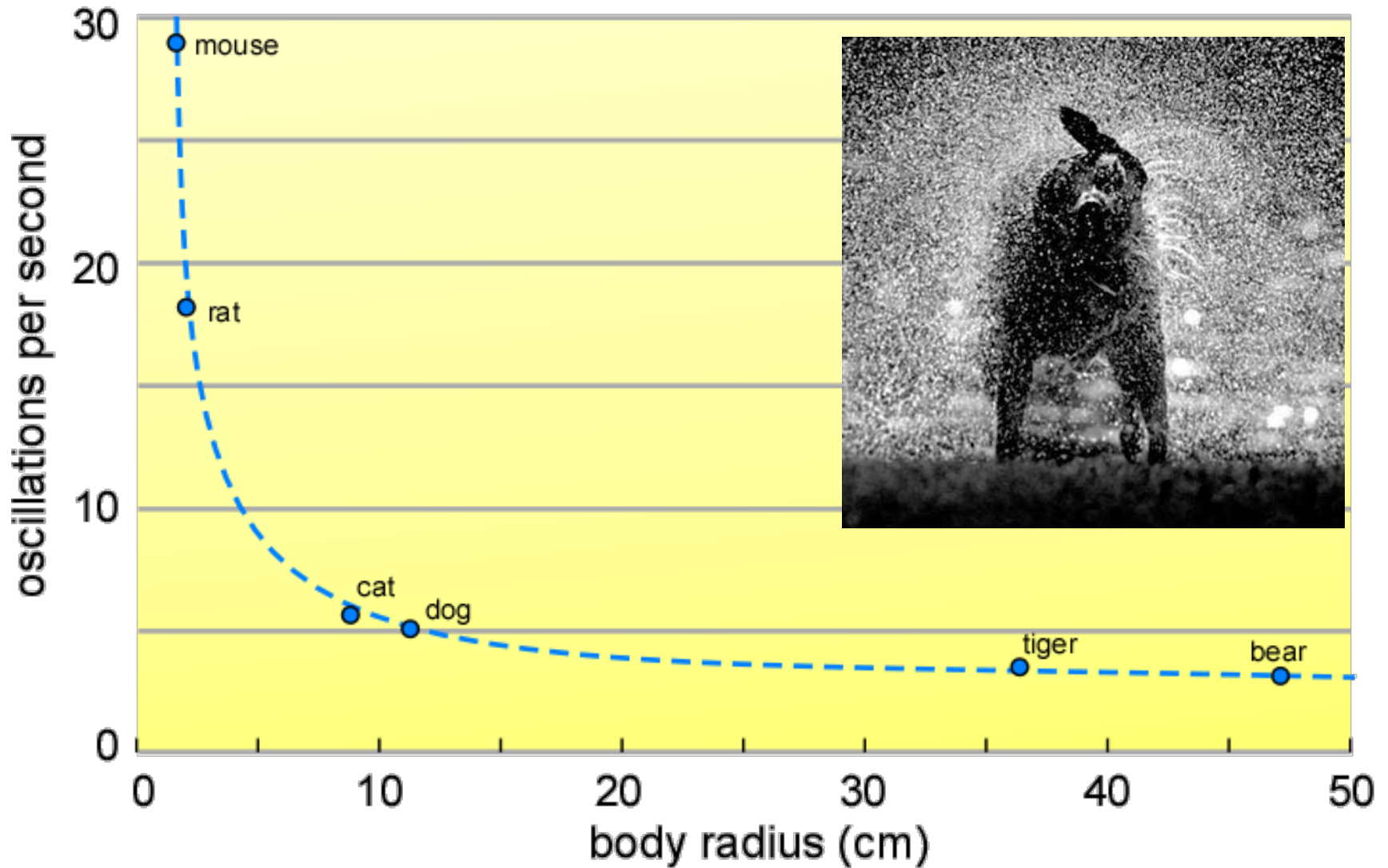


Scale Falls Quickly



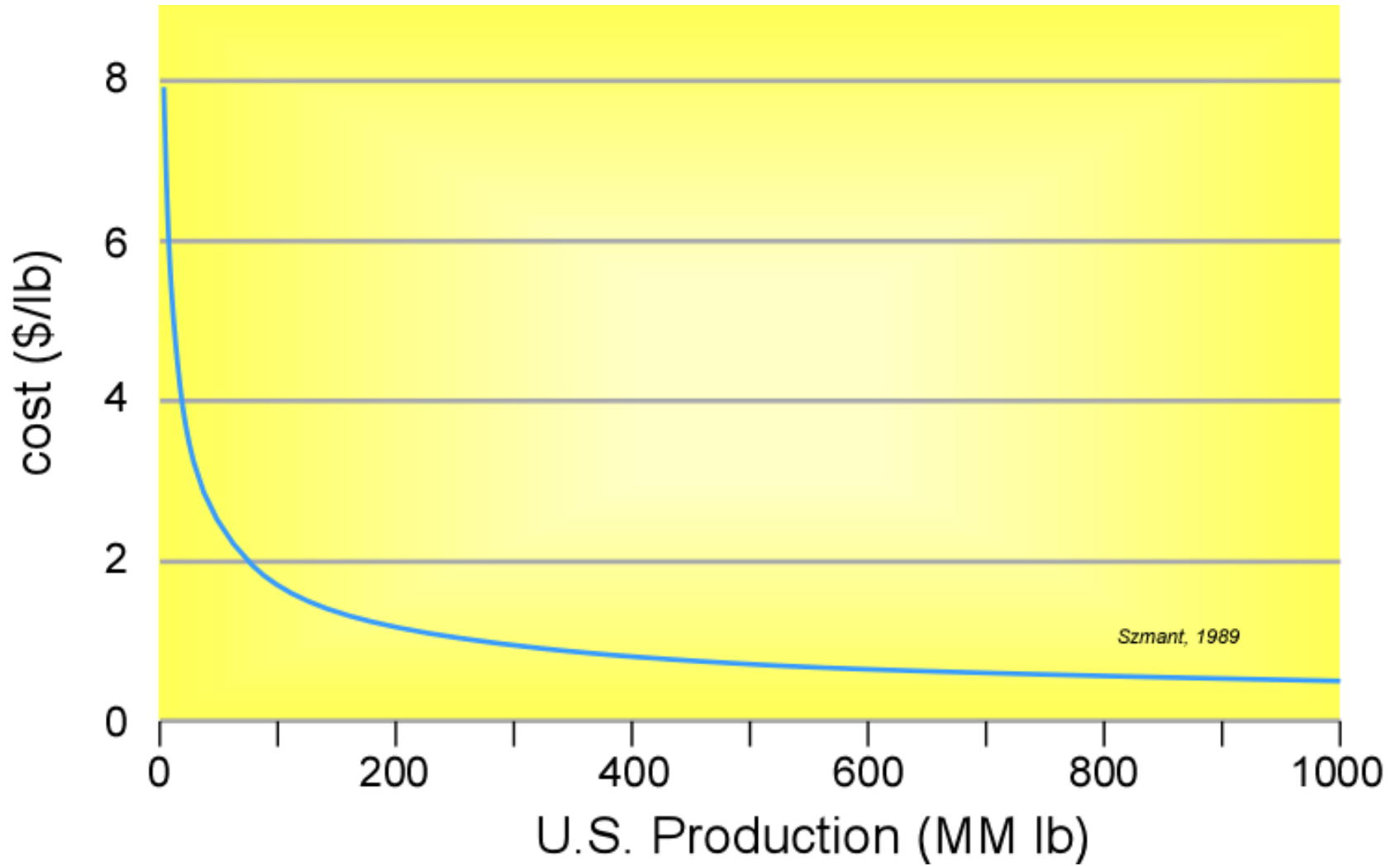
Production Scale (metric tonnes per annum)

Interesting Correlation

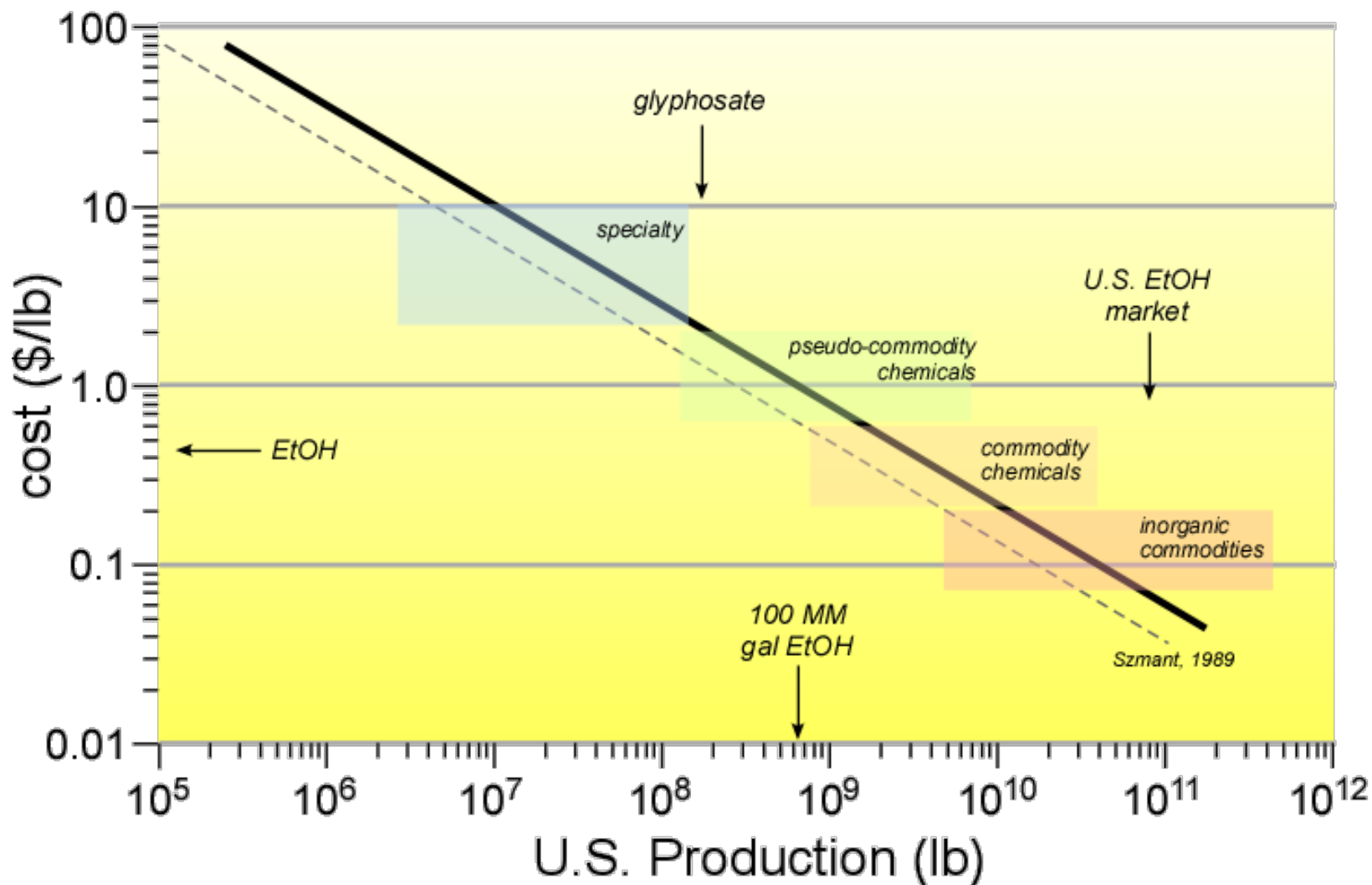


Andrew Dickerson, Grant Mills, Jay Bauman, Young-Hui Chang, David Hu, The Wet-Dog Shake, Fluid Dynamics, 15 October 2010.

Scale Matters!



Most Common Version





Green Chemistry Principles

Twelve Principles of Green Chemistry

1. Prevention: It is better to prevent waste than to treat or clean up waste after it has been created.
2. Atom Economy: Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

7. Use of Renewable Feedstocks: A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

8. Reduce Derivatives: Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modifications, etc.) should be avoided whenever possible, because such steps require additional reagents and can generate waste.

9. Safer Reagents: Reagents (as selective as possible) are preferred over stoichiometric reagents.

10. Design for Degradation: Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

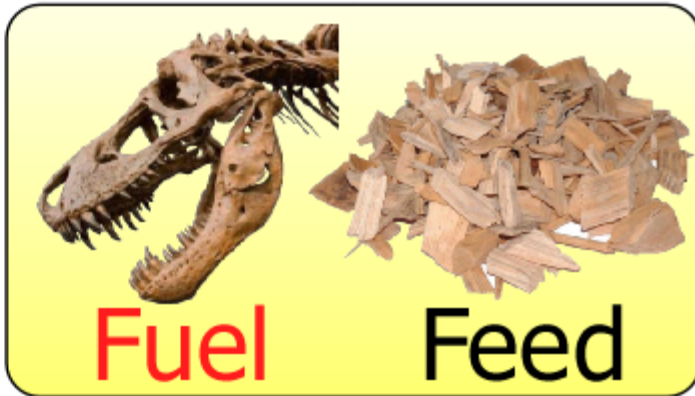
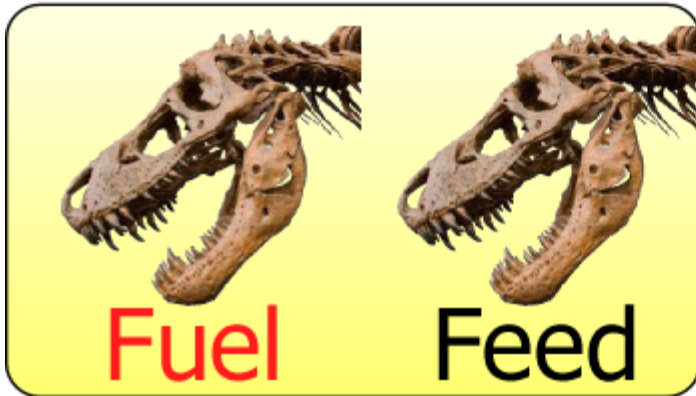
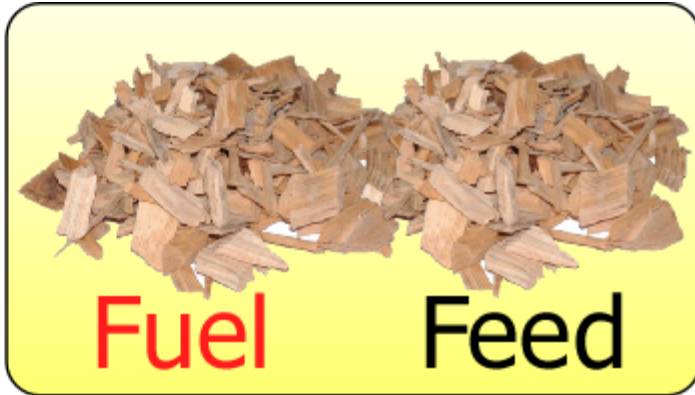
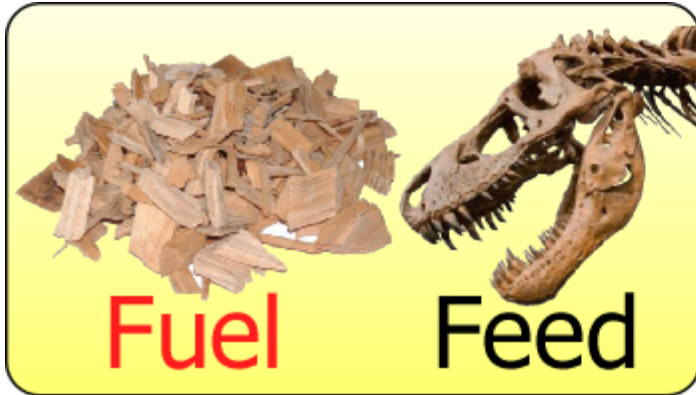
11. Process for Pollution Prevention: Analytical procedures should be further developed to allow for real-time monitoring and control prior to the formation of pollutants under various circumstances.

12. Chemistry for Accident Prevention: The form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Use of Renewable Feedstocks: A raw material or feedstock should be renewable rather than depleting whenever technically and economically feasible.



Two Carbon Flavors



Demand for Bioproducts?

PANTENE PRO-V [natureFUSION]

UP TO **10X**
STRONGER HAIR*

P&G FUTURE FRIENDLY™
NEW
PLANT-BASED
BOTTLE
(up to 59% excluding cap)

*strength against damage vs. non-conditioning shampoo ©2011 P&G

The pure, crisp taste of DASANI now comes in a better bottle. A bottle up to 30% made from plants that is still 100% recyclable.

DASANI.

Pure Taste in a Better Bottle

DASANI.

plantbottle®
Up to 30% made from plants
100% recyclable plastic bottle

P&G FUTURE FRIENDLY™
NEW
PLANT-BASED
BOTTLE
(up to 59% excluding cap)

*strength against damage vs. non-conditioning shampoo ©2011 P&G

Delta Airlines Napkin
April 2012

Midland Daily News
1 January 2012



Plant Bottles



“At full capacity, it is estimated the facility will produce 500,000 metric tons of material per year. By using plant-based materials instead of non-renewable materials, the facility will remove the equivalent of 690,000 metric tons of carbon dioxide or the equivalent of consuming more than 1.5 million barrels of oil each year.”

Coca-Cola, 27 Sept 2012



US consumption is 19 million barrels per DAY.
World, 90 million.

Vacuum The Air?





What Impact?



PET



30%



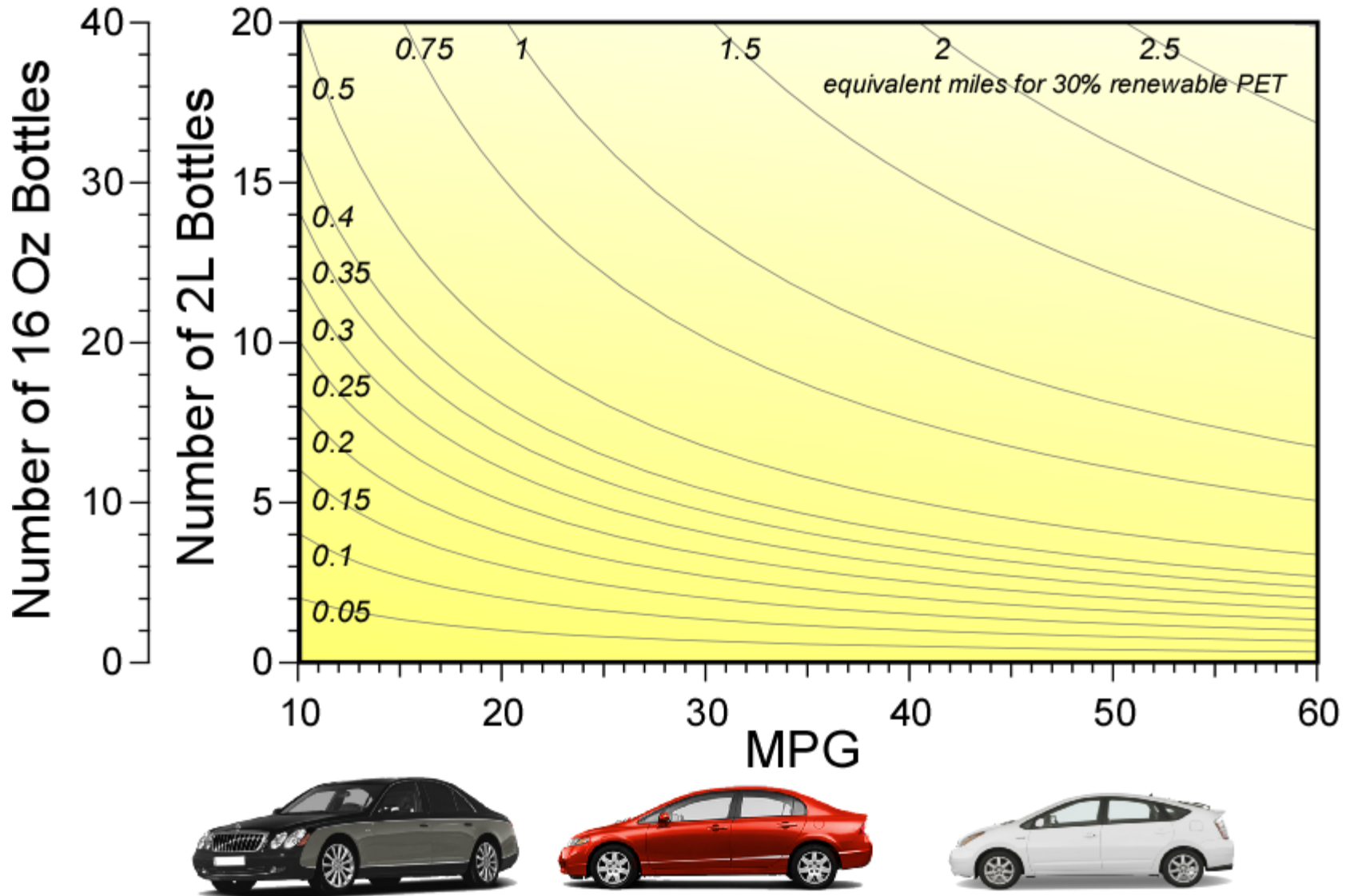
100% renewable PET (not yet available) would required ~80 2 L bottles to offset burning 1 gallon of gasoline or about 400 at today's 30%

| 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 |

data from HIS, 2012 ERS USDA, 2011 National Mining Assoc., World Bank



PET Comparison



LCA of Polymers

Biopolymers rank in the middle of LCA rankings

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



LCA of Polymers

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 |

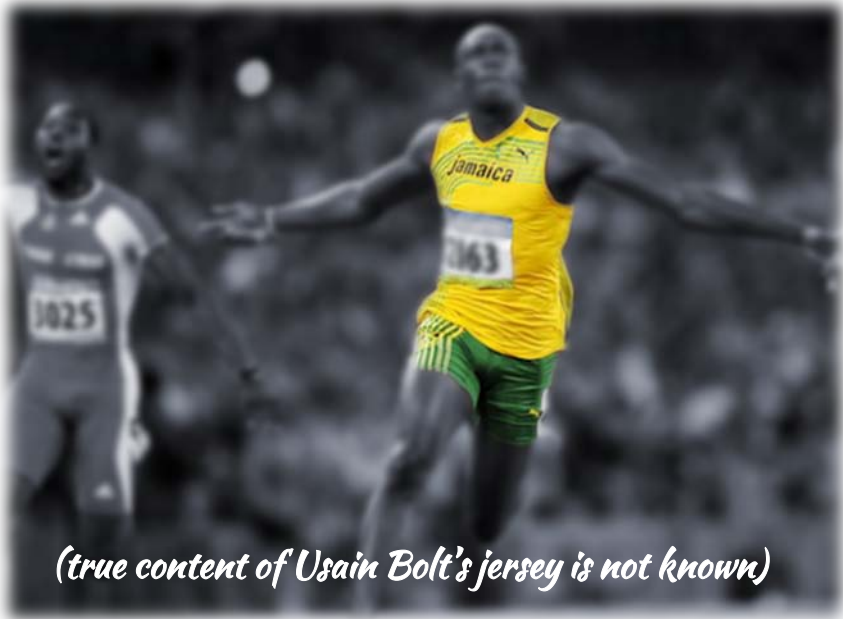


Rearranging the Deck Chairs on The Titanic



Which is Better for the Environment?

A polypropylene jersey



A polyester track suit

Sustainable Apparel Coalition Higgs Index



How Fabrics Stack Up

A look at how the Higg Index compares the environmental impact of materials used in apparel and footwear. The higher the score, the more sustainable the material. See fuller scores and rankings of more than 40 common materials at WSJ.com/LifeStyle.

| MATERIAL | SCORE | COMMENT |
|------------------------------------|-------|---|
| Polypropylene | 36.1 | A byproduct of oil refining and natural-gas processing, this material—often used in long underwear—uses little land, water or energy and produces little waste. Low use of carcinogens, endocrine disruptors or other toxic chemicals. |
| Silk fabric | 30.7 | Chemically clean and leaving little waste, it scores high for sustainability, though its production does emit a high level of greenhouse gases. |
| Leather (corn-fed) | 27.5 | There is very little waste in its production compared with other materials, so it has a higher overall score than many materials, even though it ranks lower on land use; cows require large amounts of feed (which in turn requires pesticides and fertilizer) and pasture land. Animal-welfare issues aren't considered in the score. |
| Cotton | 26.8 | Takes a hit for heavy use of land and water, as well as bleaches and other chemicals used in processing, which puts it in a middling ranking for sustainability, despite its green reputation. |
| Wool | 19.3 | Because it requires both ample land to produce and toxic, energy-intensive chemical processing (to turn the scratchy fibers soft enough for modern sensibilities), wool scores low for sustainability. |
| Bamboo rayon-viscose fabric | 18.9 | Often billed as green by manufacturers, this material scores miserably because of the heavy processing, high waste, and energy use required to turn bamboo into a fabric. |

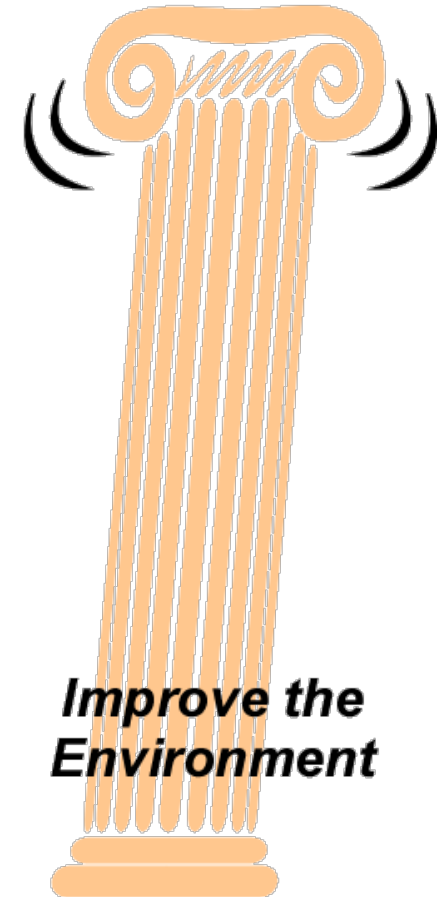
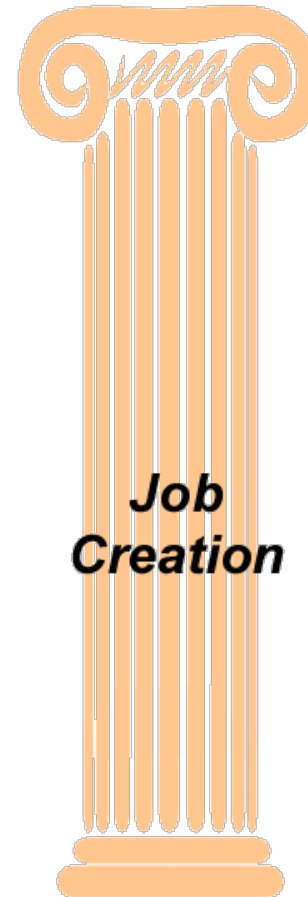
Photo Researchers Inc. (sheep, refinery); Alamy (cattle); Nike (shirt); Getty Images (3)

Biomaterials Program

Much Smaller

**Reduce
Petroleum**

**Energy
Security**



Signs of Hope



Conclusions

- You now can MacGyver a measuring cup if you ever need to. (Hopefully this has given you and appreciation of the importance of scale)
- Too much hype for the possible and not enough focus on the practical in biofuels and clean tech
 - **Incumbent fossil sources** set the standard for competition
 - Scale wins and biomass availability limits biofuels scale
- **The promise of bioproducts is not the same as biofuels.**
- **Fundamental engineering judgment** is crucial to long term innovation and must lead the discussion about our energy future.

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

- Linus Pauling

Call to Scientists and Engineers

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

We are letting society down!

Which is environmentally better?

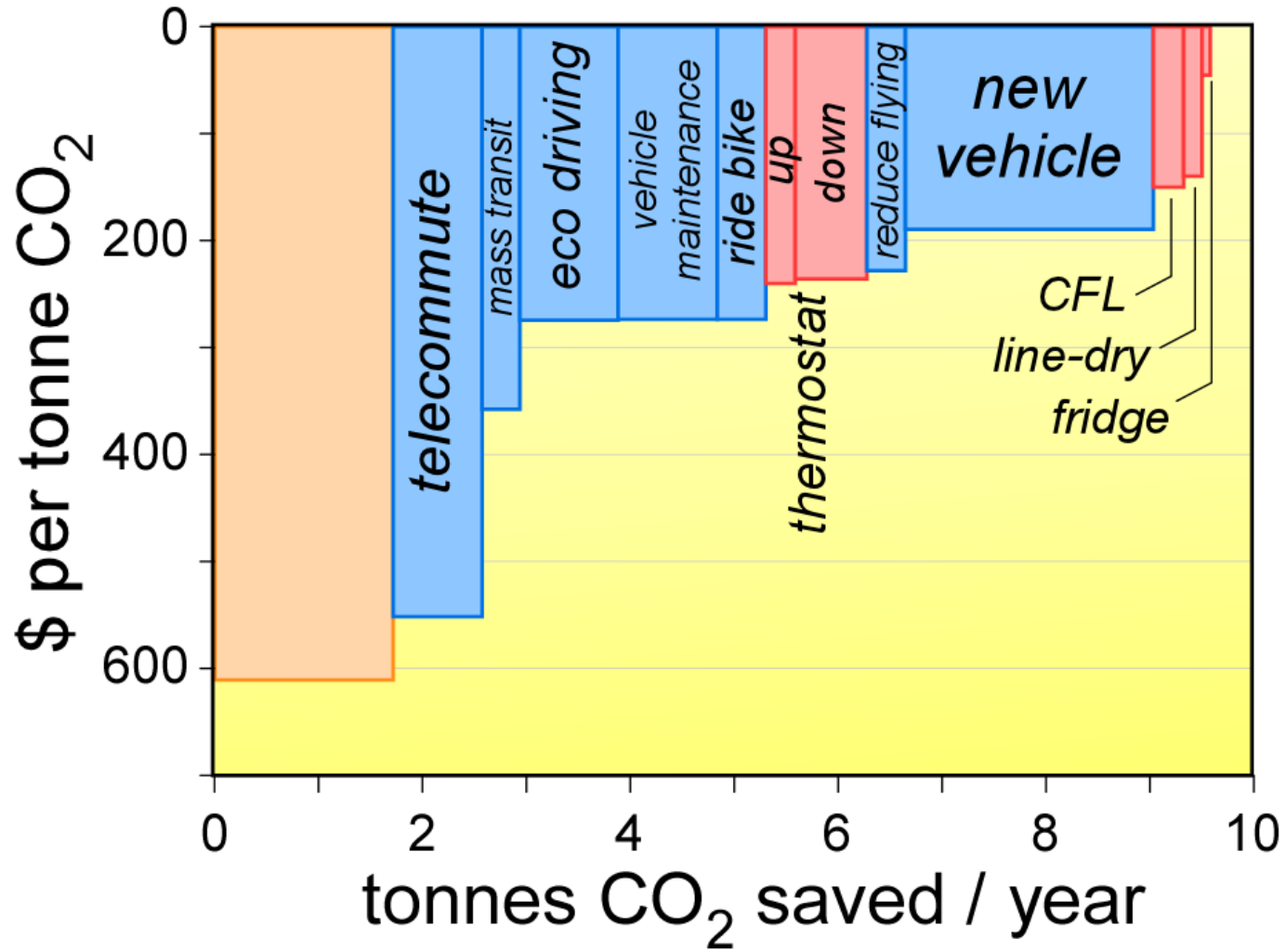
A meat-eater in a Prius



A vegan in a Hummer

Prius is a bit better

Food and Energy are Connected

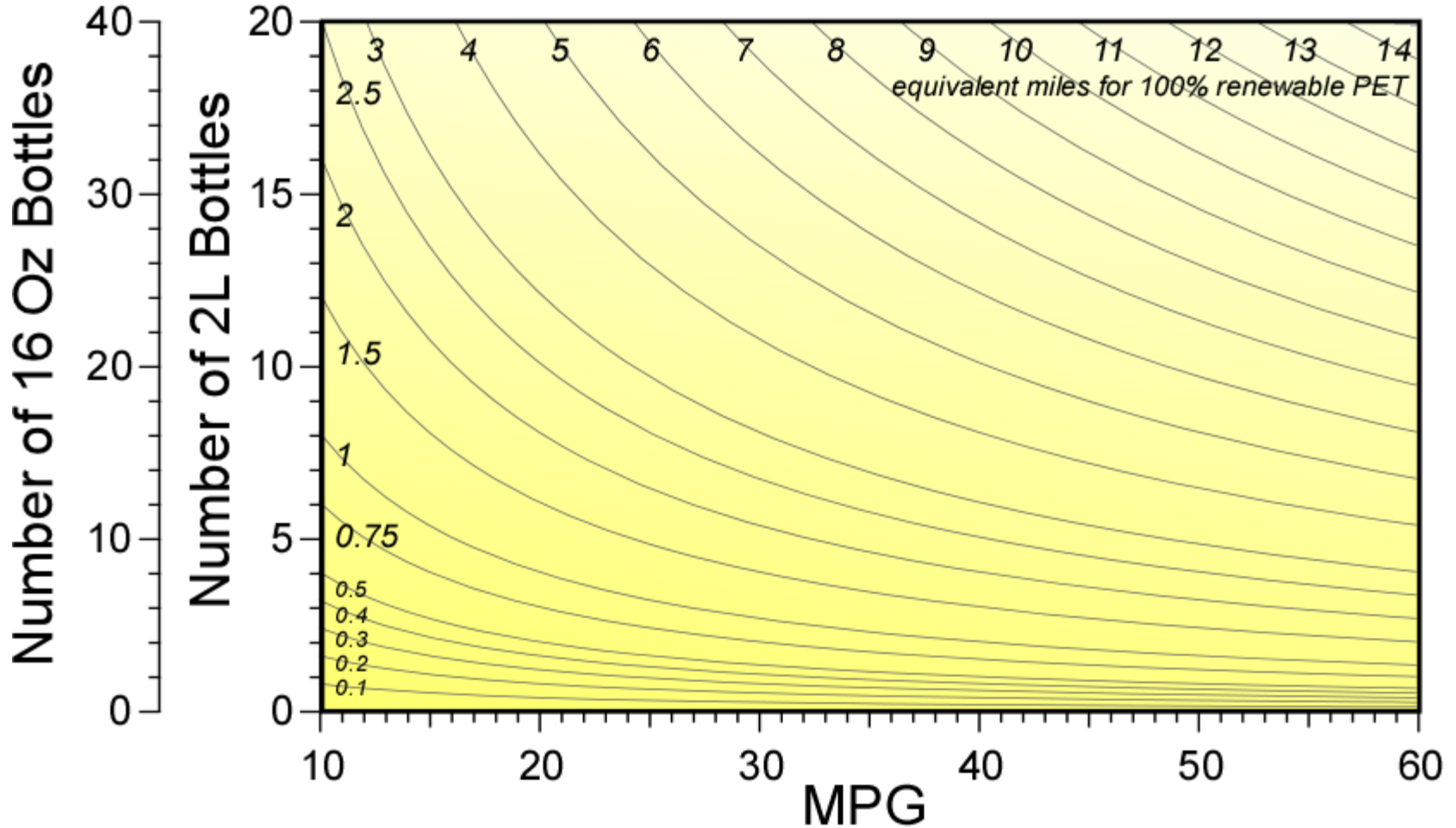


Christopher M. Jones and Daniel M. Kammen; "Quantifying Carbon Footprint Reduction Opportunities for U.S. Households and Communities", *Environ. Sci. Technol.*, 2011, 45 (9), pp 4088-4095; DOI: 10.1021/es102221h



Thank You

PET Comparison



Recognizing 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 or 15, 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

wetlands and forests, 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."

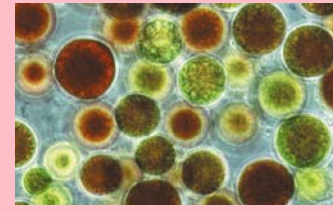
Robert Rapier



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, exited the JV in 2004.

NatureWorks

Cargill

THE WALL STREET JOURNAL

"Sun Chips Bag to Lose Its Crunch"



Photo: Associated Press

Bio based packaging launched in 2009 but 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

Metabolix

Which Uses Less Total Energy To Go A Mile? (option 3)

*2011 compressed
natural gas Civic*



*2011 Leaf
electric vehicle*



*2011 Civic
using E-85*



U.S. average gas

current corn ethanol

natural gas combined cycle

Which Uses Less Total Energy To Go A Mile? (option 3)

*2011 compressed natural gas
Civic*



U.S. average gas

*2011 Leaf electric
vehicle*



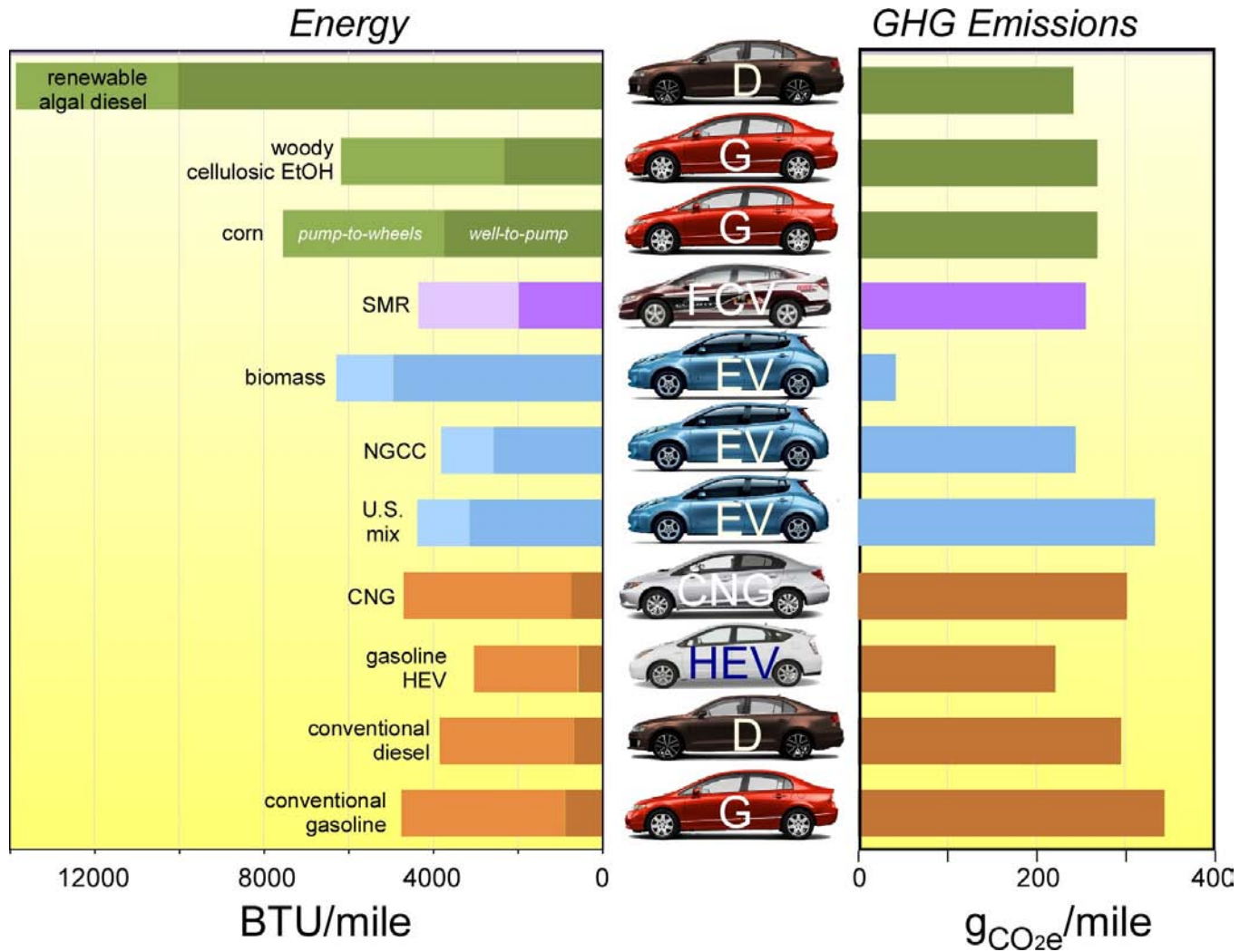
2011 Civic using E-85



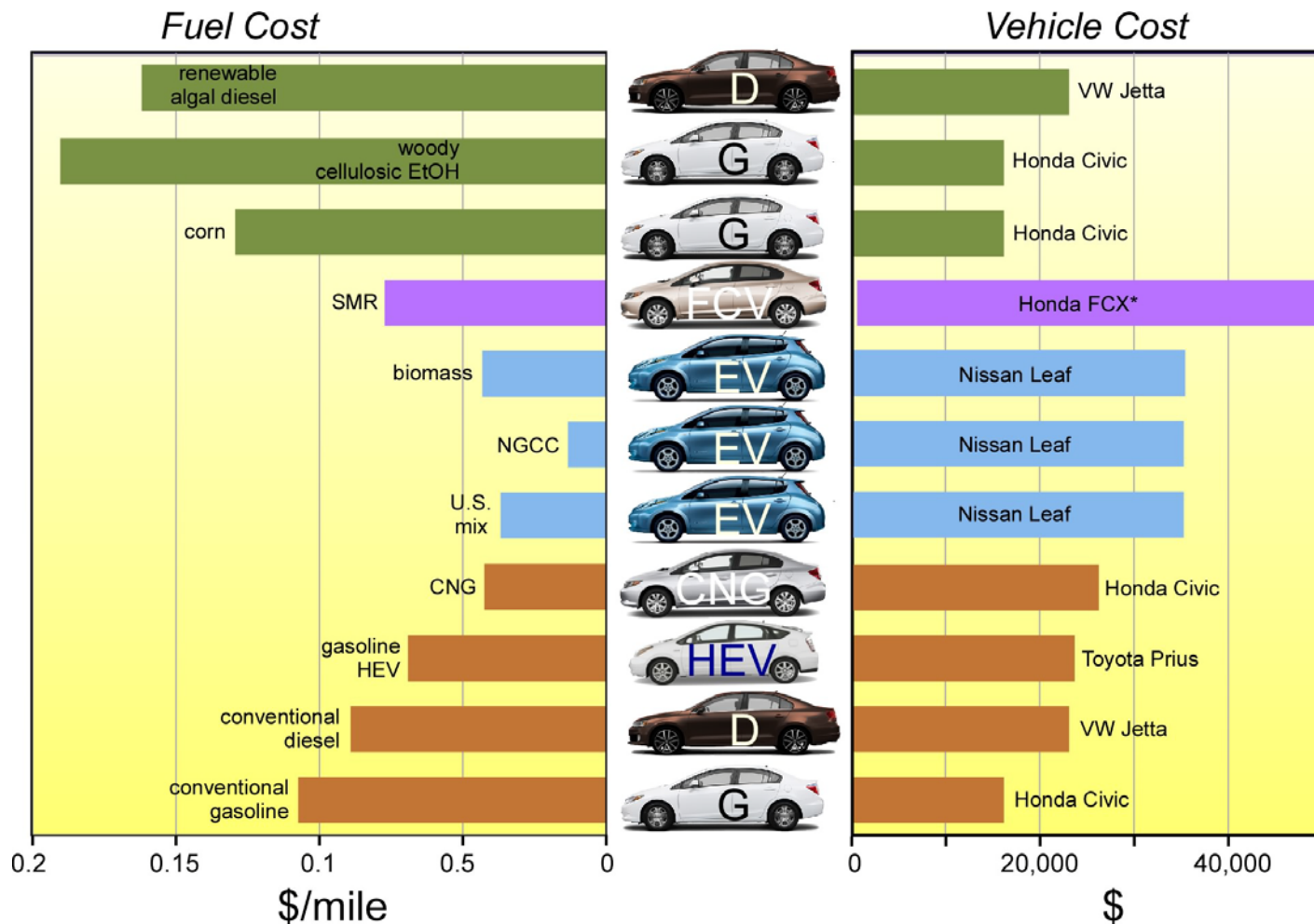
*current corn ethanol
U.S. average power*

natural gas combined cycle

Electrification Beats Biofuels

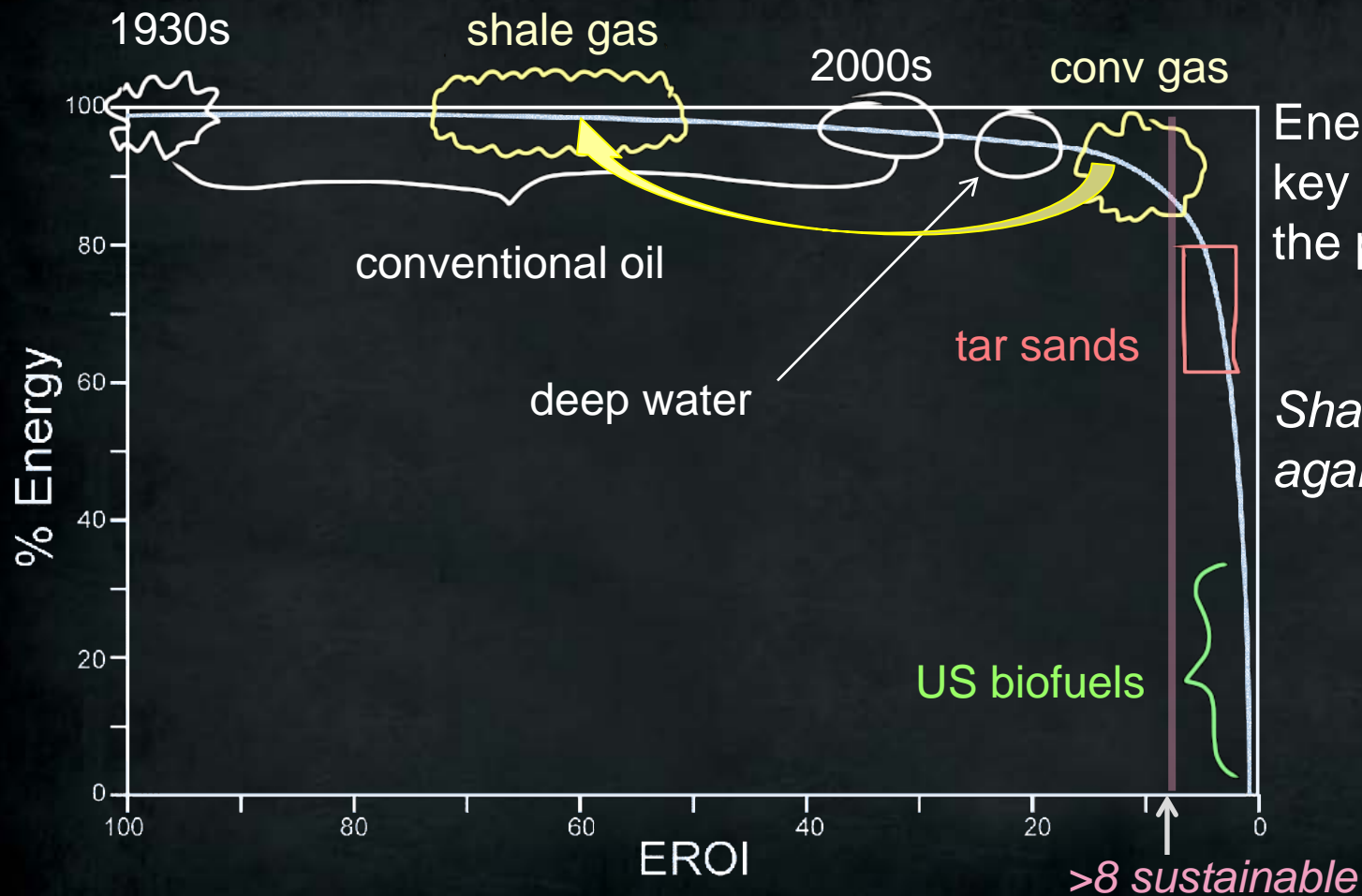


Electrification Beats Biofuels





Thermodynamic Entitlement



Energy return is a key parameter when the products are fuels

Shale gas goes against recent trends.

What Consumers Buy

