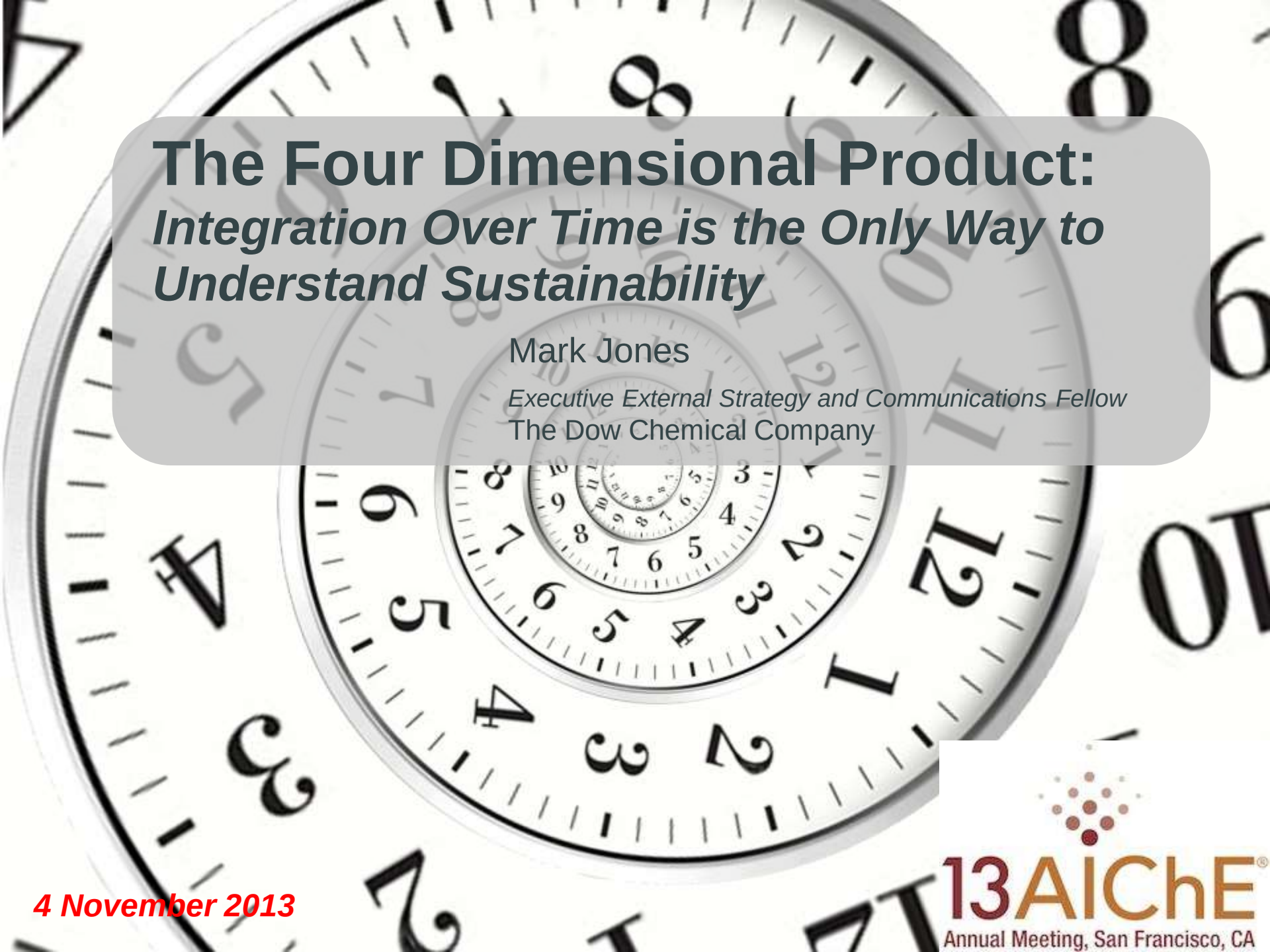
The Four Dimensional Product:
Integration Over Time is the Only Way to Understand Sustainability

Mark Jones
Executive External Strategy and Communications Fellow

The Dow Chemical Company
4 November 2013

13AIChE
Annual Meeting, San Francisco, CA



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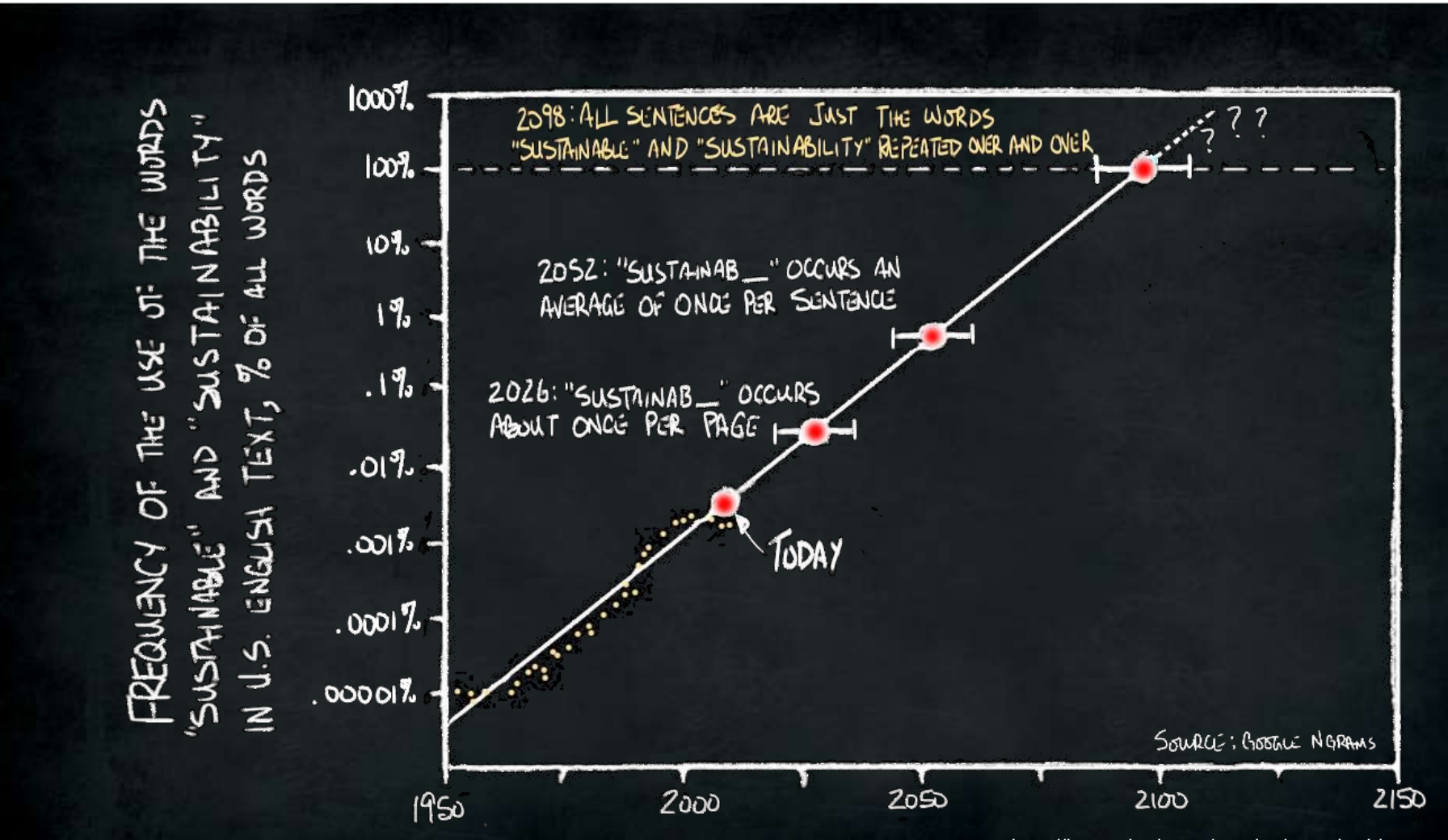
Sustainability is Unsustainable?



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

Plastic Cups

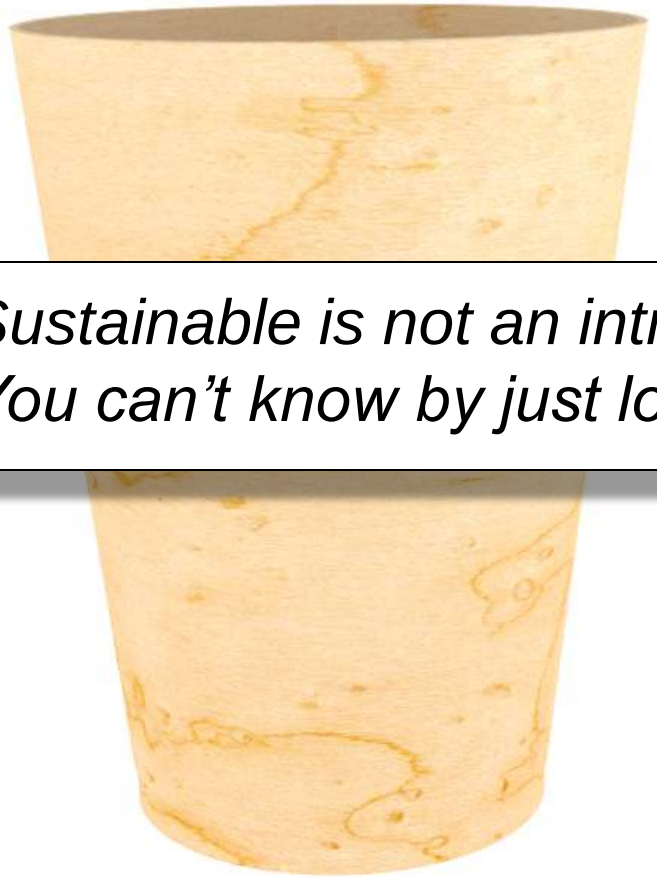
Ordered

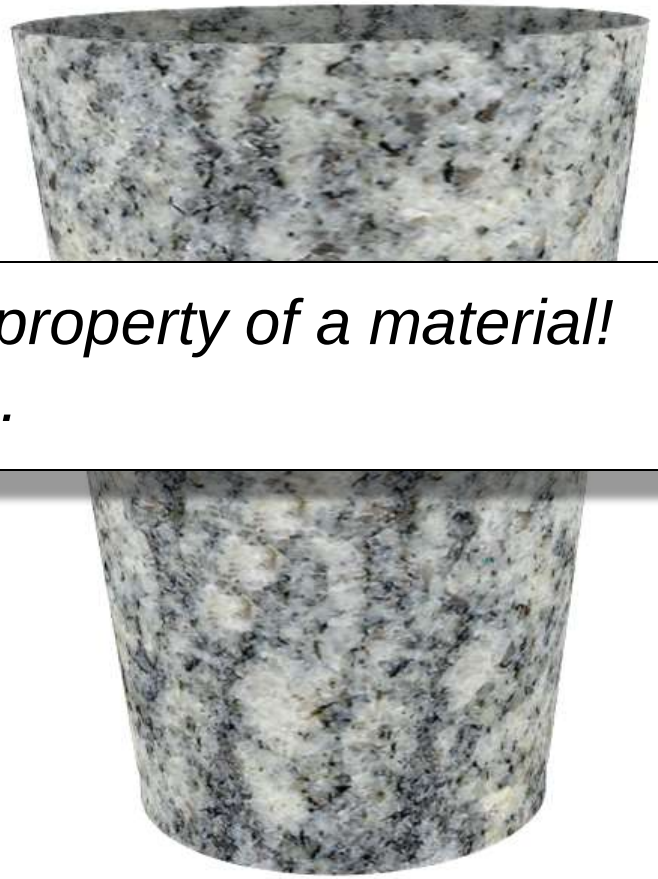
Disordered

Sustainable?

Is this Cup Sustainal

Is this Cup Sustainable?





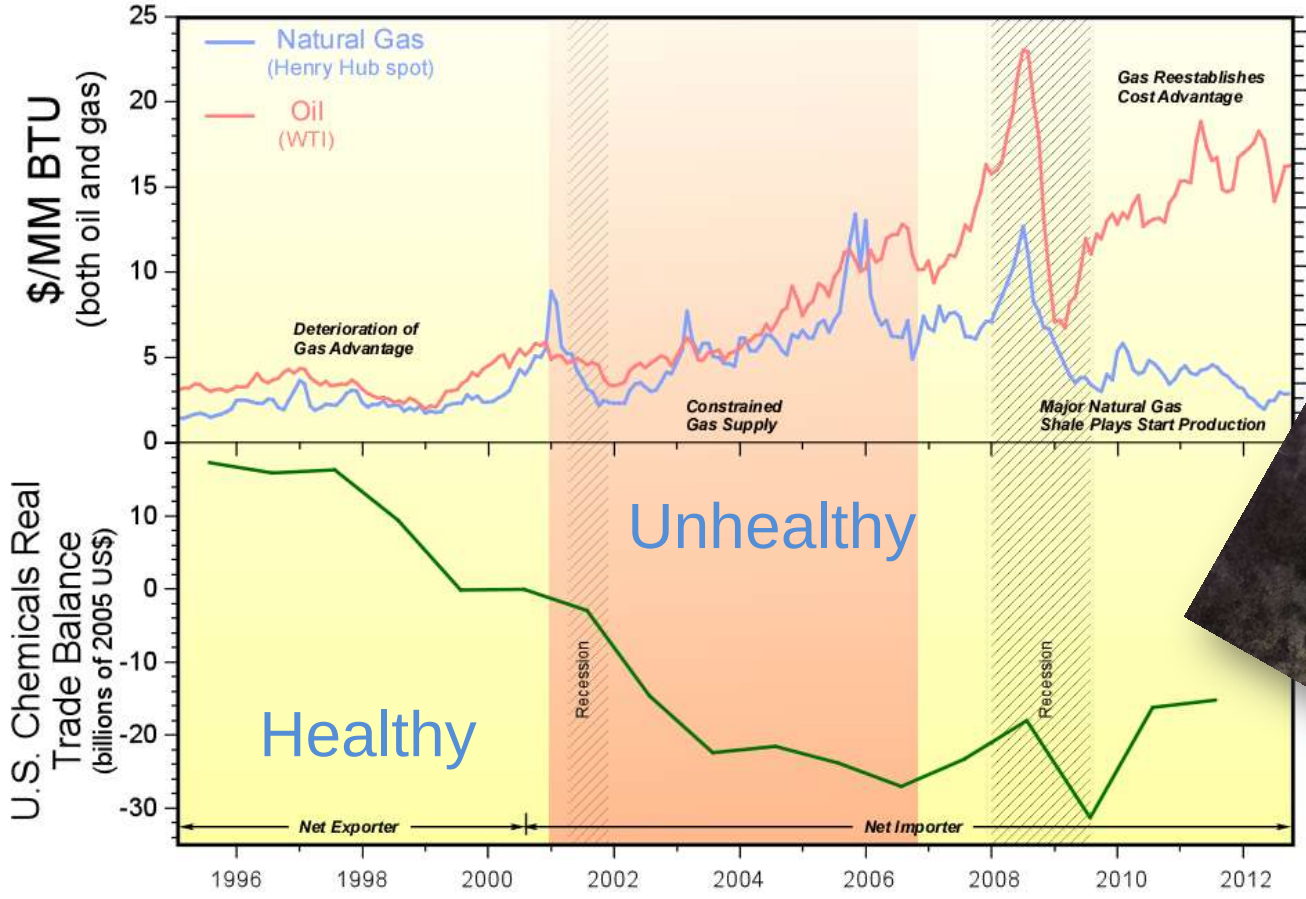
Sustainable is not an intrinsic property of a material!
You can't know by just looking.

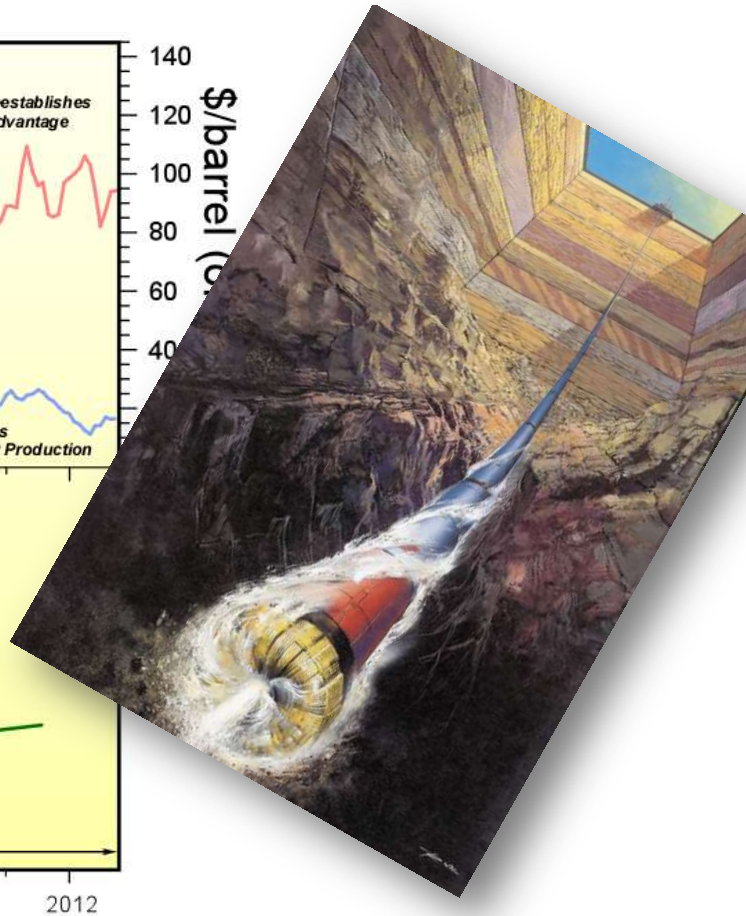
How about this one?

Sustainability Is A Balance

What Unhealthy Looks Like

Chemical Industry Health



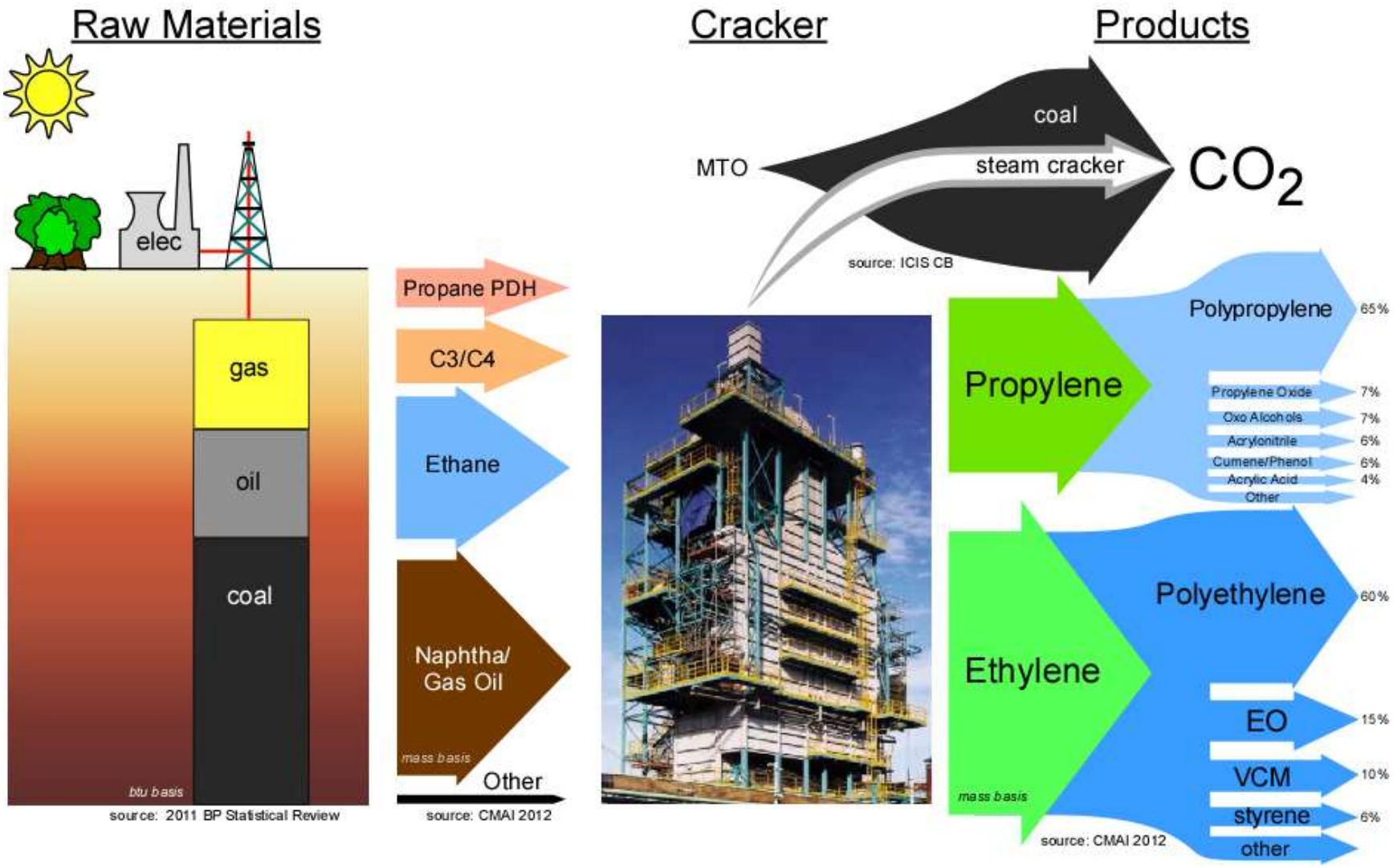


IHS Global Insight, "The Economic and Employment Contributions of Shale Gas in the US", prepared for America's Natural Gas Alliance, December 2011.

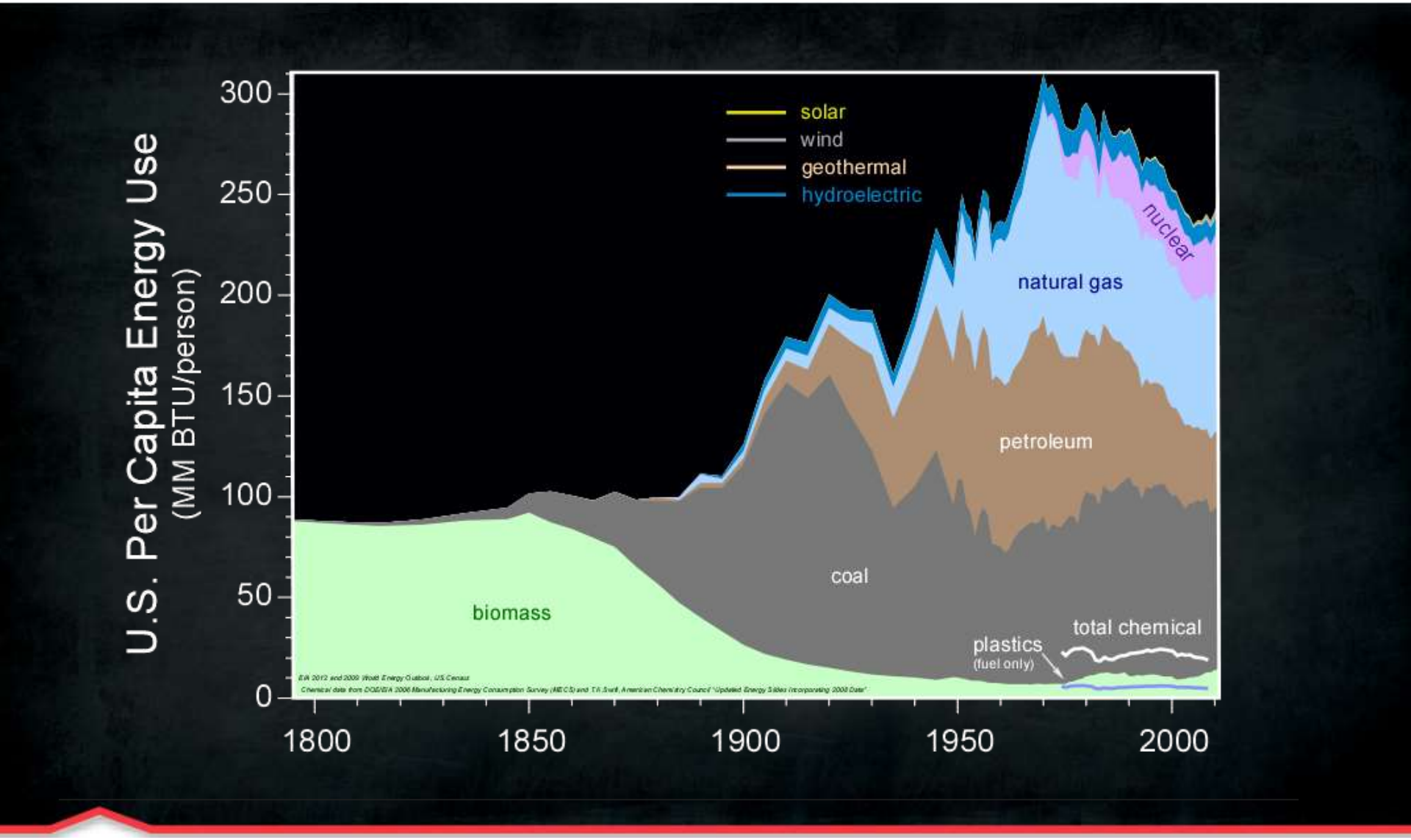

R.I.P.
U.S. CHEMICAL
INDUSTRY
1776-2008

Live Long and Prosper

Chemical Industry Snapshot



Per Capita Energy Use



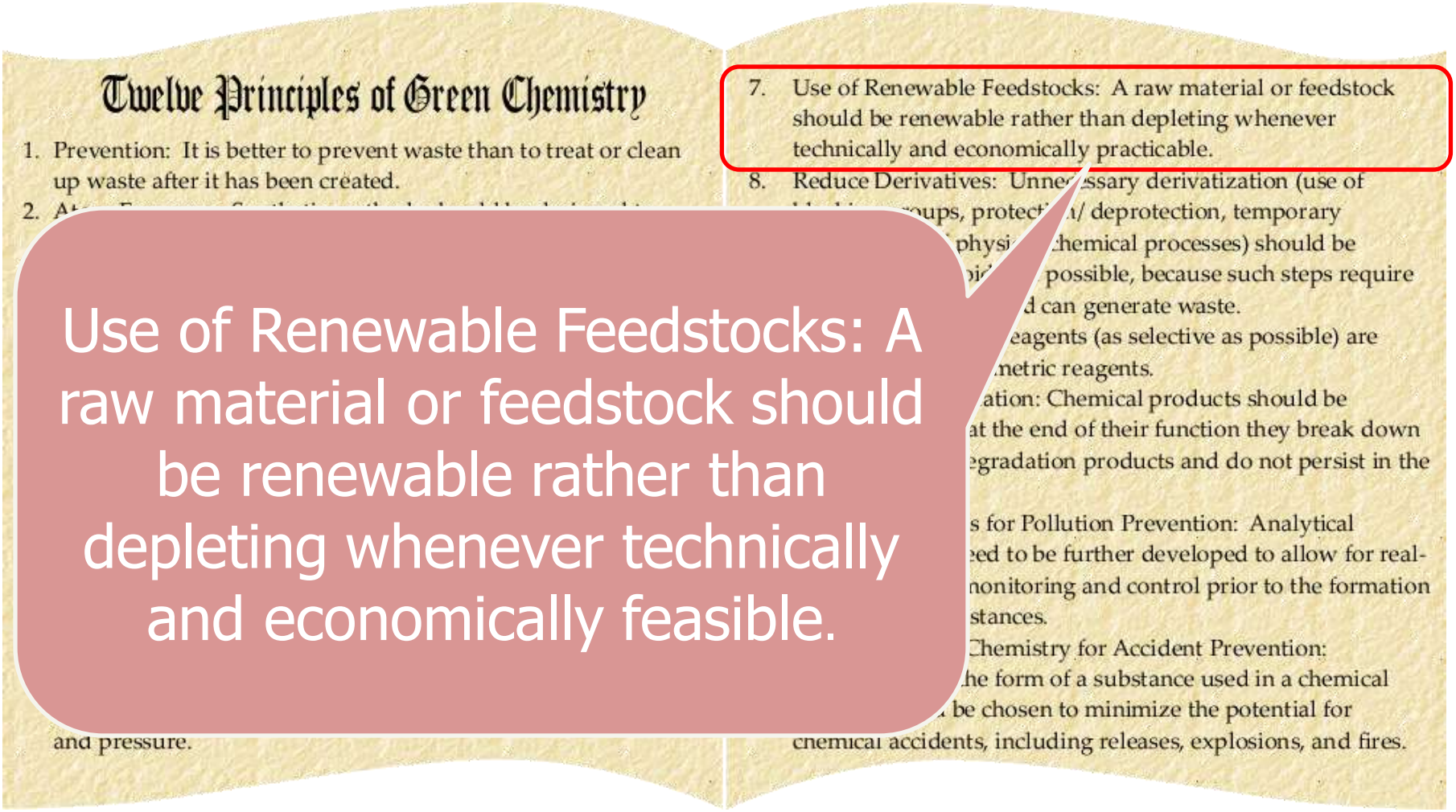
Green Chemistry Principles

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.
3. Less Hazardous Chemical Syntheses: Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Designing Safer Chemicals: Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. Safer Solvents and Auxiliaries: The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. Design for Energy Efficiency: Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
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 modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. Catalysis: Catalytic reagents (as selective as possible) are superior to 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. Real-time analysis for Pollution Prevention: Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. Inherently Safer Chemistry for Accident Prevention: Substances and 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.

DOW

Green Chemistry Principles



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

Life Cycle Analysis

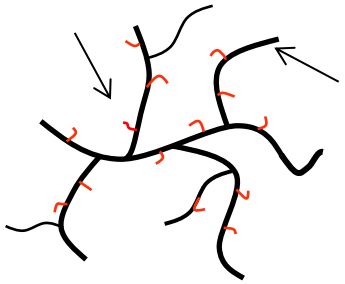
Unapologetically Polyethylene

- improving our production methods
- making improved materials
- replacing materials with larger footprints
- creating advantages in use

The Evolution of Polyethylene

LDPE

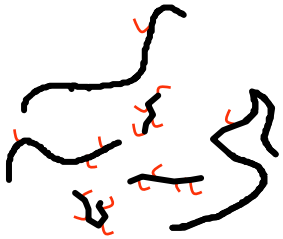
Radical mechanism (1933)
- Ethylene only polymerization
- Very high temperature & pressure
- Complicated kinetics



Highly Branched:
- Excellent flow properties
- Fast extrusion rates
- Poor mechanical properties

LLDPE

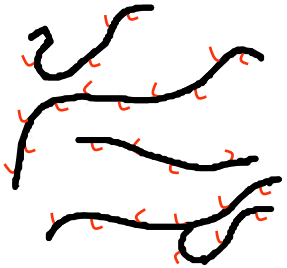
Coordination catalysis (1950's)
- Ethylene/α-olefin polymerization
- Low Temperature & Pressure
- Ti, Cr catalysts
- Multiple catalytic sites



Linear Backbone:
- PE homopolymer: crystalline
- Copolymers: flexible and tough
- Blend of polymers produced

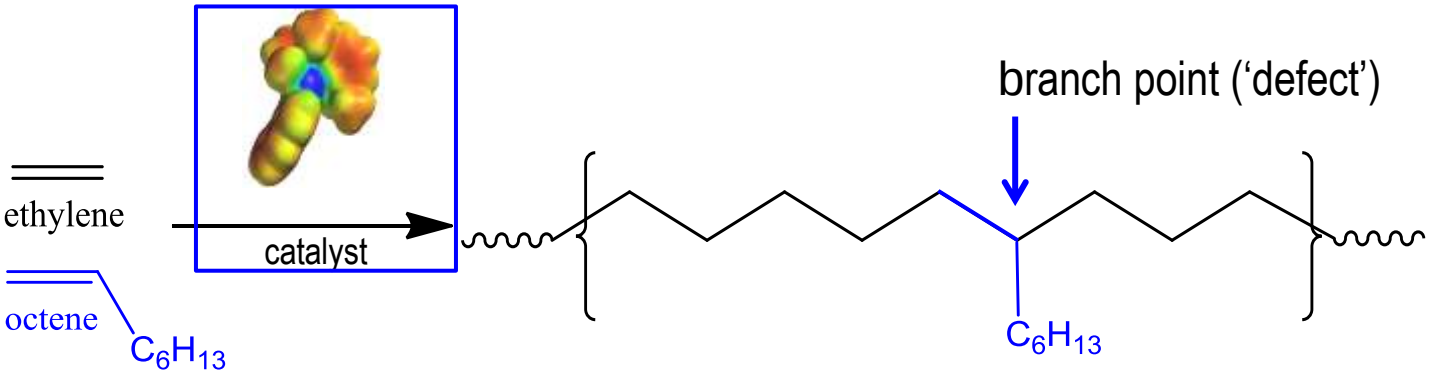
mPE

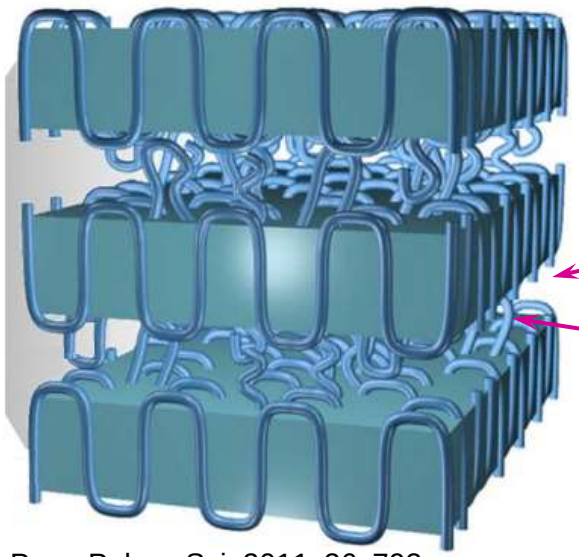
"Single Site" catalysts (1990's)
- Ethylene/α-olefin polymerization
- Molecular catalysts
- Kinetics the same for each catalytic site



Homogeneous Polymers:
- Narrow molecular weight distribution
- Narrow comonomer distribution
- New monomer combinations
- Long chain branching

Polymer Properties Determined by Catalysis





Prog. Polym. Sci. 2011, 36, 793.

Lamella: long sequences of polyethylene units fold into crystallites

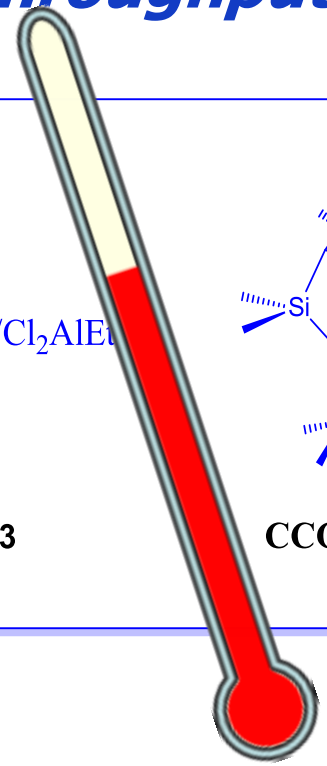
Interfacial regions: "defects" are excluded into amorphous regions

Tie molecule: bridge more than one lamellar crystallite

Catalysis → Molecular Structure of Polym. Chains → Bulk Structure → Polyethylene Properties

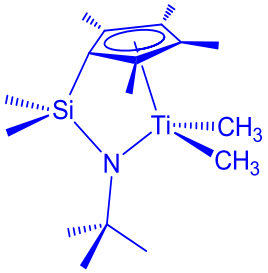
Counter-intuitive Catalysis Improves Process

Polyethylene: Higher Efficiency and Plant Throughput Through Improved Catalyst Design

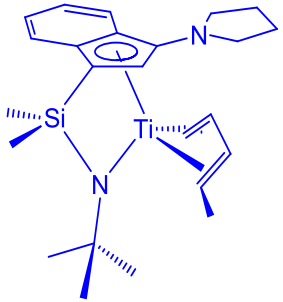


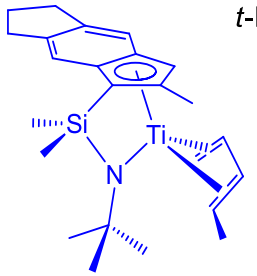
$TiCl_4/MgCl_2/Cl_2AlEt$

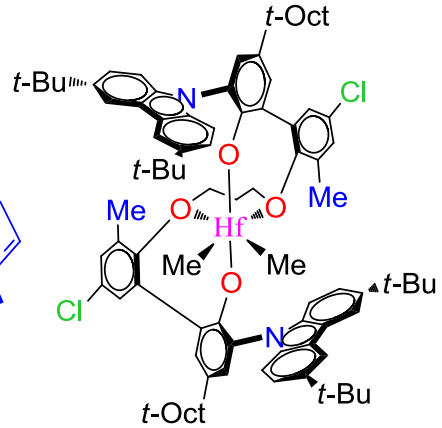
HEC-3



CCG-gen 1







Increasing Thermal Stability and Efficiency

Stand-up pouch packaging reduces waste and brings energy savings

Package Type	Contents	Impact per 100 oz Cereal		
		Landfill Discards* (g)	Process GHG** (kg CO^2 Eq)	Total Energy** (MJ)
Paperboard and HDPE Liner	11 oz	380.0	.861	12.1
Stand-Up Pouch	12 oz	117.5	.265	9.25

Reduction vs Box	
Landfill Discards	**68%**
GHG	**69%**
Energy	**23%**

Flexible Packaging Examples

greenerpackage.com

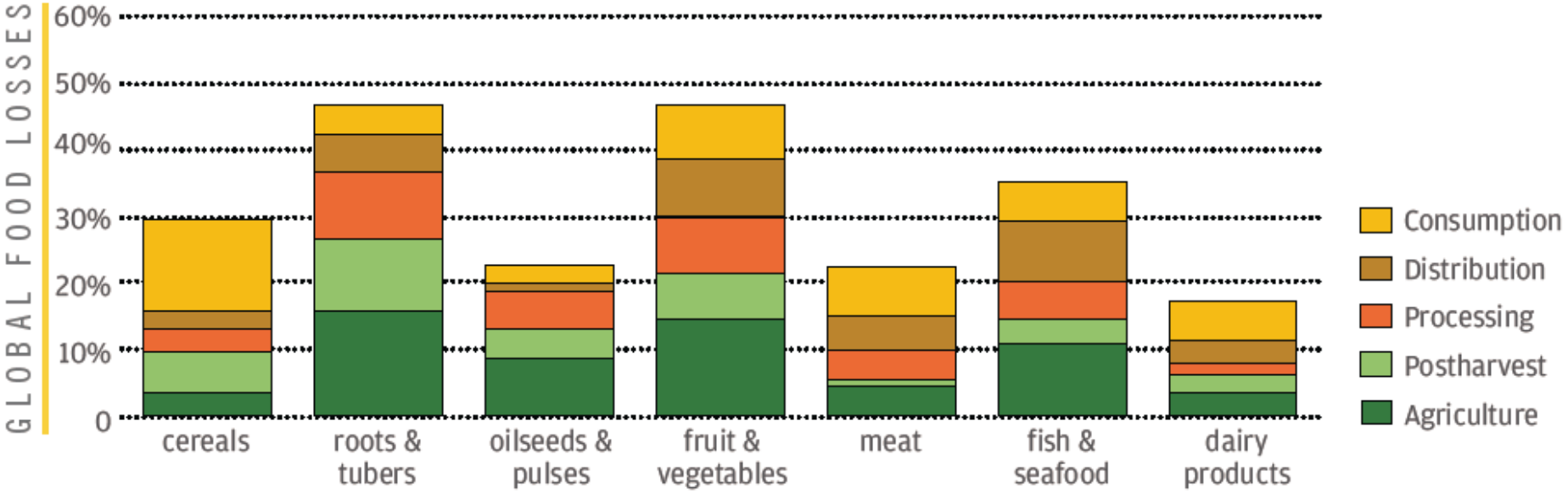
nestle-shop.ch

….utilizing life cycle thinking, choosing solutions with multiple environmental, social & economic attributes

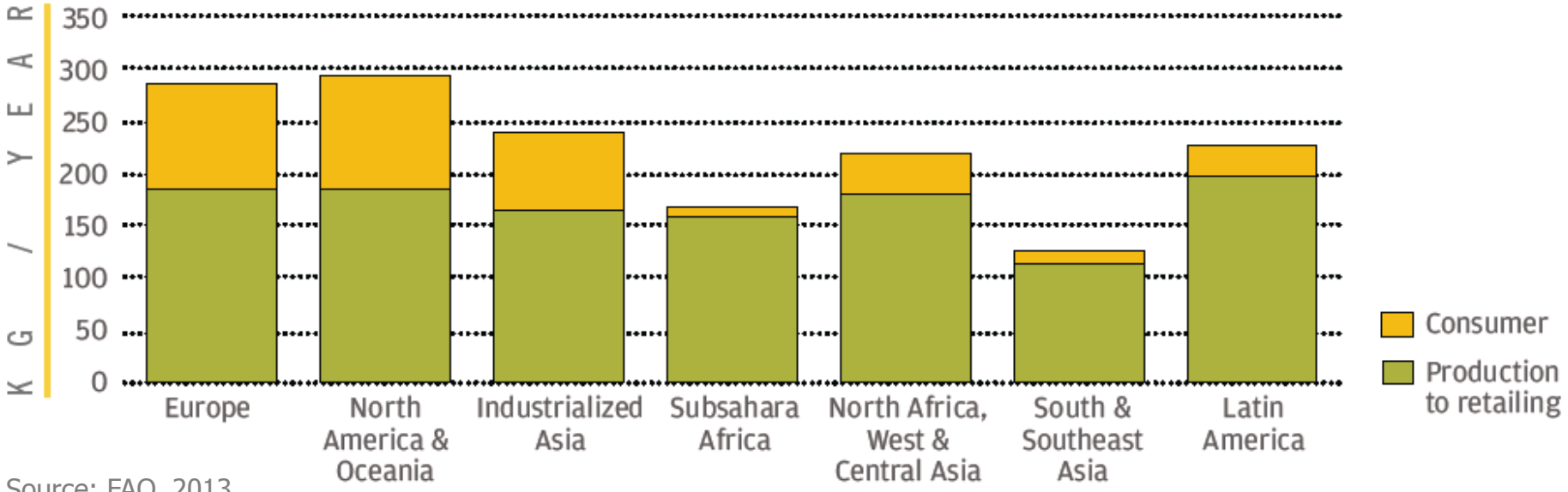
Performance
or
Value

Resource Use
or
Footprint

PART OF THE INITIAL GLOBAL PRODUCTION LOST OR WASTED

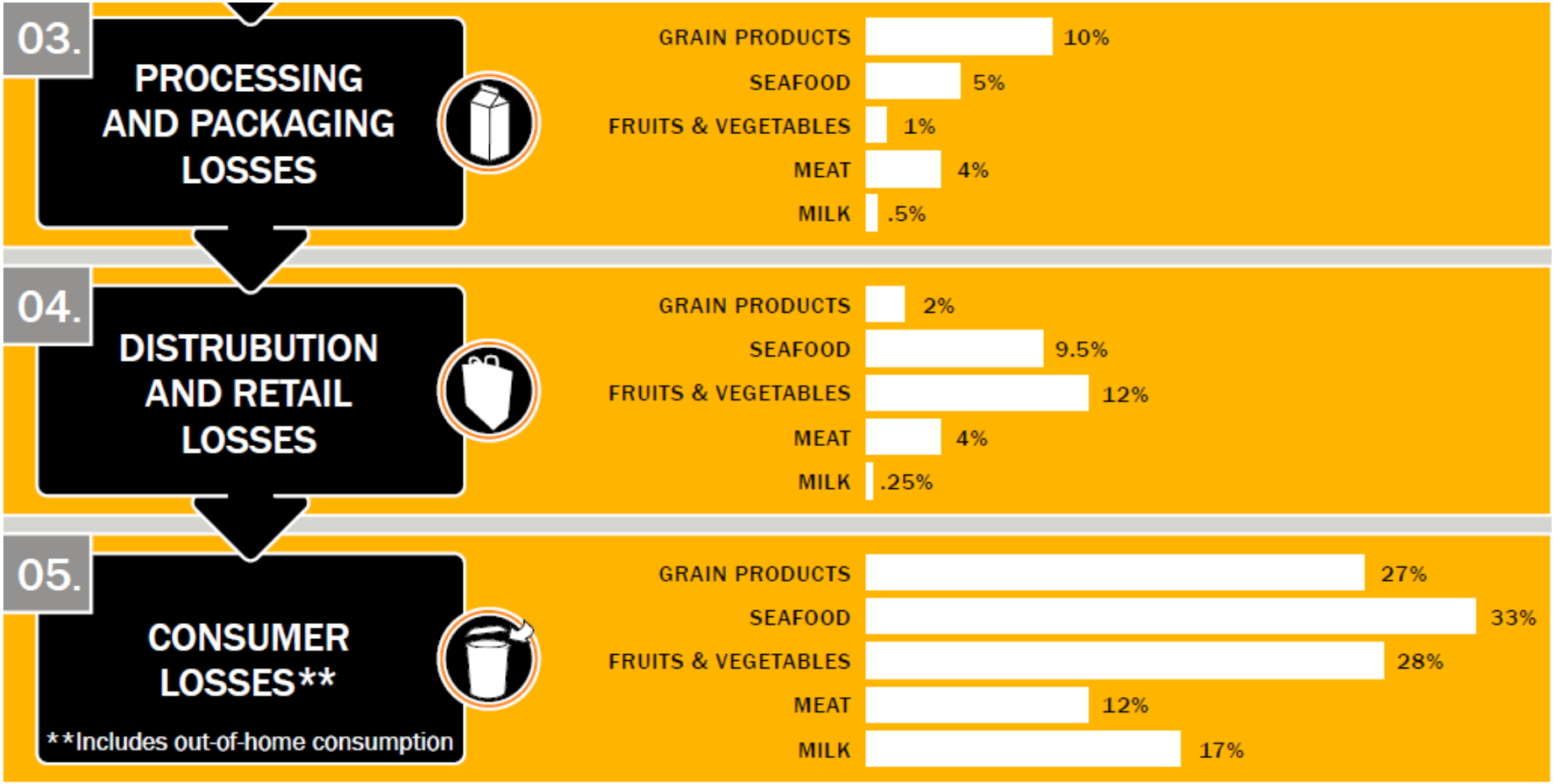


PER CAPITA FOOD LOSSES AND WASTE, AT CONSUMPTION AND PRE-CONSUMPTION STAGES

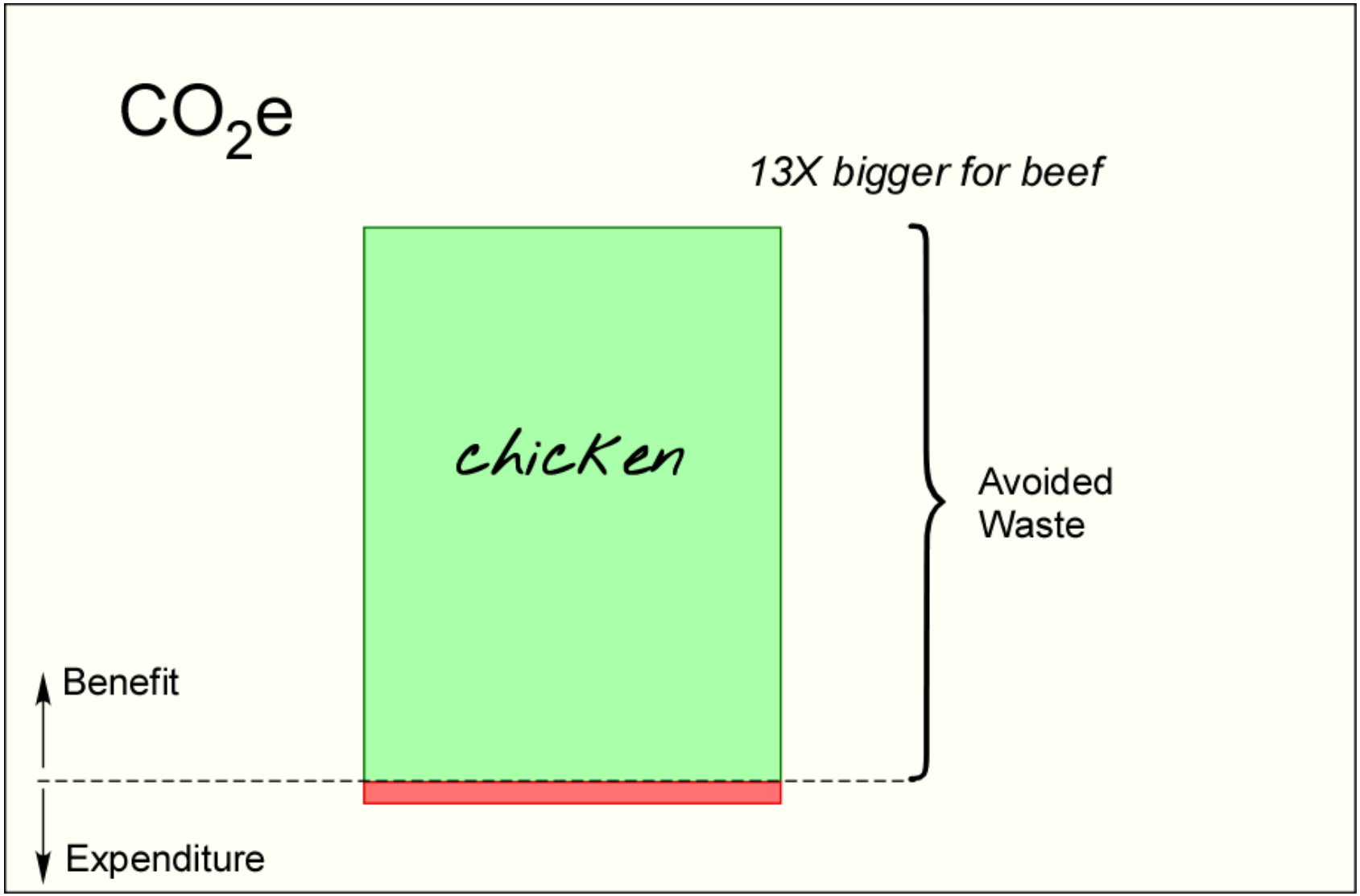


Source: FAO, 2013

North American Food Losses Processing to Plate



Source: FAO, 2011


CO_2e
13X bigger for beef
chicken
Avoided Waste
Benefit
Expenditure

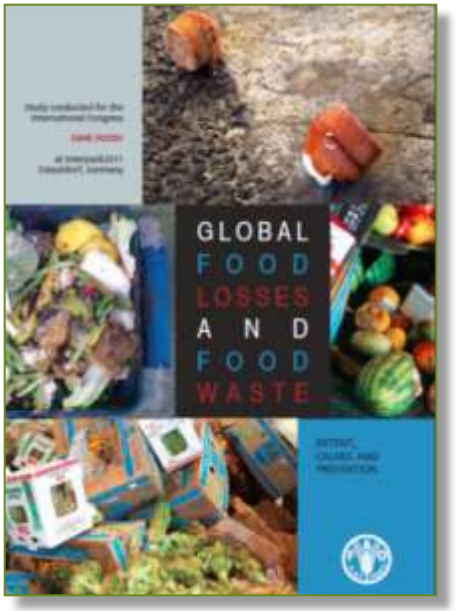
Why Focus on Packaging

Need to Reduce Food Waste Creates Opportunities

Arable land for food production remains the same

One-third of the food produced for human consumption – about 1.3 billion tons per year – gets lost or wasted*

Innovative food packaging improves both food preservation and food safety and can address this opportunity



* Source: Food and Agriculture Organization of the United Nations, May 2011

Why Focus on Packaging

The Sustainability Benefits of Plastic Packaging

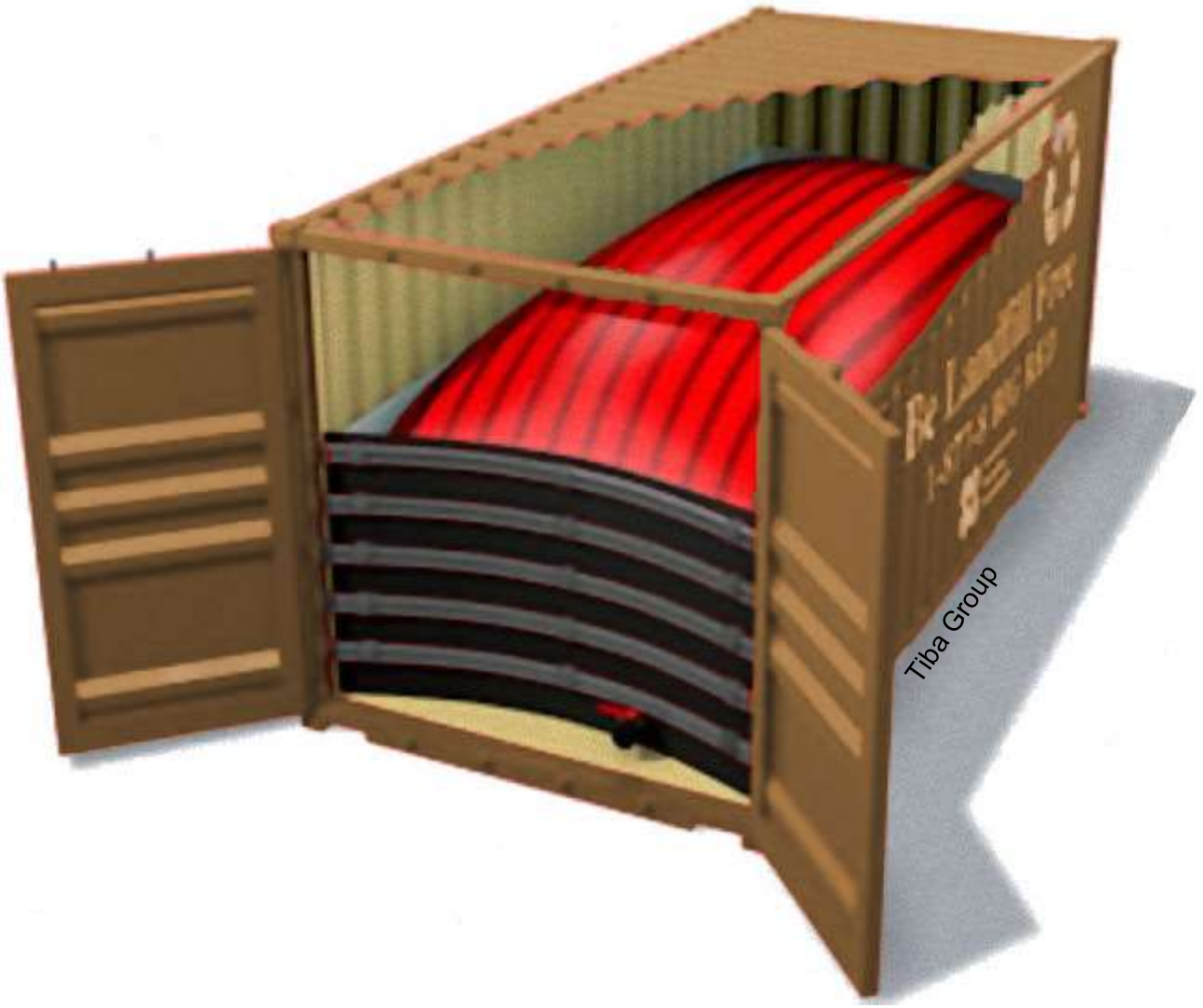
A Great Solution!

Lightweight, durable, and flexible – the protective properties of plastic make it one of the world's most sustainable performers in delivering environmental, economic and social value.

Sustainability Profile: Plastic Packaging:

- *Reduces materials* – 2 lbs of plastic deliver the same amount of liquid as 3 lbs of aluminum, 8 lbs of steel, or 27 lbs of glass.
- *Saves energy* – 1 truck of flexible packages replaces 25 trucks carrying the same amount of food in cans.
- *Reduces harmful emissions* – Organic waste in landfills emit methane: a GHG with 23 times more global warming potential than CO_2 and plastic packaging helps keep food out of the landfill.
- *Saves resources* – By preventing food from spoiling and protecting consumer goods from damage during distribution.
- *Reusable resource* – Can be recycled to polymer or for energy at the end of its initial life.

Large Scale Shipping



Flexible packaging helps increase shelf life

Using only a few grams of flexible plastic packaging extends the shelf life of a cucumber by more than three times.

FLEXIBLE PLASTIC PACKAGING
HELPS IN-STORE WASTE
REDUCE
3 percent to under 1 percent
BY INCREASING
SHELF LIFE

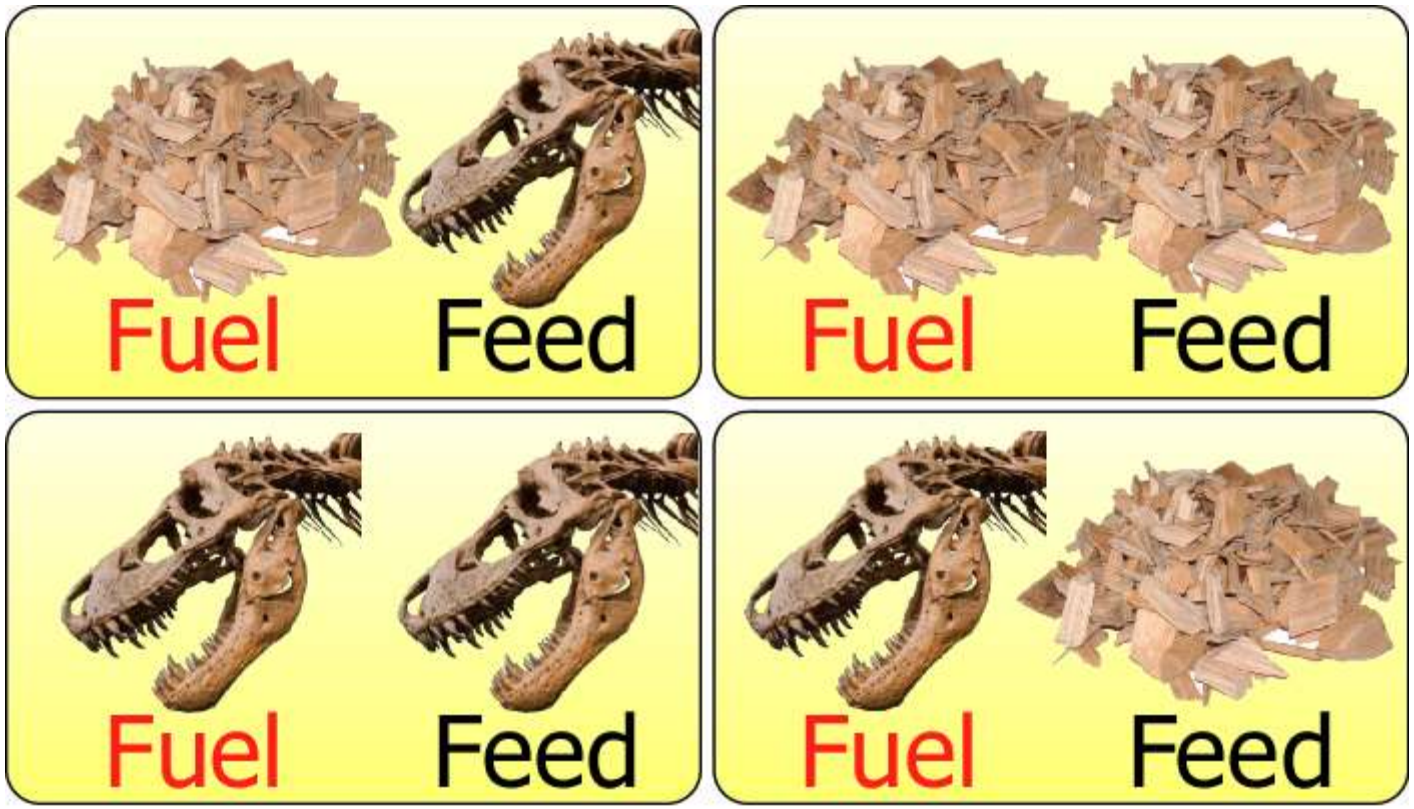
Source: Incpen

Demand for Bioproducts?

Midland Daily News
1 January 2012

Delta Airlines Napkin
April 2012

Two Carbon Flavors



What Impact?

PET

30%

plantbottle

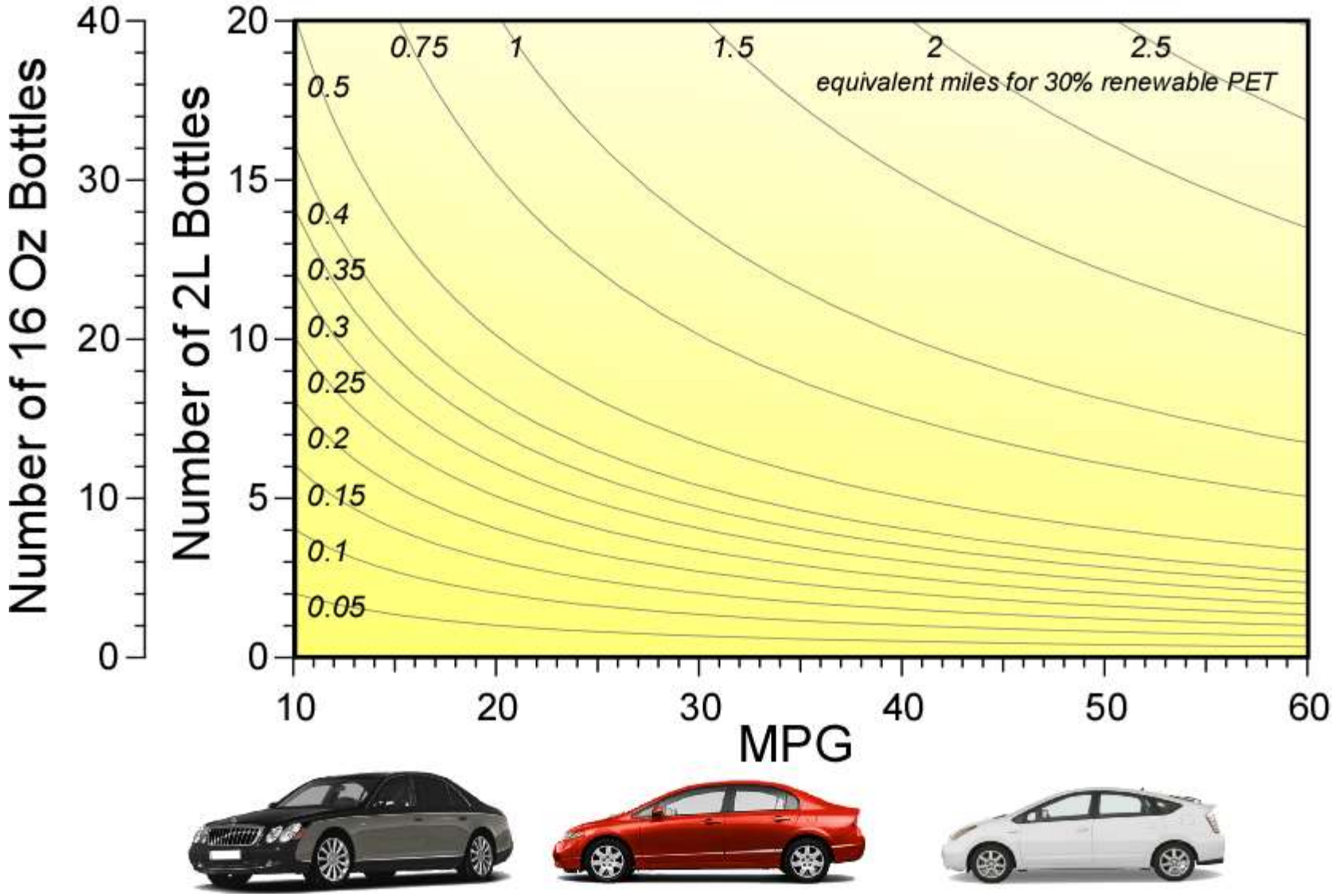
100% renewable PET (not yet available) would required ~80 2 L bottles to offset burning 1 gallon of gasoline or about 400 at today's 30%

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

DOW

PET Comparison



STYROFOAM™ Structural Insulated Sheathing yields significant energy savings for homes

Description

STYROFOAM SIS™ Brand Structural Insulated Sheathing is a first-of-its-kind residential wall system that combines shear bracing, insulation and water-resistive barrier protection in one product.

2009
AWARD WINNER
Building Products Magazine
"Green Product Award"

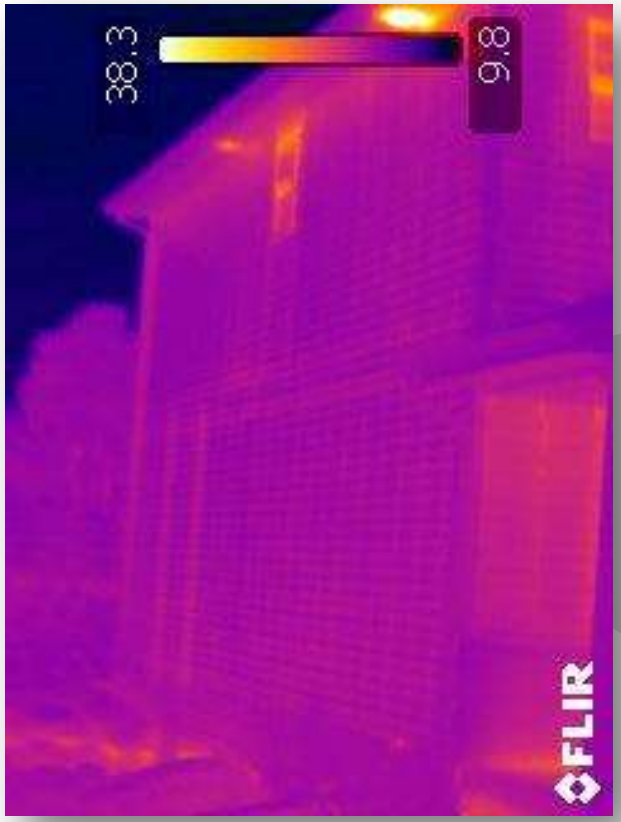
Sustainability Profile

- Easy integration of energy-efficiency into building practices
- Made up of 80% post-consumer recycled content, Energy Star-qualified
- Potential to save homeowners up to $500 USD/year in energy
- Reduction in home energy use helps reduce carbon emissions

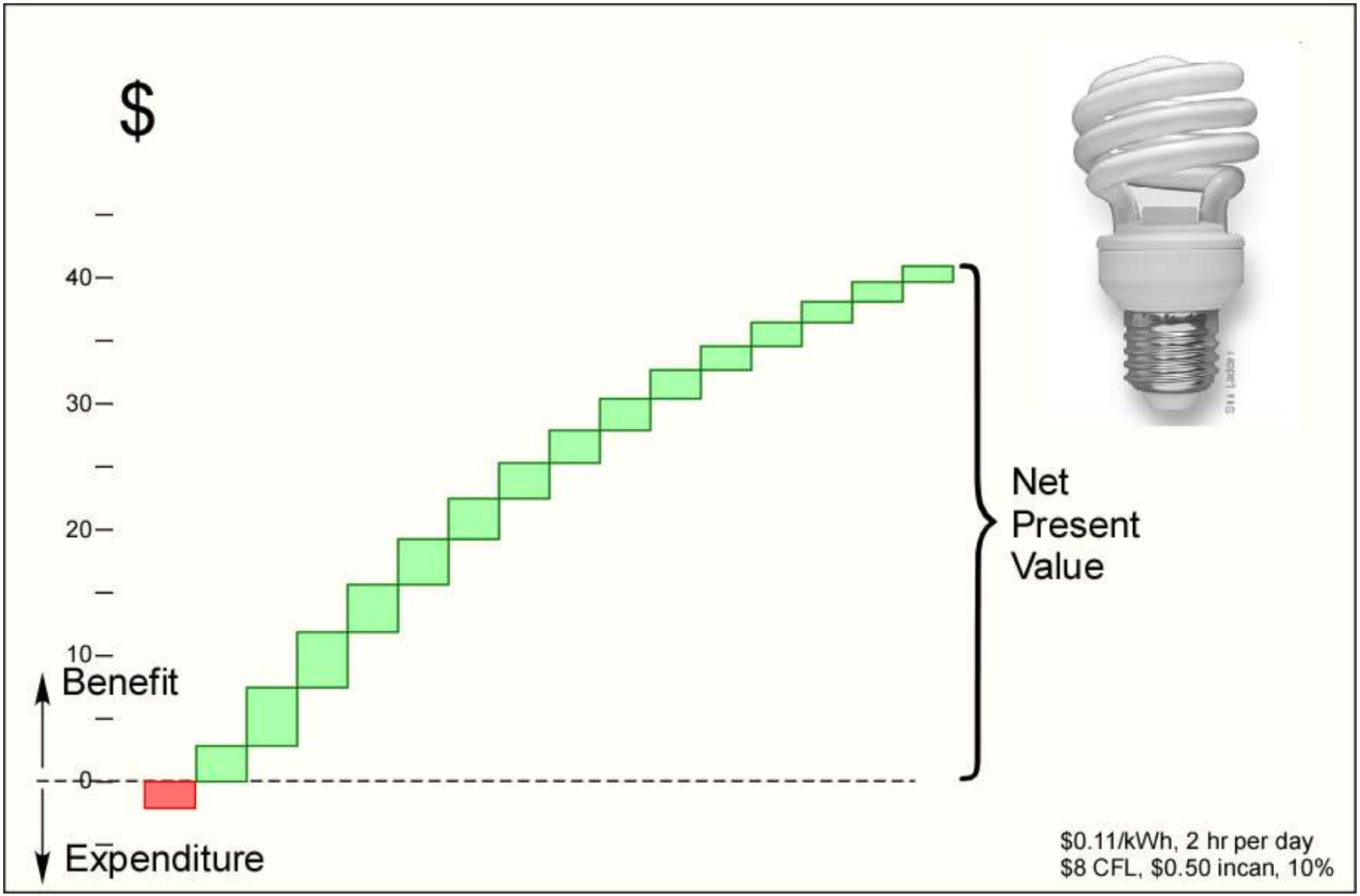
Continuous, spray foam insulation can drive additional efficiency, further enhancing savings

Insulation at US Building Code Minimums

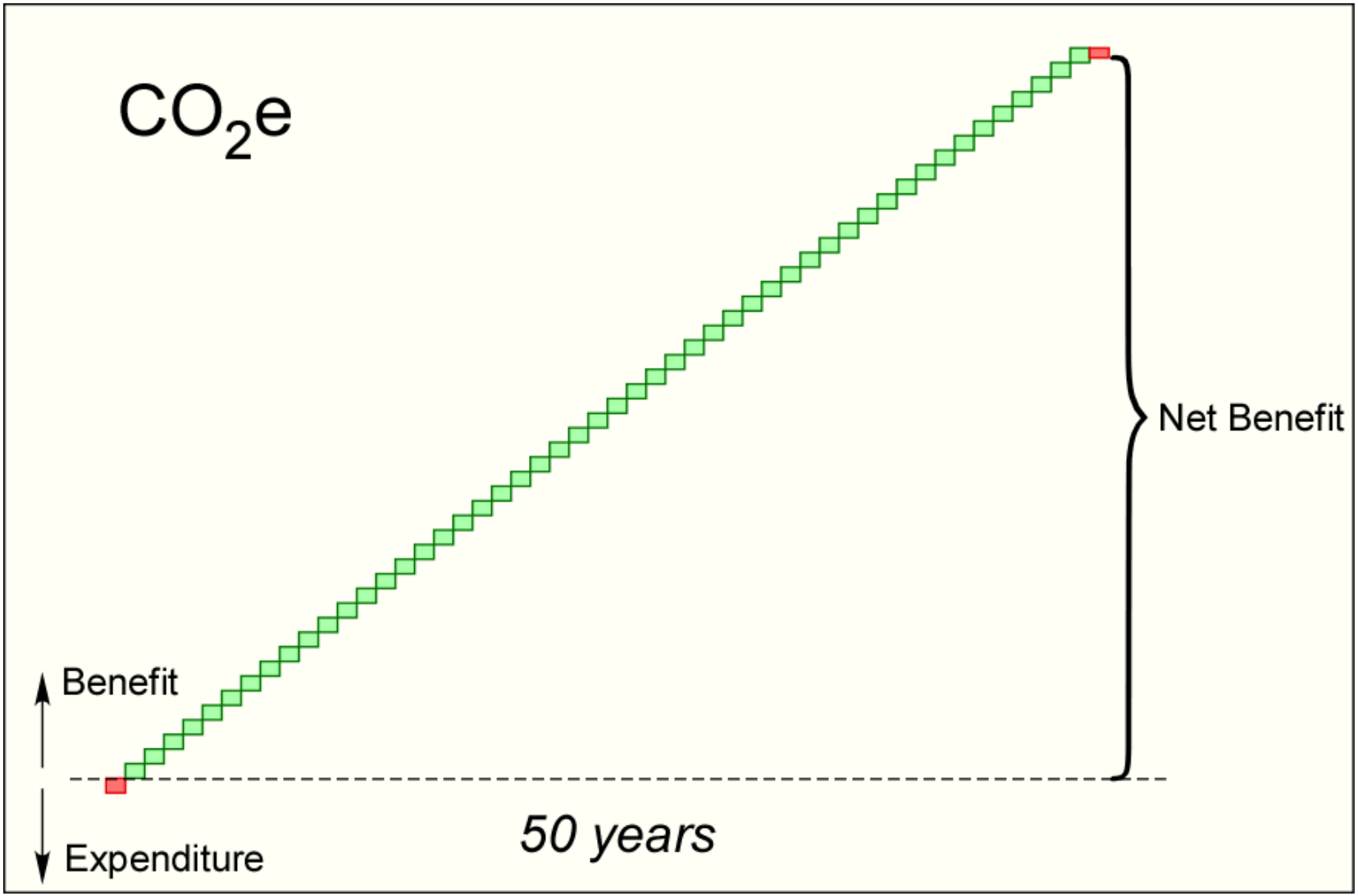
Continuous Insulation



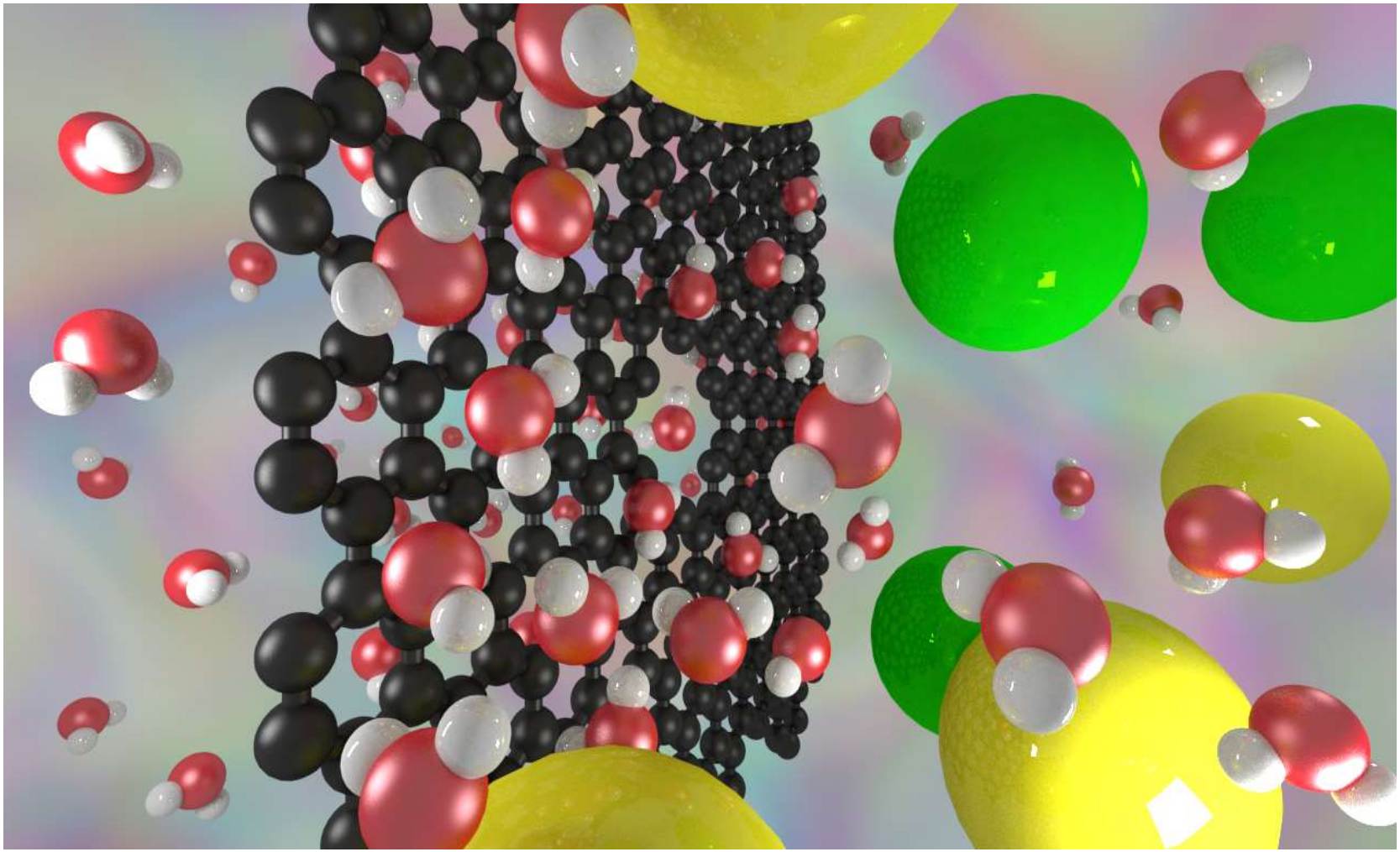
Financial Way of Looking At Benefit



Insulation Benefit

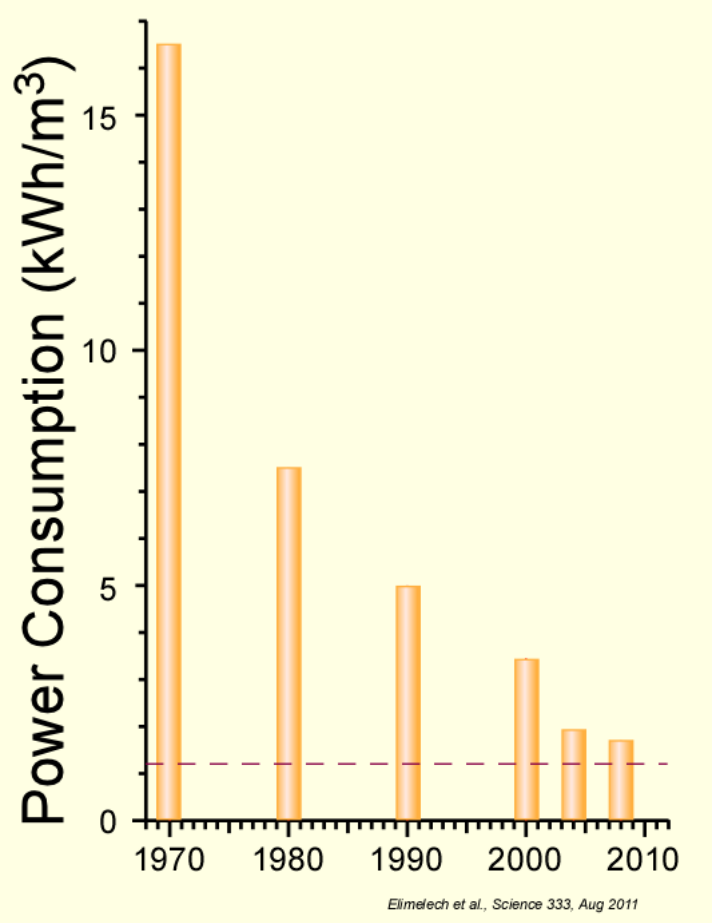


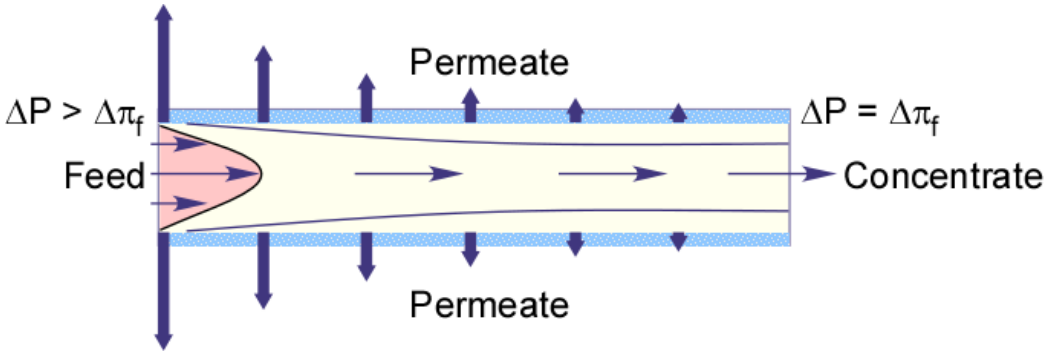
Misconceptions Demean Advances

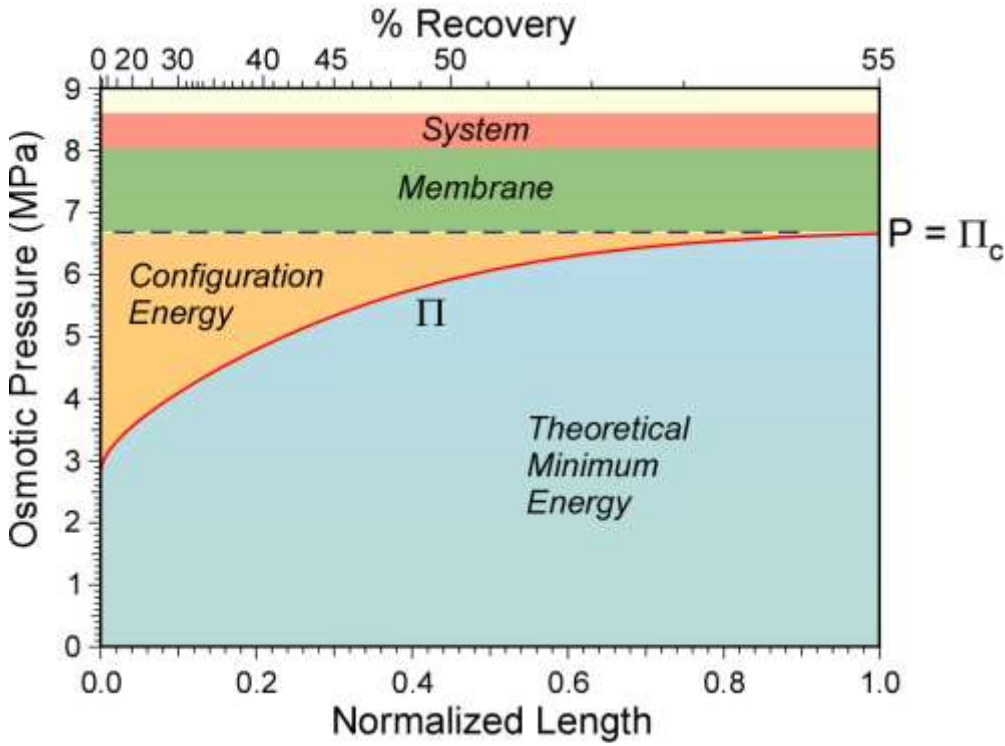


Fresh Water Production

Simple Distillation ~600 kWh/m^3

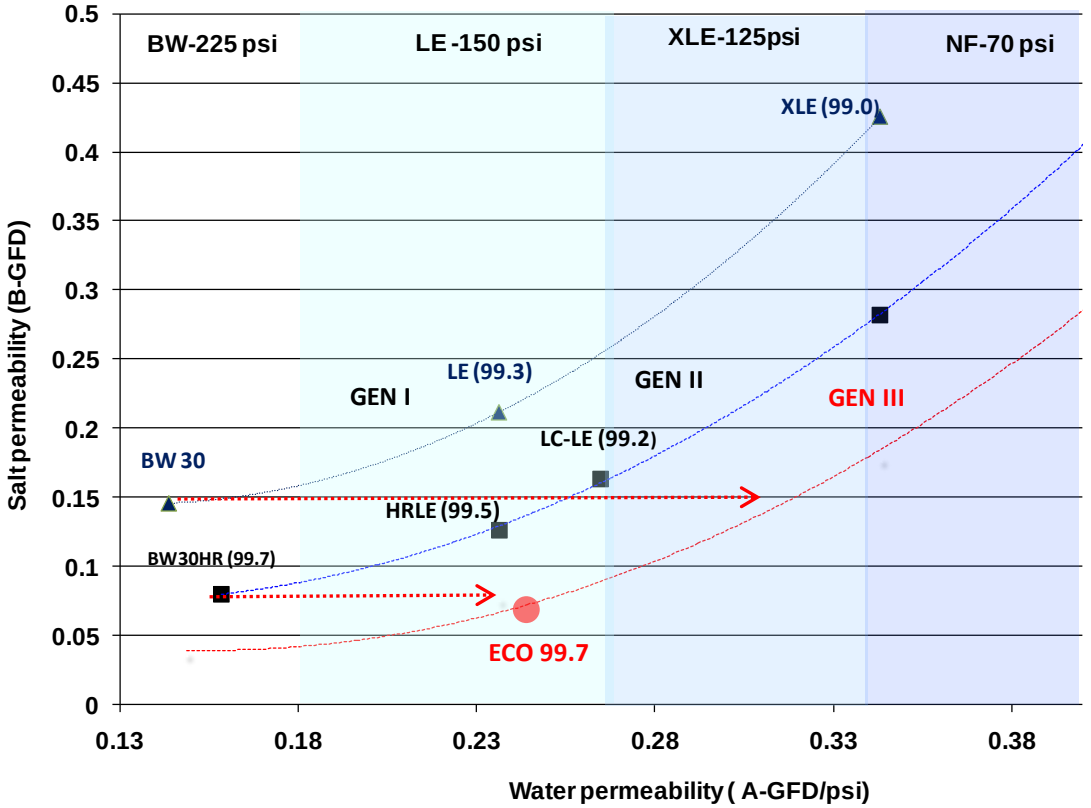






FILMTEC™ Membranes
Novel Low Energy Membranes

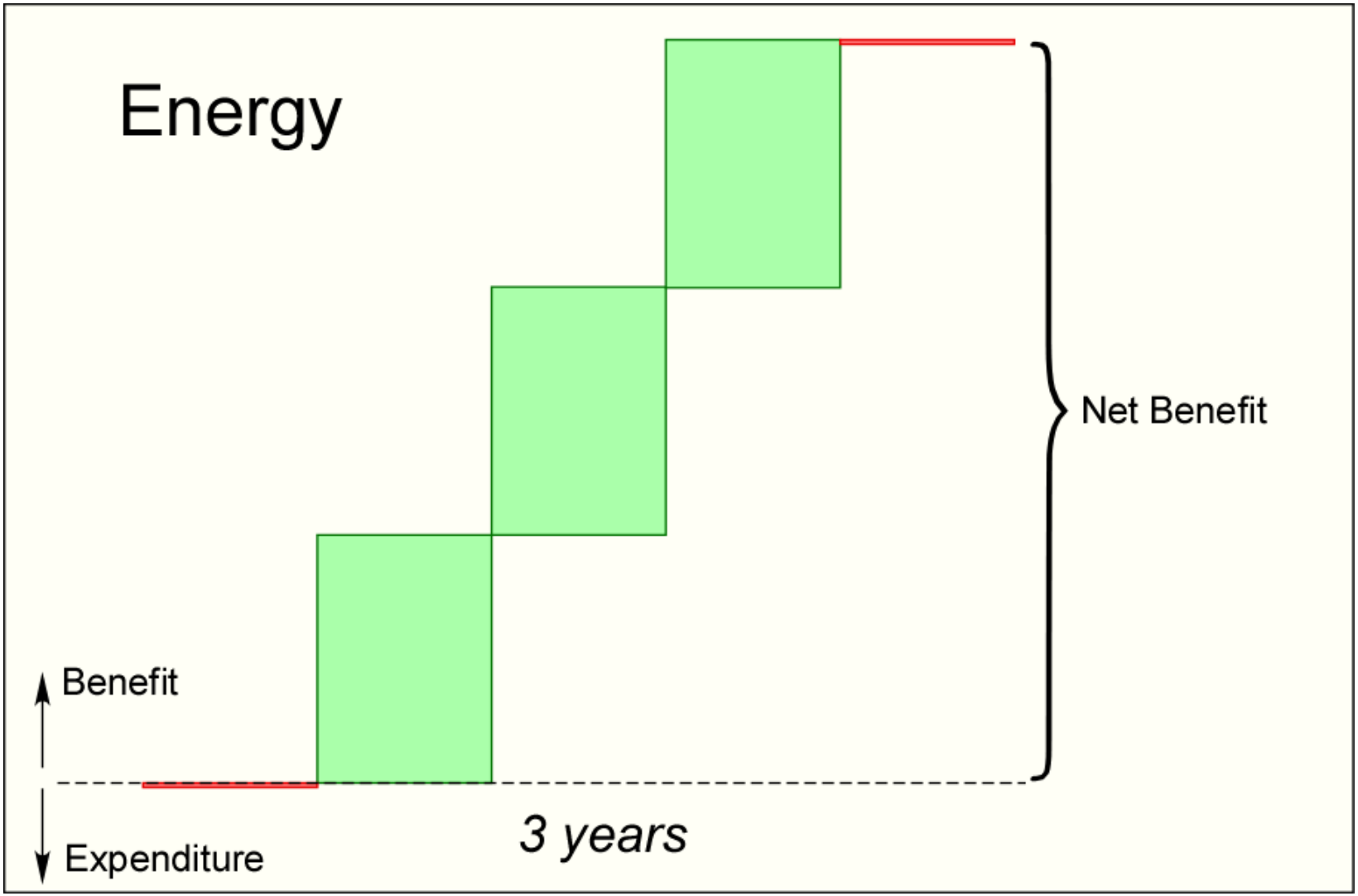
- Step-change in performance
- Next generation membrane technology
- Low energy elements enable new levels of rejection
- Energy savings ≥30+% with 99.7% salt rejection



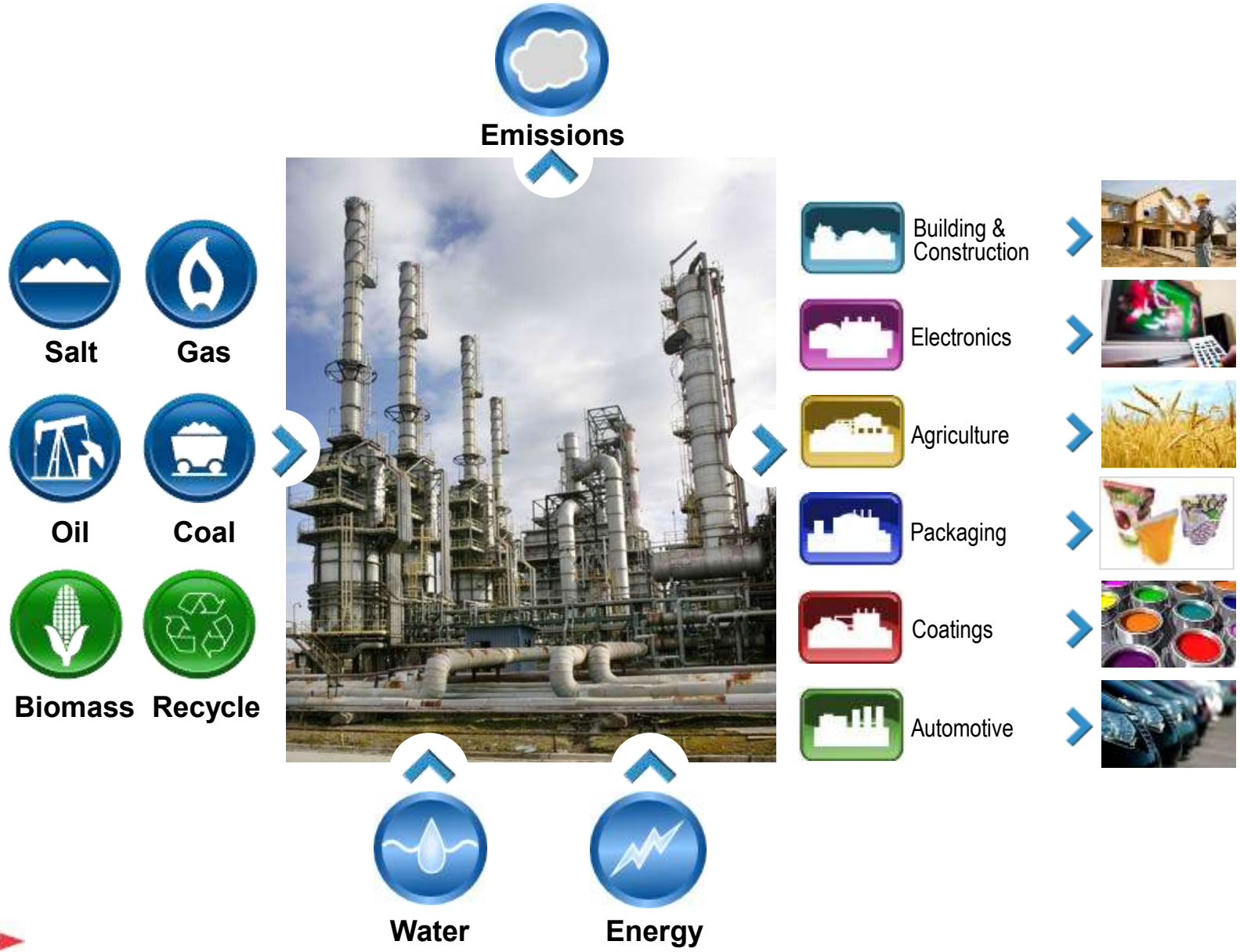
Energy-efficient DOW FILMTEC™ Water Treatment Membranes yield savings on water purification

Process	Operating Energy Consumption (Kwh/m^3)	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	

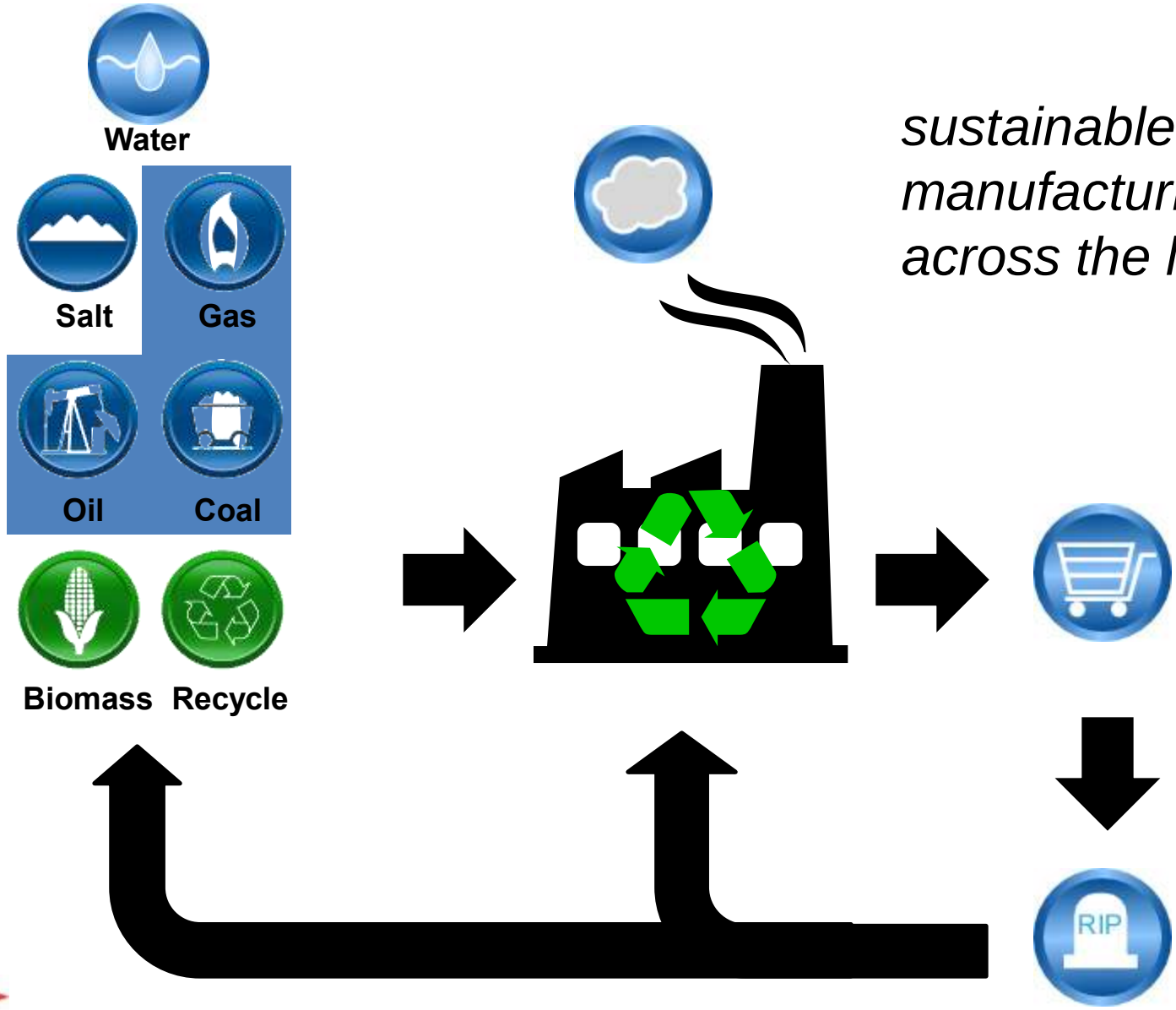
RO Cartridge Benefit



Chemical Industry Snapshot



Sustainable Manufacturing Requires Broader Look

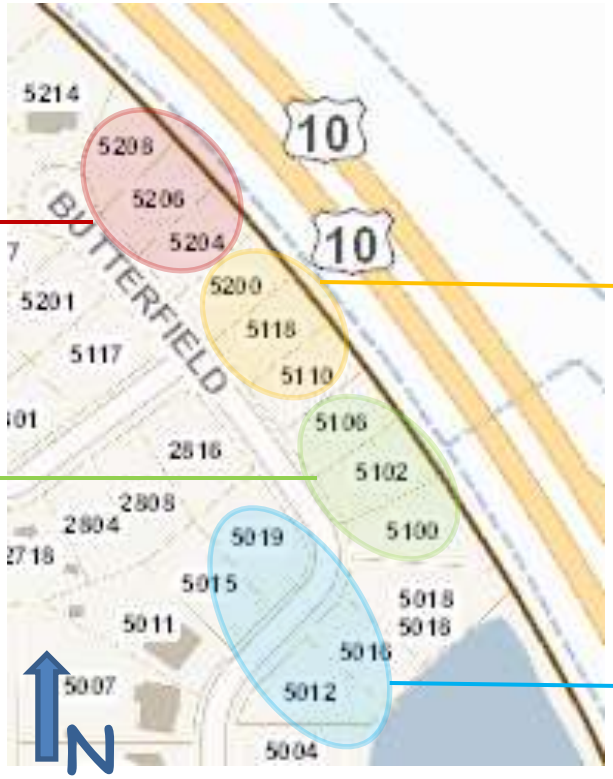


sustainable manufacturing looks across the life-cycle

Energy Performance Research Neighborhood

Cobblestone Homes/Dow Building Solutions – Midland, MI

2006 IECC



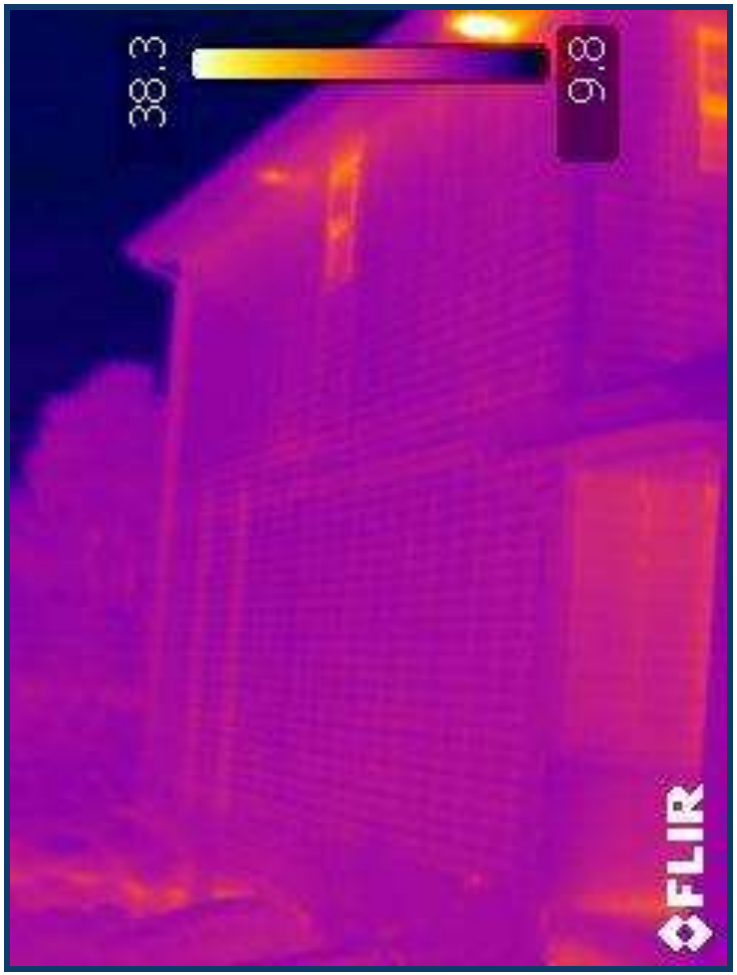
2012 IECC

2012 IECC Premium

Beyond 2012 IECC

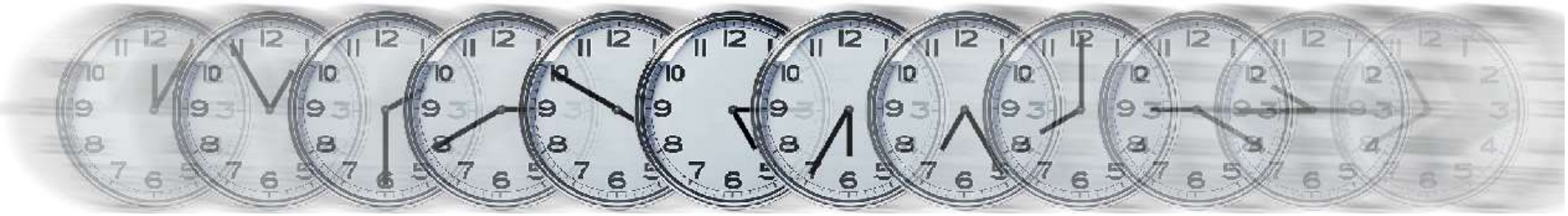
Both Homes are 2012 IECC Compliant

OSB Plus Housewrap



R-5 Continuous Insulation

Go After the 21,000 lbs




DOW
®