Renewable Energy:
an investment perspective

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Oct 2008

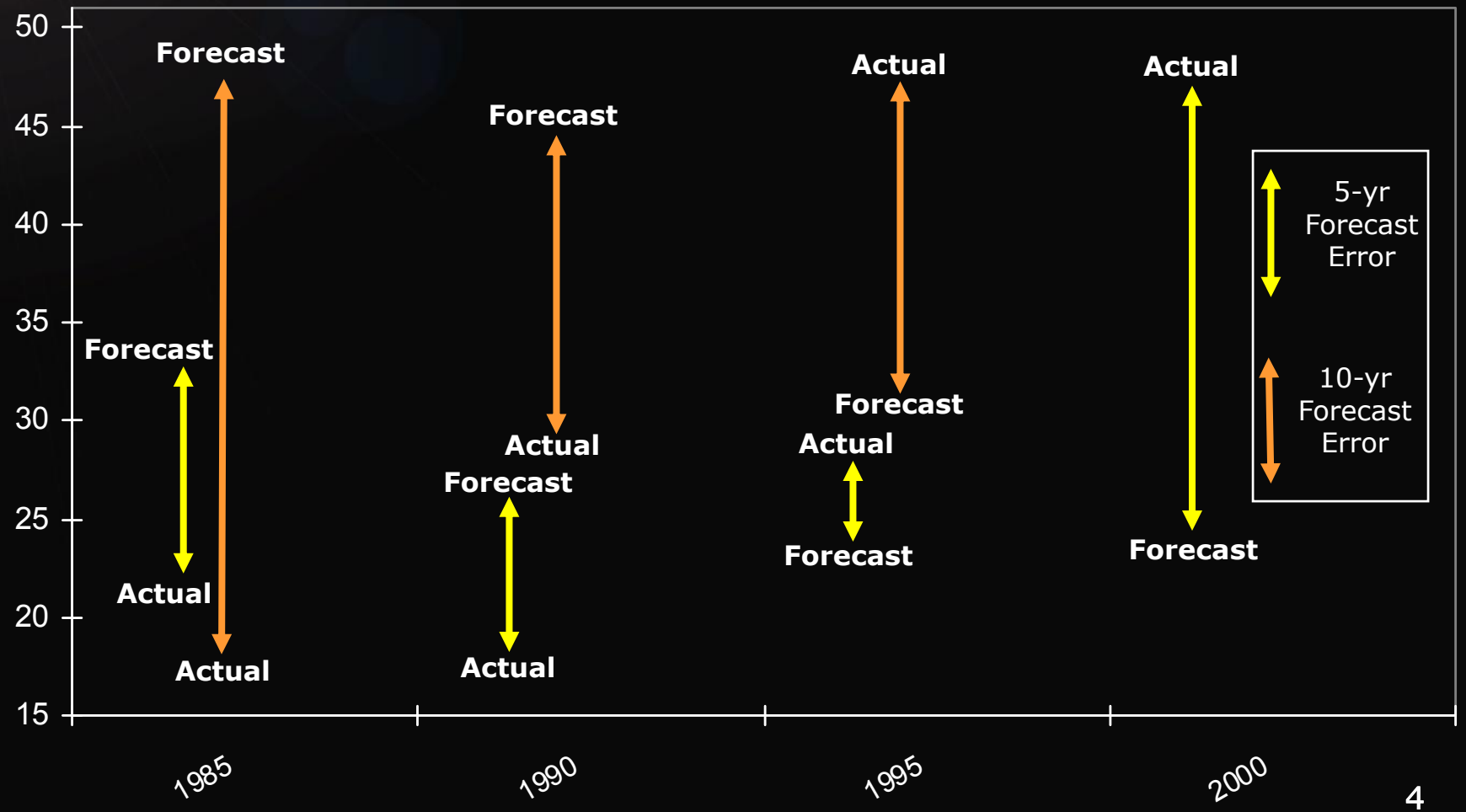
“all progress depends on the unreasonable man”

George Bernard Shaw

"Any sufficiently advanced technology is indistinguishable from magic."

-Arthur C. Clarke

oil price forecasts (1985-2005)



Data/Source: World Oil Prices (current $ / Barrel)- EIA Office of Integration Analysis and Forecasting

the US market for mobile subscribers

Source	Forecasts	Actual
Fortune (1984 => 1989)	1M	3.5M
McKinsey for AT&T (1980 => 2000)	0.9M	109M
Herschel Shosteck (199[illegible] => 2004)	60-90M	182M

The same mistakes are repeated again and again!

Source: American Heritage Magazine - http://www.americanheritage.com/articles/magazine/it/2007/3/2007_3_8.shtml

yesterday's technology, tomorrow's forecast

- 1980's phone

- The actual market

…”relevant cost”
…”relevant scale”
…”relevant adoption”

Beyond cost, scale & adoption risk

…trajectory (cost, carbon, and scalability)
…capital formation
…optionality
…carbon reduction capacity

…the chindia test

only scalable if competitive unsubsidized

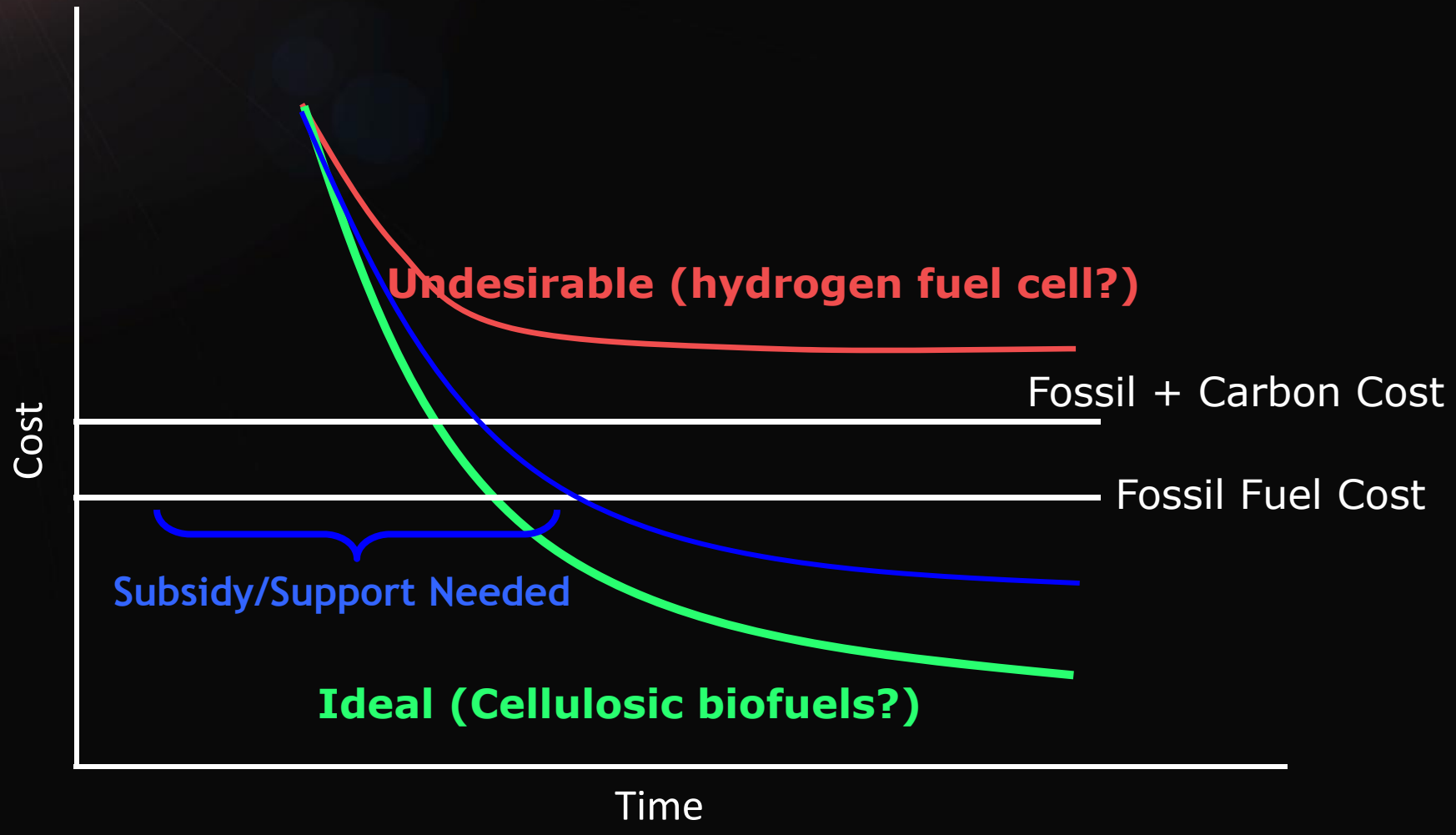
…the scaling model

brute force or exponential, distributed…

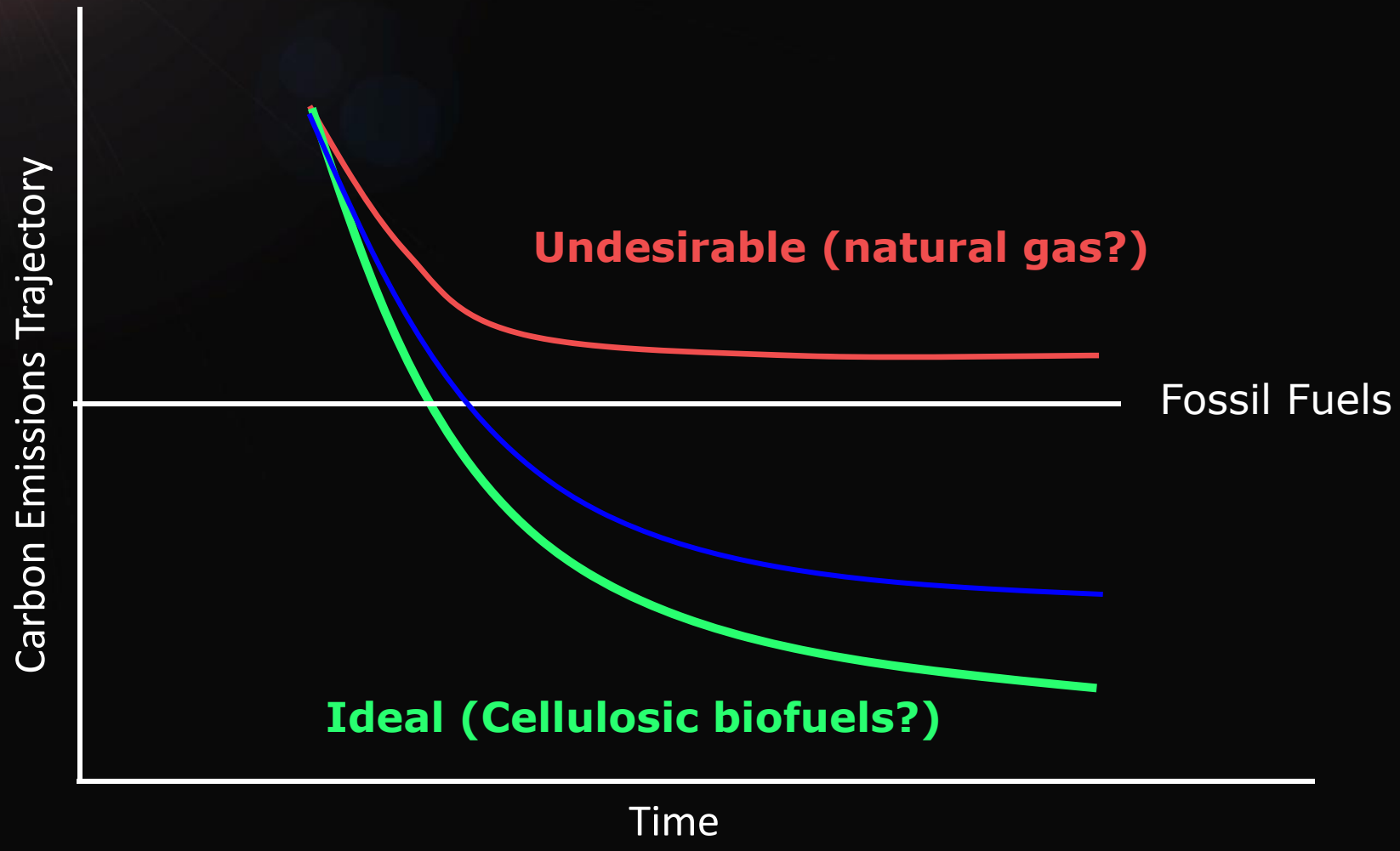
…the adoption risk

financial, consumer acceptance, market entry

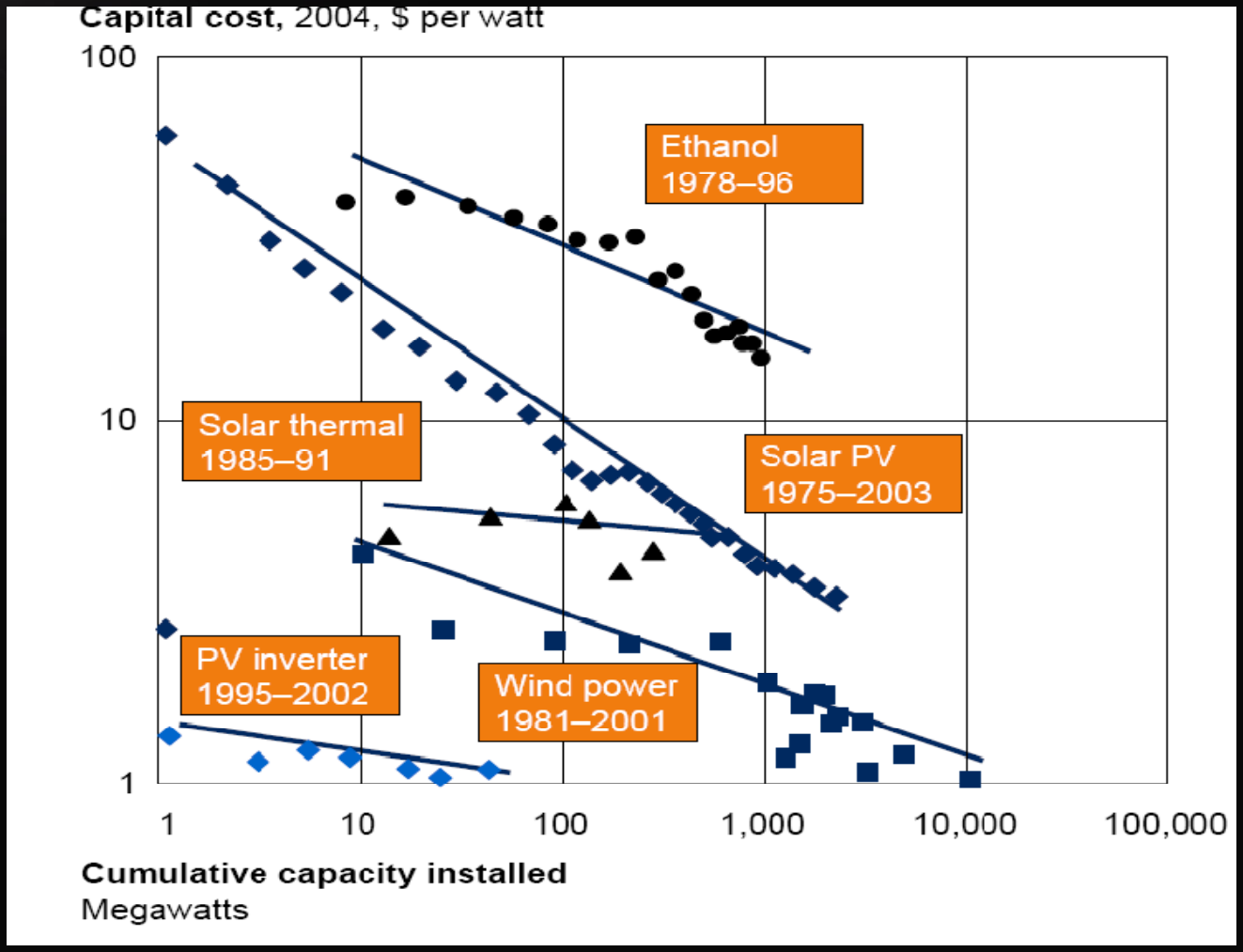
Cost trajectory:



Carbon trajectory:

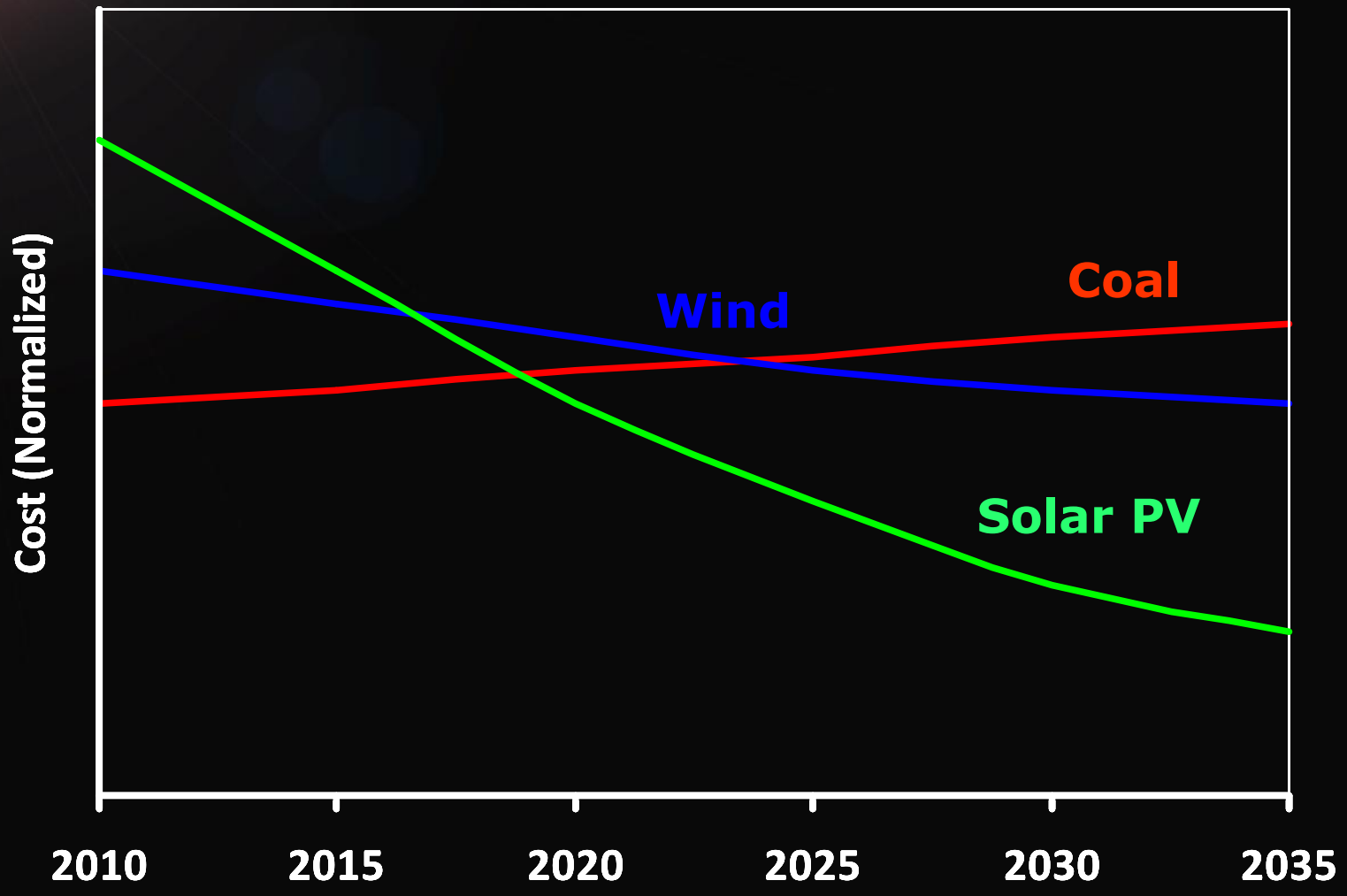


cost: driving down the cost curve



Source: "The Carbon Productivity Challenge", McKinsey – Original from UC Berkely Energy Resource Group, Navigant Consulting

cost: not all technology curves are the same



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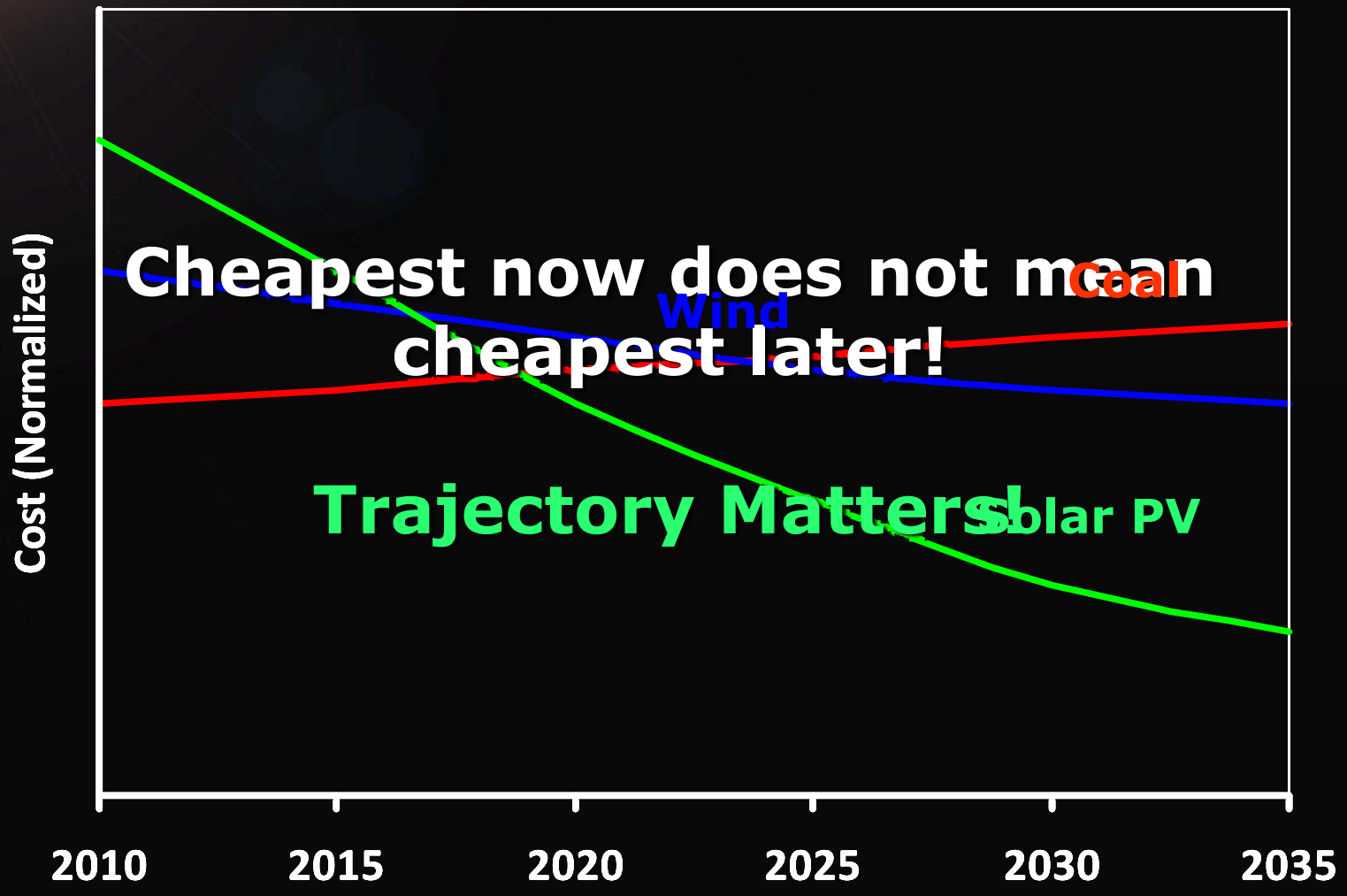
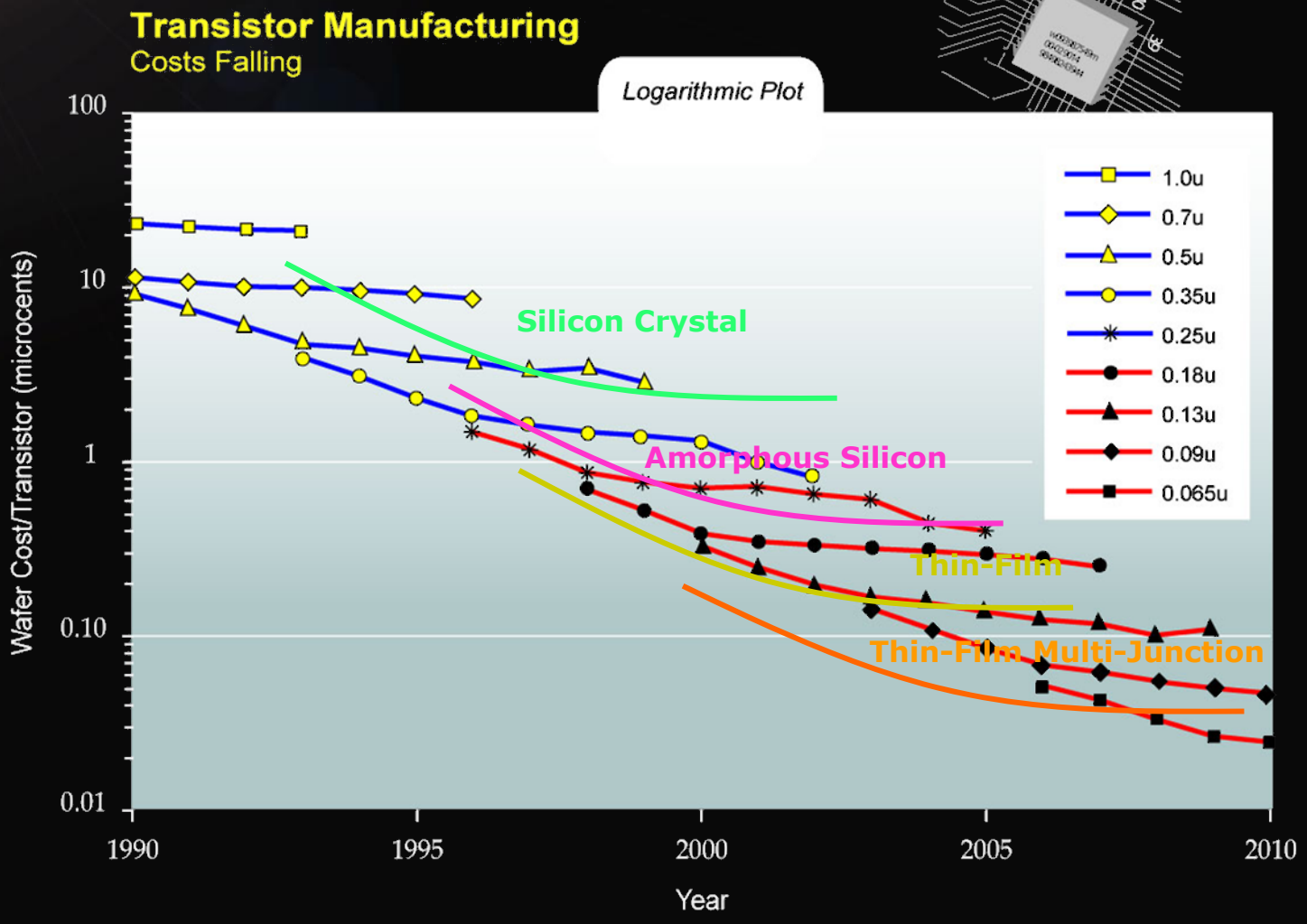
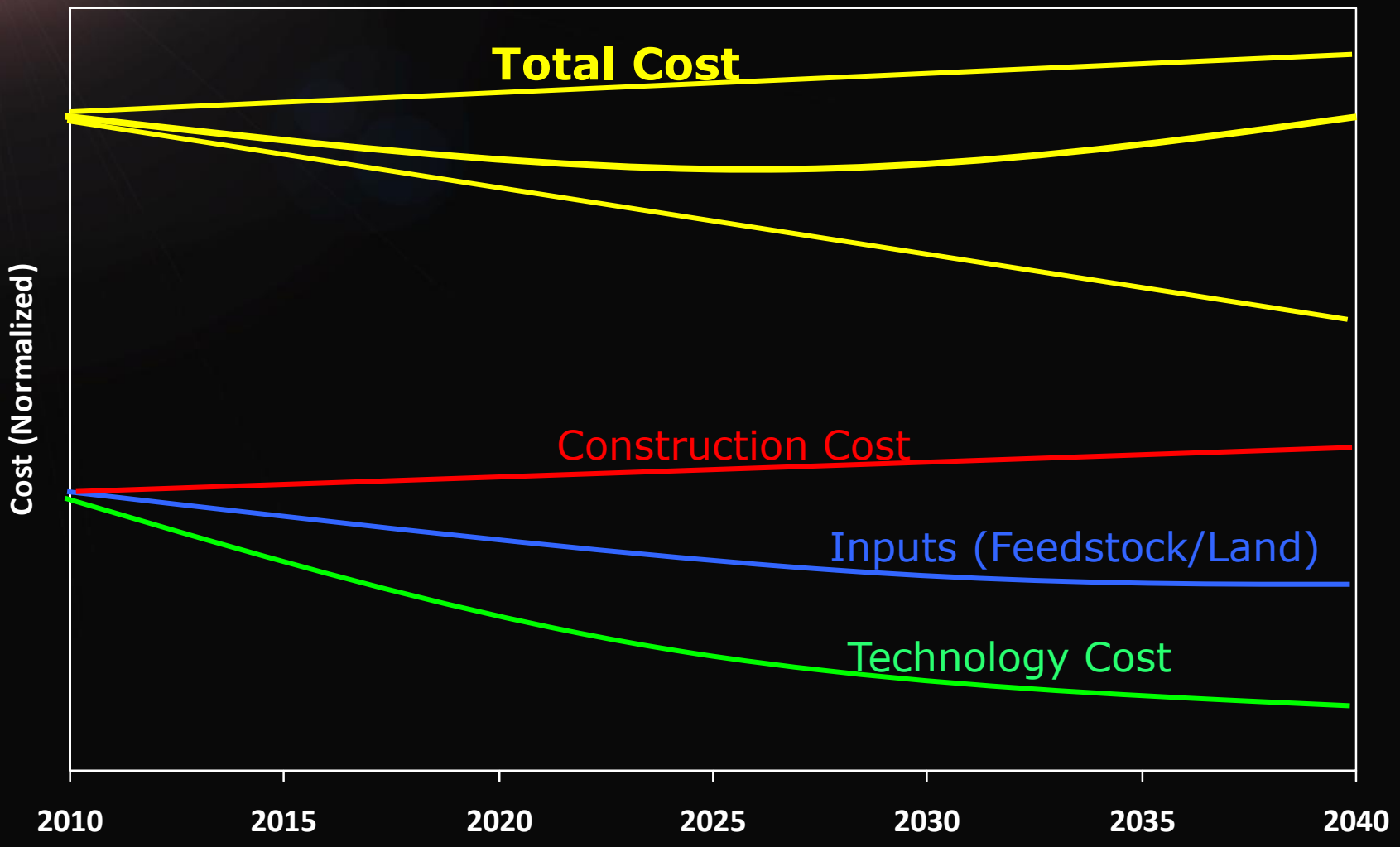


declining technology cost...

Generations of Solar Photovoltaics...



but tech cost decline isn't enough…



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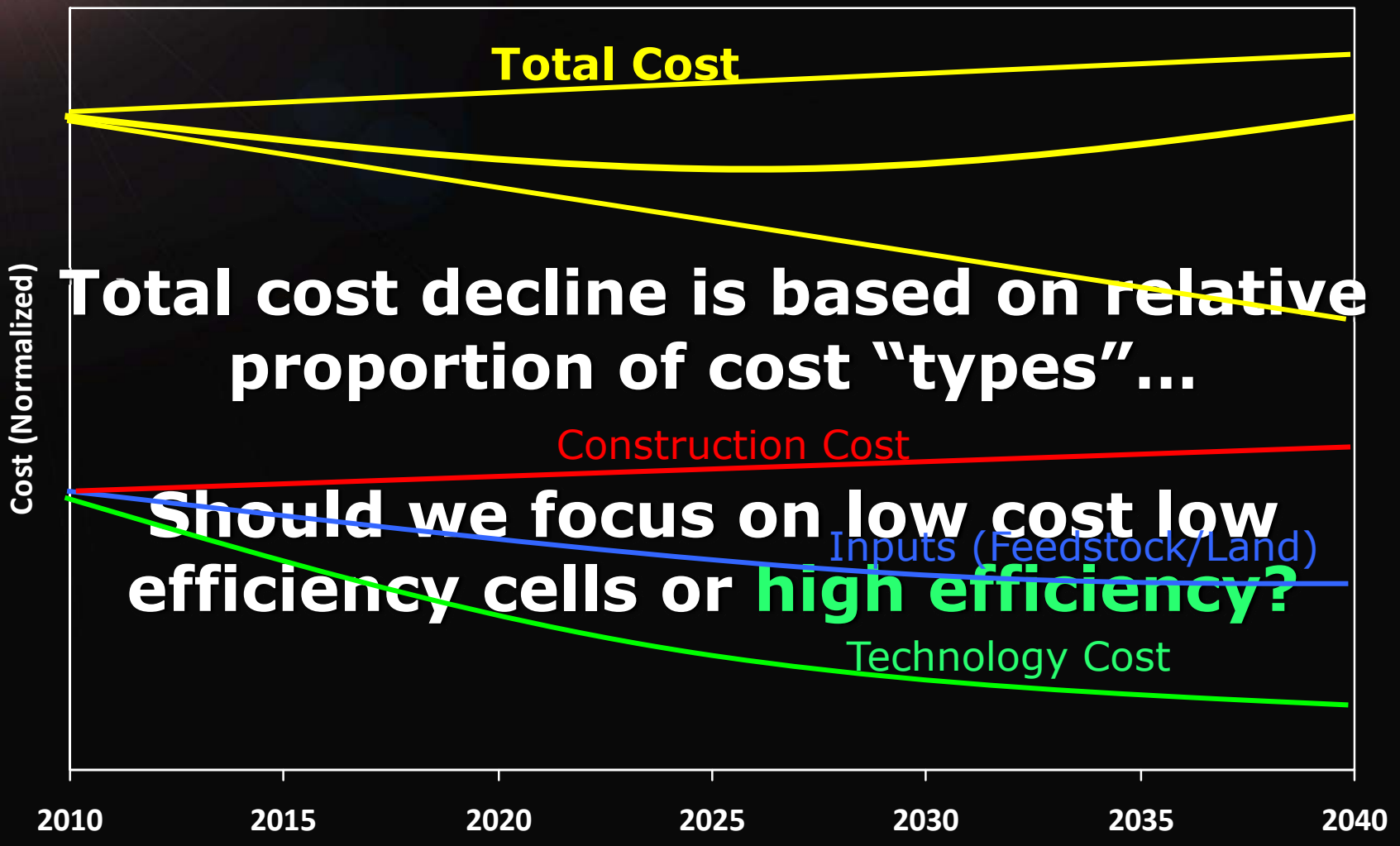
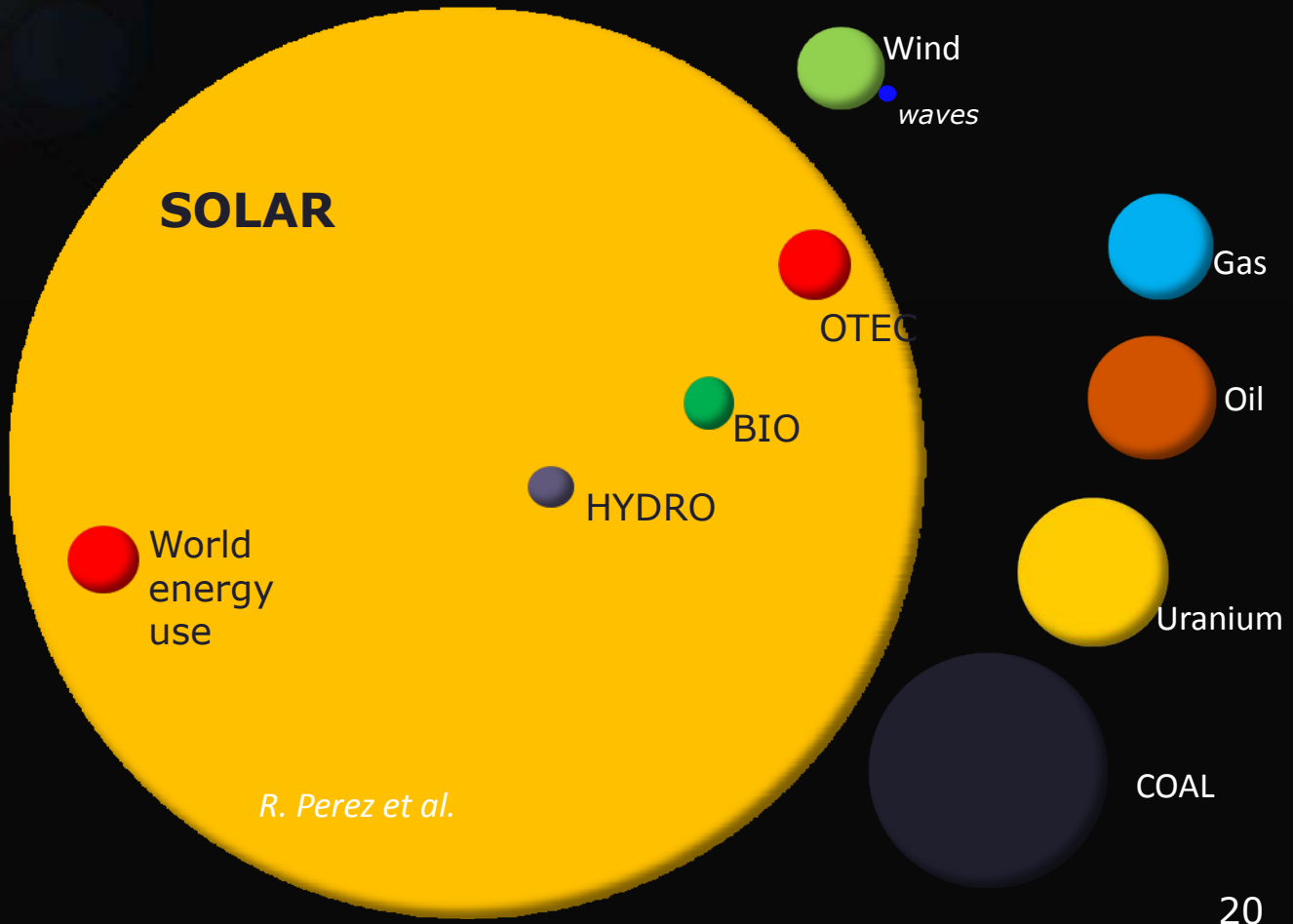
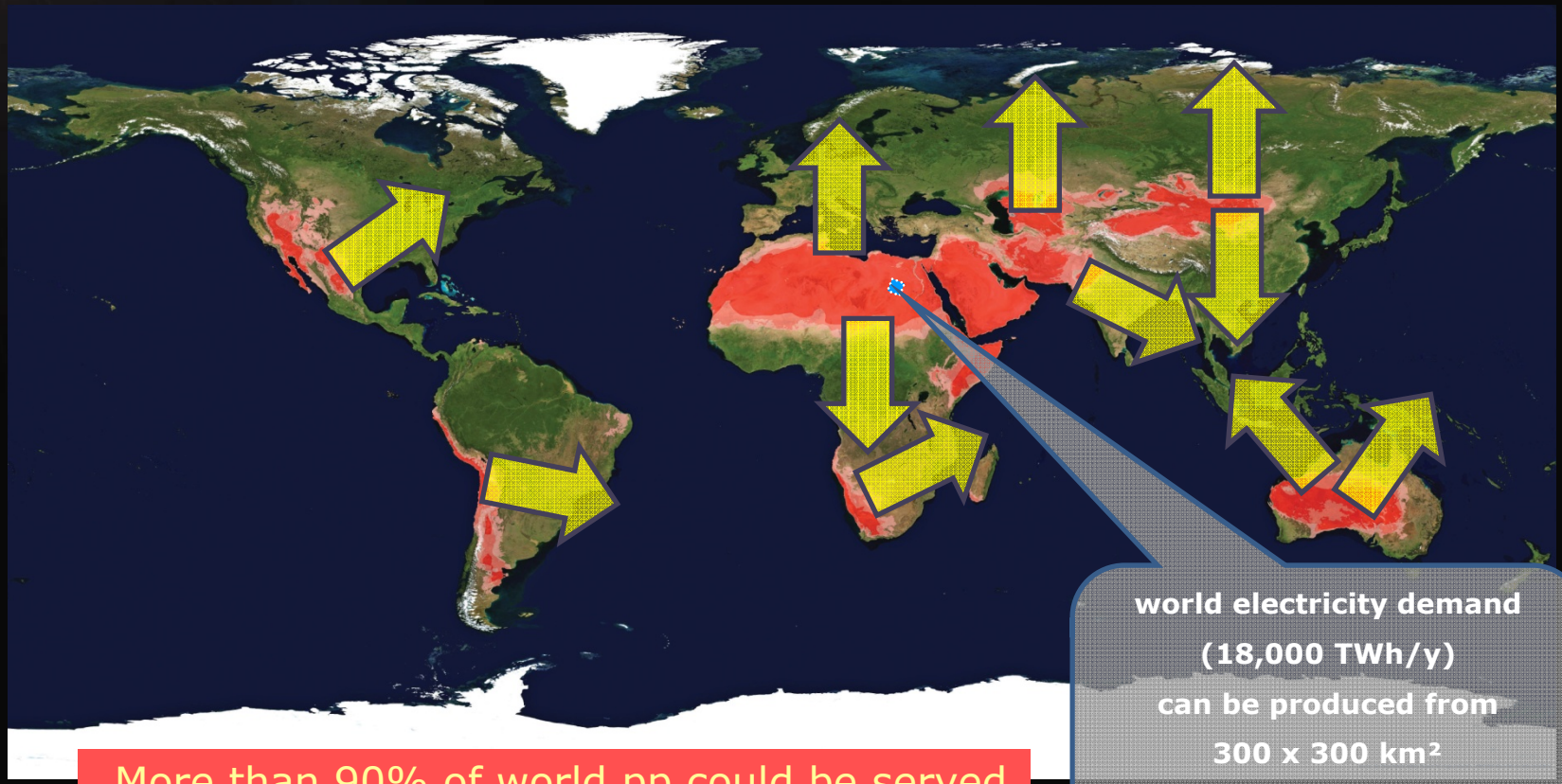


Scalability: solar



Scalability: Land is not (remotely) a constraint

3000 km



world electricity demand
(18,000 TWh/y)
can be produced from
300 x 300 km²
=0.23% of all deserts
distributed over "10 000" sites

More than 90% of world pp could be served
by clean power from deserts (*DESERTEC.org*) !

scalability shortfalls

- Geothermal, Wind
  - not enough availability, dispatchability

Scale differentiates a niche solution from a material one!

- Electric Cars
  - limited by battery cost trajectory

- "Classic" Biodiesel
  - limited room for optimization; low land efficiency

example: solar PV

… but

- solar cell costs are only 30-40% of total cost; installation costs increasing; inverters on slow curve
- Scale: no storage, no base-load power
- Rooftop = need better sun locations

Solutions:

- High cell efficiency = lower installation costs/kw
- Better locations for more KW per hour

example: wind

Good:

- Wind turbine shows declining costs over time

... but

- Technical: Betz limit (59.6%)
- Scalability: good sites declining
- Systems for distributed sources
- Cost: increasing cost with scale

Storage is the key for wind power

example: natural gas automobiles

Good:

- Moderate CO2 reductions

… but **Picken's plan is a dead end street**

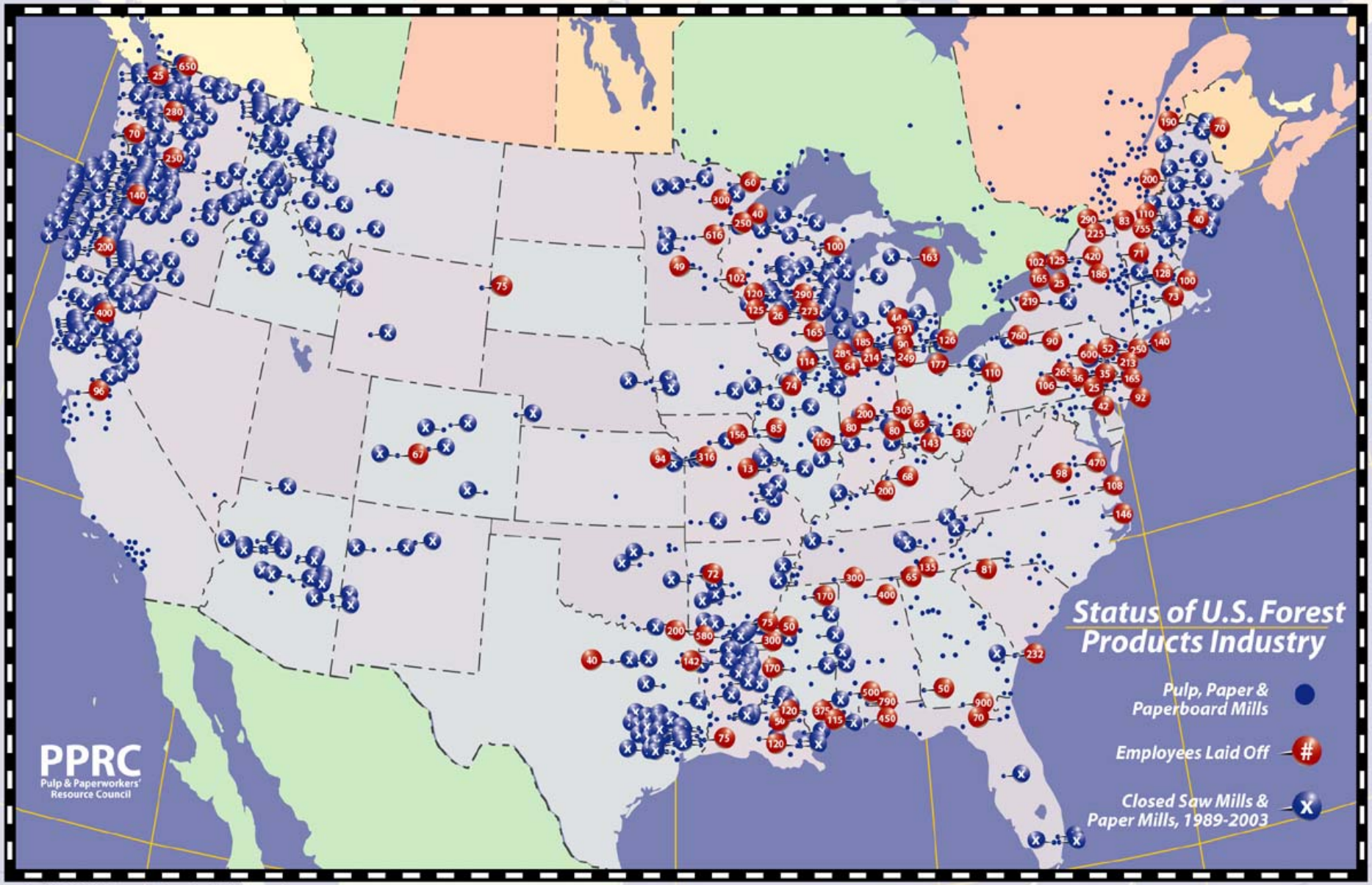
- Commodity price variability & supply risk
- Mature technology with "fossil" carbon limits
- No capacity building towards 80% reduction

adoption risk - $2,500 nano

… ICE or hydrogen?

…the Chindia test on relevance

adoption risk: U.S. mill closures

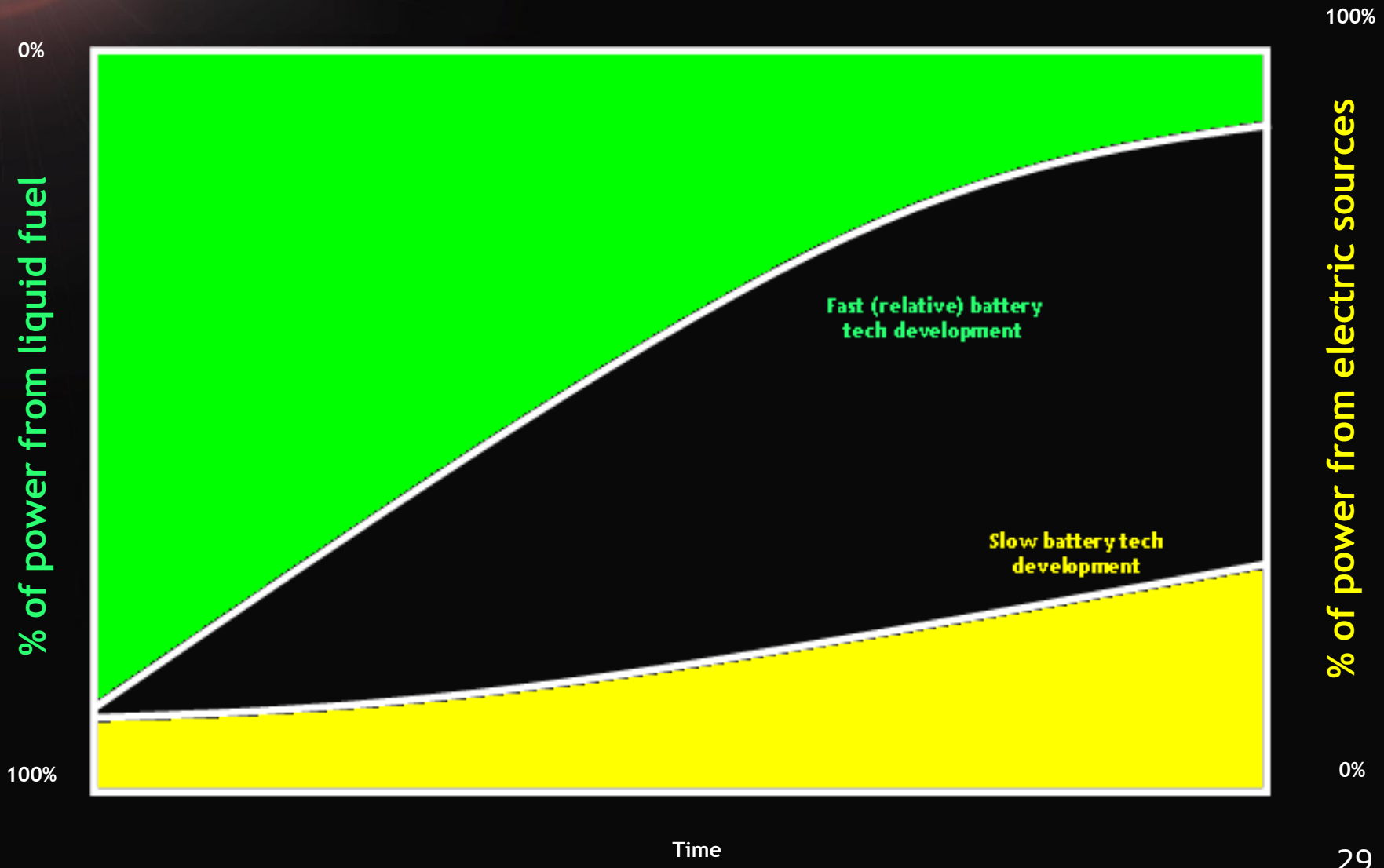


capital formation

- **Short Innovation Cycles (3-5 years)**
  - Not "fusion"; Not "nuclear"; Not CCS
- **Mitigate technical AND/OR market risk quickly and cheaply**
  - (technical) - solar thermal
  - (market) – corn ethanol
- **Investor returns at each stage of technology development**
- **Unsubsidized market competition: 7-10 years**

Private money will flow to ventures that return investment in 3-5 year cycles!

optionality: hybrids or biofuels?



goal:

cost, carbon reduction capacity, carbon & scaling trajectory, capital formation, low adoption risk, & optionality

…"relevant scale" solutions for

… oil

… coal

… materials

… efficiency

…"lets face the facts"

… Prius: vs. painting 1000 sq-ft of roof white

… Wind & PV: unscalable solutions without storage!

… "Classic" Biodiesel: a technological dead-end!

… CCS Coal: "FutureGen" or "Nevergen"?

… Hydrogen powered cars: a bridge to nonsense?

“extrapolation of the past”

vs.

“inventing the future”

"no change bigotry"

vs.

"environmental everything"

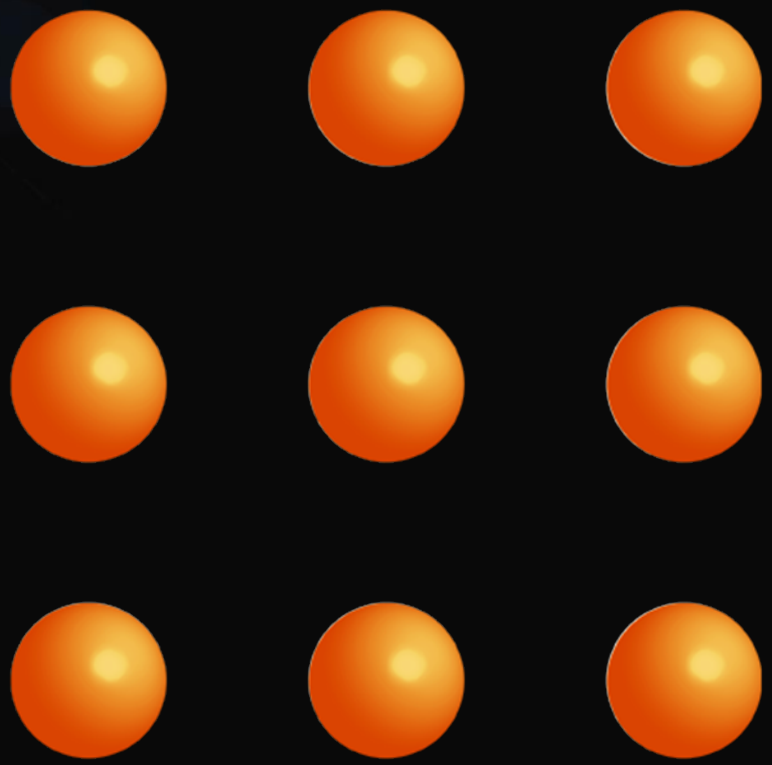
vs.

pragmentalists

Challenge conventional wisdom!

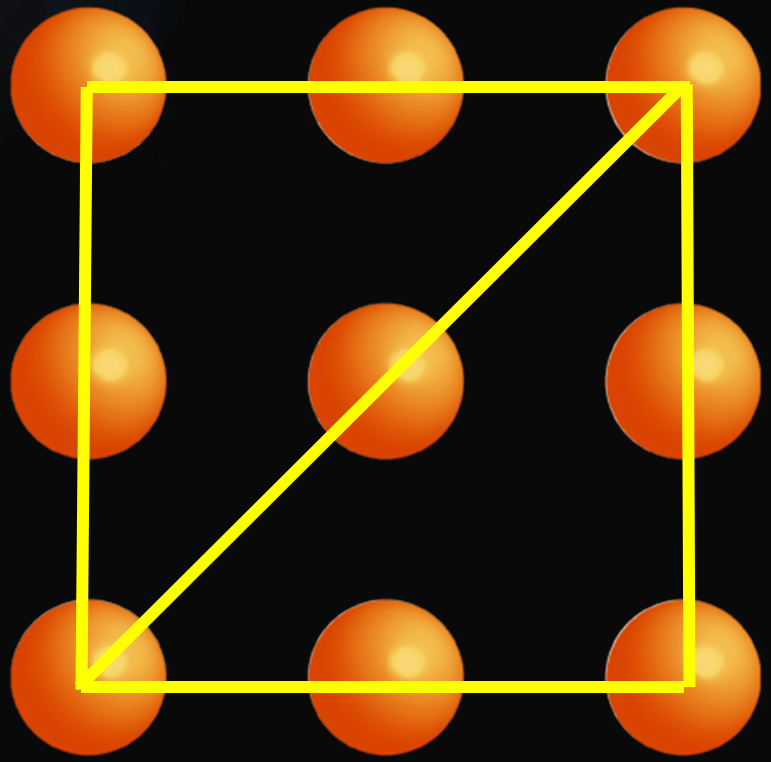
The nine dots problem…

The nine dots problem



Source: Amory Lovins, RMI

Standard solution: Five lines



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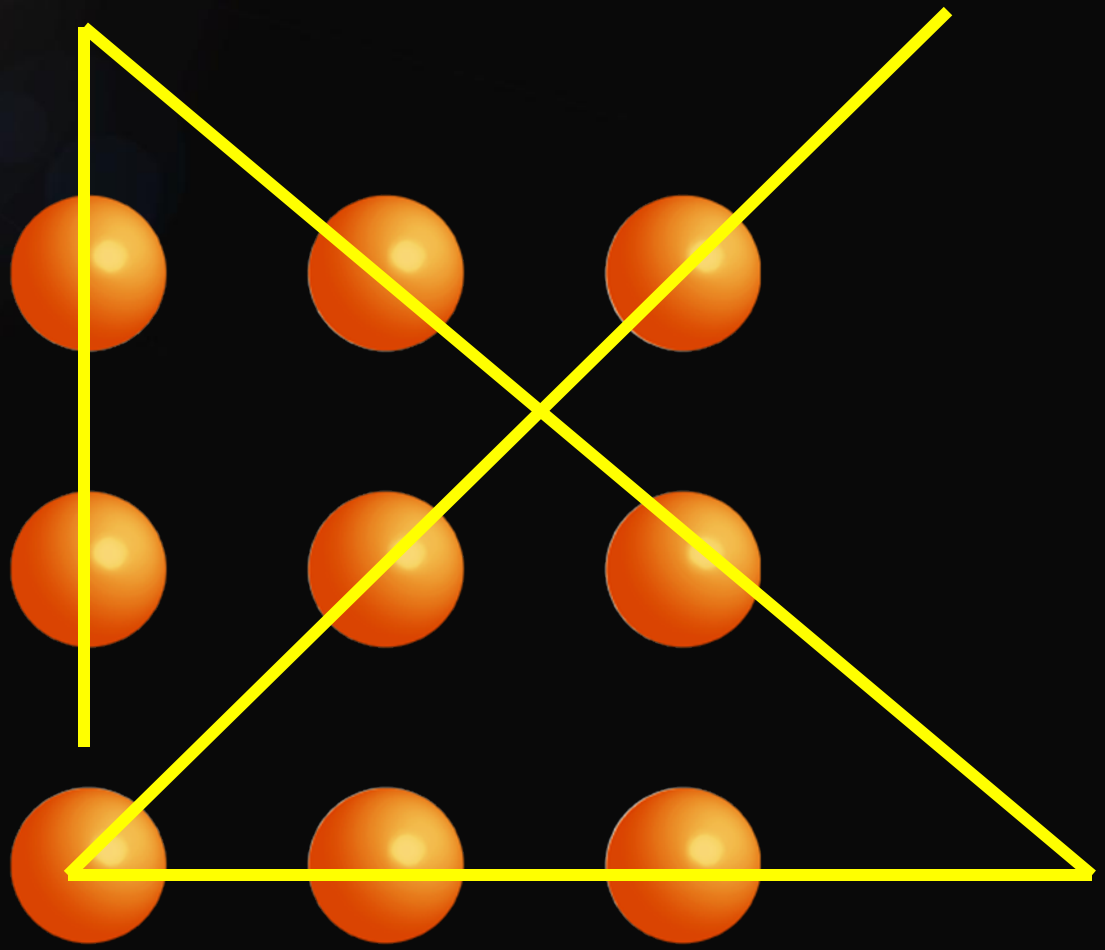
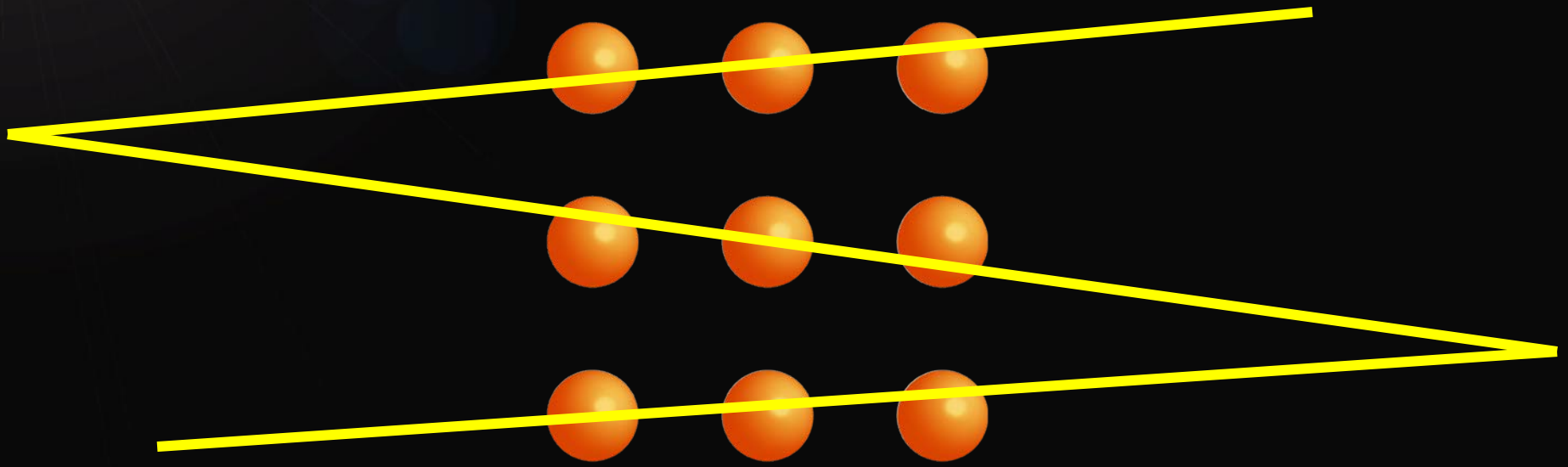
Four Lines



Source: Amory Lovins, RMI

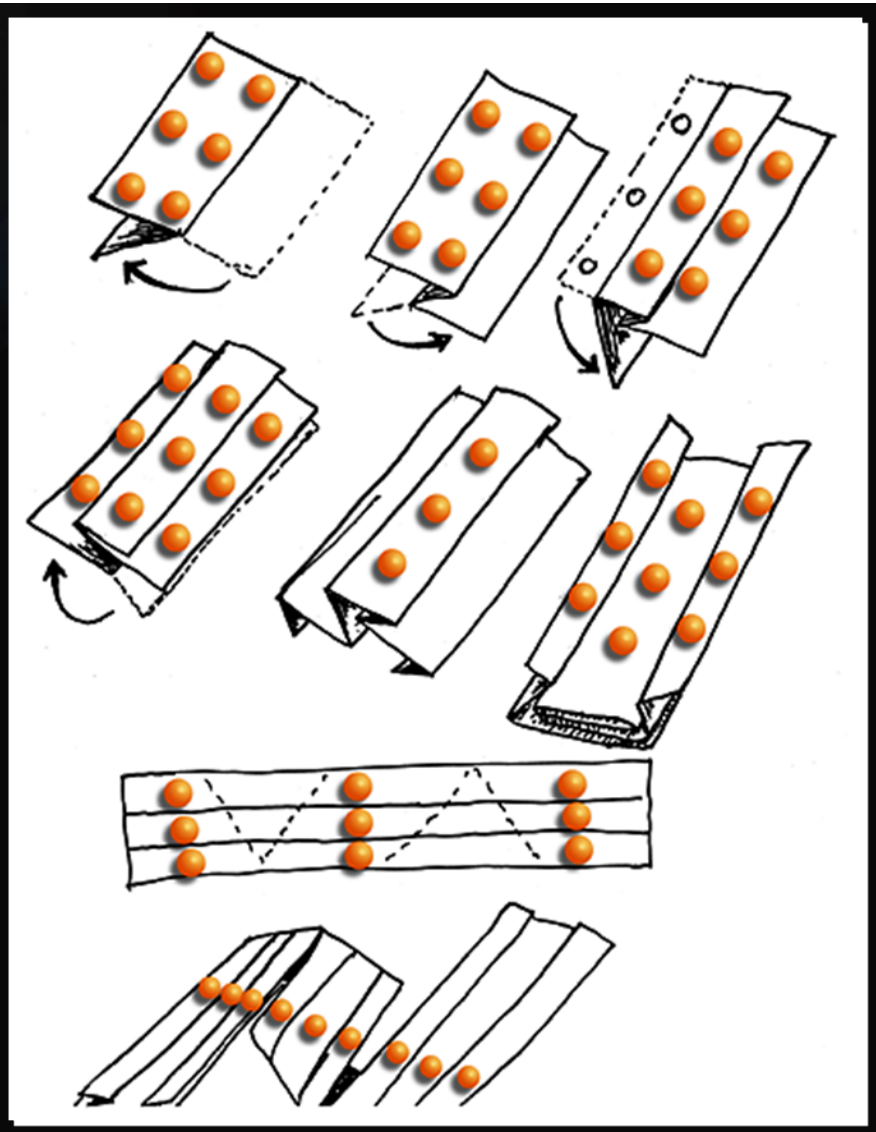
Better: use just three lines



But…how about just *one* line?

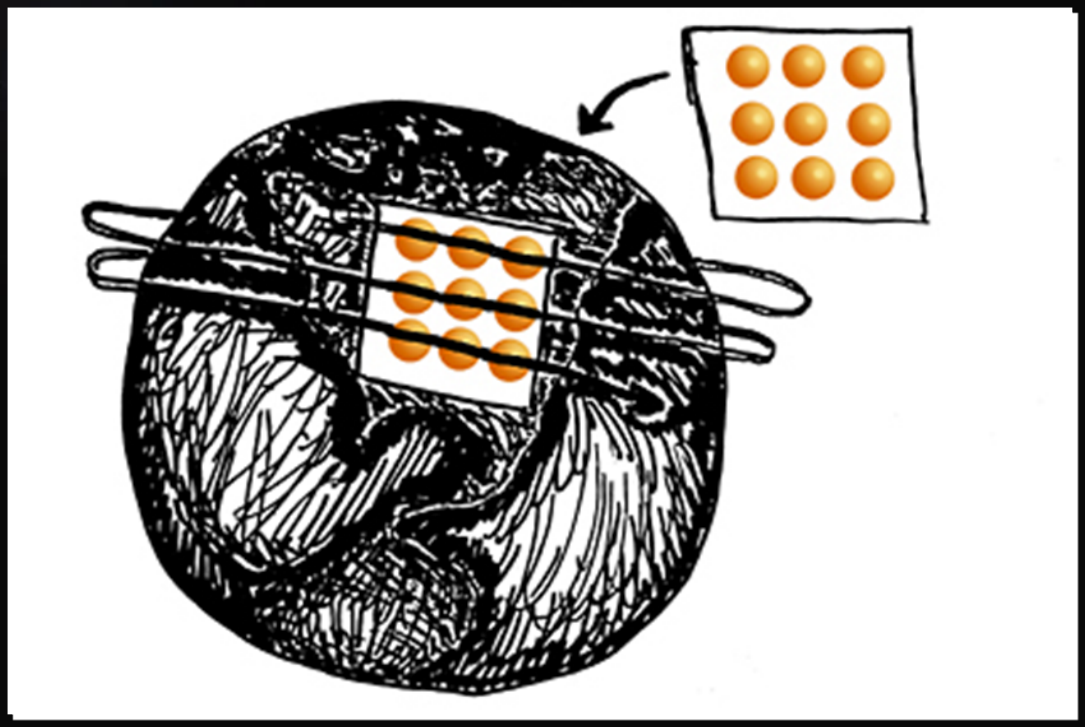
Source: Amory Lovins, RMI

Origami Solution



Source: Amory Lovins, RMI

Geographer's Solution

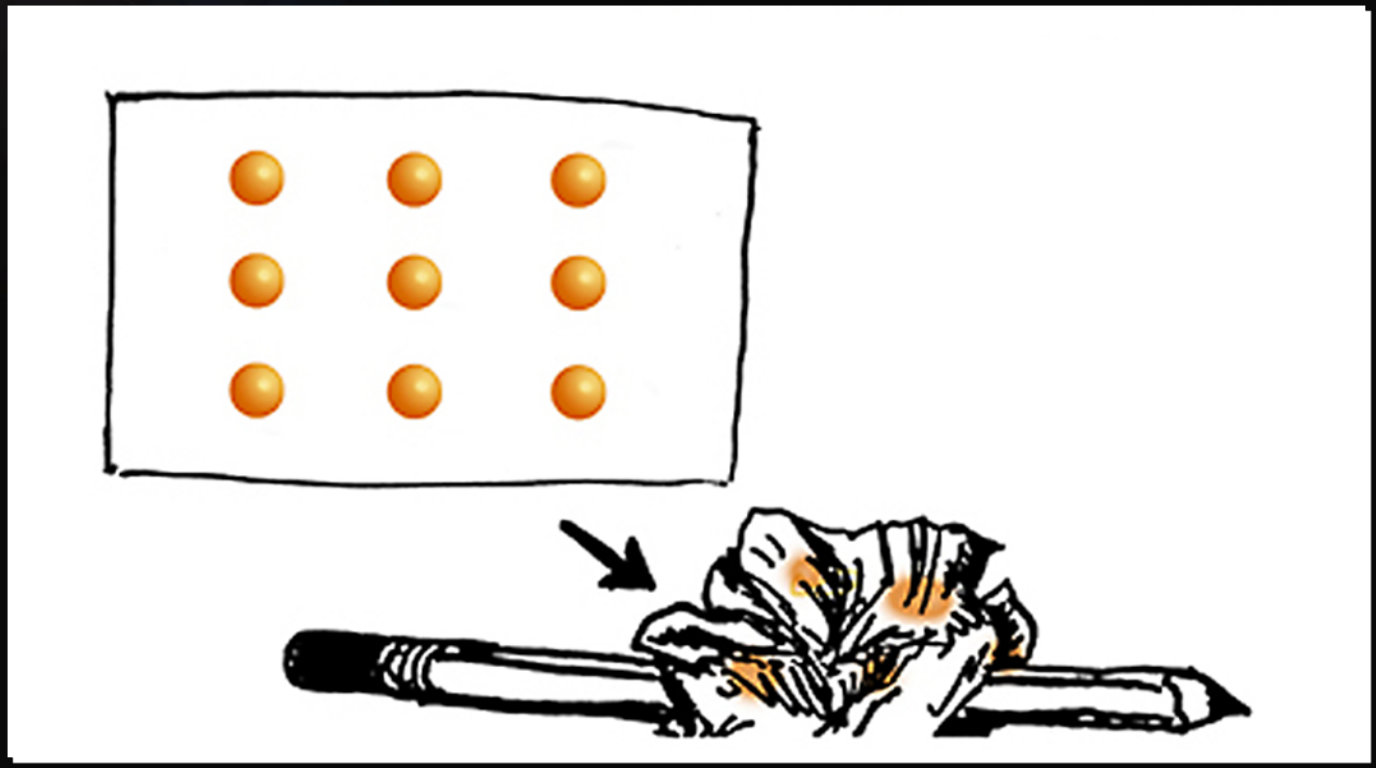


Source: Amory Lovins, RMI

Mechanical Engineer's Solution

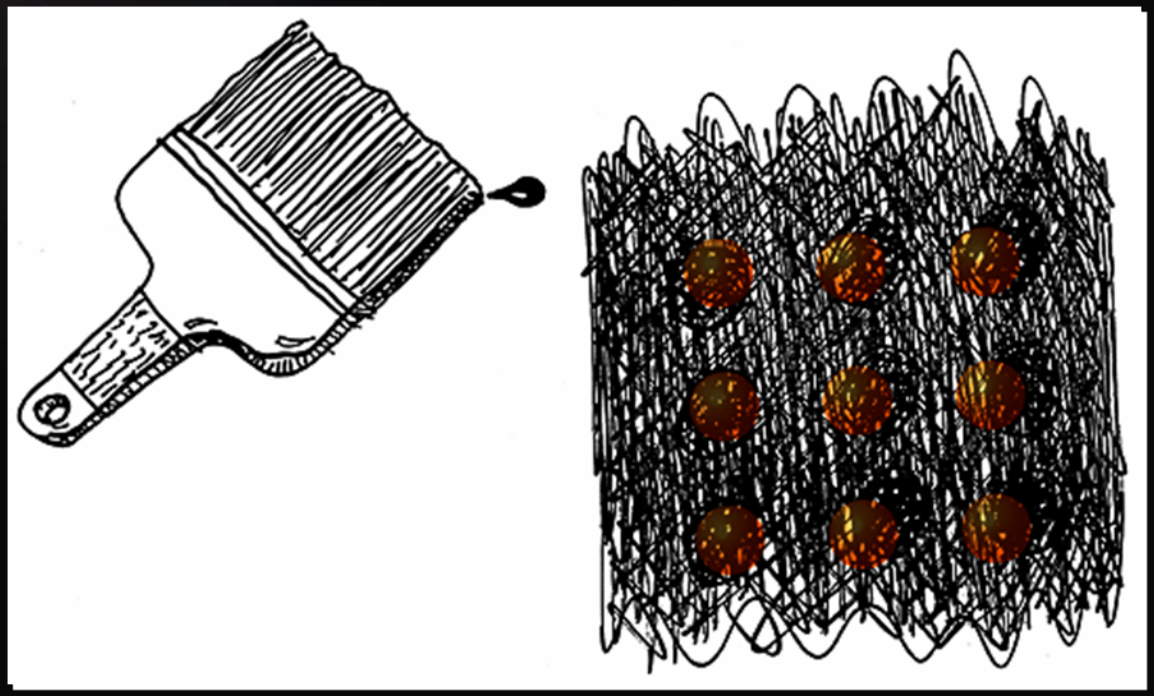
Source: Amory Lovins, RMI

Statistician's Solution



Source: Amory Lovins, RMI

Wide Line Solution



Source: Amory Lovins, RMI

"black swan" solutions ?

Black Swans events are:

- Outliers: outside realm of traditional expectations
- Material: make significant, game-changing impact
- Justifiable: not predicted, but justified on ex-post basis

"rarity, extreme impact, and retrospective (though not prospective) predictability"

Source: Nassim Nicholas Taleb, author of "The Black Swan"

"black swan" solutions ?

Black Swans events are:

- Outliers: outside realm of traditional expectations
- Material: make significant, game-changing impact
- Justifiable: not predicted, but justified on ex-post basis

Technology shocks are classic "Black Swans"!

Strategy: More "at bats"; "shots on goal"

"rarity, extreme impact, and retrospective (though not prospective) predictability"

Source: Nassim Nicholas Taleb, author of "The Black Swan"

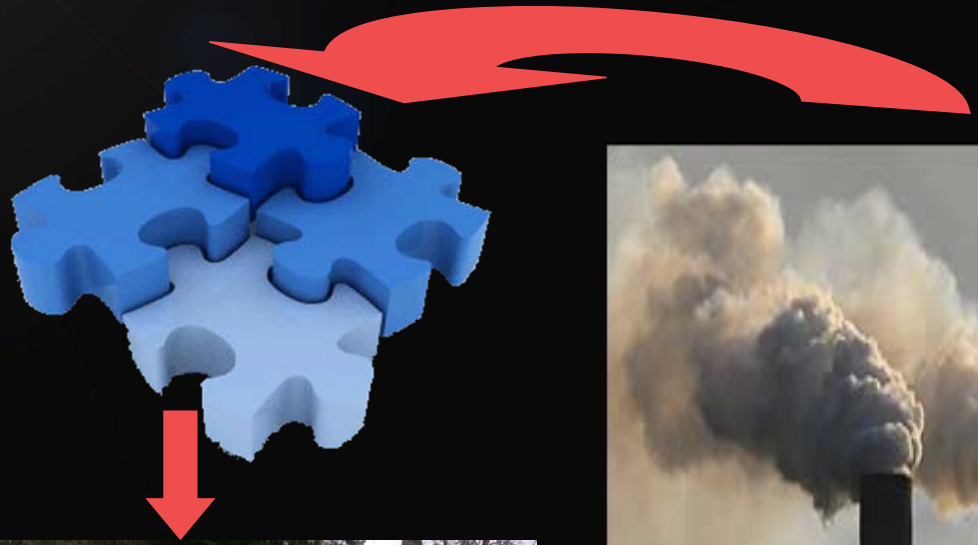
“what if…”

- “more coal plants meant cleaner air”
- “more driving meant less carbon”
- “cement was carbon negative & free”
- “a million year crude production cycle reduced to hours?”
- “engines were twice as efficient cutting world oil consumption in half”

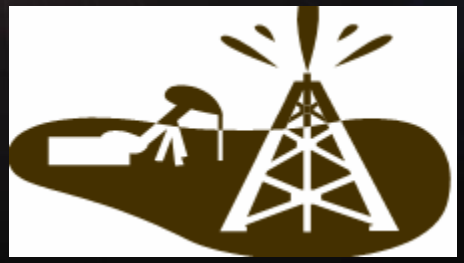
We are working on these & imagining the future!

Calera

- Cement that sequesters CO2, instead of emitting it!



“biocrude” replaces crude



Crude oil

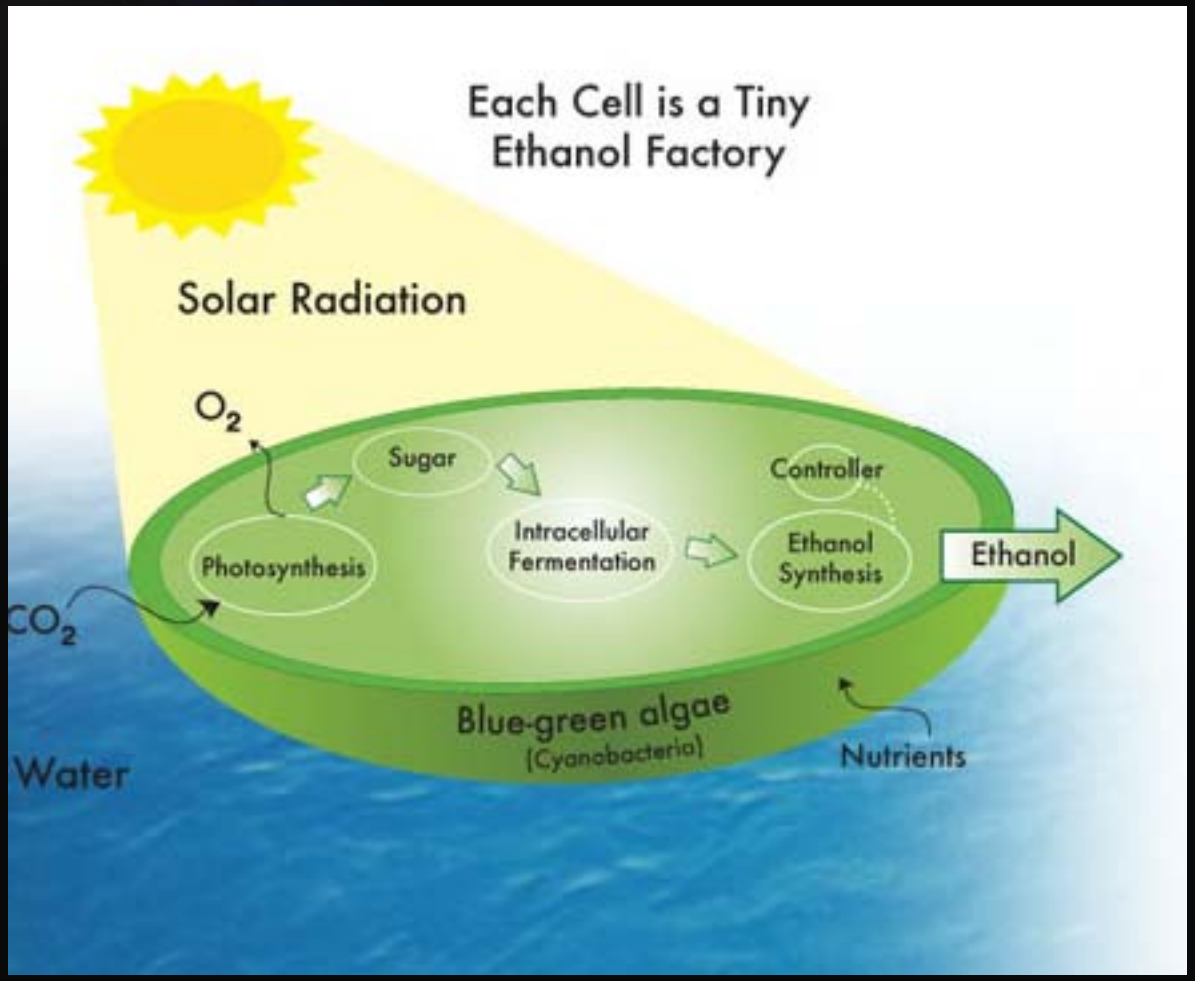
KiOR Biocrude

EESTOR ceramic battery

- Up to 10X energy density of lead-acid battery
- Up to 1/10th weight and volume!

Algenol

- Direct "algae to ethanol" technology
- Yields > 6,000 gallons per acre



not your niche markets anymore!

The New Green

The Markets You Think Of

- Engines ($200B)
- Lighting ($80B - US)
- Appliances ($10'sB+)
- Batteries + Flow Cells ($50B+)

- Corn Ethanol
- Biodiesel
- Solar PV
- Wind
- Geothermal

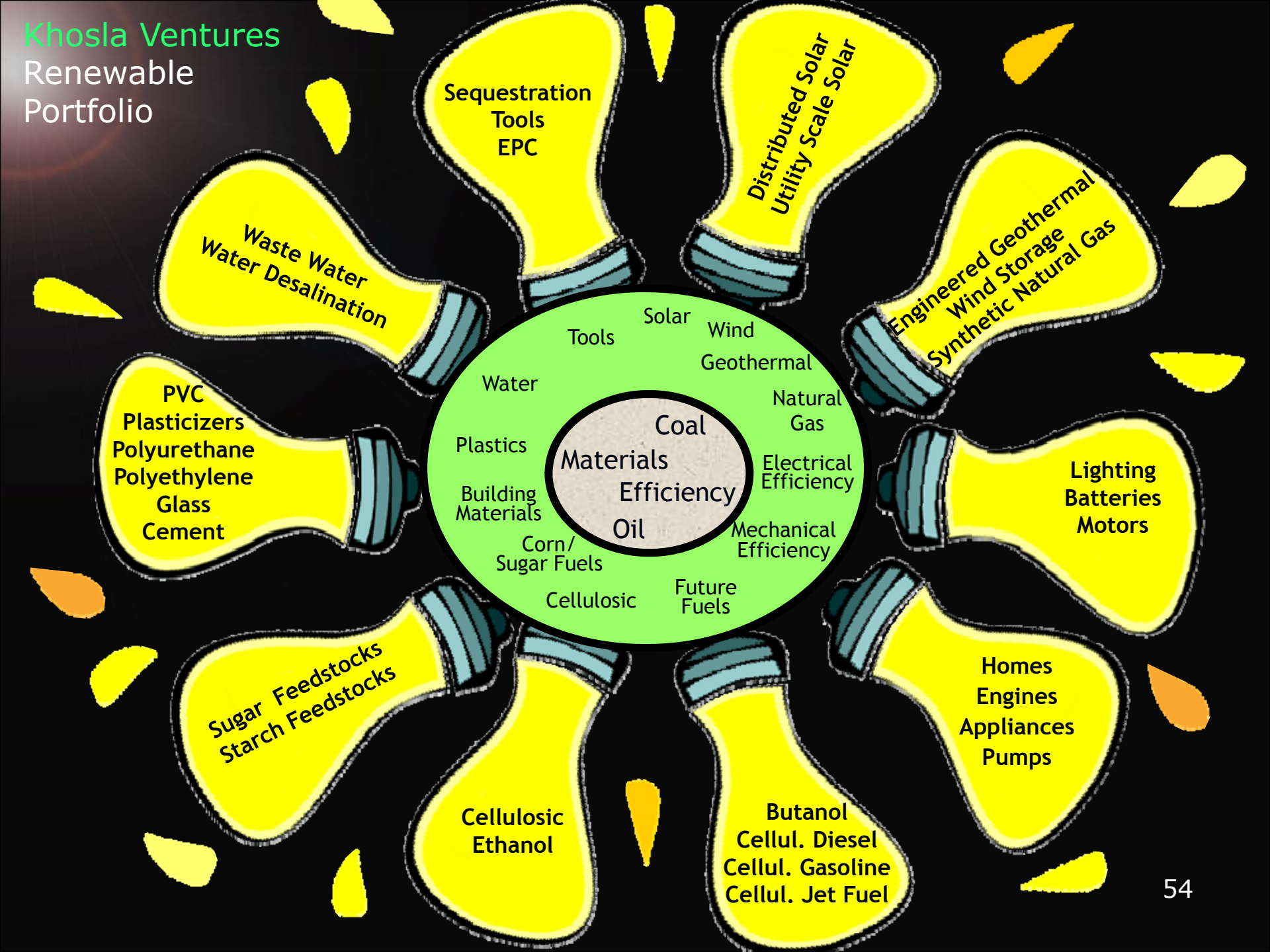
- Gasoline ($500B+)
- Diesel ($500B+)
- Jet Fuel ($100B+)

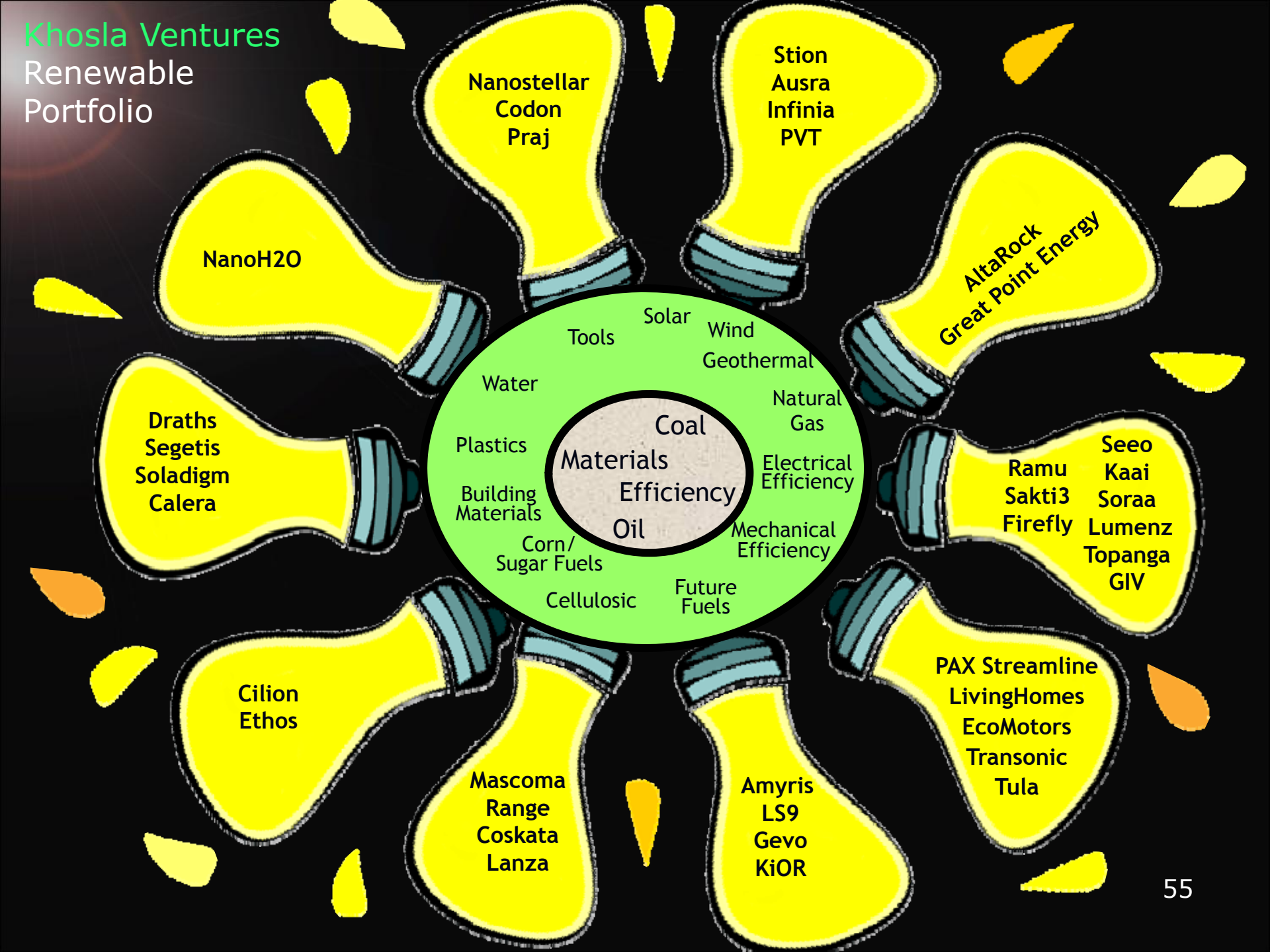
- Cement ($100B+)
- Water ($500B+)
- Glass ($40B)
- Home Building (!!!)
- BioPlastics ($10'sB+)

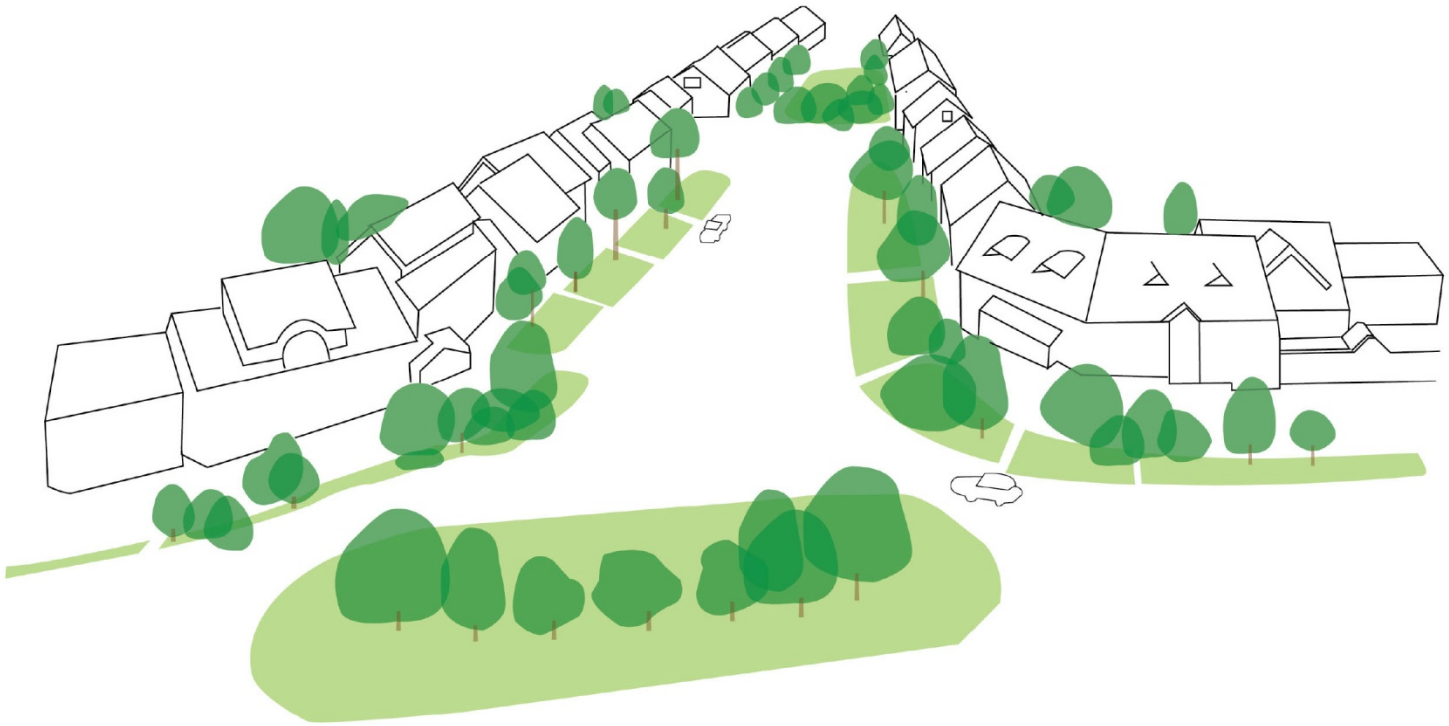
<u>Generation - $250B - US</u>

- Solar Thermal
- EGS
- Clean Coal
- New Nukes

…our renewable portfolio


Khosla Ventures
Renewable
Portfolio
Sequestration
Tools
EPC
Distributed Solar
Utility Scale Solar
Waste Water
Water Desalination
Engineered Geothermal
Wind Storage
Synthetic Natural Gas
PVC
Plasticizers
Polyurethane
Polyethylene
Glass
Cement
Lighting
Batteries
Motors
Sugar Feedstocks
Starch Feedstocks
Cellulosic
Ethanol
Butanol
Cellul. Diesel
Cellul. Gasoline
Cellul. Jet Fuel
Homes
Engines
Appliances
Pumps
Tools
Solar
Wind
Geothermal
Water
Natural
Gas
Plastics
Coal
Materials
Efficiency
Oil
Electrical
Efficiency
Building
Materials
Mechanical
Efficiency
Corn/
Sugar Fuels
Cellulosic
Future
Fuels

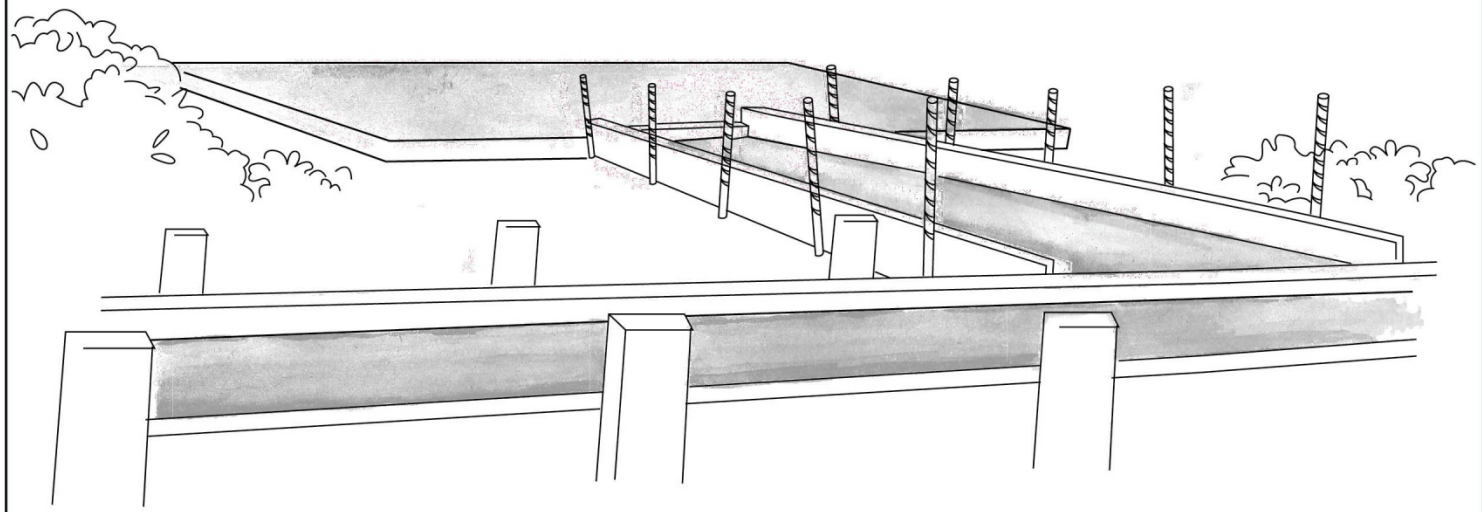

Khosla Ventures
Renewable
Portfolio
Nanostellar
Codon
Praj
Stion
Ausra
Infinia
PVT
NanoH2O
AltaRock
Great Point Energy
Solar
Wind
Tools
Geothermal
Water
Natural
Gas
Coal
Plastics
Materials
Electrical
Efficiency
Efficiency
Building
Materials
Oil
Mechanical
Efficiency
Corn/
Sugar Fuels
Future
Fuels
Cellulosic
Draths
Segetis
Soladigm
Calera
Seeo
Kaai
Soraa
Ramu
Lumenz
Sakti3
Topanga
Firefly
GIV
Cilion
Ethos
PAX Streamline
LivingHomes
EcoMotors
Transonic
Tula
Mascoma
Range
Coskata
Lanza
Amyris
LS9
Gevo
KiOR



Together, our products will improve the way all people live

Companies

Calera Corporation



Built on carbon negative cement

Companies

Living Homes

And prefabricated, environmentally friendly, cheaper, LEEDS homes

Companies

Soladigm

Using electrochromatic windows

Fueled from renewable sources

Companies

- Amyris
- LS9
- Gevo
- Kior
- Mascoma
- Range Fuels
- Coskata
- LanzaTech

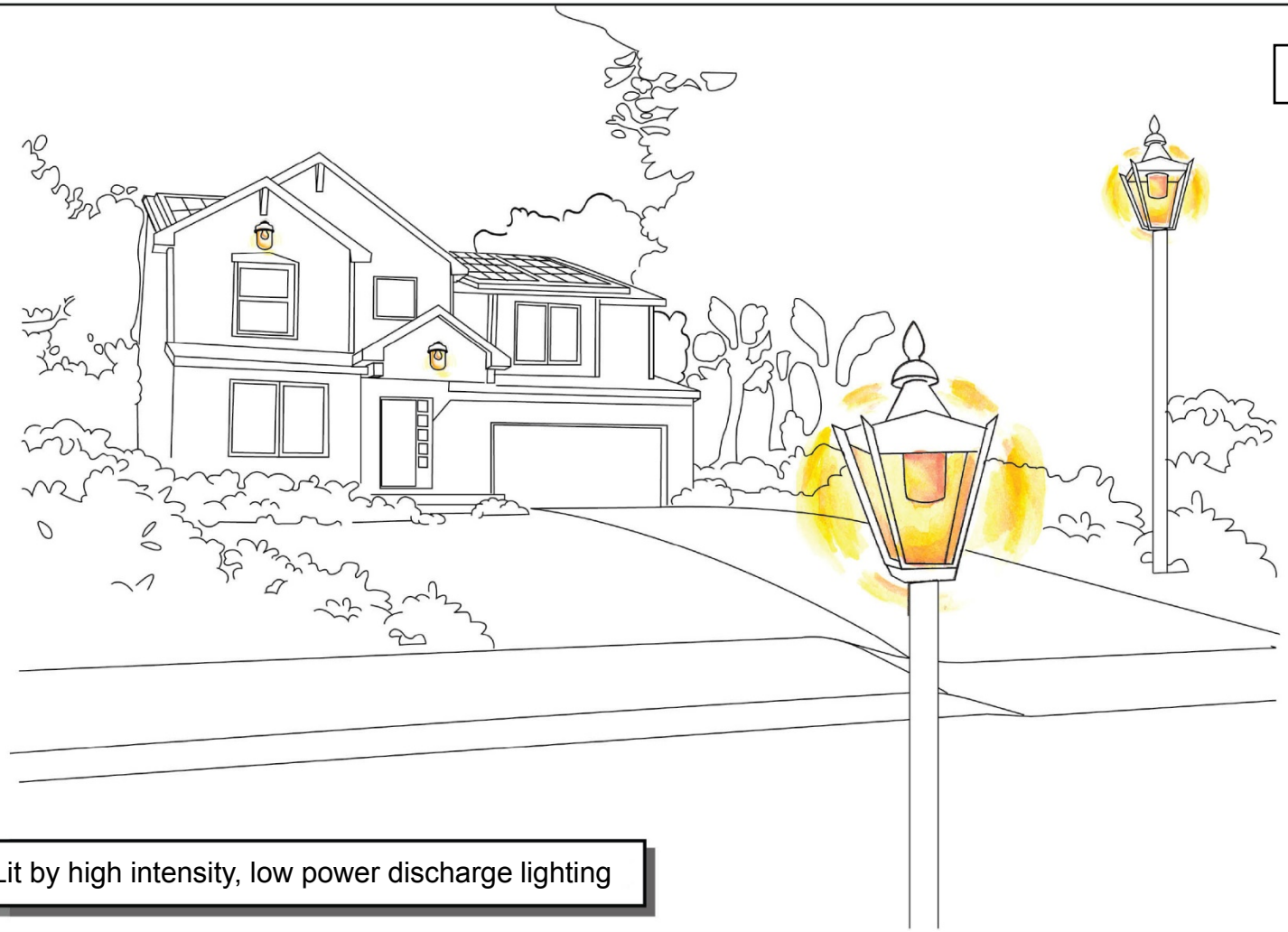
Companies

- Ramu
- EcoMotors
- Transonic
- Firefly
- Seeo
- Sakti3
- Nanostellar
- Tula Technologies

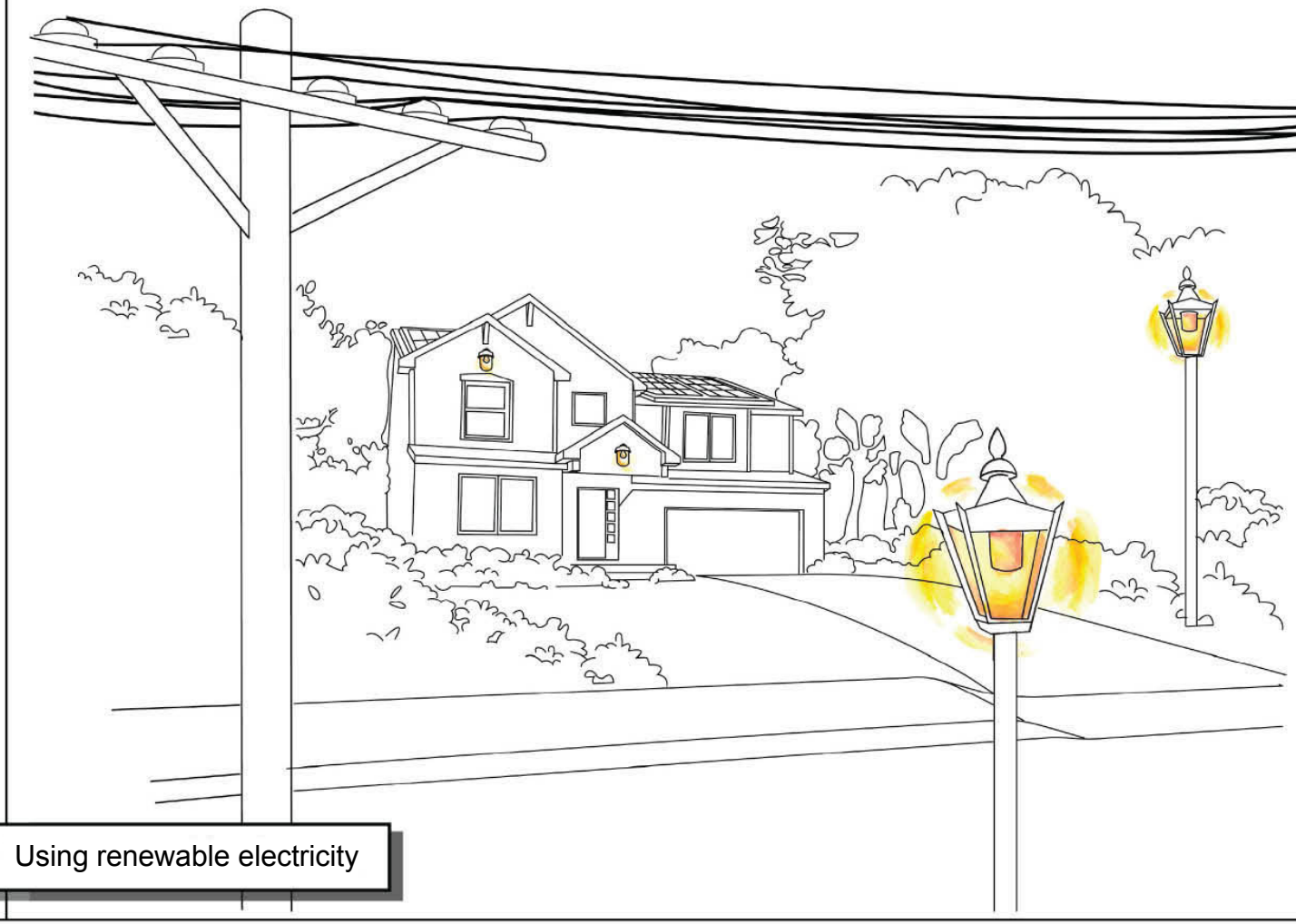
With reduced fuel consumption and CO_2 emissions

Companies

Topanga



Lit by high intensity, low power discharge lighting



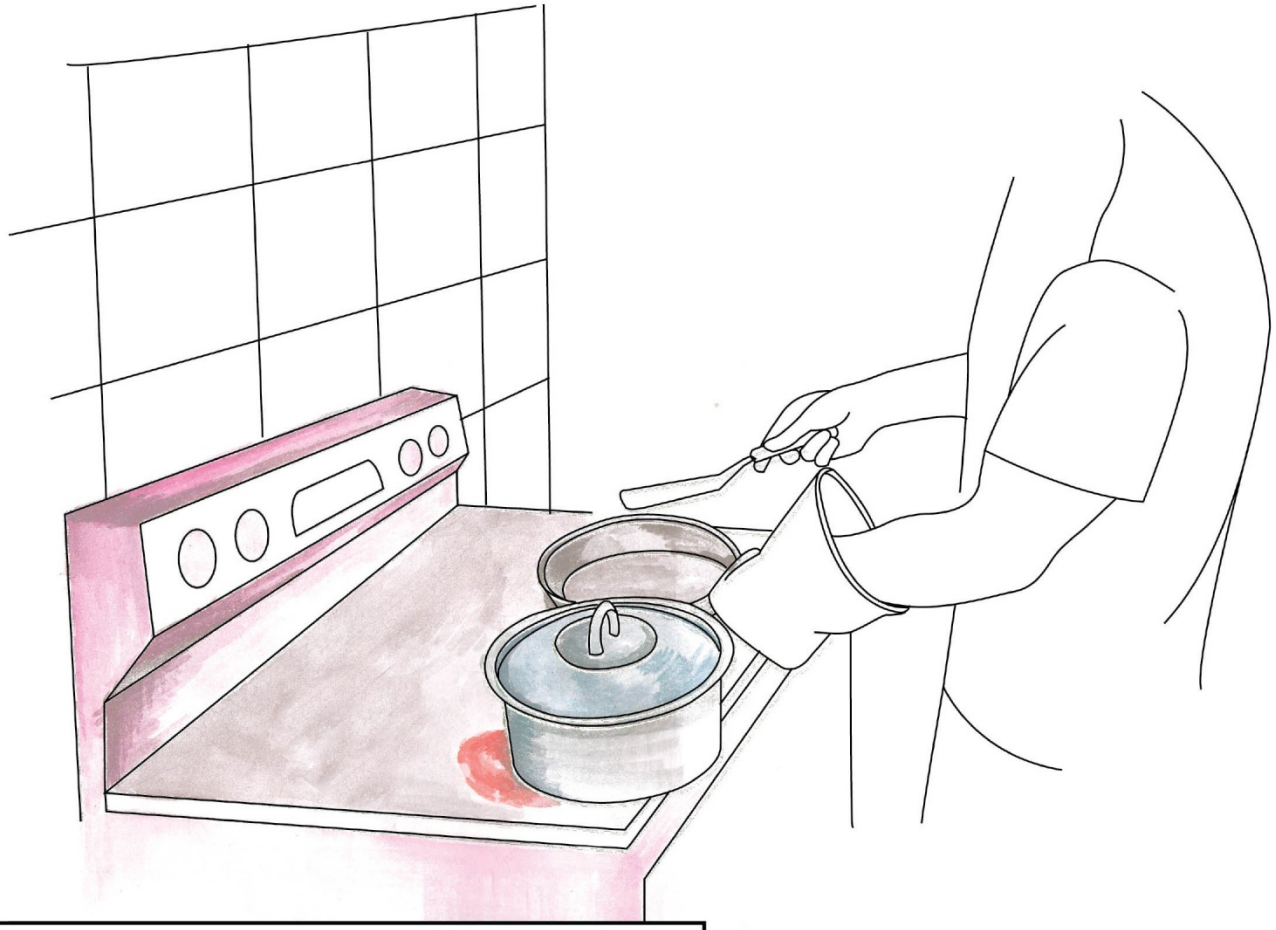
Using renewable electricity

Companies

- Ausra
- Altarock
- Infinia
- Stion
- PVT Solar

Companies

Great Point Energy



Cooking with natural gas from clean coal & biomass

Companies

Lumenz

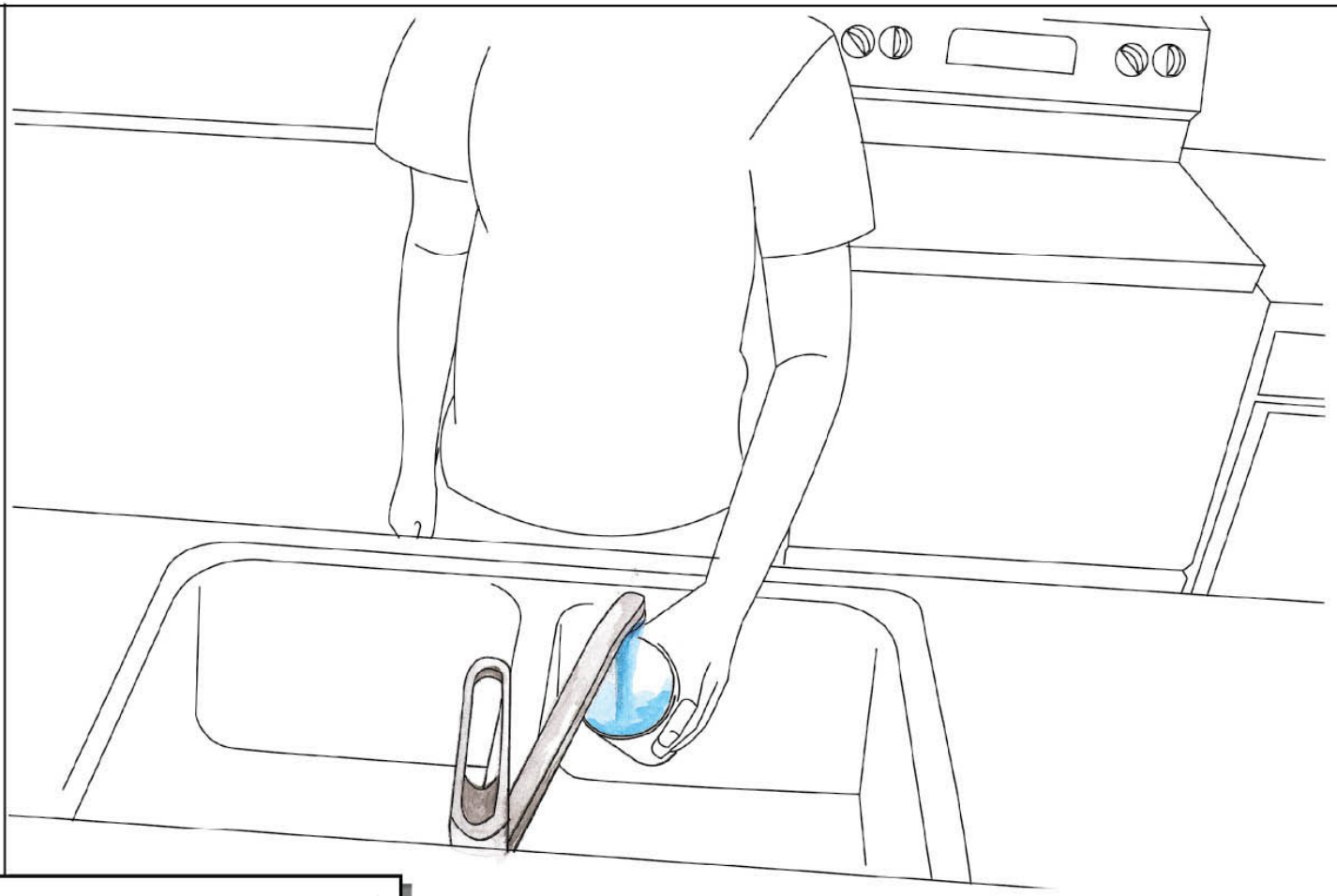
Group IV

Soraa

Reading with LED lighting

Companies

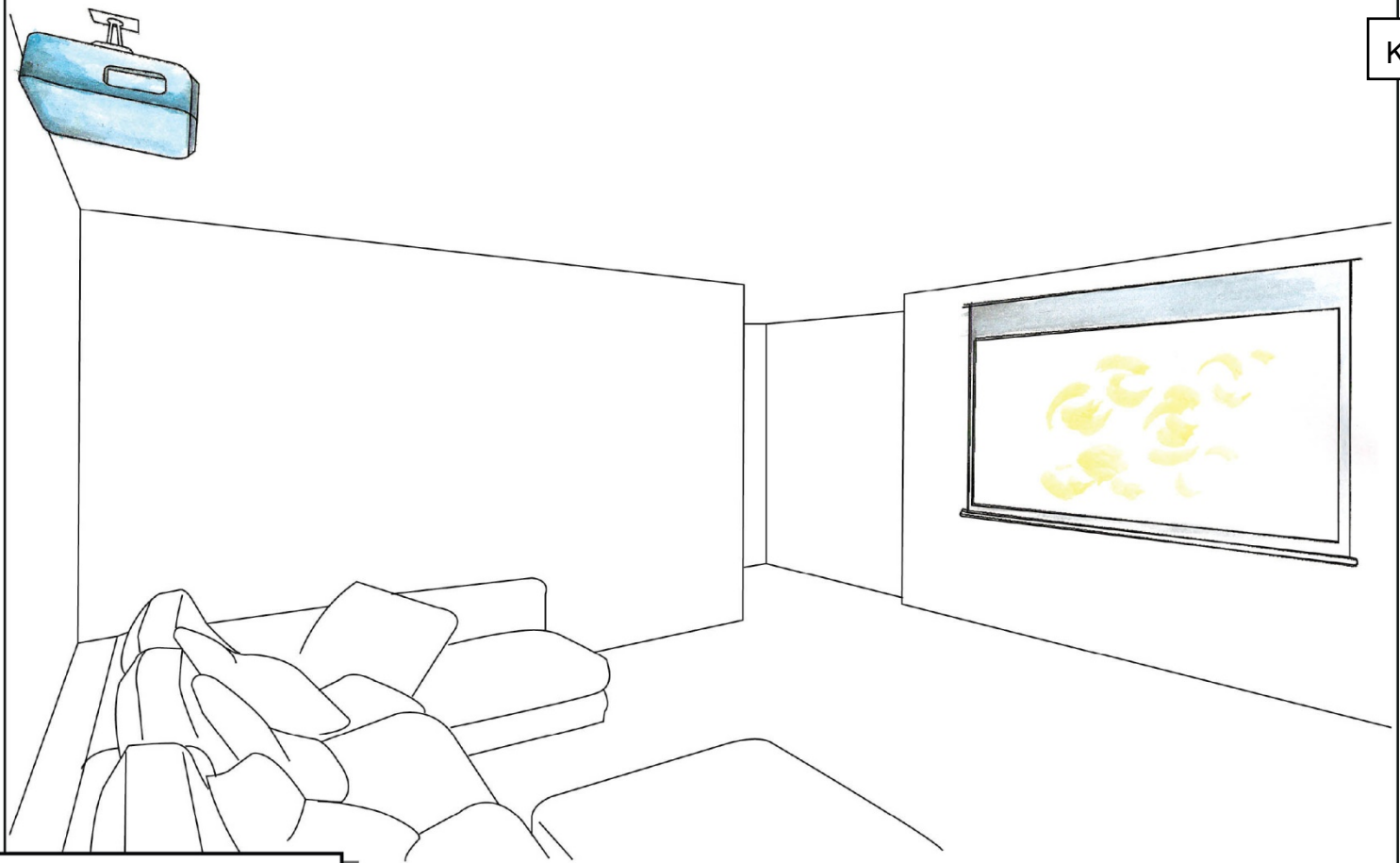
NanoH2O



Drinking desalinated water

Companies

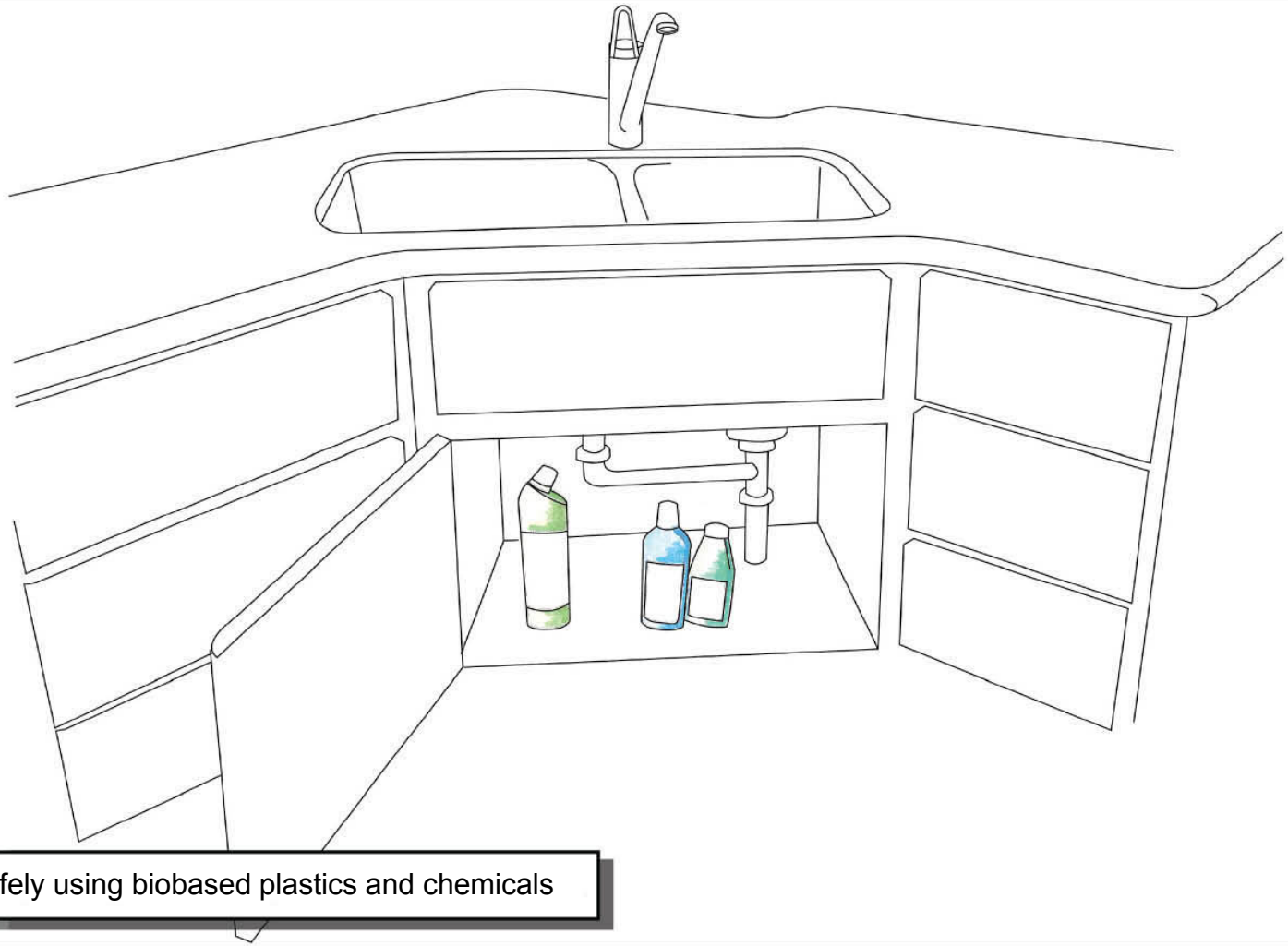
Kaai



Watching HD laser TV

Companies

Segetis



Safely using biobased plastics and chemicals

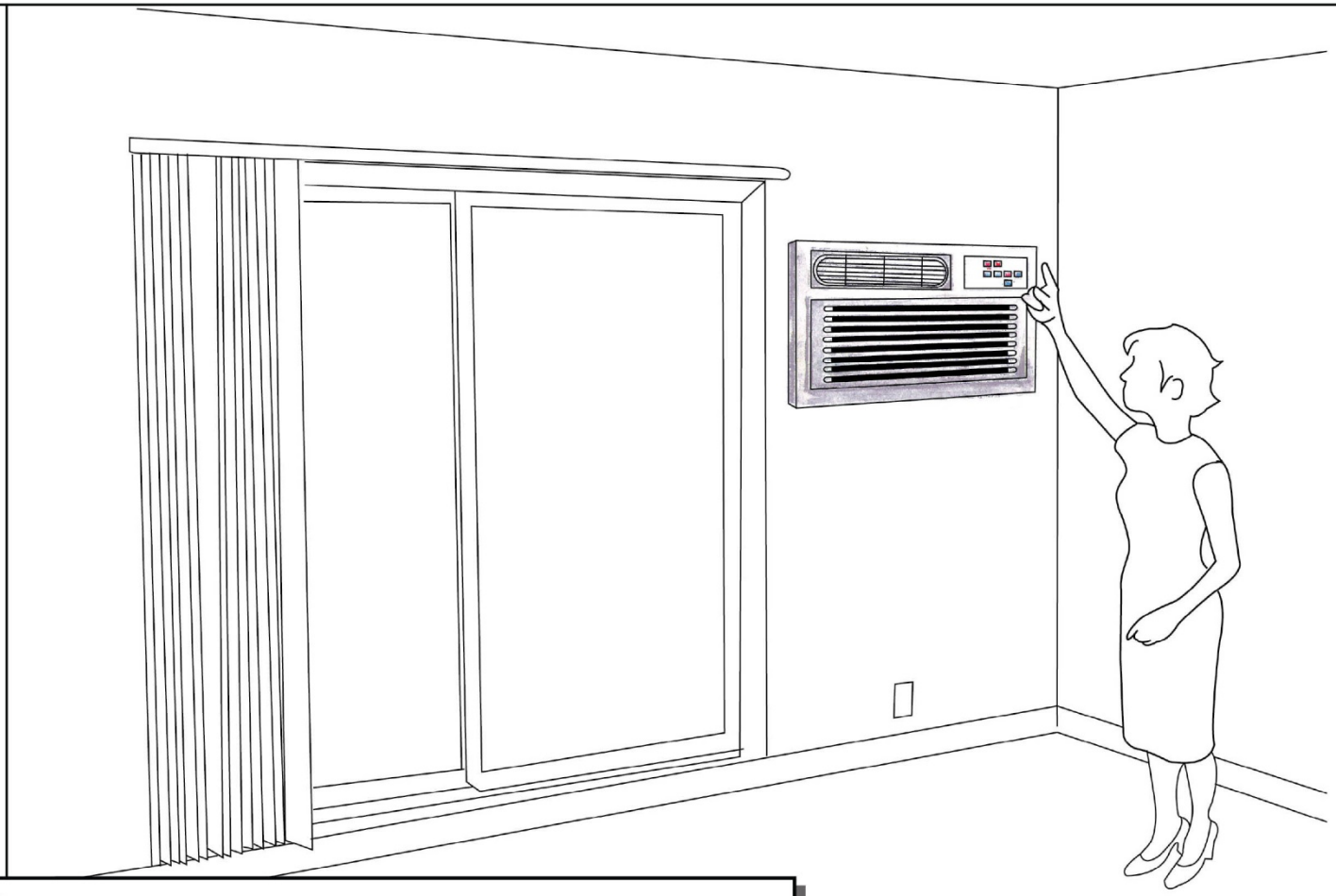
Companies

Draths

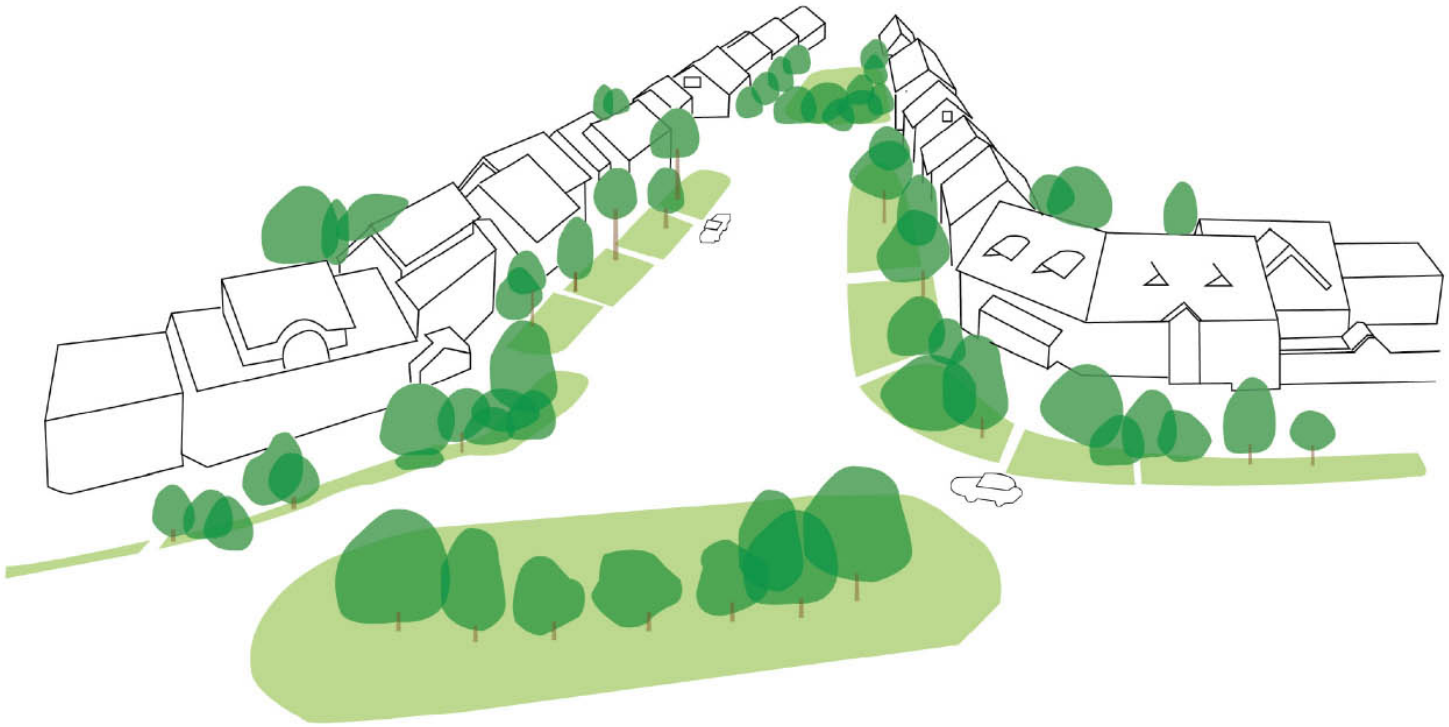
Biobased materials for your home

Companies

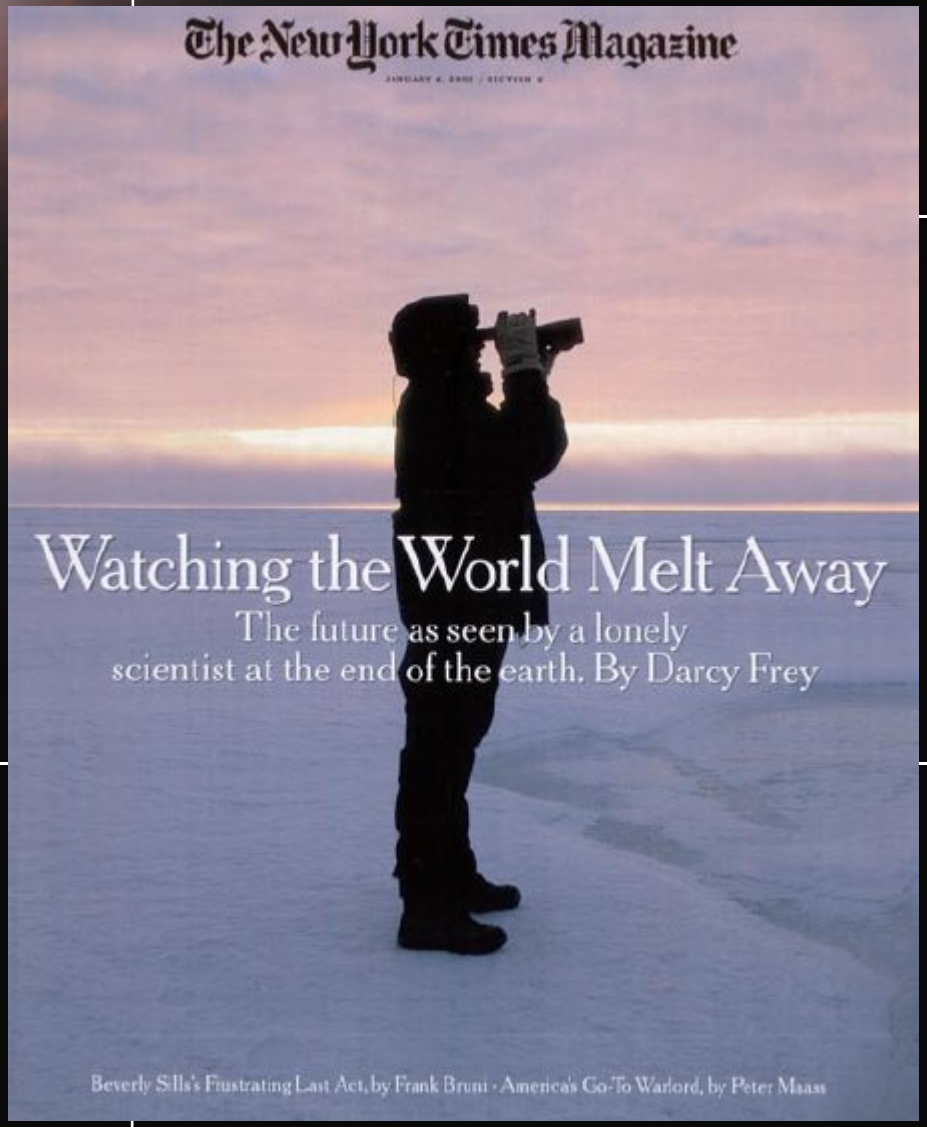
Pax Streamline



Staying comfortable with more efficient air conditioning



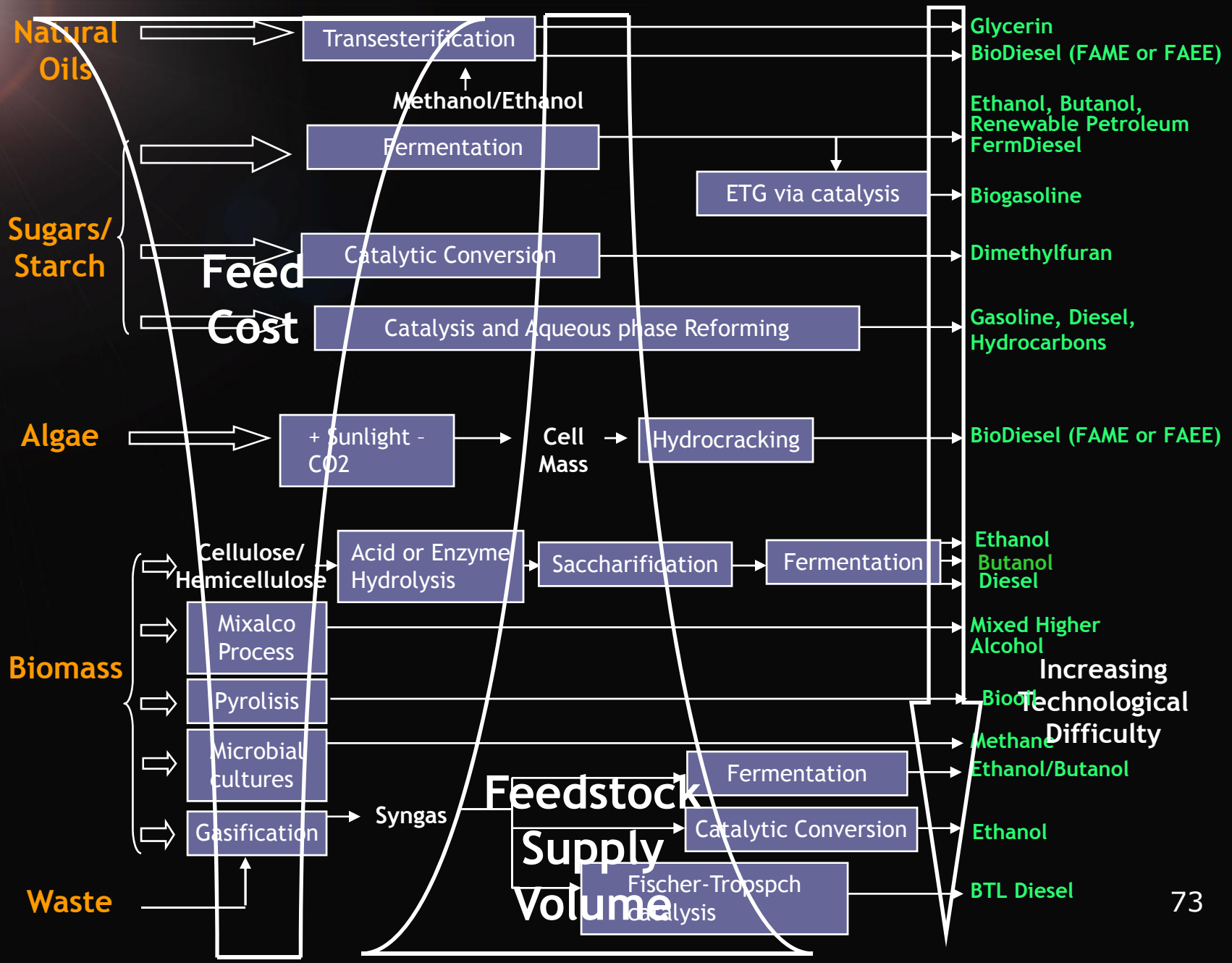
Change every aspect of daily living



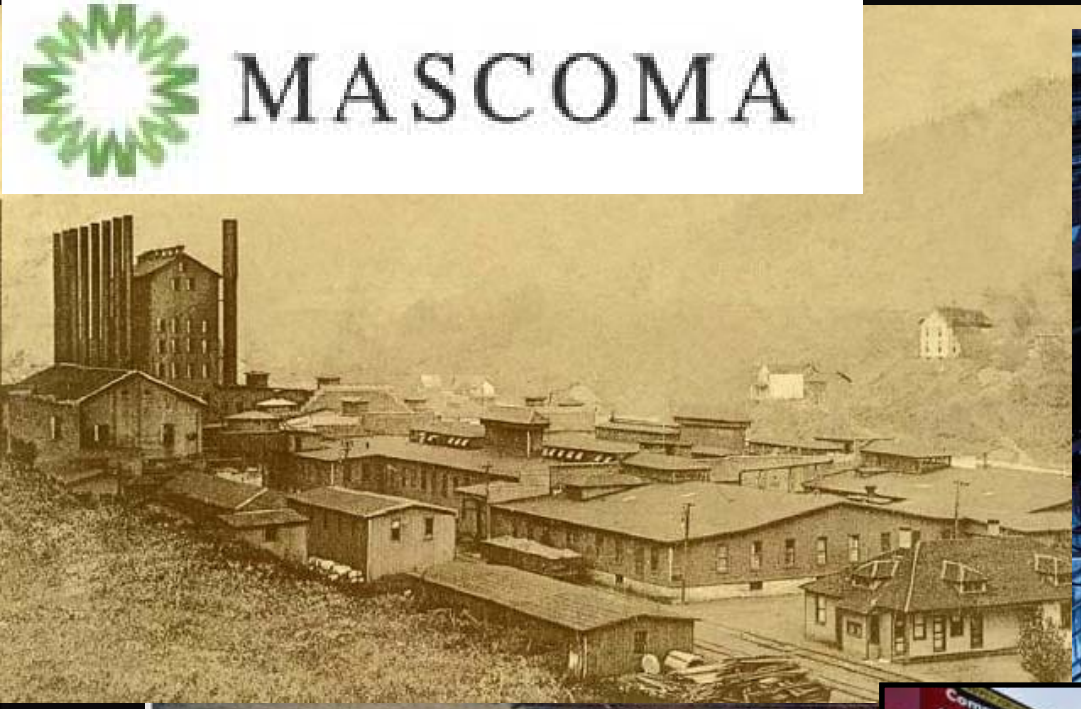
...or get to work

vk@khoslaventures.com
khoslaventures.com/resources.html

optionality: biofuels feedstocks & pathways …



MASCOMA



AVAILABLE HERE
E85
85%
ETHANOL


UNLEADED
E85
85% Ethanol
conoco
conoco

Range Fuels

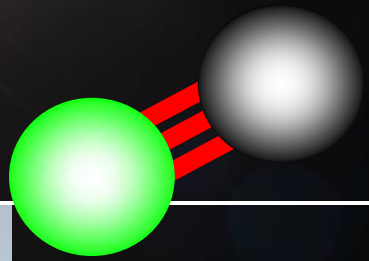
pilot plant

coskata

Gasifier

Fermenter

waste gas to fuel



Carbon monoxide gas

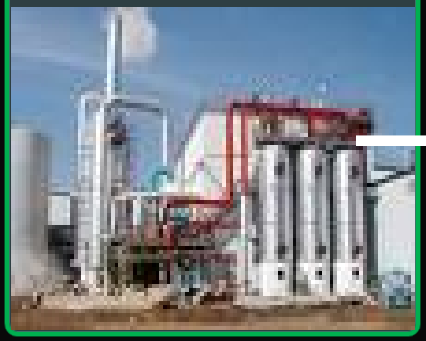
Steel mill waste gas

OR

Biomass syngas

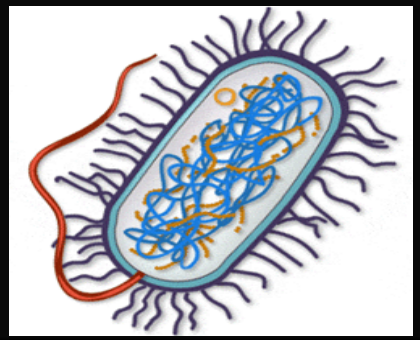
+

LanzaTech Process



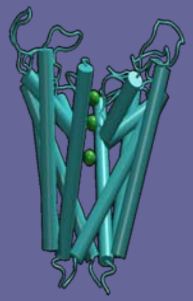
→ Ethanol & Butanol fuels

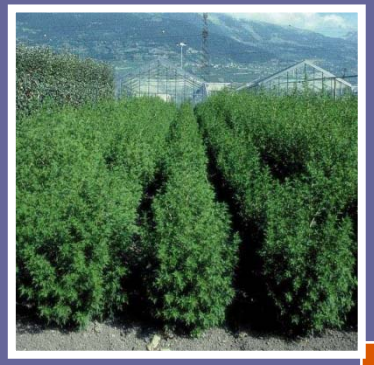
+



AMYRIS

Synthetic Biology **Anti-Malarial**





Gene 1

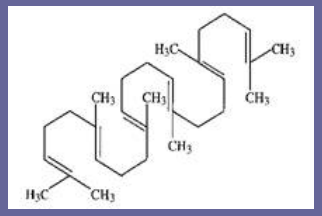
Source of genes

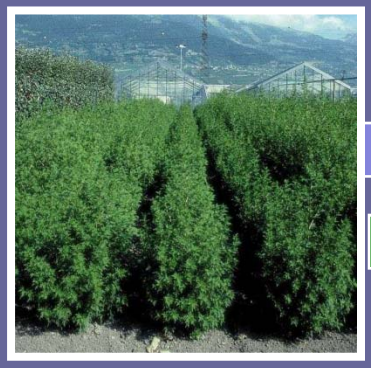
Custom-Built Microbe

Artimisinin
Recombinant Small Molecule Bio-Synthetic Pathway

AMYRIS

Synthetic Biology Fermentation Diesel





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Gene 2

Gene 3

Gene 4

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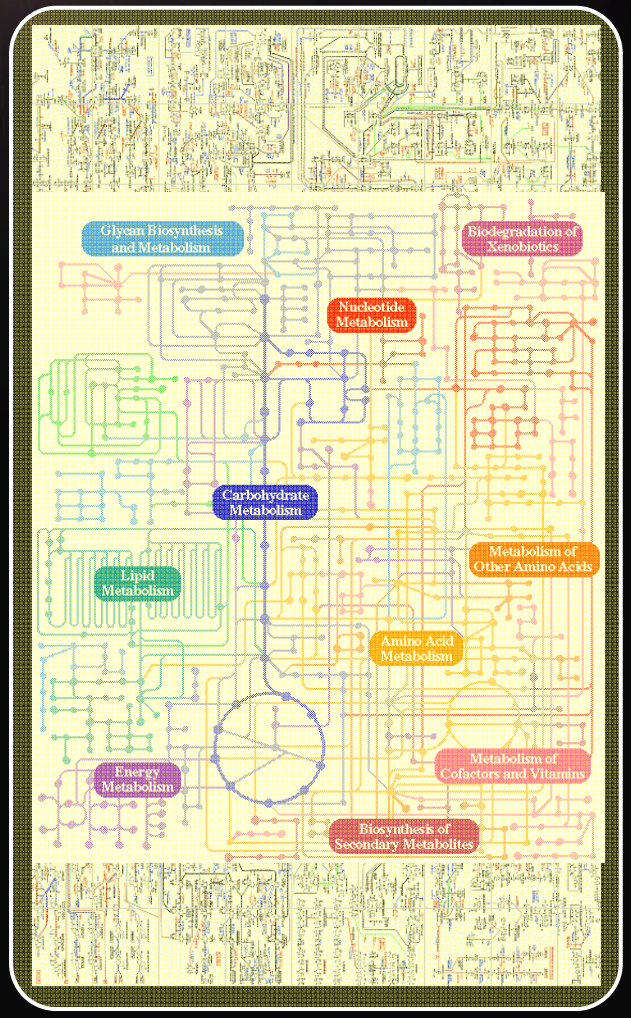
Recombinant Small Molecule Bio-Synthetic Pathway

LS9, INC.
the renewable petroleum company™

Hydrocarbon Biosynthesis
Nature's Energy Storage



Metabolic modeling
+
Synthetic biology

Renewable Feedstock

Hydrocarbons

>90% Energetic Yield From Feedstock

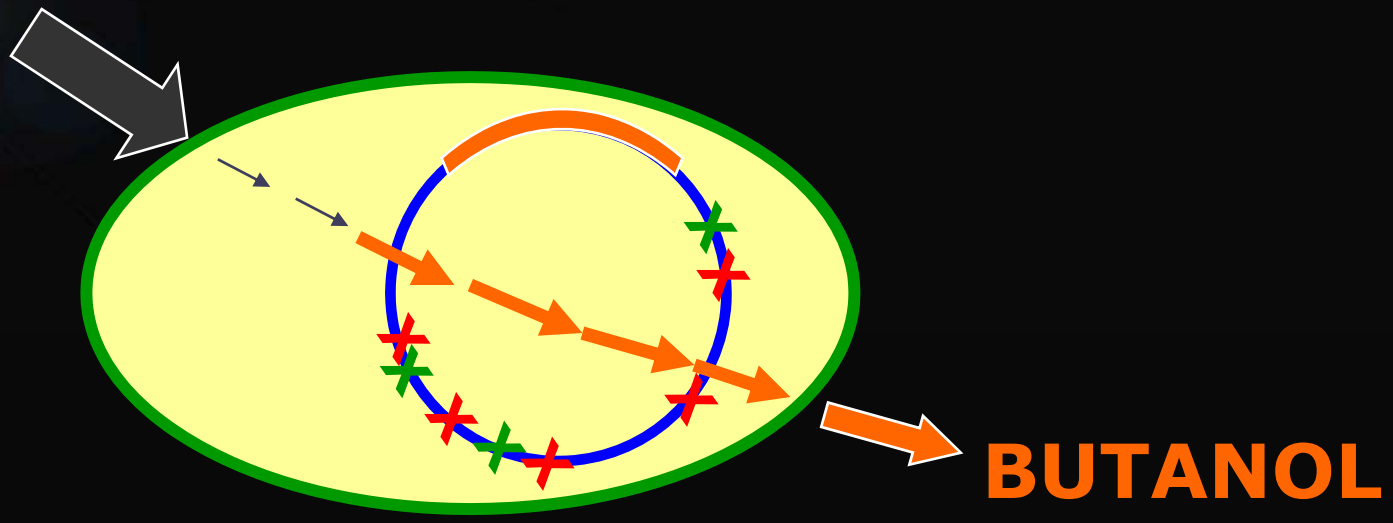
LS9 Designer Biofuels & Chemicals

gevo

Advancing the New Era of Renewables

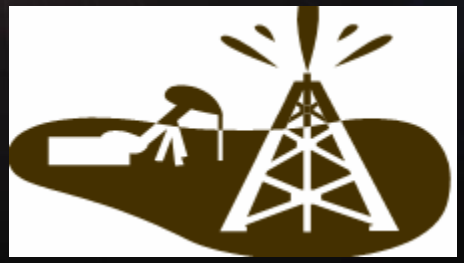
metabolic engineering

Biomass Hydrolysate



Classical and genetic techniques are used to improve **butanol** tolerance.

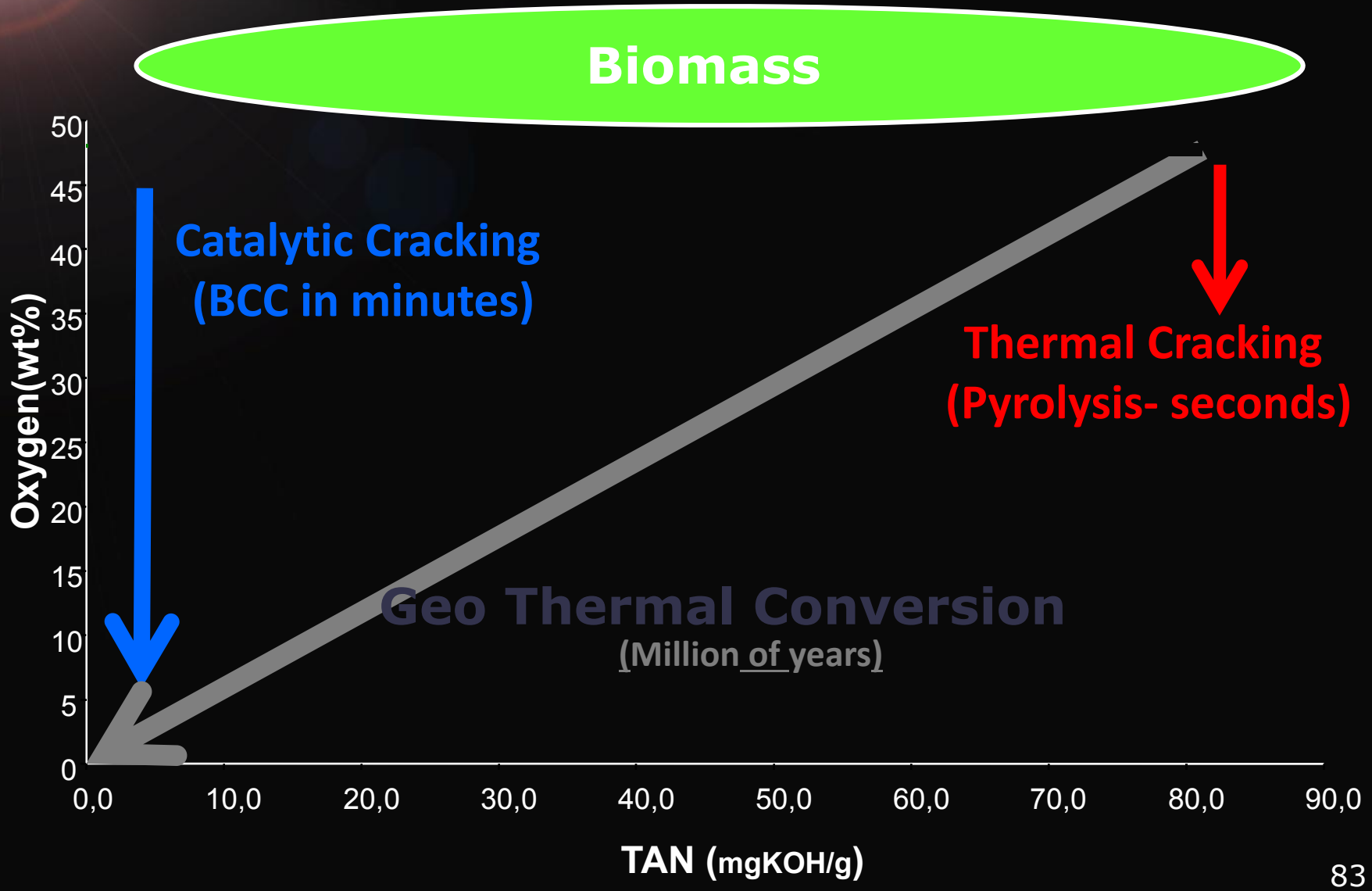
“biocrude” replaces crude



Crude oil

KiOR Biocrude

Kior: millions of years ➔ minutes!



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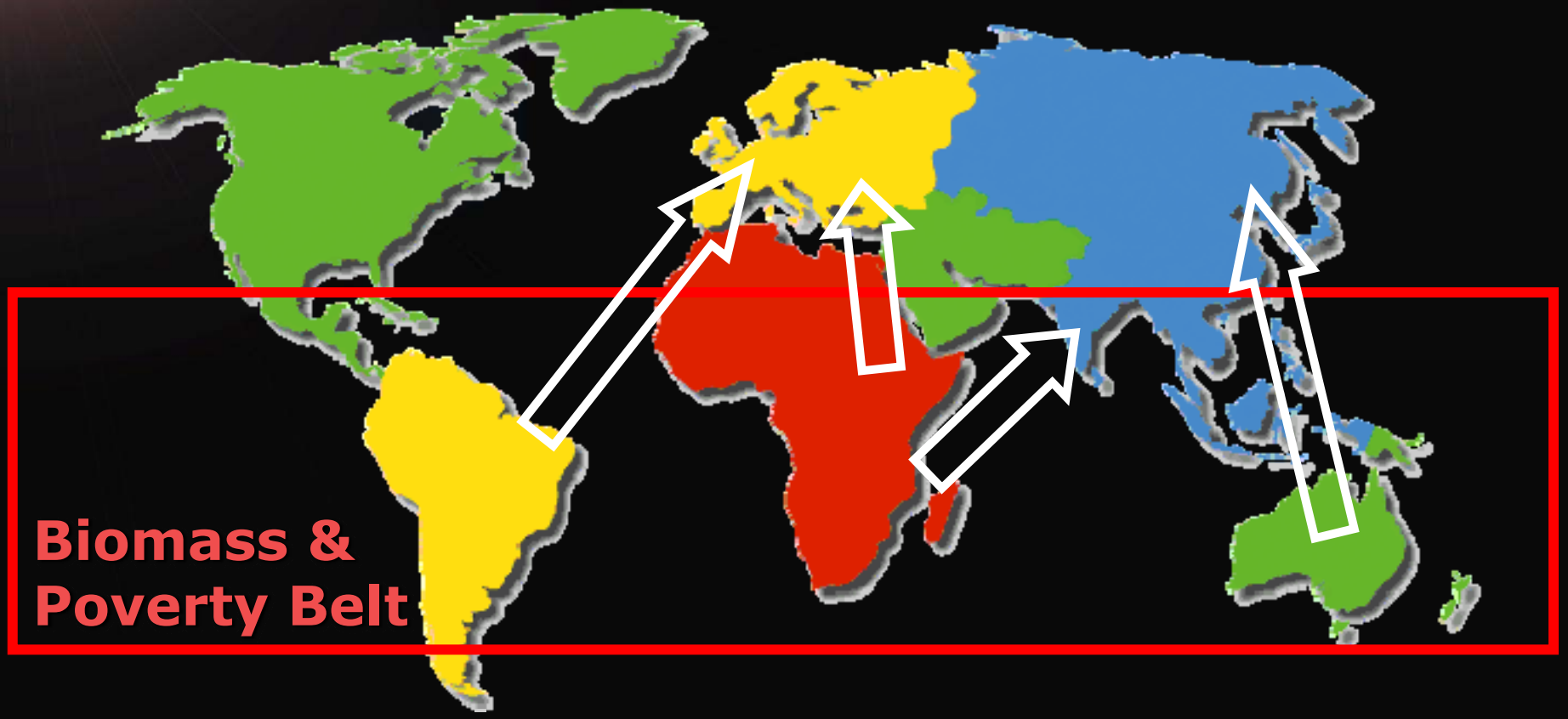
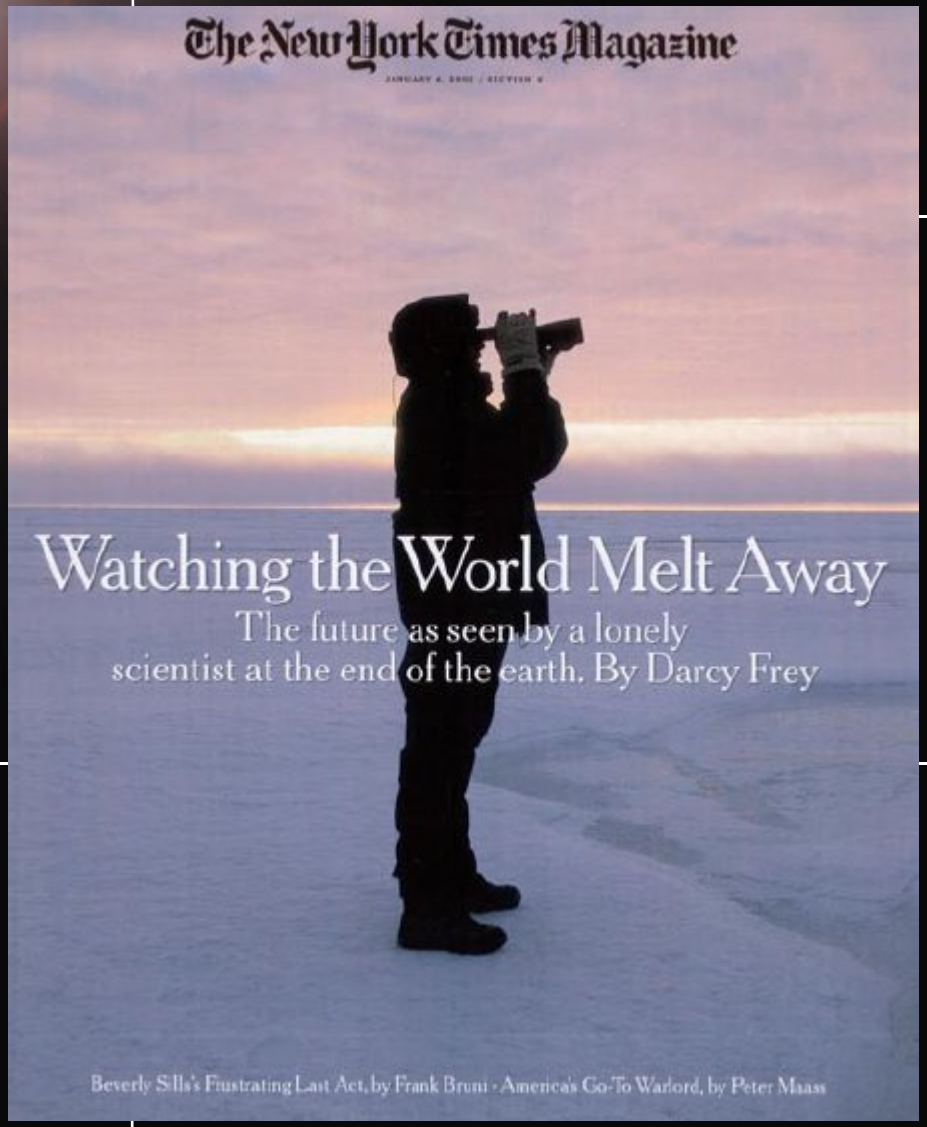




...or get to work

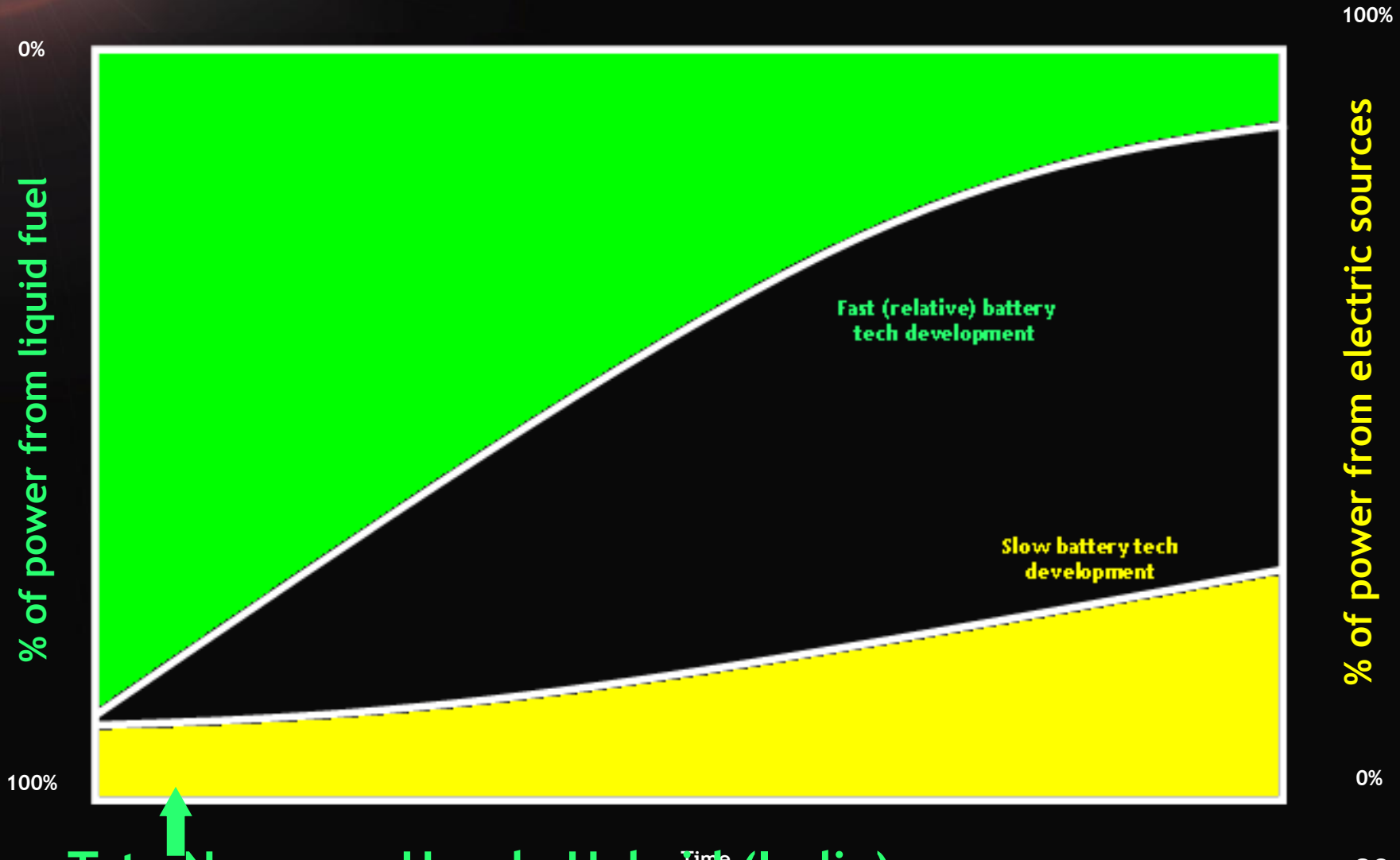
vk@khoslaventures.com
khoslaventures.com/resources.html

Biofuels Case Study

trajectory: reducing our oil dependence

	Ethanol	"Classic" Biodiesel	Cellulosic Hydrocarbons	Hybrids	PHEV's	Natural Gas
CO_2 Reduction – 2008	20%	80%	N/A	20%	N/A	30%
CO_2 Reduction – 2017	80%	80%	80%	25-35%	?	30%
Scalability – 2030	High	Limited	High	Med	?	Med
Sustainability - 2030	High	Poor	High	Med	Elec. source	Med
Quality	Good	Poor	Very Good	Good	Good	Good
Unsubsidized Market Competitiveness (worldwide – 10 yrs)	High	Poor	High	Low-Med	Low-Med	Med
2010/20 Production Cost	Med/Low	High/High	Med/Low	High/?	High/?	Med/Med
Technology	In process	Poor Good:Algae	Nascent	Developing	Need Black Swan	Limited

optionality: hybrids or biofuels?



Tata Nano vs. Honda Hybrid (India)
2010: >100X the volume?

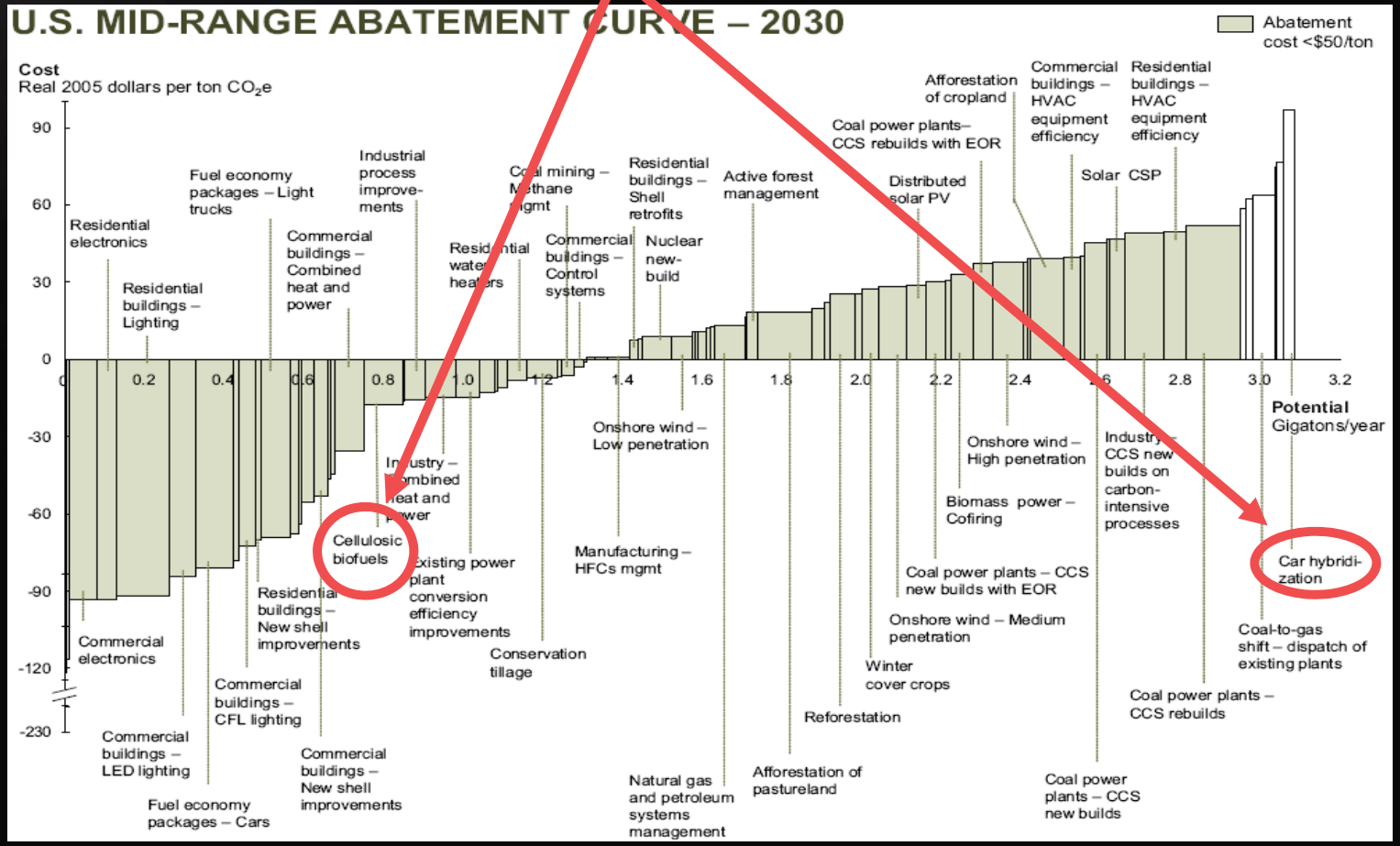
Trajectory 2017: Carbon Emissions

Car	CO2 Emissions - grams per mile	Monthly Cost (Car + Fuel)
Toyota Prius - 1.6KWh, $21,200	238	$490
Toyota Corolla - (hypothetical FFV, Cell. E85, $14,500)	88	$355
Honda Civic Hybrid - (On Gasoline, $22,600)	260	$524
Honda Civic - (FFV - on Cell. E85, $15,110)	94	$372
GM Volt - (16 Kwh, $30,000) - Electricity	144	$623
GM Volt - (16 Kwh, $30,000) - Cell. E85	55	$641
Public Transportation - US "Heavy Rail" (Subway) System	157	N/A

Source: Khosla Ventures analysis, American Public Transportation Association

trajectory: market or carbon?

Hybrids are an inefficient carbon solution



Source: Reducing U.S Greenhouse Gas Emissions: How Much at What Cost?", McKinsey – December 2007

Adoption Risk - $2,500 Nano

Biofuel Myths

- **Prices:** Food CPI is affected by oil 2-3X more than corn
- **Corn usage**: 16oz steak = 1 gallon of ethanol
- **Carbon reduction**: Hybrid = Corn Ethanol (at 1% of the cost!)
- **Choice**: Biofuels or tar sands?
- **Biofuels vary**: A cocaine and aspirin "drug" of biofuels

CLAW: doing biofuels right

- C – CARBON relative to gasoline
- L –net LAND use impact
- A – AIR quality impact
- W – WATER use relative to gasoline

- **We propose**
  - Facility-level individual certification
  - "LEEDS" like goodness rating
  - Tradable CLAW certificates

the problems with the "iLUC" standard

- Claim: modeling of "real uncertainities"
  - does not account for changes in economic signals
  - cannot cover range of fuels, crops, agronomy
- Belief: iLUC more dangerous than beneficial
  - no recognition of value of optionality
  - non-zero iLUC = more promising technologies discouraged!
- Claim: no proof of benefits using degraded cropland
  - but iLUC standard would penalize energy crops in advance!
  - Lack of quantitative modeling = lack of technology

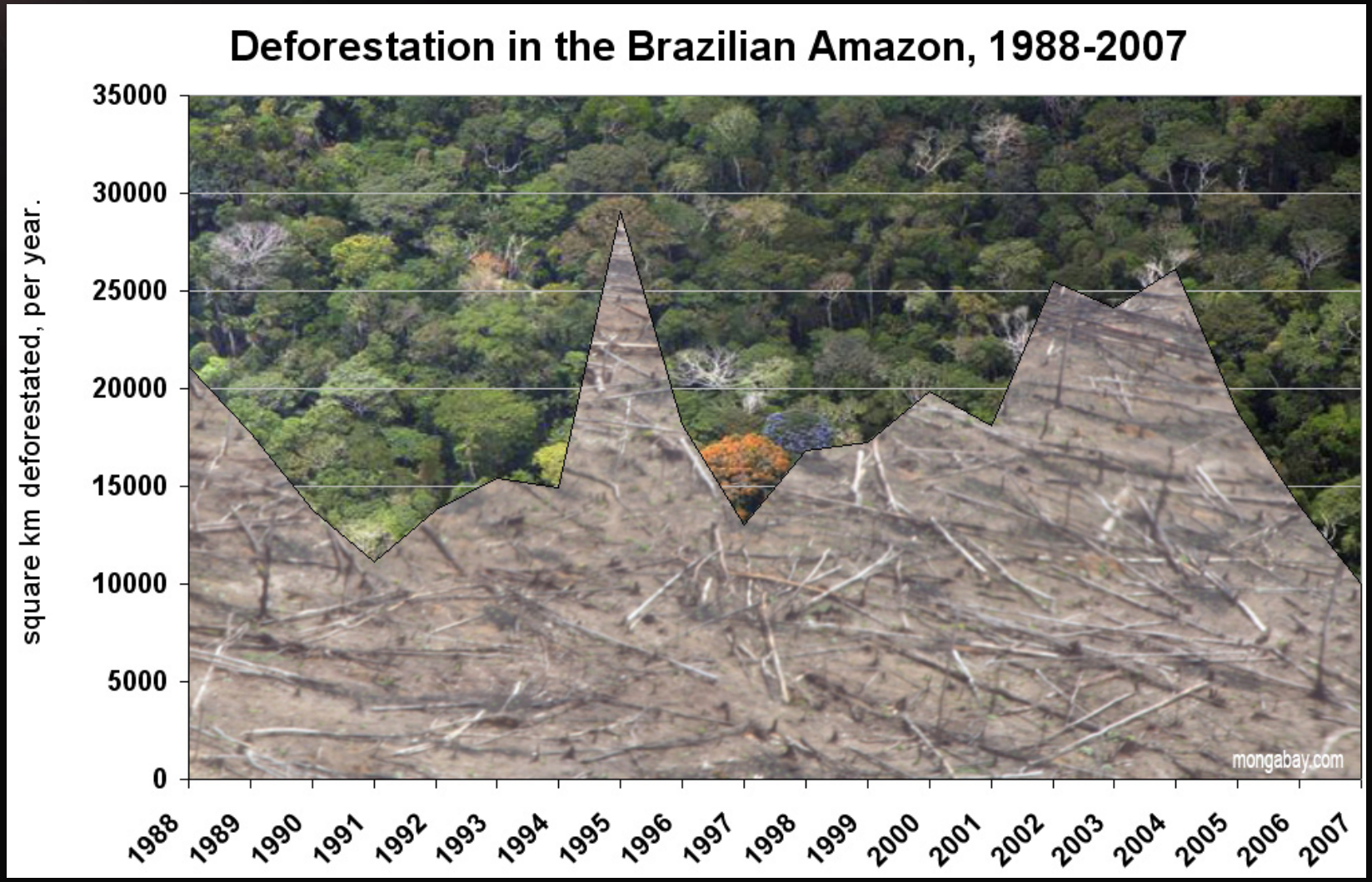
iLUC = akin to using coal power plants to assess electric cars

Searchinger

right model, wrong interpretation

- Agronomic Output
  - Steven Long data: 250% error in feedstock potential
  - Potential for 20-24 tons/acre by 2050?
- Biofuel Innovation
  - Biocrude increases energy yield by 200% or more?
- Agronomic Innovation: increase sequestration
  - Polyculture, perennial systems to increase soil carbon
  - Biochar & "terra peta"
  - Many biofuels will use non-land based feedstocks
- Tool for deforestation or reforestation?
  - Policy to encourage correct behavior?
  - What if WTO prohibit exports from countries that don't meet reforestation targets?

are biofuels root cause of deforestation?



- Source: Brazilian deforestation from Mongabay – citing Brazilian national Institute of Space Research

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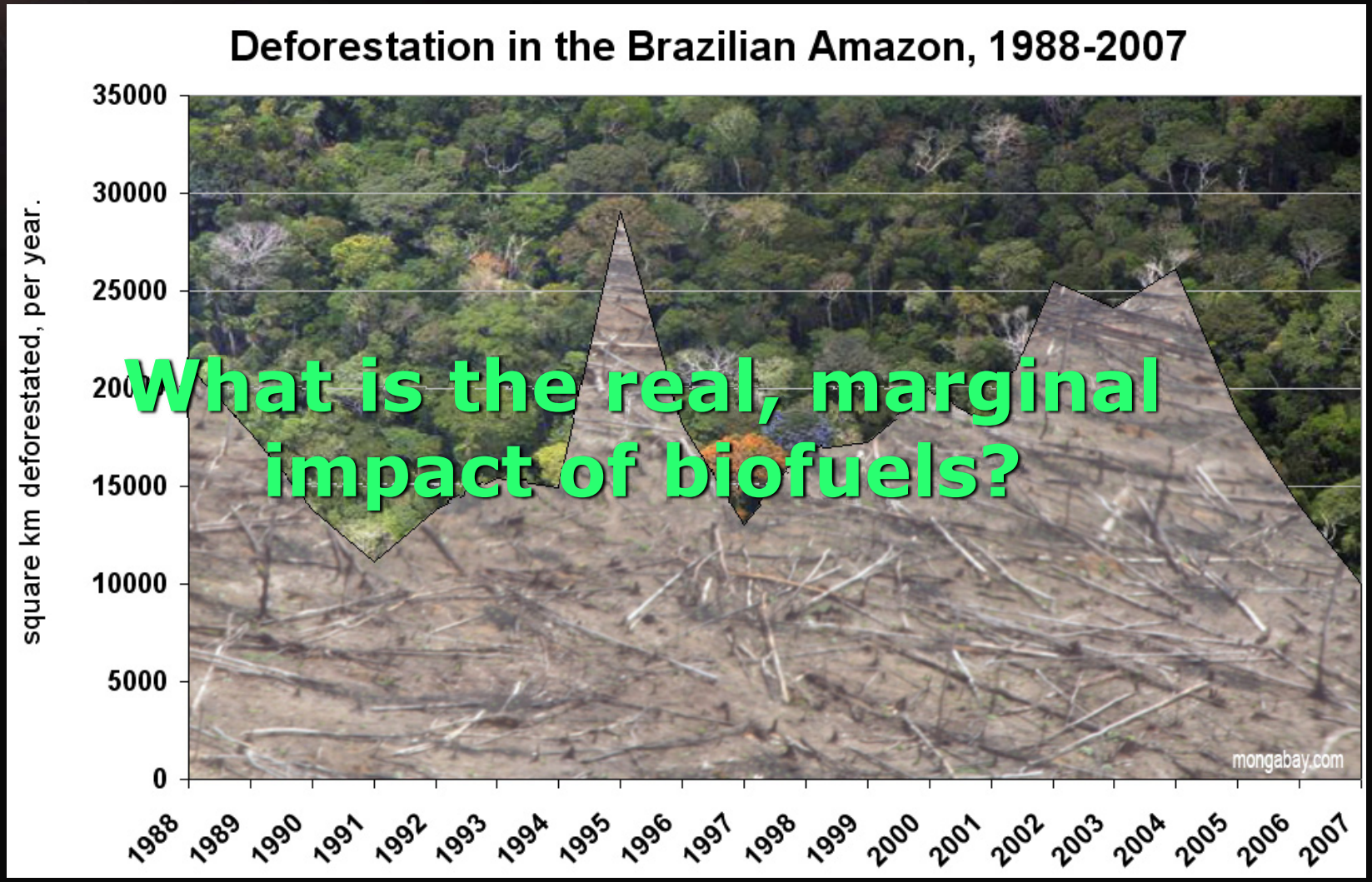

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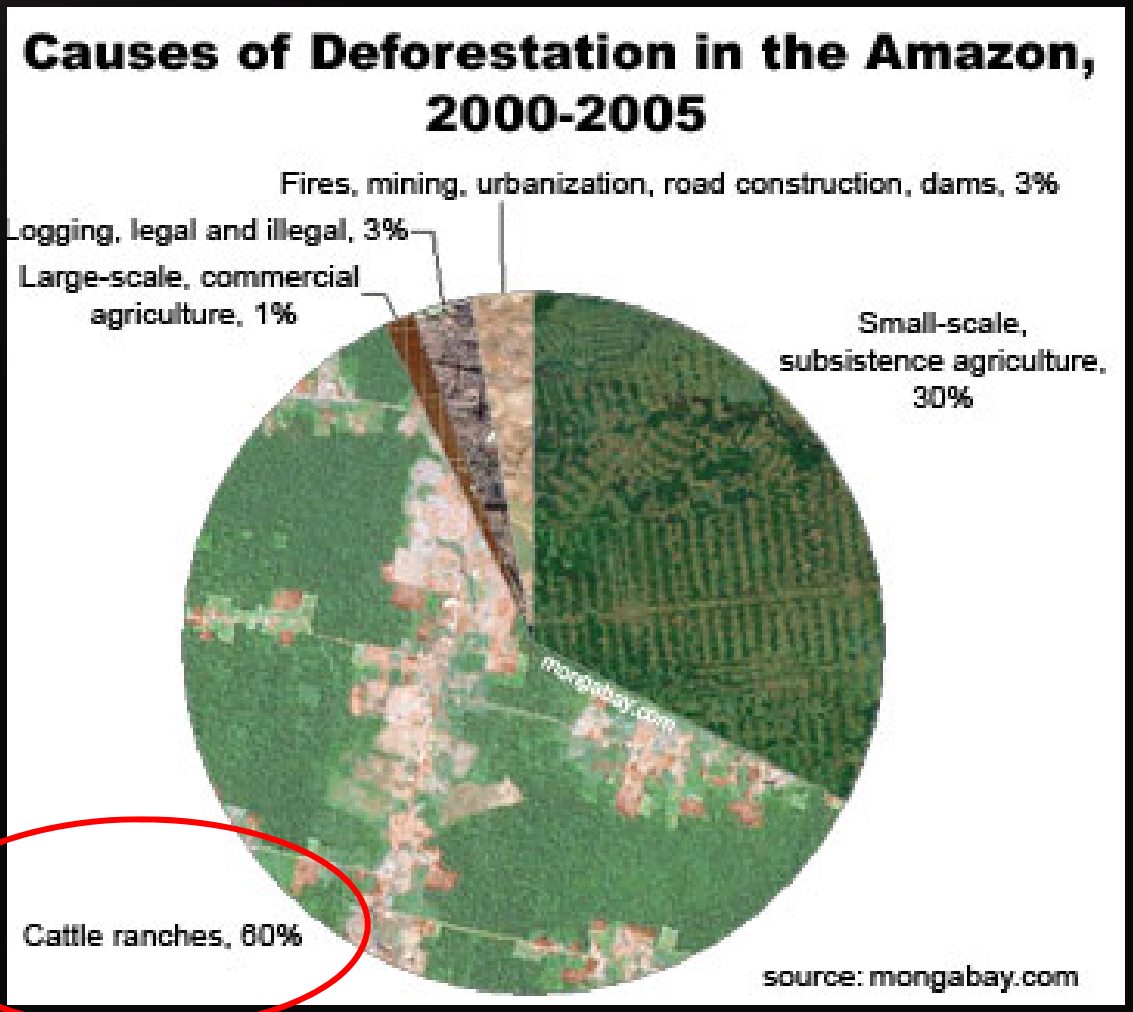
a pound of steak or a gallon of ethanol?



- Source: Mongabay.com

livestock - the numbers

70% (50%) of the agricultural output of the US (world) goes to feed its livestock.

Source: http://www.goveg.com/environment.asp

Source: “The Climate Healers”, Saliesh Rao

US land: Little land use next 10 years

- Reality of Land Use
  - Economics means lowest cost sources used first (waste)
  - Source: DOE 1.3B dry tons with "modest changes in land use"
  - Source: Winter cover crops: no marginal land usage
  - Sources: GMO, better worldwide yields, marginal or unused lands…

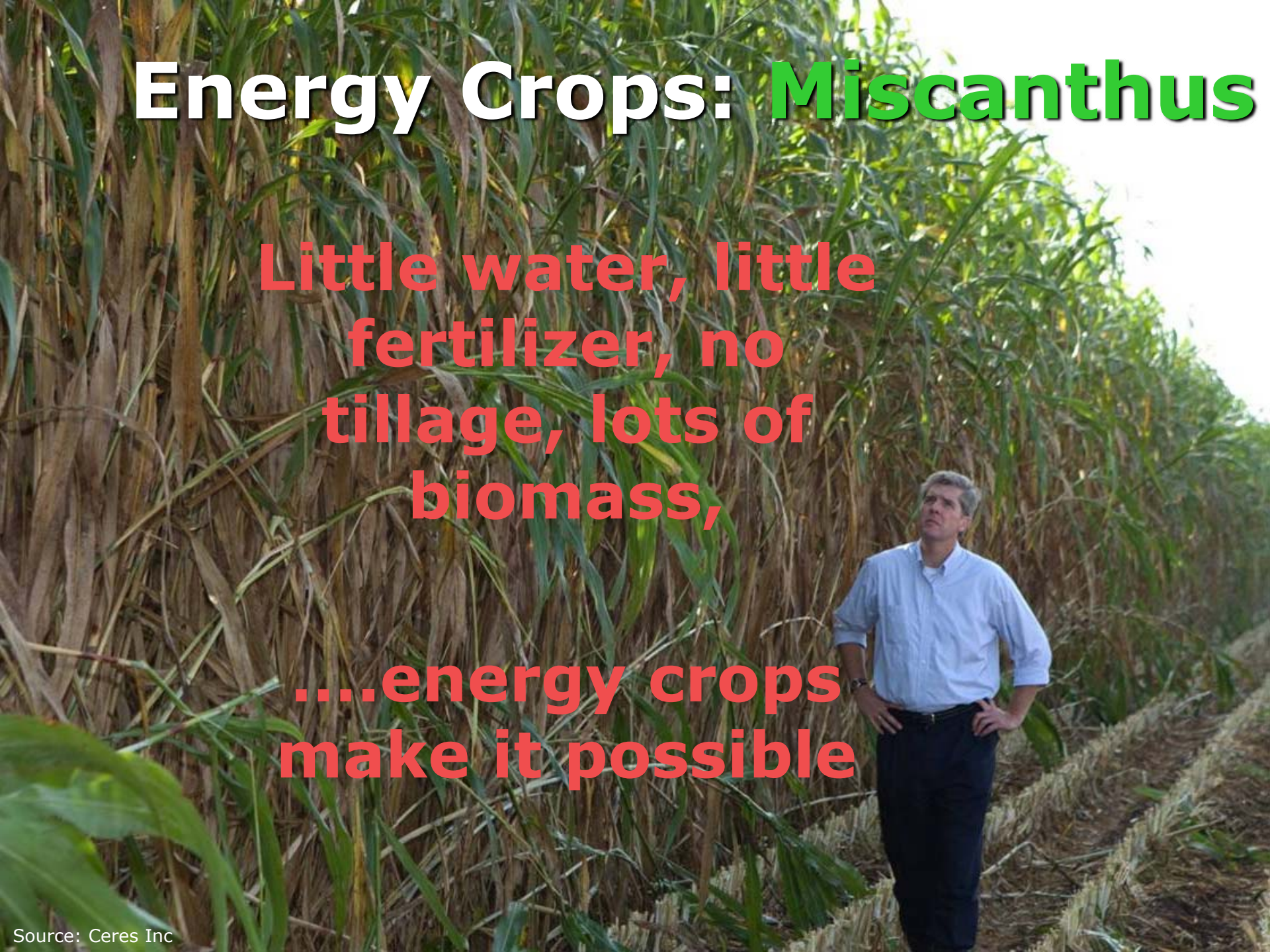
- Propagating the ILUC Myth:
  - ignore range of crops, practices, economic signals, value of optionality
  - The "best science" is not good enough to use
  - Lack of zero ILUC model: absence of proof is not proof of absence

Land use will be immaterial through the current RFS standard!

trajectory: biodiesel vs. ethanol vs. cellulosic Diesel

	"Classic" Biodiesel	Ethanol	Cellulosic Diesel
Carbon reduction - 2008	80%	20-30%	Not Available
Carbon reduction – 2012	80%	80%	80%
Scalability (2030 Gallons/acre)	600-900	2500 (cellulosic)	2500 (cellulosic)
Sustainability (2030)	Poor	High	High
Unsubsidized 10 yr market competitiveness	Poor (@ $45 oil price)	Good (@ $45 oil price)	Good (@ $45 oil price)

Energy Crops: Miscanthus



Source: Ceres Inc

energy crops: Sorghum

25 tons/acre (Prof. Holtzapple- Texas A&M)

the perennial advantage

Perennial crops:

- **less land erosion**
- **Better water/ nutrient management**
- **Diversity protects against epidemics and diseases**

Source: Wes Jackson, Land Institute

the perennial advantage

…perennial biomass polyculture crops can produce more than their annual counterparts, while requiring less human/energy inputs – on a sustainable basis!

Perennial crops:

- **less land erosion**
- **Better water/ nutrient management**
- **Diversity protects against epidemics and diseases**

Source: Wes Jackson, Land Institute

the polyculture advantage

Source: Wes Jackson, Land Institute


SWITCHGRASS
FALLOW
Previously Switchgrass
Previously Fallow

Where Will Biomass Come From?

Scenario 1:

Demand - 2030		Waste	Winter Cover Crops	Forest Excess Waste	Dedicated Crop Land
1,363M tons - 150 billion gallons at 110 gal/acre	=	136M tons equiv. - 15 billion gallons of production	735M tons - (158.5M acres at 4.6 tons/acre)	158M tons	334M tons - 13.6M acres at 24 t/acre - 27.3M acres at 12 t/acre

- **2030 Assumptions (Production):**
  - 50% of annual crop land for winter cover crops and 70% of forest excess waste used
  - Yields of 110 gallons per acre
  - No recovery of degraded land is modeled; note 15.5M acres (or 70%) of land used for corn ethanol will be reclaimed in this scenario

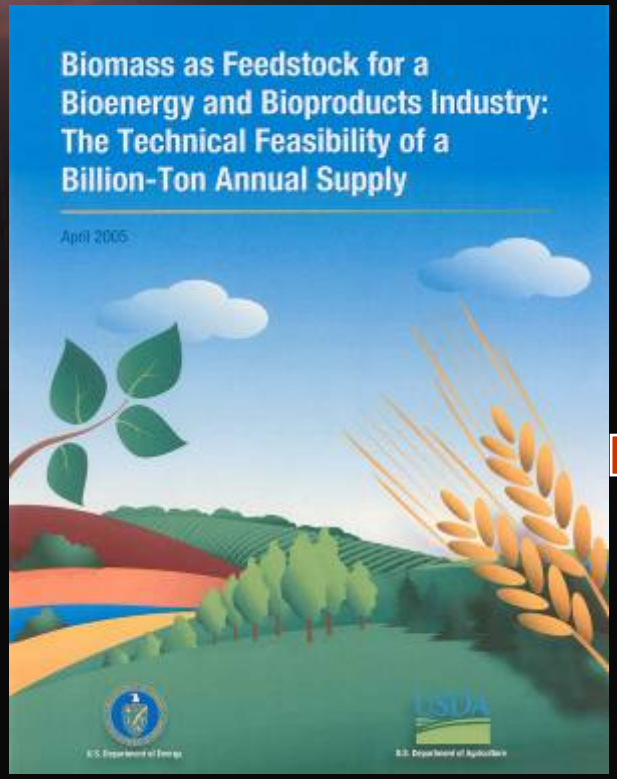
- **2030 Assumptions (Demand):**
  - 2030 AOE projections for US reduced by 20% to reflect CAFE / Energy Bill
  - Ethanol mileage discount of 15%
  - 90% of fleet is FFV

meeting biomass needs - scenarios

	Waste Resources (% of total 2030 demand)	Winter Cover Crop (% of annual crop land acres)	Winter Cover Crop Yield (Tons / Acre)	Excess Forest Biomass (dry tons – millions)	Biofuel Yields (gallons per ton)	Dedicated Land Use @ 24/18/12 tons/acre	Net Land Use @ 24/18/12 tons/acre
1	10% - 15B gallons	50%-159M	3-4.6	70%-158M	90-110	13.6 / 18.2 / 27.3	-1.9 /2.7/11.8
2	-	50%-159M	3-4.6	50%-221M	90-110	21.0 / 28.1 / 42.1	5.5/12.6/16.6
3	-	50%-159M	3-4.6	70%-158M	90-130	12.5 / 16.6 / 25.0	-3.0/1.1/9.5
4	-	50%-159M	3-4.6	70%-158M	90-130	10.6 / 14.2 / 21.3	-4.9/1.3/5.8
5	-	50%-159M	3-4.6	100%-226M	90-130	7.9 / 10.5 / 15.7	-7.6/-5.0/0.2
6	10% - 15B gallons	70% - 221M	3-4.6	100%-226M	90-130	-	-15.5

Trivial amount of land to replace oil

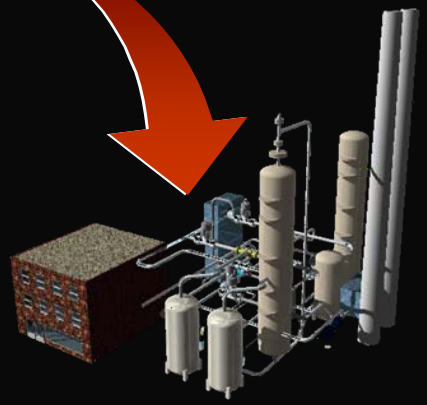
Biorefining Industry Goals



~1.3 Billion tons/yr
US Biomass Potential

Displace gasoline demand

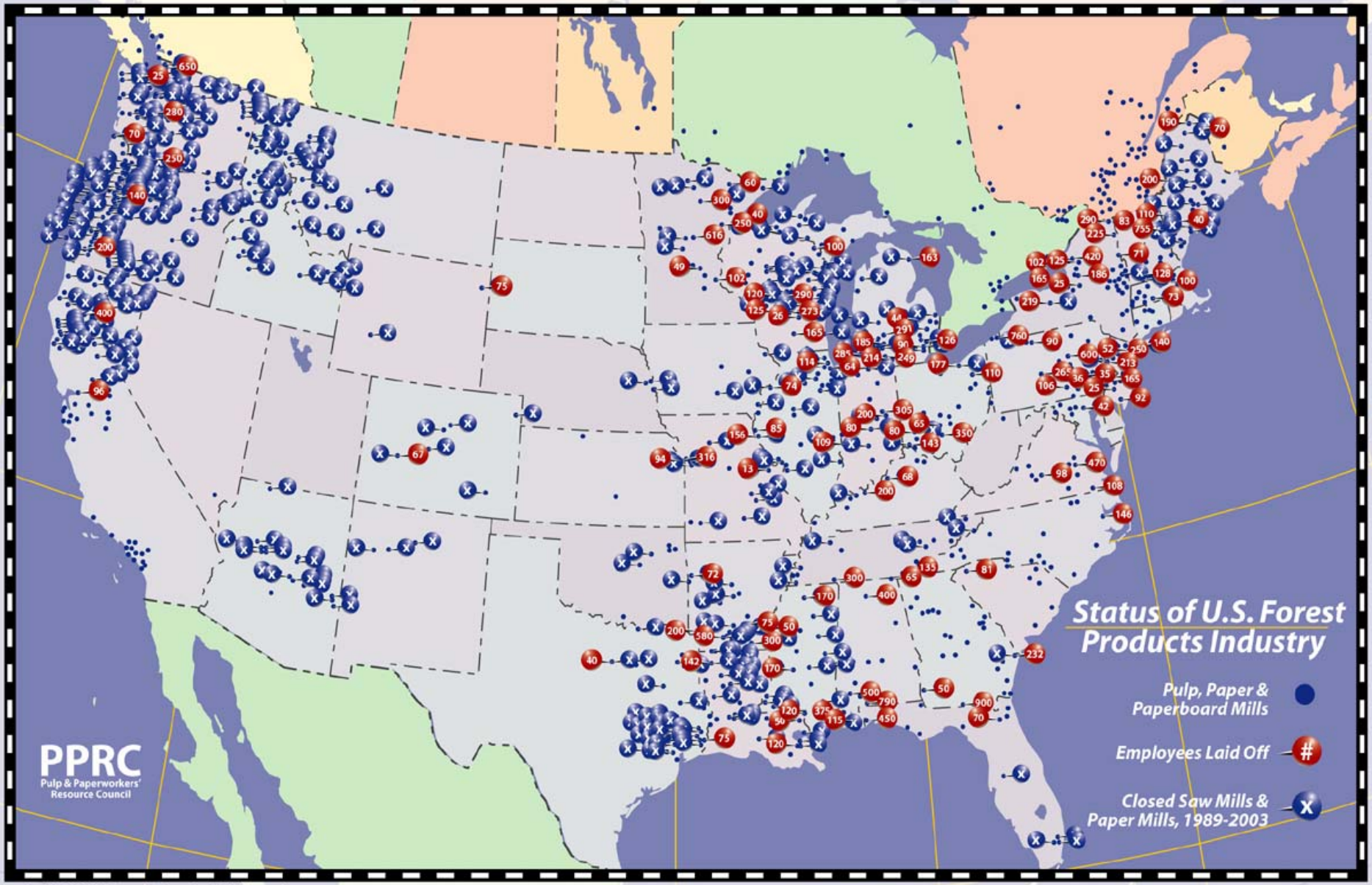
Sugar Platform



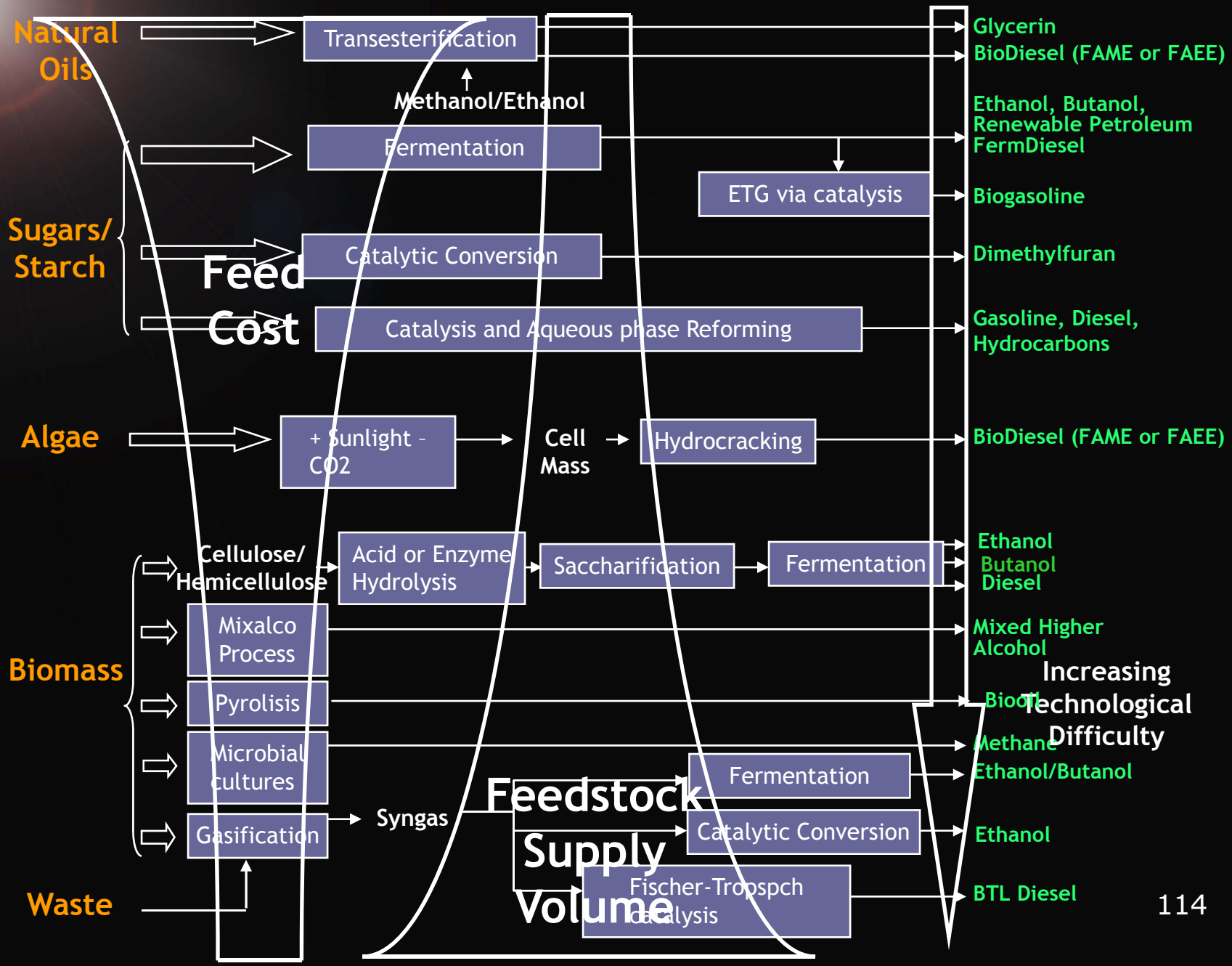
Ethanol Cost Target = $1.07/gal

Syngas Platform

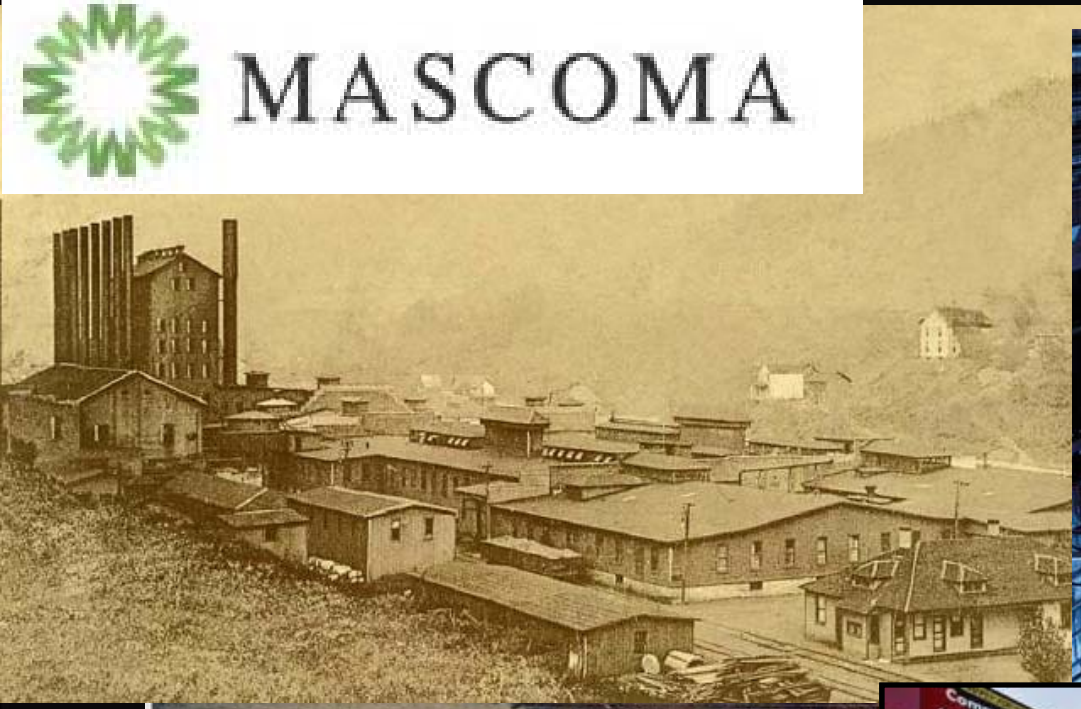
adoption risk: U.S. mill closures



optionality: biofuels feedstocks & pathways …



MASCOMA



AVAILABLE HERE
E85
85%
ETHANOL


UNLEADED
E85
85% Ethanol
conoco
conoco

Range Fuels

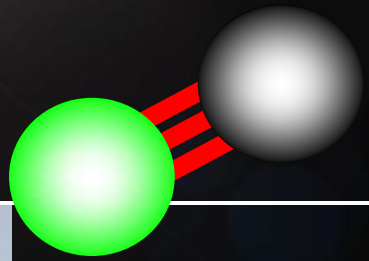
pilot plant

coskata

Gasifier

Fermenter

LanzaTech waste gas to fuel



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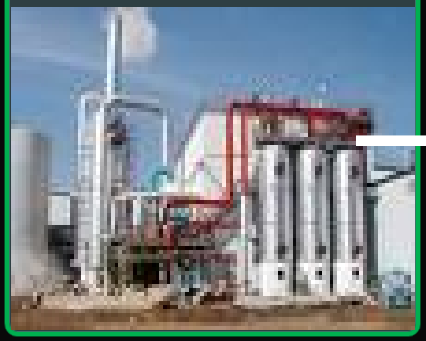

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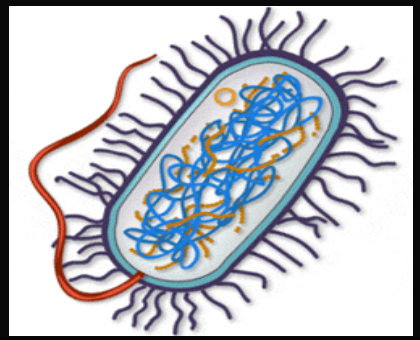

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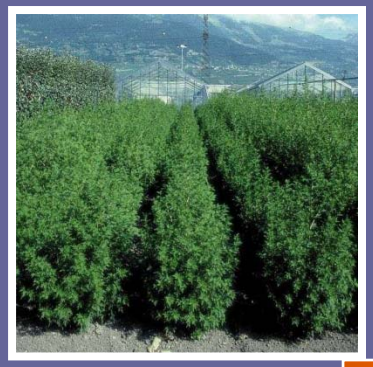

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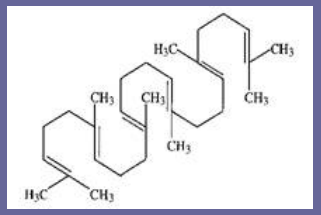

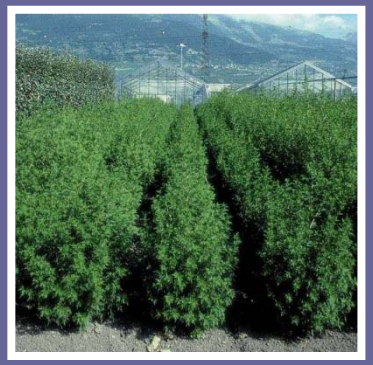

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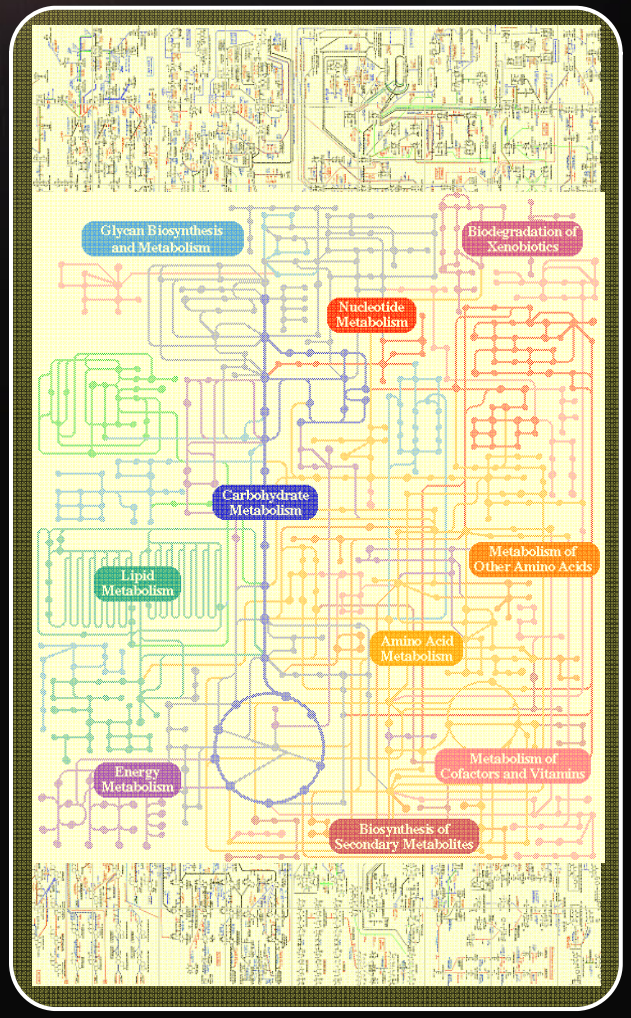
Nature's Energy Storage



Metabolic modeling
+
Synthetic biology

Renewable Feedstock

Hydrocarbons

>90% Energetic Yield From Feedstock

LS9 Designer Biofuels & Chemicals

gevo

Advancing the New Era of Renewables

metabolic engineering

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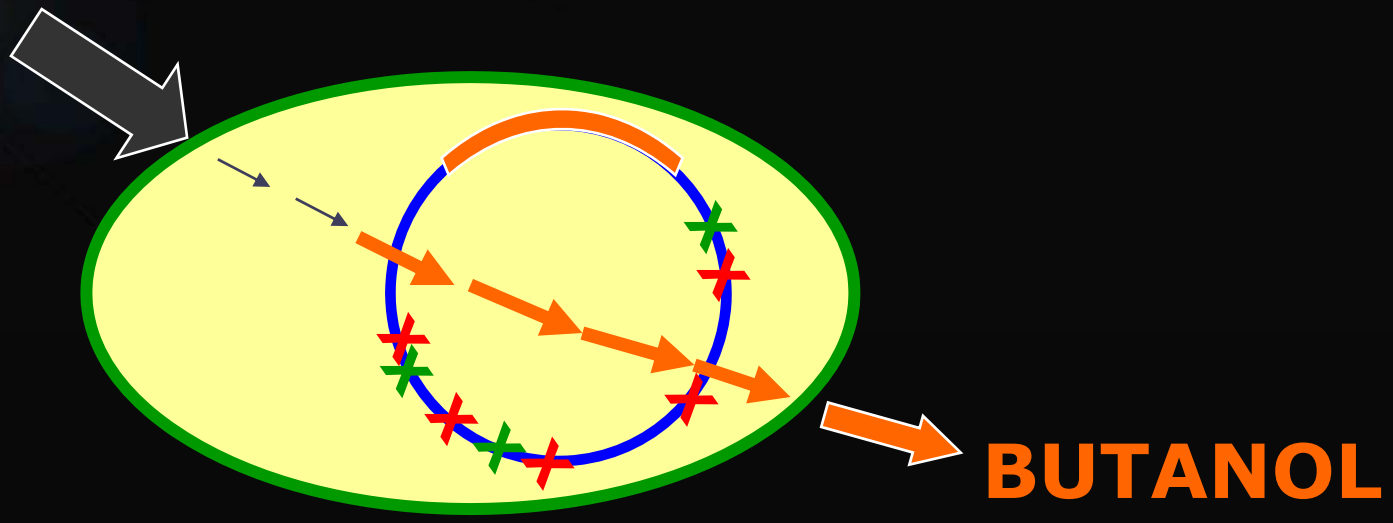

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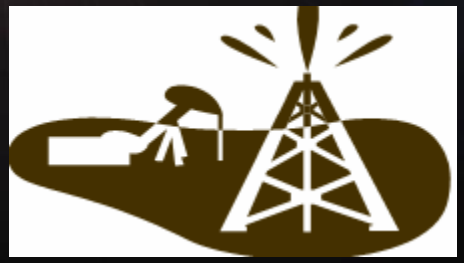
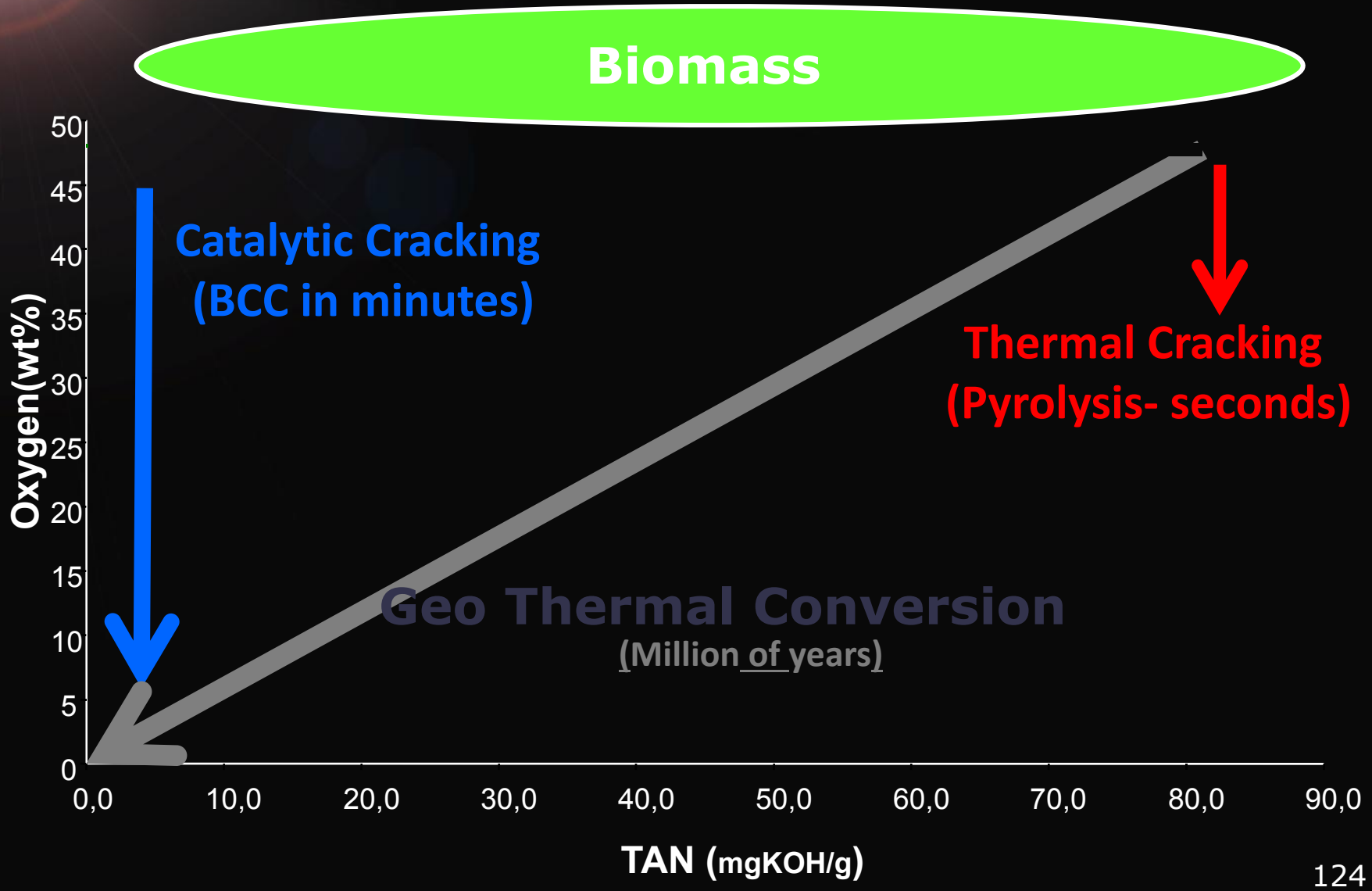


Crude oil

KiOR Biocrude

Kior: millions of years ➔ minutes!



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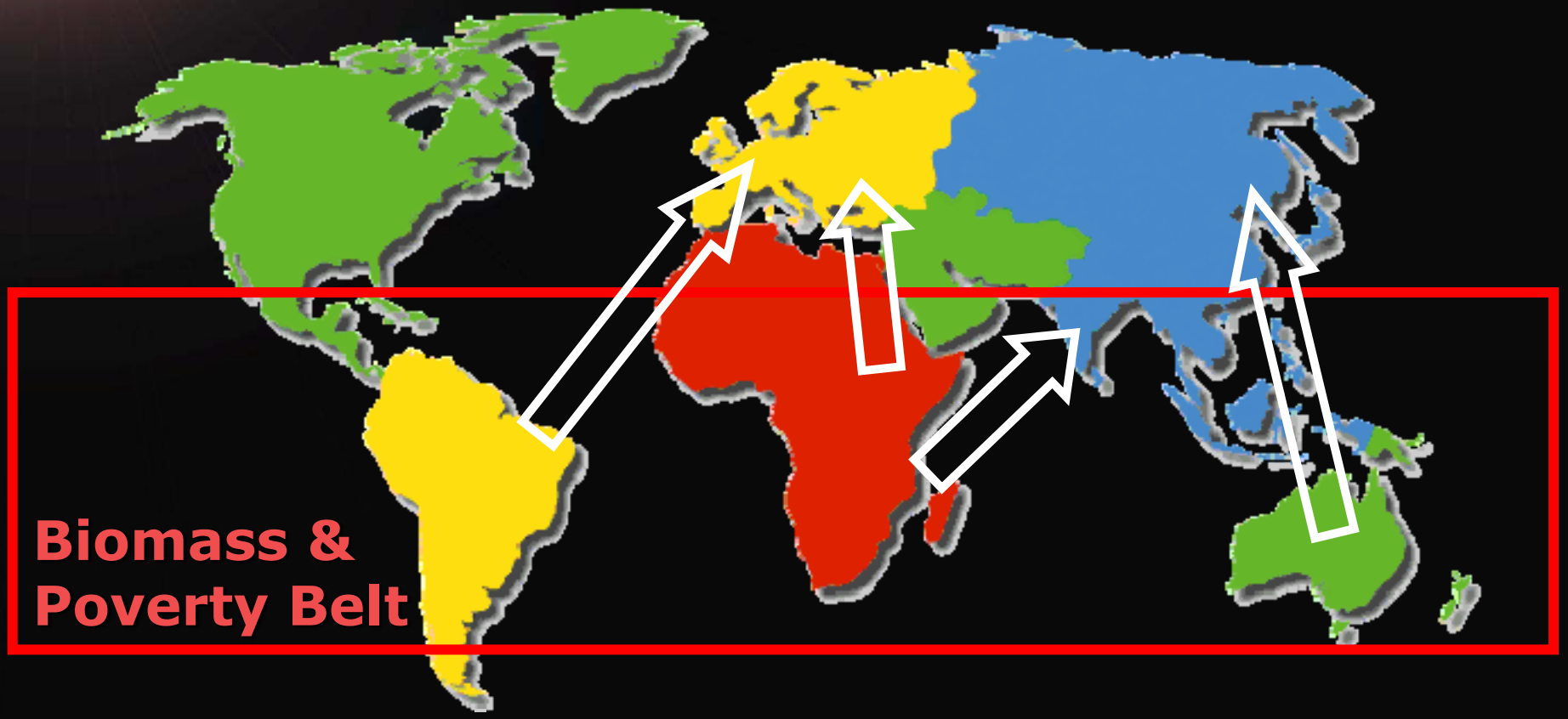

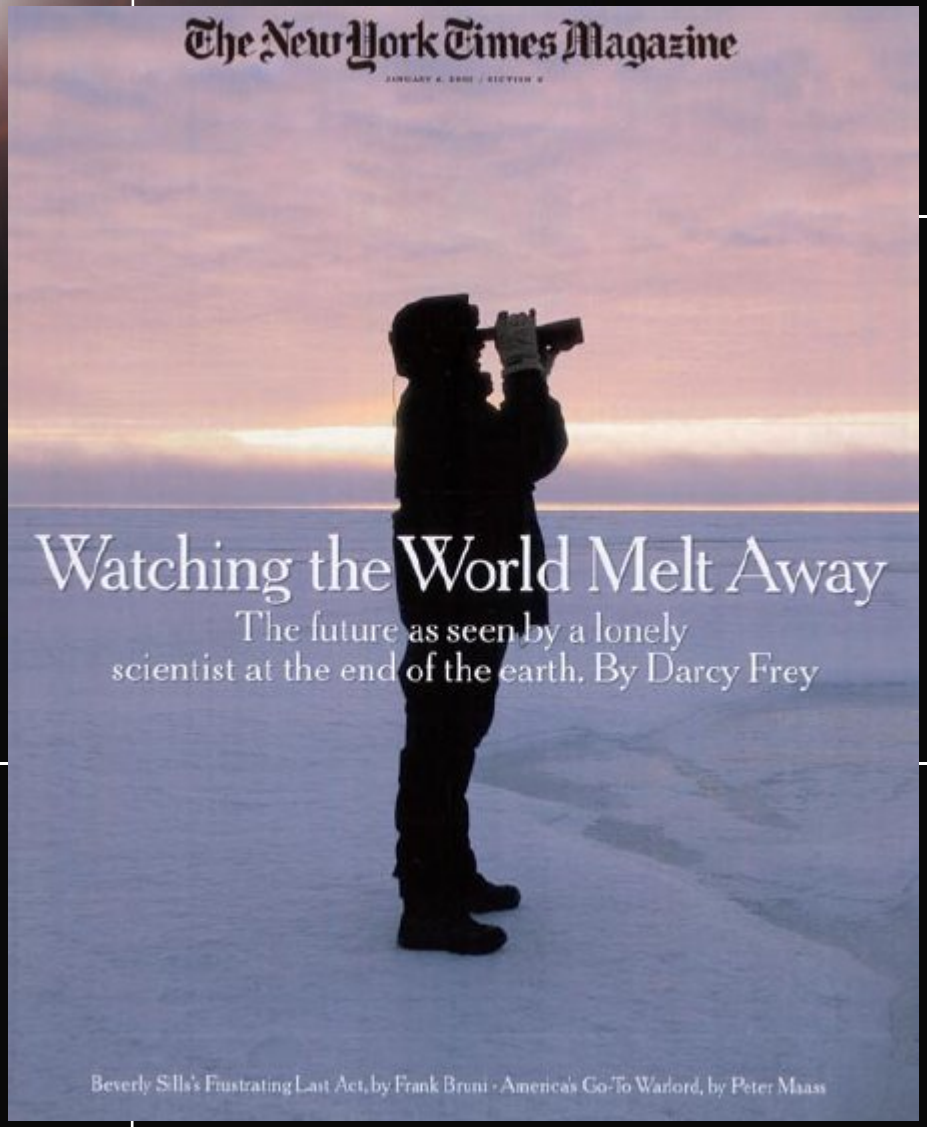

...or get to work

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