

Renewable Energy:

Maintech, not Cleantech

Vinod Khosla
Khosla Ventures
April 2009



“all progress depends on the
unreasonable man”

George Bernard Shaw

“A crisis is a terrible thing to waste.”

Paul Romer

Problem: Misunderstanding
Technology

“The ‘telephone’ has too many shortcomings to be seriously considered a means of communication”

-Western Union Internal Memo,
1876

Excuse: Missing
Applications

“There is no reason for any individuals to have a computer in their home”

-Ken Olsen, President, Chairman and Founder of DEC, 1977

Problem: Understanding of
Physics

“Heavier-than-air flying
machines are impossible”

-Lord Kelvin, President, Royal Society 1895

Problem: Tunnel
Vision

“Airplanes are interesting toys
but of no military value”

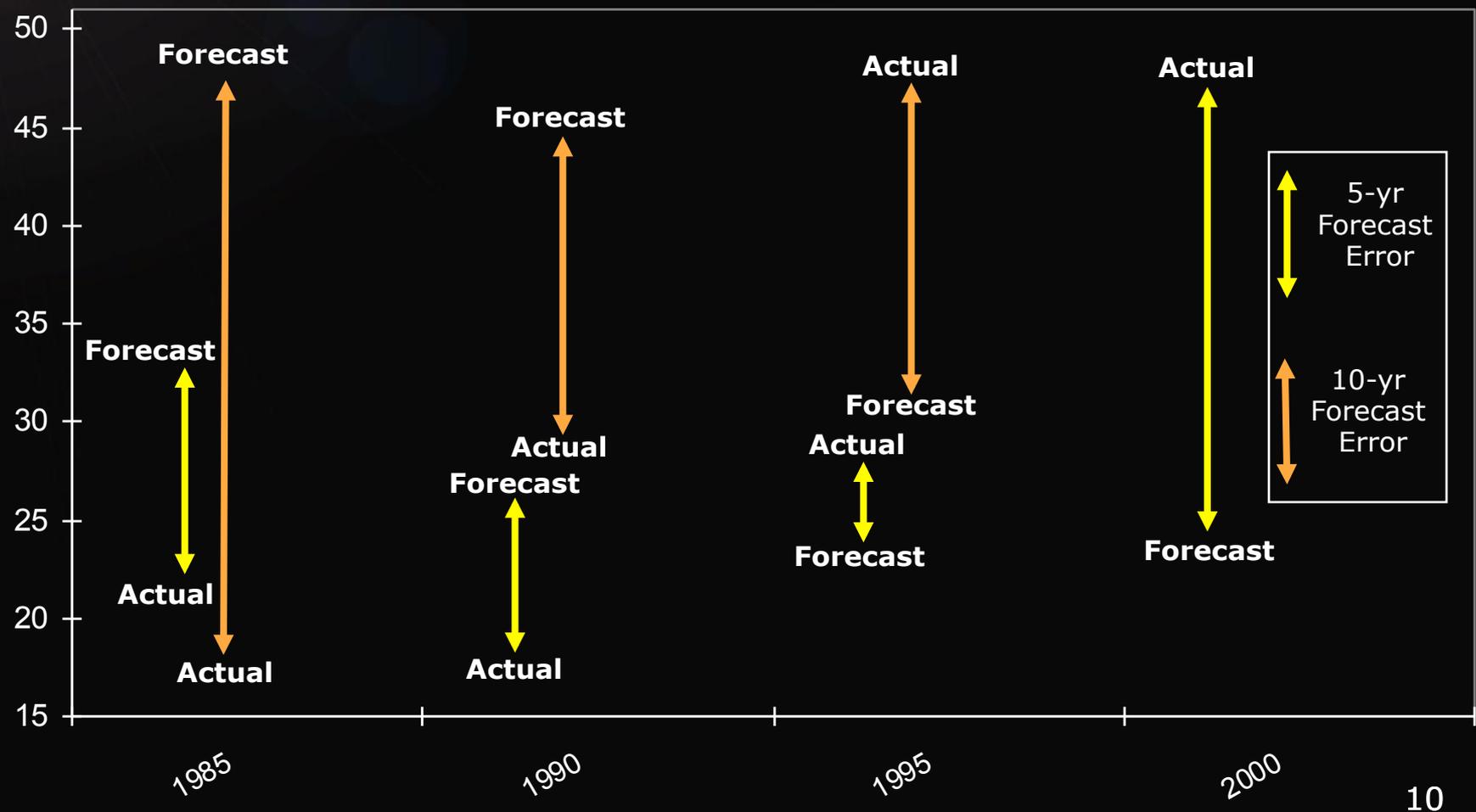
-Marshall Ferdinand Foch,
Professor of Strategy,
Ecole Superiure de Guerre

Forecasting

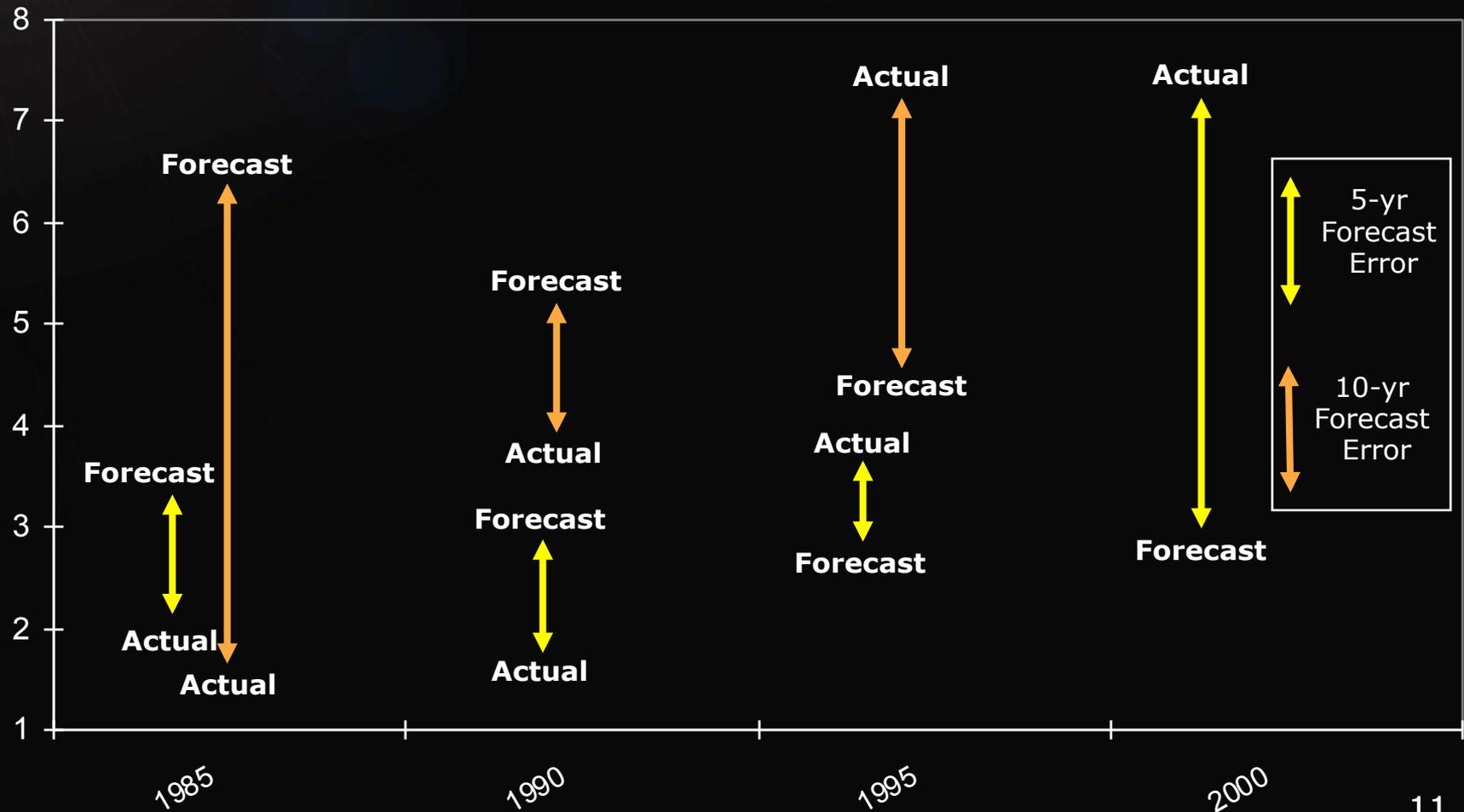
“It is the mark of an educated person to look for precision only as far as the nature of the subject allows.”

Aristotle

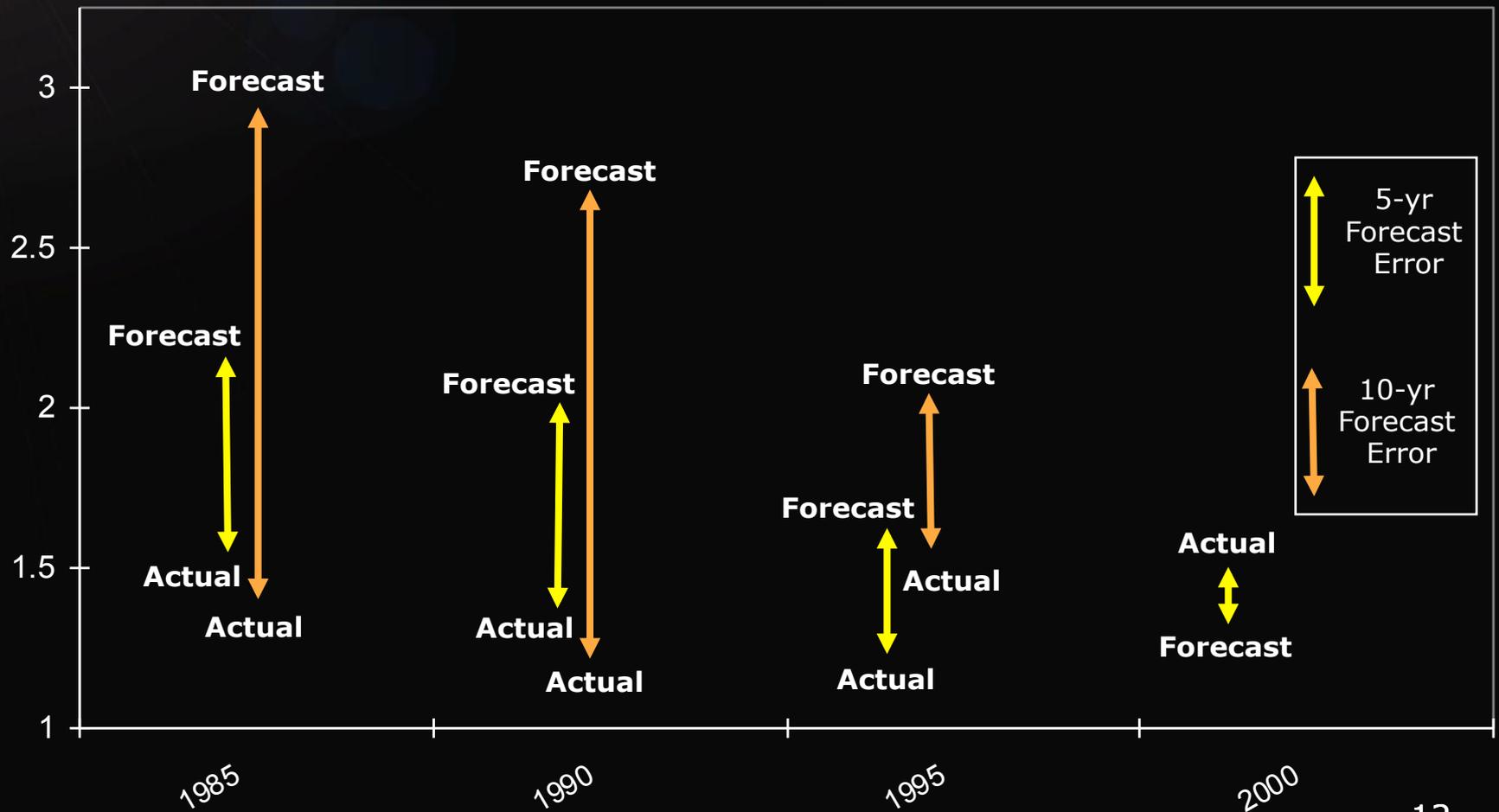
oil price forecasts (1985-2005)



gas price forecasts (1985-2005)



coal price forecasts (1985-2005)



the US market for mobile subscribers

Forecast

Actual

McKinsey for AT&T
(1980 => 2000)

> 0.9M

> 109M

yesterday's technology, tomorrow's forecast

> 1980's phone



> The actual market



quantitative modeling flaws

- > Models with given inputs are precise but inaccurate
 - > low “standard deviation”, but with high “standard error”
 - > input the measurable, ignore the immeasurable Black Swan’s
 - > obscured embedded assumptions

- > Food price controversy
 - > World Bank study 75% of price rise due to biofuels
 - > USDA notes only 3% of total price change

“extrapolation of the past”

VS.

“inventing the future”

Redefining swans...



“black swan” solutions ?

Technology shocks are classic “Black Swans”!

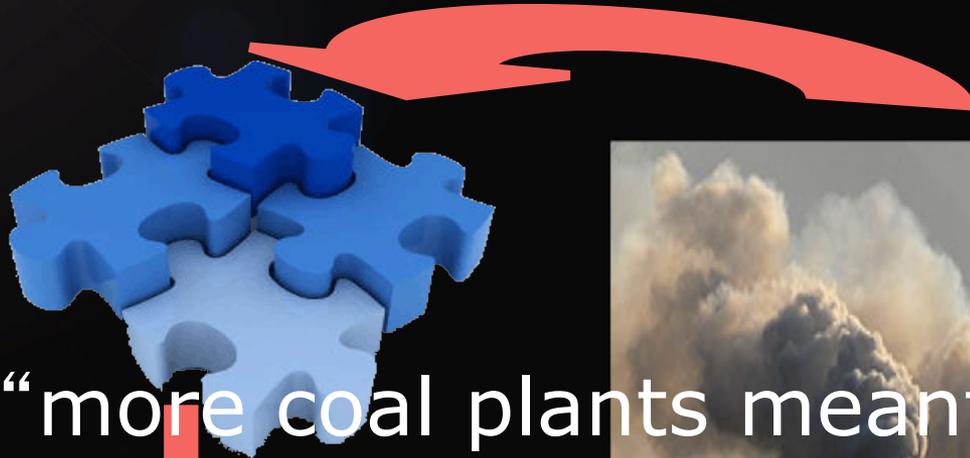
“rarity, extreme impact, and retrospective (though not prospective) predictability”

Strategy: More “at bats”; “shots on goal”

“what if...”

Calera

- > Cement that sequesters CO₂, instead of emitting it!



“more coal plants meant cleaner air”



“cement was carbon negative & free”



Kior: “biocrude” replaces crude



Crude oil

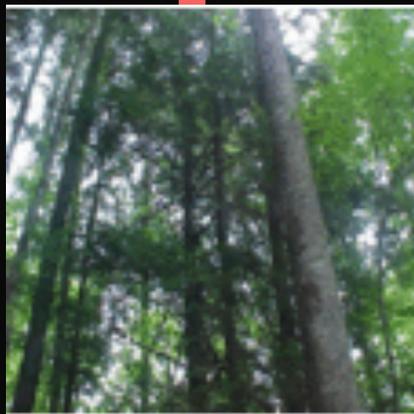
“more driving meant less carbon”

Refinery



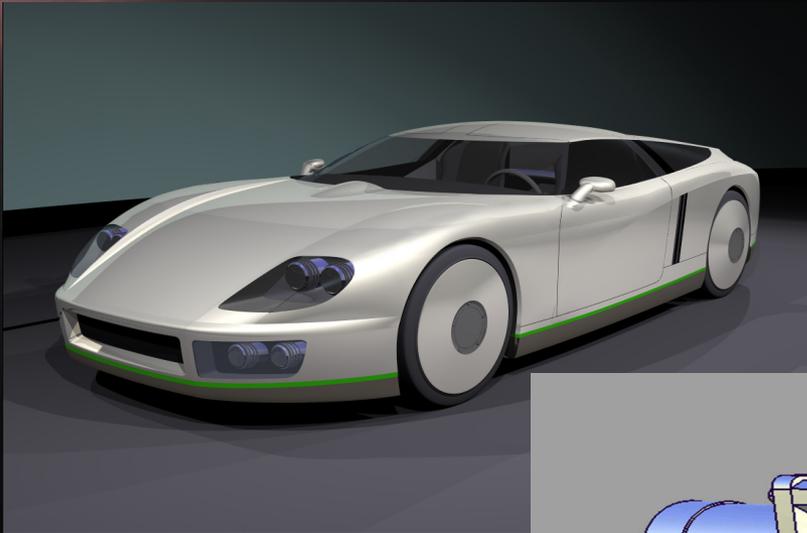
Millions of Years

“a million year crude production cycle reduced to hours?”

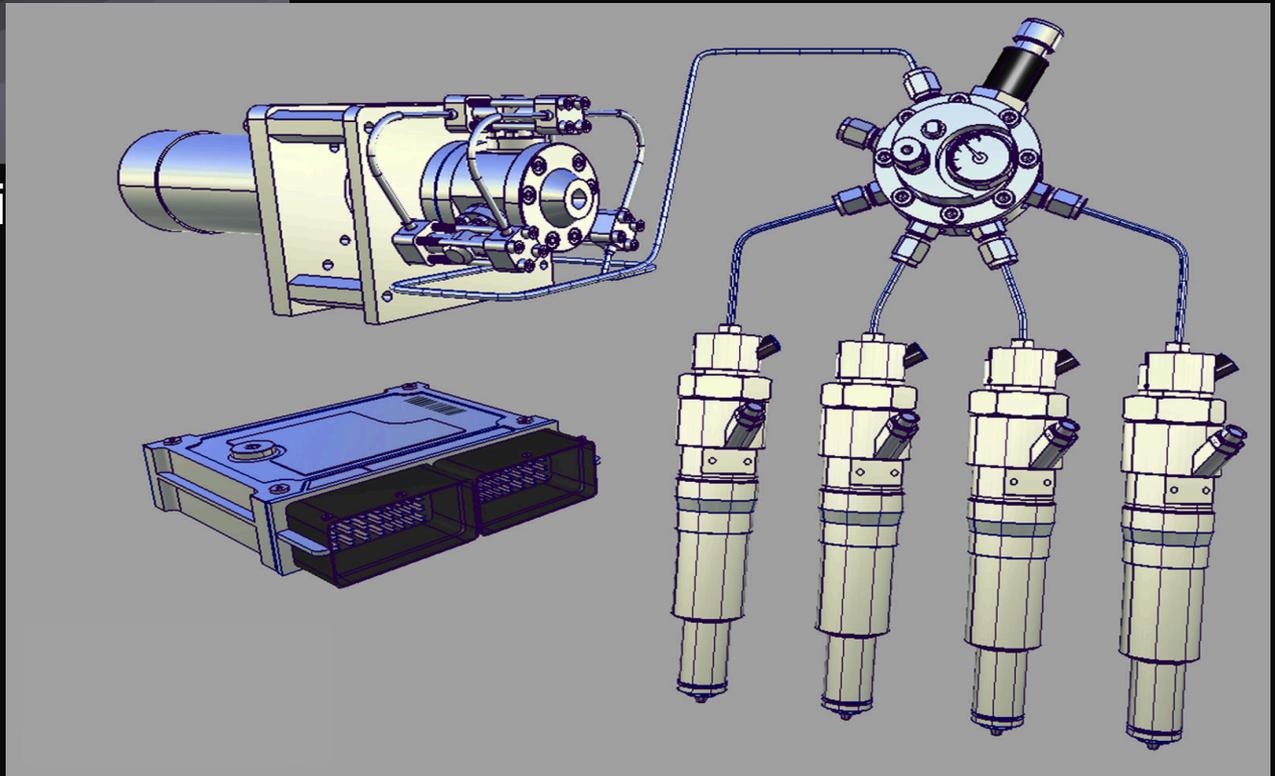


KIOR
Biocrude

Transonic



“2X efficient engi



Battery Black Swan?

...probably the only battery worth working on

... for both cars & wind/solar storage

... along with other Black Swan's

... ”relevant scale” solutions for

... oil

... coal

... materials

... (efficiency of oil & coal use)

But how do we evaluate solutions...?

... "relevant cost"

... "relevant scale"

... "relevant adoption"

...the chindia test

only scalable if competitive unsubsidized

1990: Chindia \approx 13% of CO₂ emissions

2005: Chindia \approx 23% of CO₂ emissions

2030: Chindia \approx 34% of CO₂
emissions

EIA

“China and India together
account for 79 percent of the
projected increase in world coal
consumption from 2005 to
2030”

EIA

Unsubsidized market competitiveness?

...the scaling model

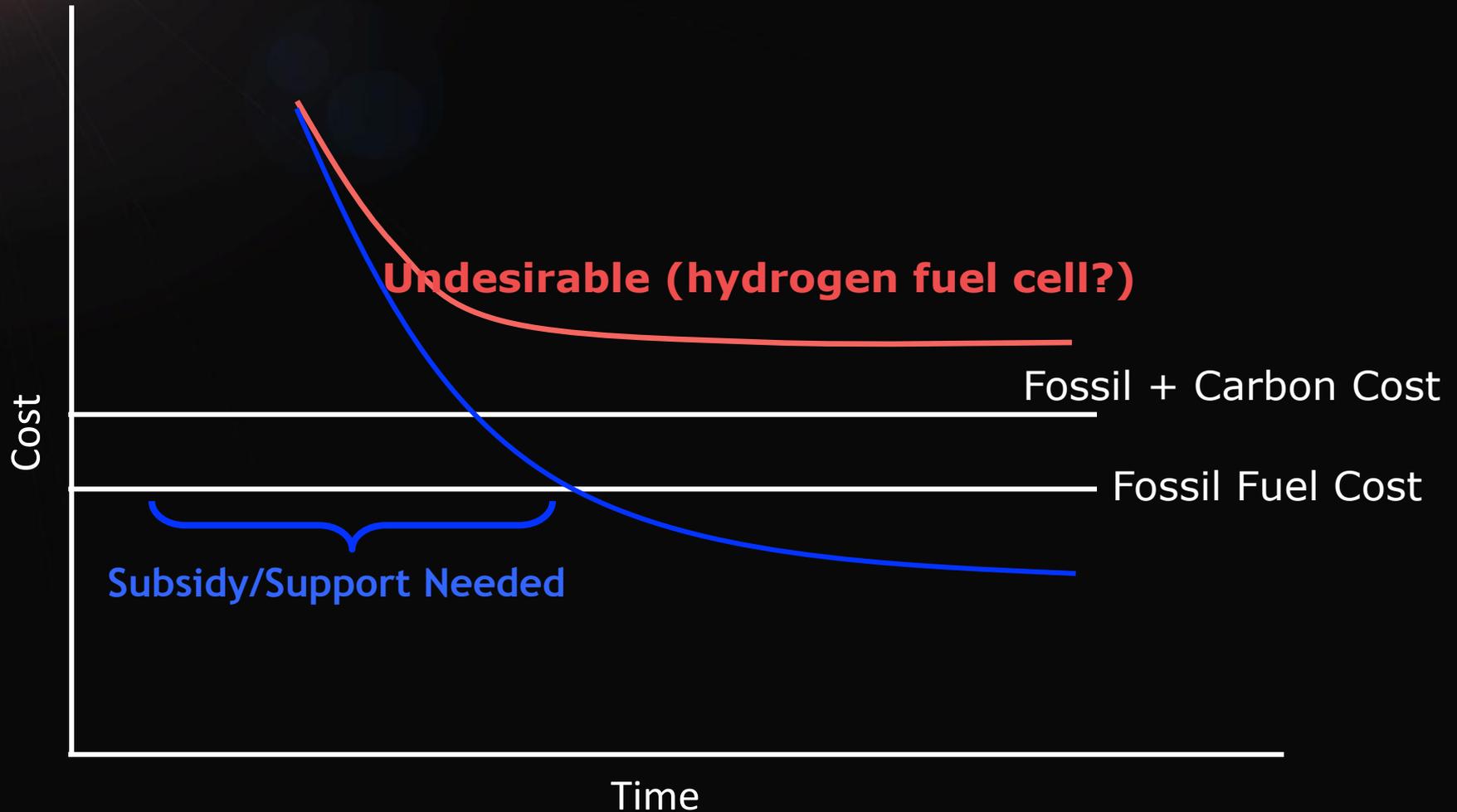
brute force or exponential, distributed...

key criteria

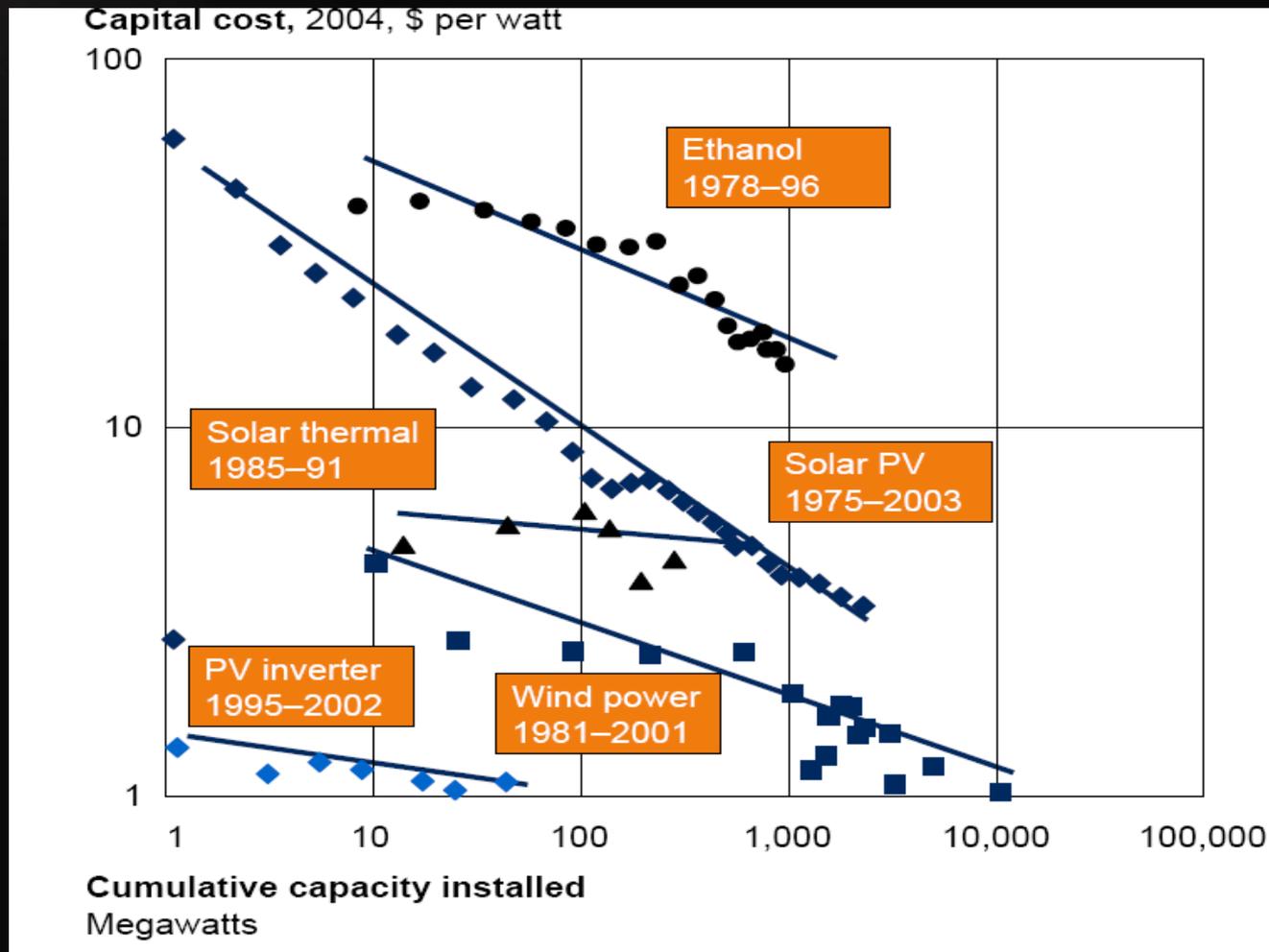
- > Trajectory: “What is” or “What Can Be”
 - > Cost Trajectory
 - > Scalability Trajectory
- > Adoption Risk
- > Capital Formation
- > Optionality
- > Carbon Reduction Capacity

...cost and carbon trajectory

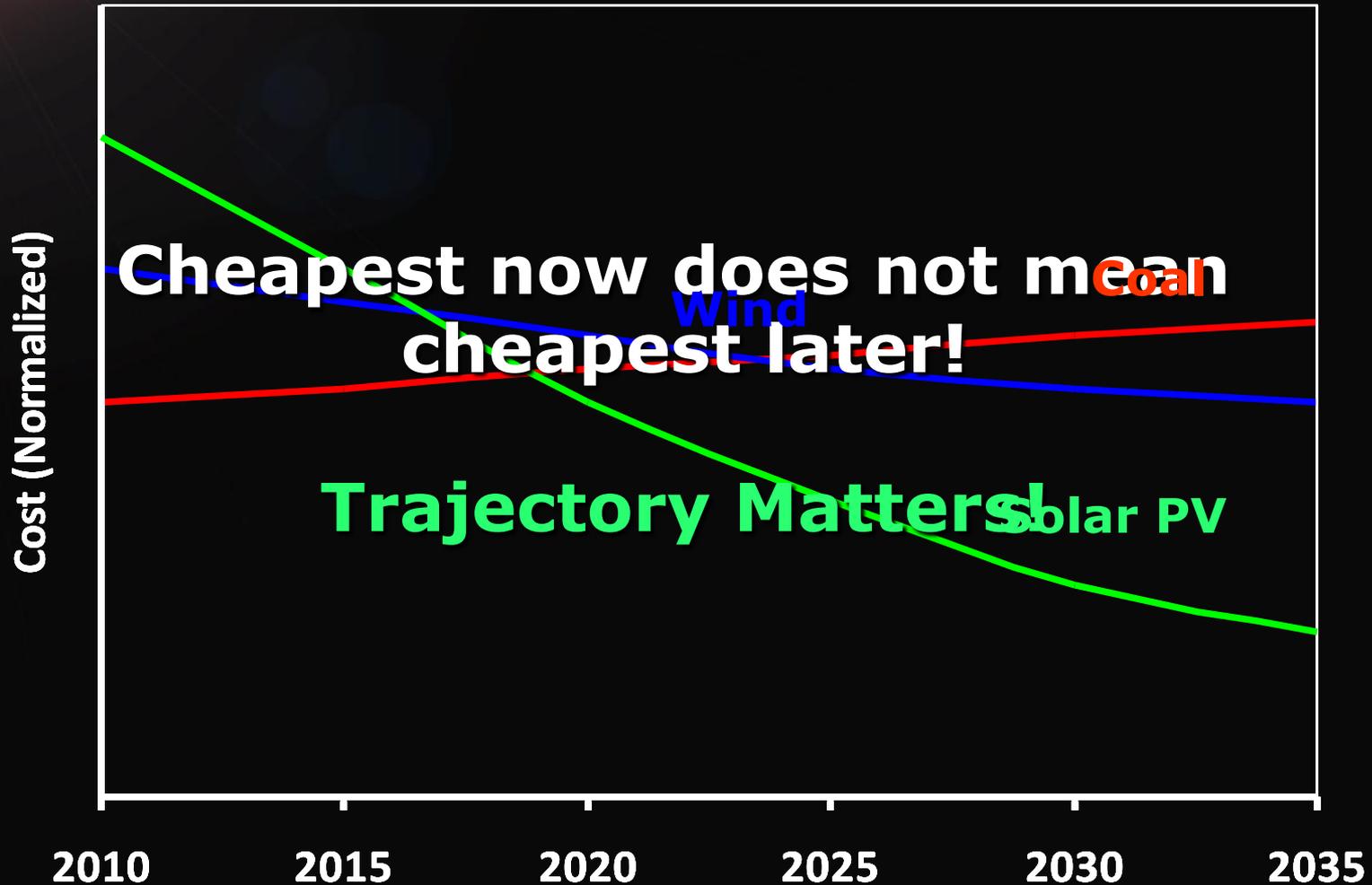
Cost trajectory:



cost: driving down the cost curve

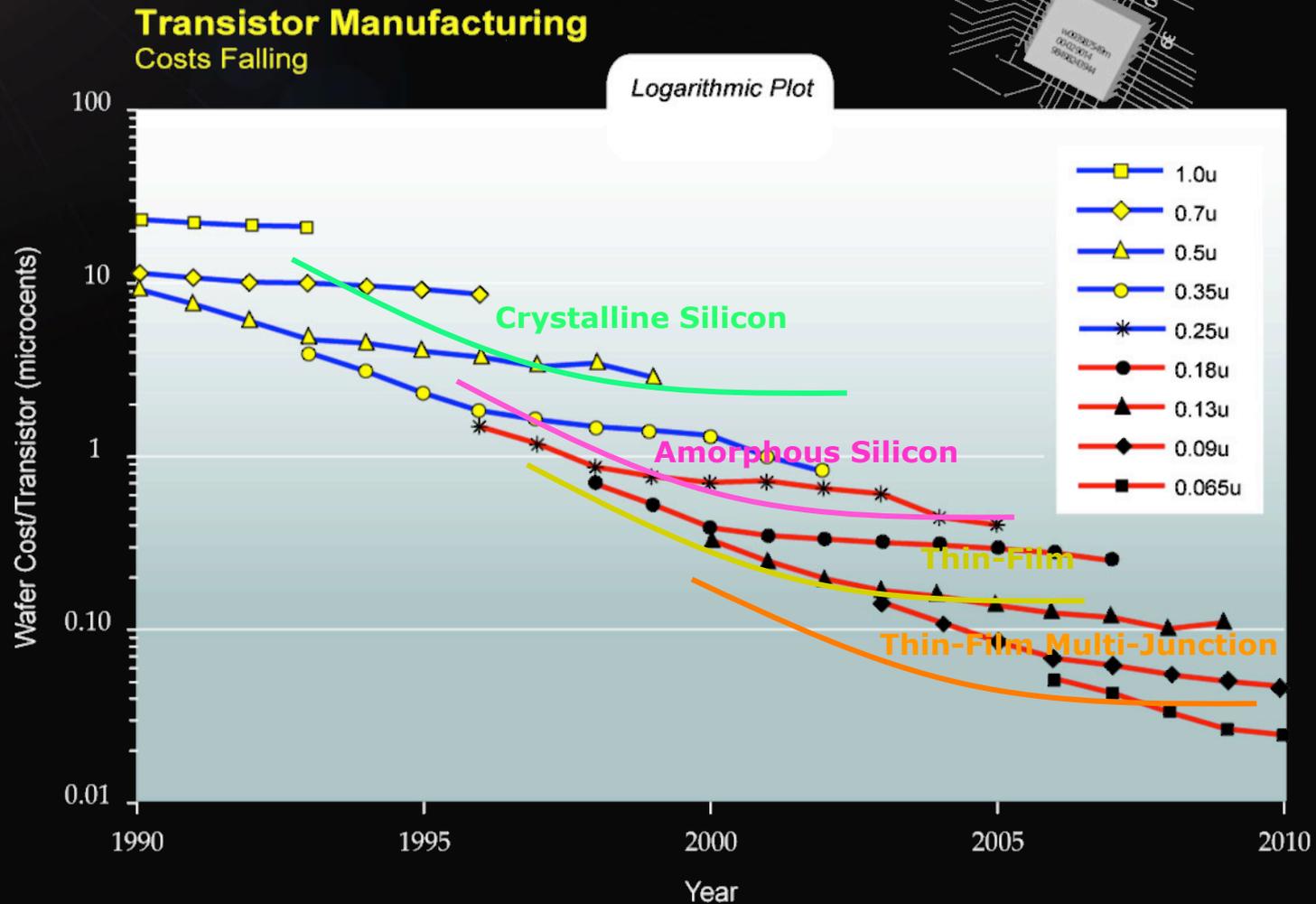


cost: not all technology curves are the same

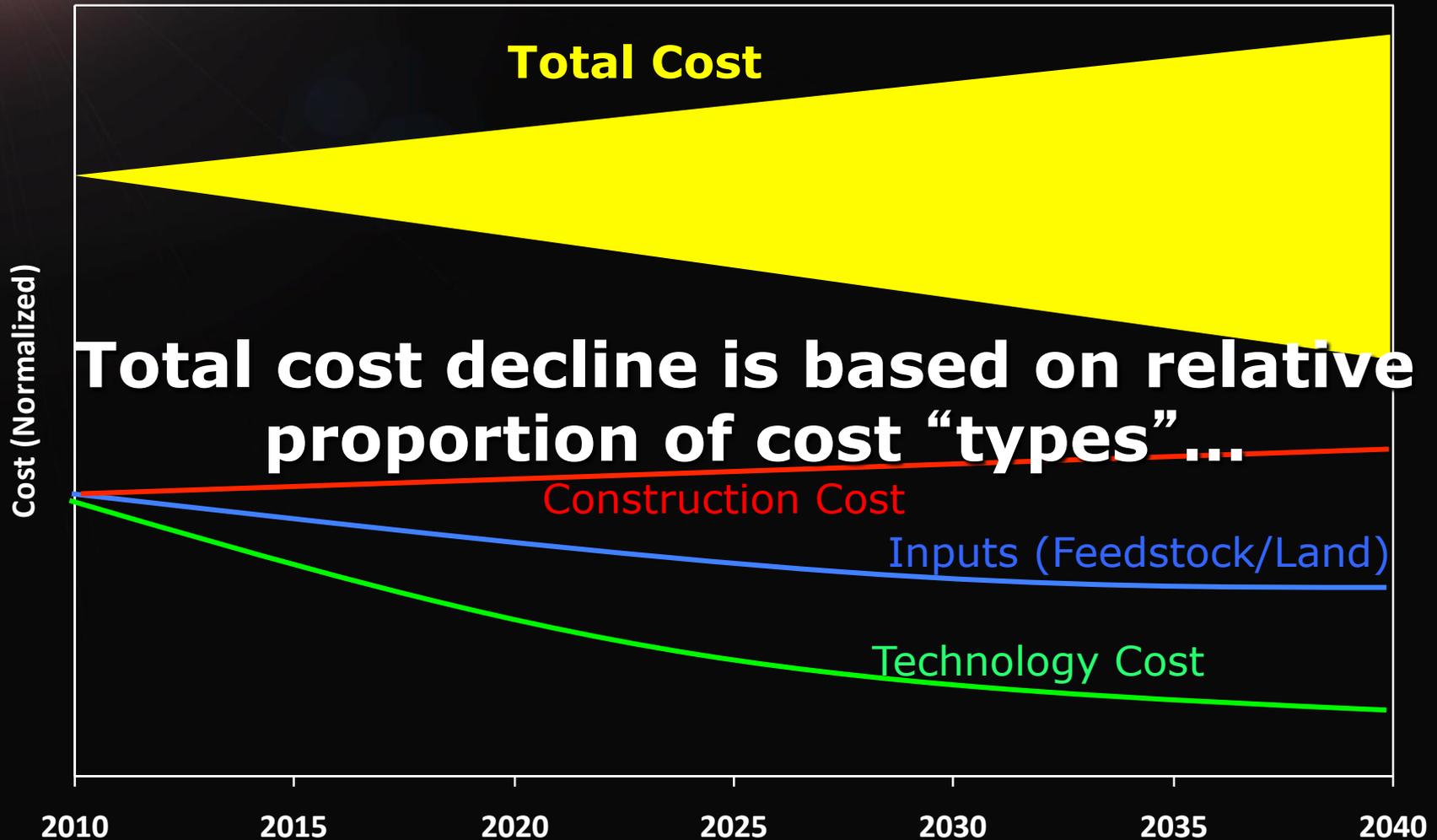


declining technology cost...

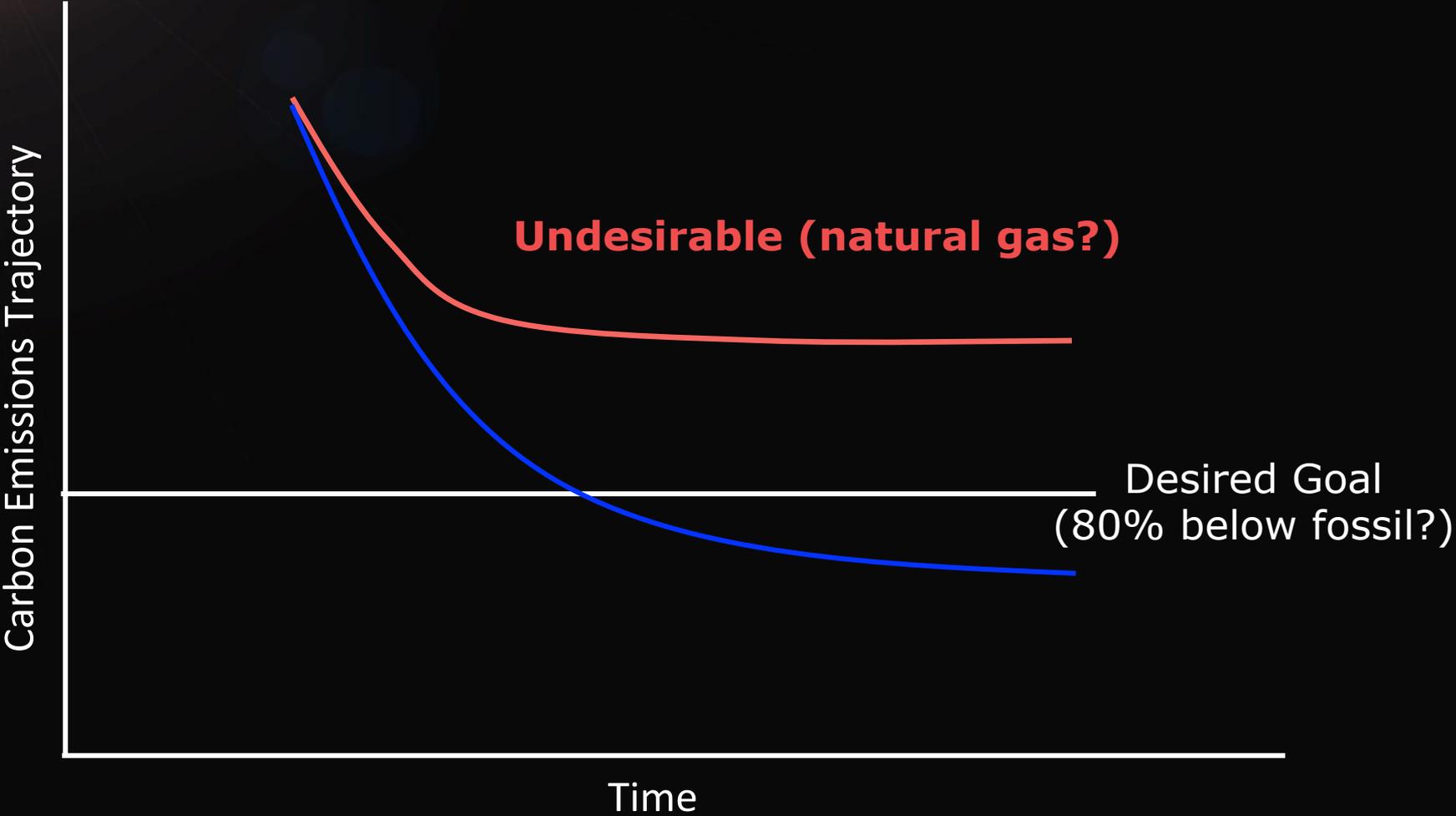
Generations of Solar Photovoltaics...

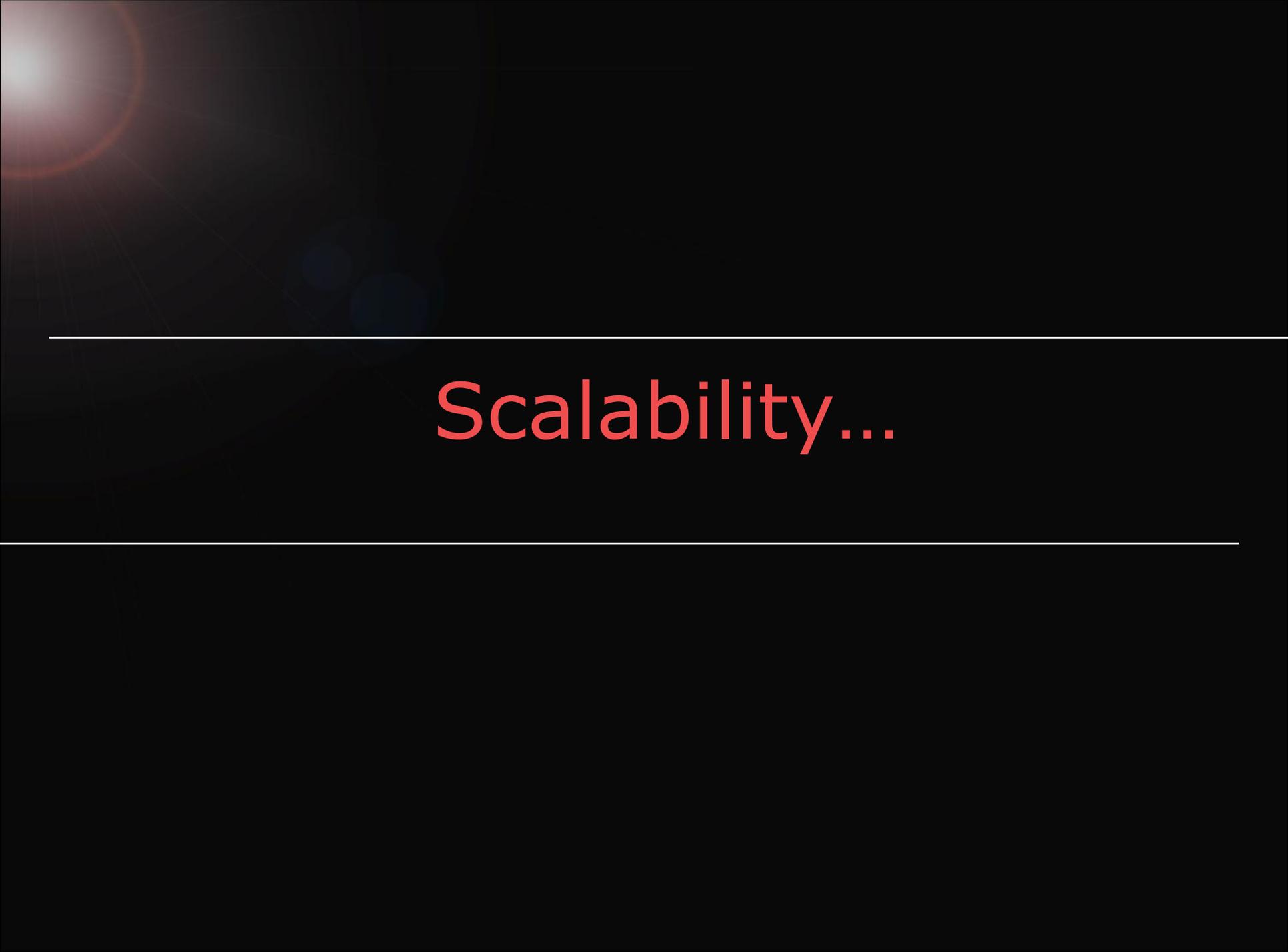


but tech cost decline isn't enough...



Carbon trajectory:

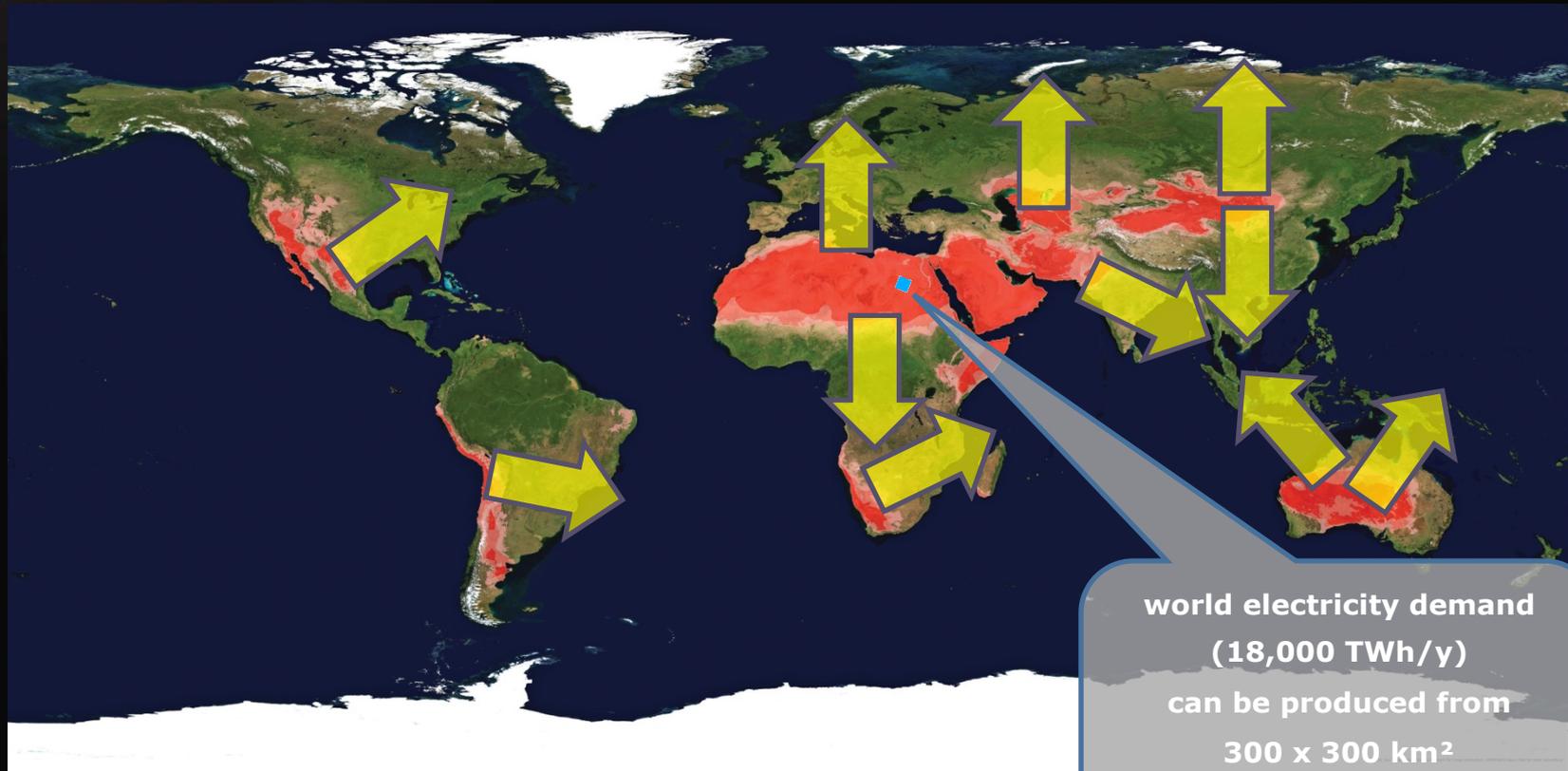




Scalability...

Scalability: Land is not (remotely) a constraint

→ 3000 km



world electricity demand
(18,000 TWh/y)
can be produced from
 $300 \times 300 \text{ km}^2$
= 0.23% of all deserts
distributed over "10 000" sites

area requirements to power the USA

(150 km)² of Nevada covered with 15% efficient solar cells could provide the USA with electricity

1/2 as much land with 30% efficient turbines



...the adoption risk

financial, consumer acceptance, market entry

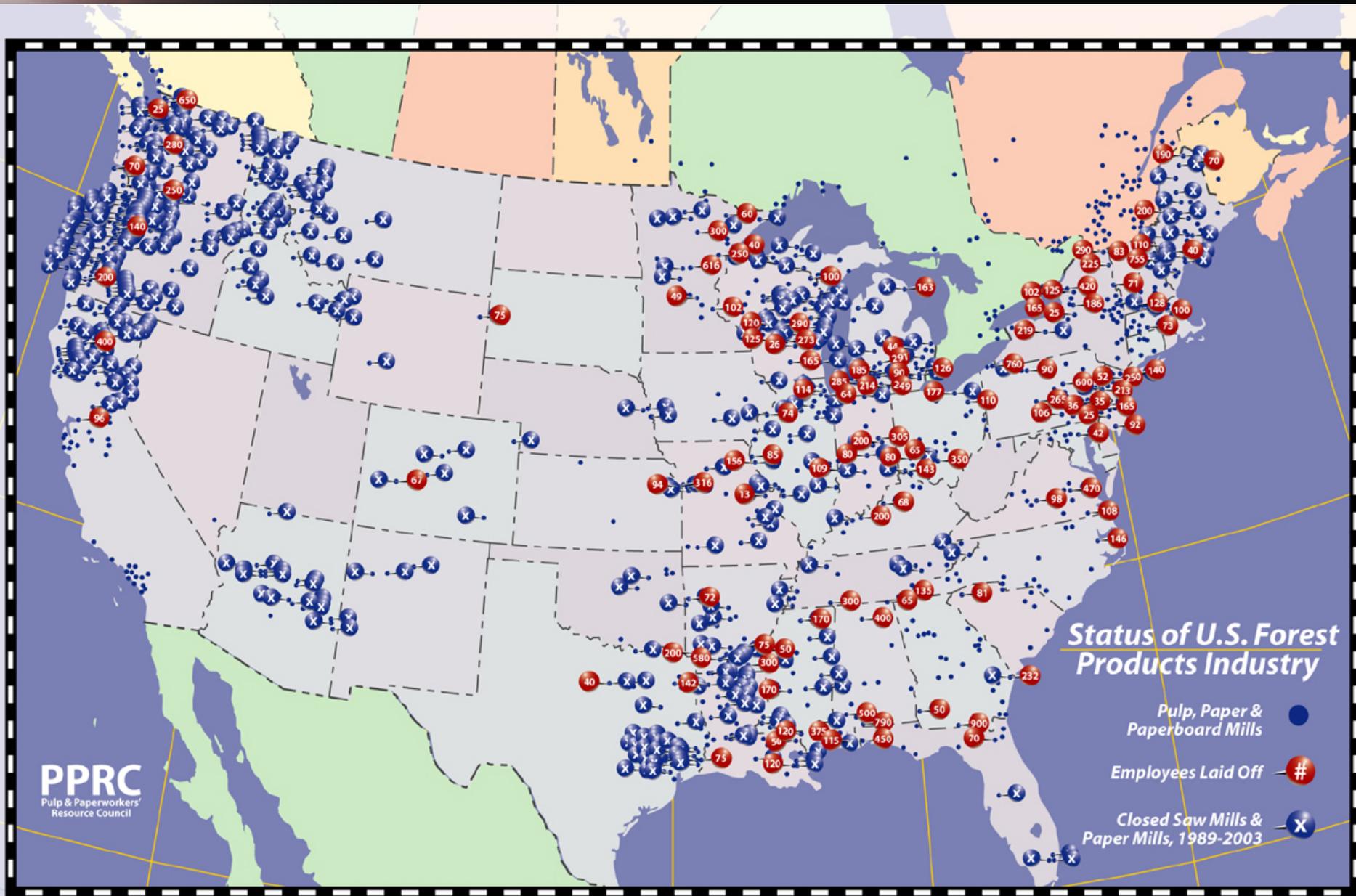
adoption risk - \$2,500 nano

**Internal combustion engine
or
Hydrogen / electric?**

TATA nano

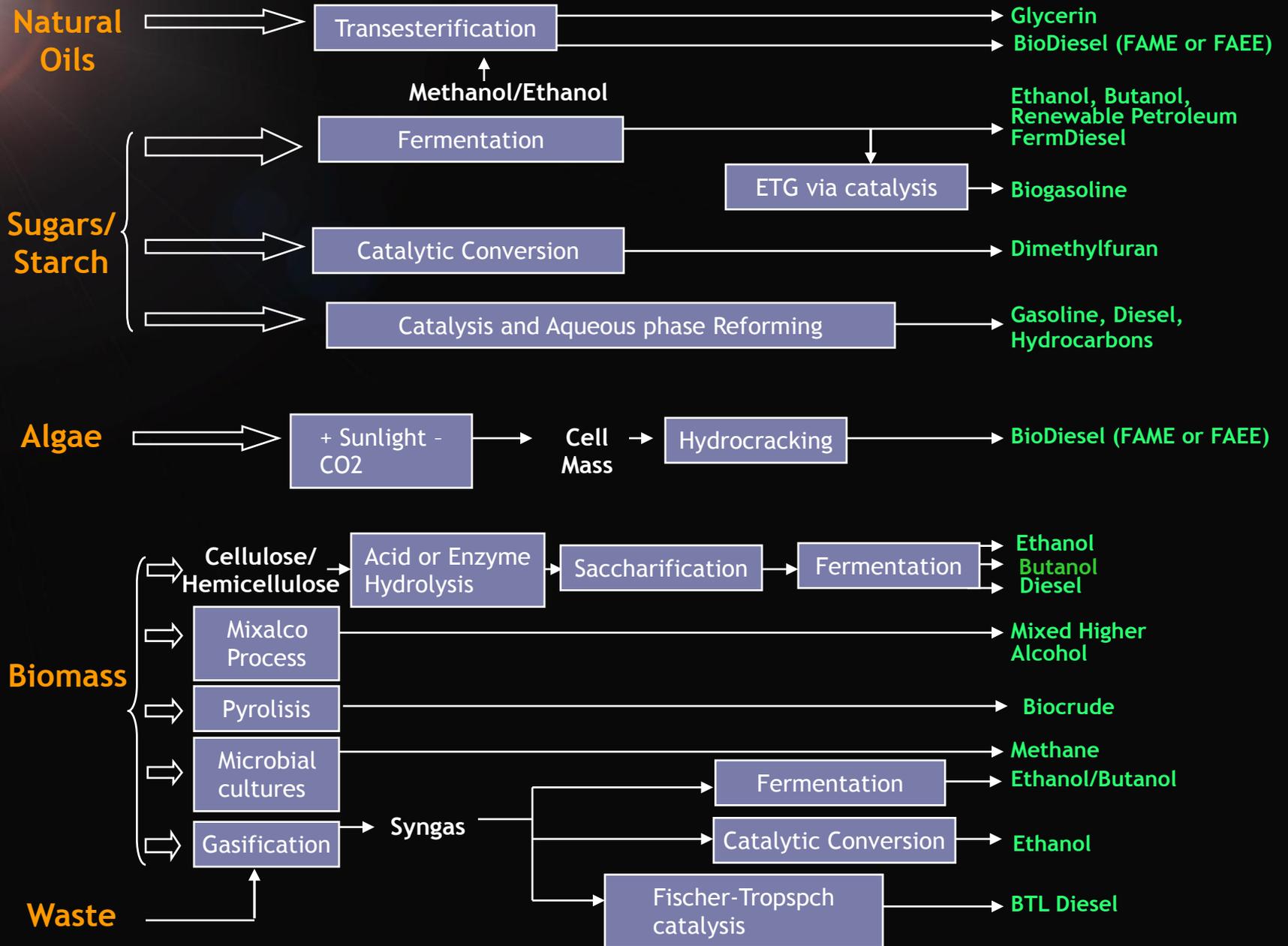
A red Tata Nano car is shown from a front-three-quarter view. The car is compact and has a black front bumper. The license plate area displays "TATA nano". The car is parked on a dark surface, and the background is dark with some blue lighting. The text "adoption risk - \$2,500 nano" is at the top, and "Internal combustion engine or Hydrogen / electric?" is overlaid on the car's hood. The Tata Nano logo is visible on the front of the car.

adoption risk: U.S. mill closures

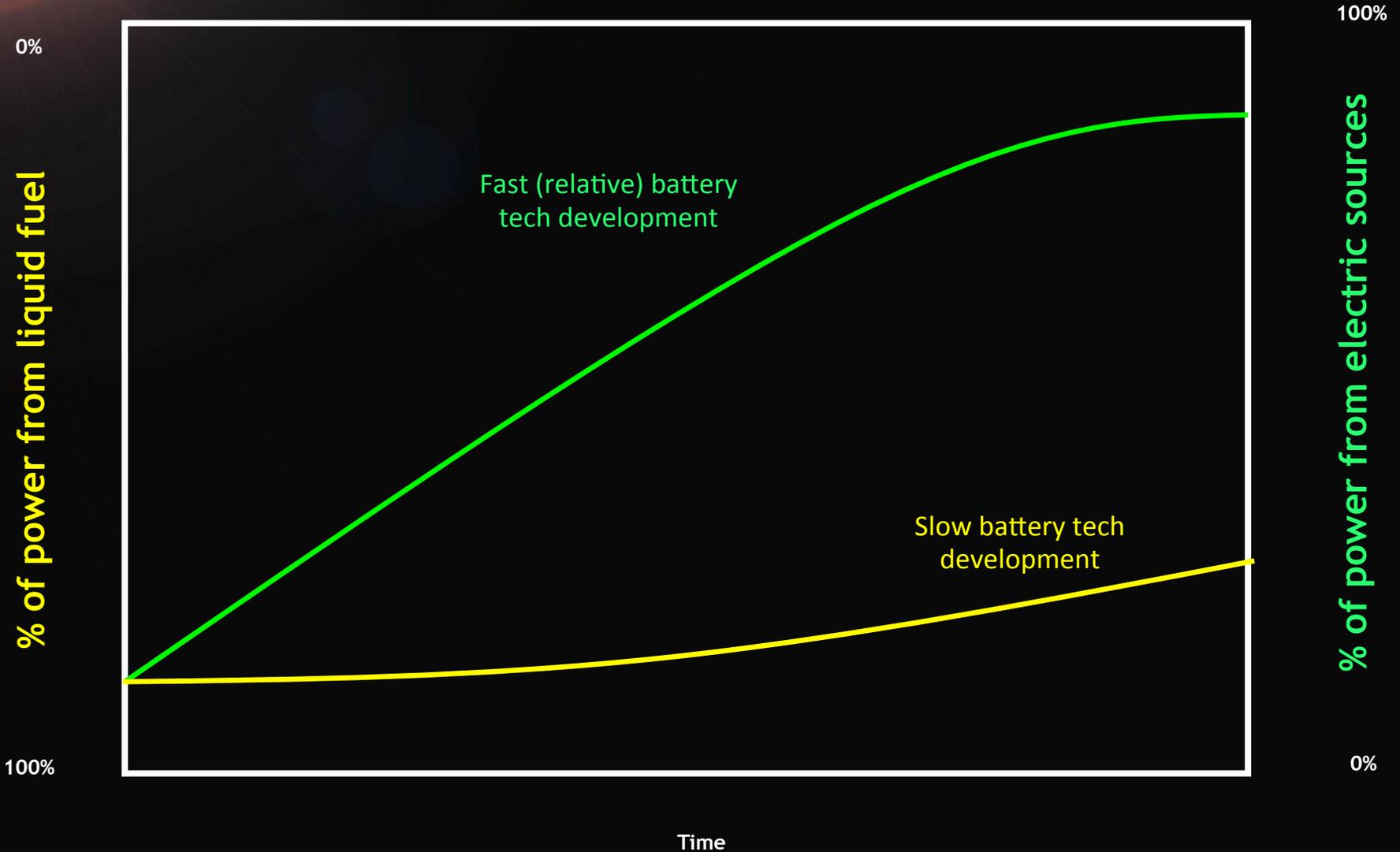


...optionality

optionality: biofuels feedstocks & pathways ...



optionality: hybrids or biofuels?



...capital formation

capital formation

> **Short Innovation Cycles (3-5 years)**

> **Short investor return cycles**

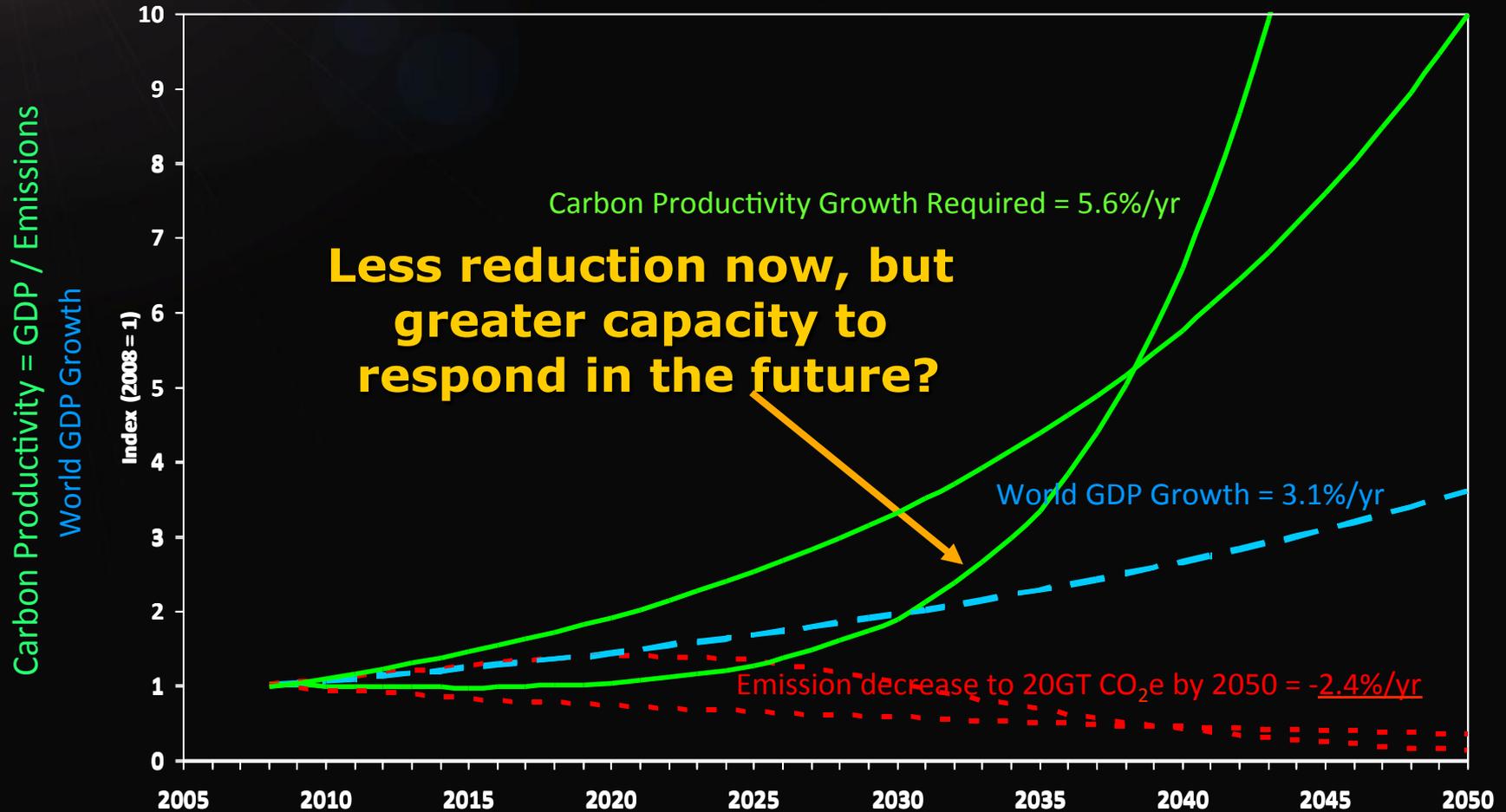
Private money will flow to ventures that return investment in

> **Mitigate technical & market risk cheaply**
3-5 year cycles!

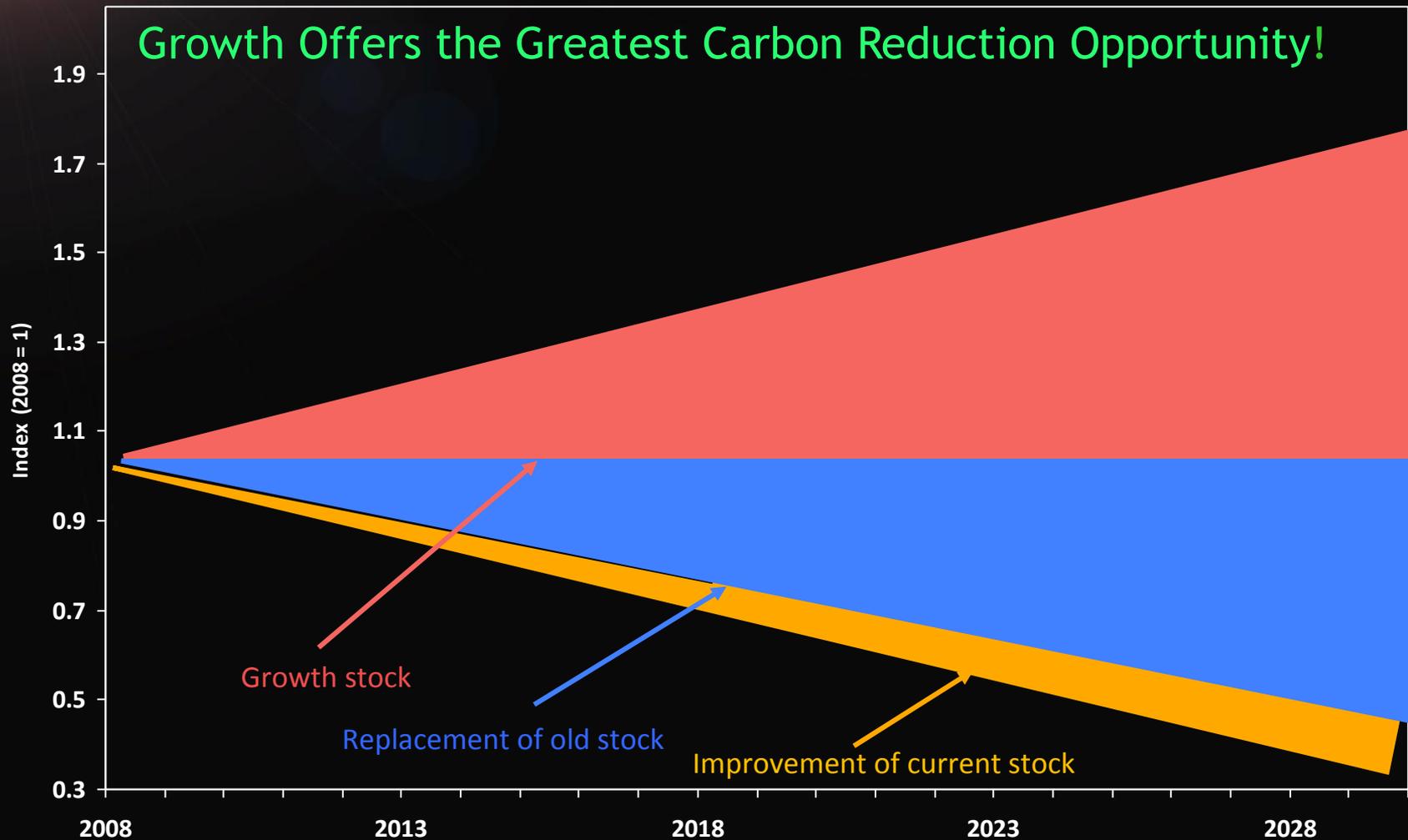
> **Unsubsidized market competition**

...carbon reduction capacity

carbon reduction capacity: 10X increase in carbon productivity!



carbon reduction capacity is key



goal:

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

But be wary of irrational ideas....

irrational ideas: toilet paper

I propose a limitation be put on how many squares [sic] of toilet paper can be used in any one sitting. Now, I don't want to rob any law-abiding American of his or her God-given rights, but I think we are an industrious enough people that we can make it work with only one square per restroom visit, except, of course, on those pesky occasions where 2 to 3 could be required.

- Sheryl Crow

irrational ideas: “green bikinis”

eco bikini from niksters

by Maureen @ 11:57 am

[1 comment »](#)



It's time to add some eco sizzle to your collection of eco swimwear. This two-piece Eco-Bikini from Nikster features a Bandeau-style top, and Brazilian-cut bottom with white ruffles. Created with soy, organic cotton and spandex fabrics.

made in the old US of A
\$100.00 @ nikster.com

Related: [previously on altCon](#)

[eco swimsuits - green is sexy](#)

[hemp on the beach](#)

[Ashley Paige - eco chic](#)

irrational ideas: eat kangaroos, not cows!

Farming kangaroos instead of sheep and cattle could cut greenhouse gases produced by grazing livestock...

irrational ideas: “no flags, no footprint”

But a few days into the Euro 2008 football championships fans are being advised not to fly their flags - because they could damage the environment...

- The Guardian

irrational ideas: Shell's "sustainable" tar sands

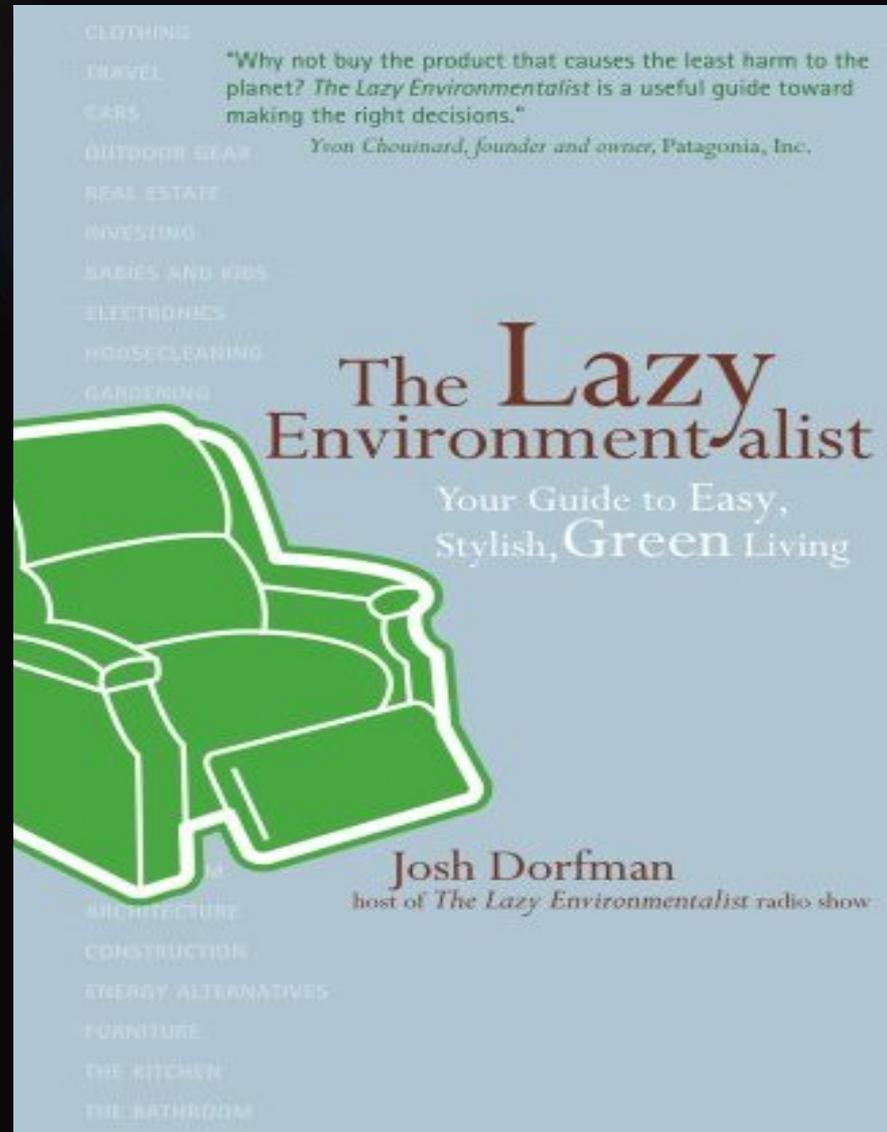
We invest today's profits in tomorrow's solutions

The challenge of the 21st century is to meet the growing need for energy in ways that are not only profitable but sustainable. As our 2007 results show, we're investing heavily in new technology and assets to safeguard the interests of our shareholders and future generations. In Canada we're harnessing our global network of technical and financial expertise to unlock the potential of the vast Canadian oil sands deposit. In the USA we're helping to build what will be the nation's largest refinery. And we're exploring a new generation of biofuels made from non-food sources. Difficult, yes. Impossible, no.

For more details on our 2007 results: www.shell.com/investor

- UK advertising authority: Shell mislead public by claiming tar sands as "sustainable" source!

irrational ideas: “how to green” books



irrational ideas: zero-emission buses?

3-year Oakland pilot : zero-emission hydrogen fuel cell buses

**solutions must make
economic sense!**

diesel @ \$1.61/mile vs. hydrogen @ \$51.66/mile!

San Francisco Photovoltaics?



Irrational ideas: scalable wind

Good:

- > Wind turbine shows declining costs over time

Storage is the key for wind power

... but

- > Technical: Betz limit (59.6%)
- > Scalability: good sites declining
- > Adoption Risk: Systems for distributed sources

irrational ideas: Zero Emission Buildings

... the new fashion?

irrational ideas: palm-oil based biodiesel

“The European Union was recently shocked to learn that some of its imported biodiesel, derived from palm trees planted on rain-forest lands, **was more than twice as bad for climate warming as petroleum diesel**”

- David Tilman and Jason Hill

... "lets face the facts"

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

... Electric cars?

Electric Cars?



and renewable electricity?

...stacking one risky transformation on another?

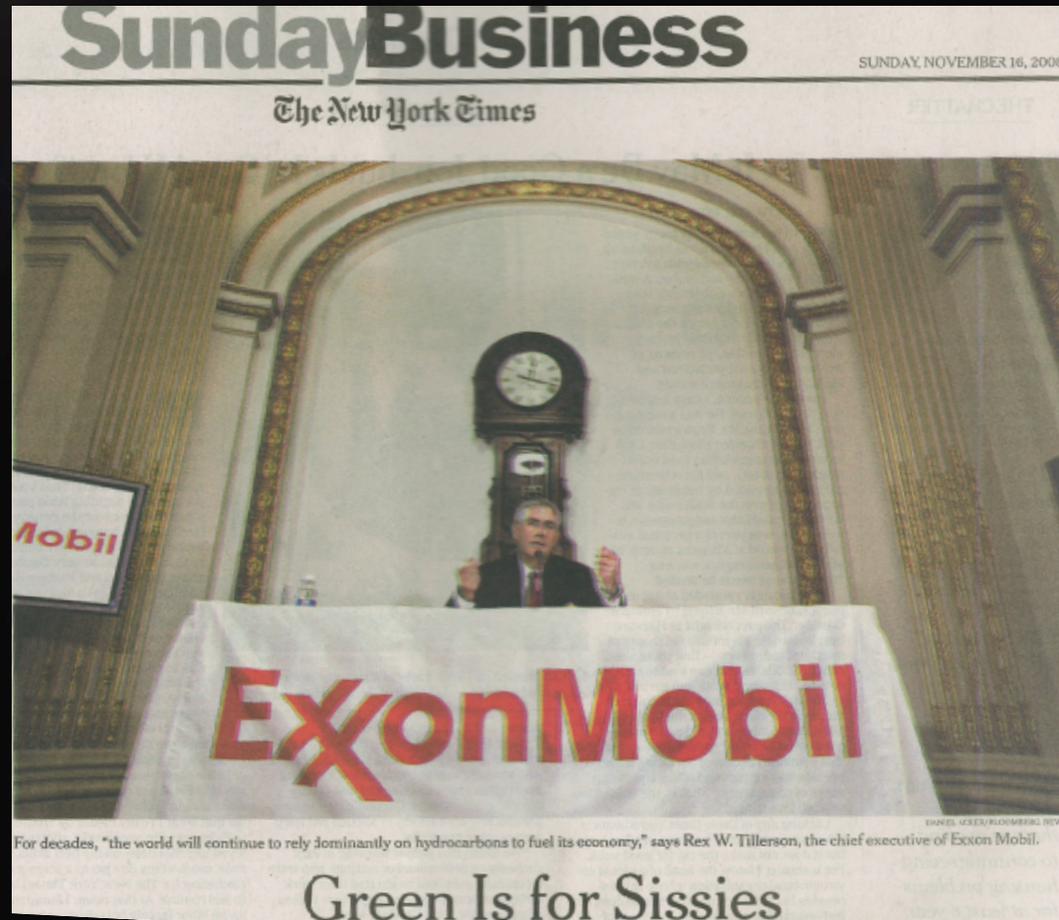
Shower or Not?

- > Showering/Drinking (in North America): 100-250L
- > Growing 1 KG of Wheat: 1,000L

**If you really want to save water,
become a vegetarian!**

- > Growing 1 KG of Beef: **15,000L!**

T00rational ideas: the “Exxon view”?



- Discipline, Patience, Vision ≠ Green!

“no change bigotry”

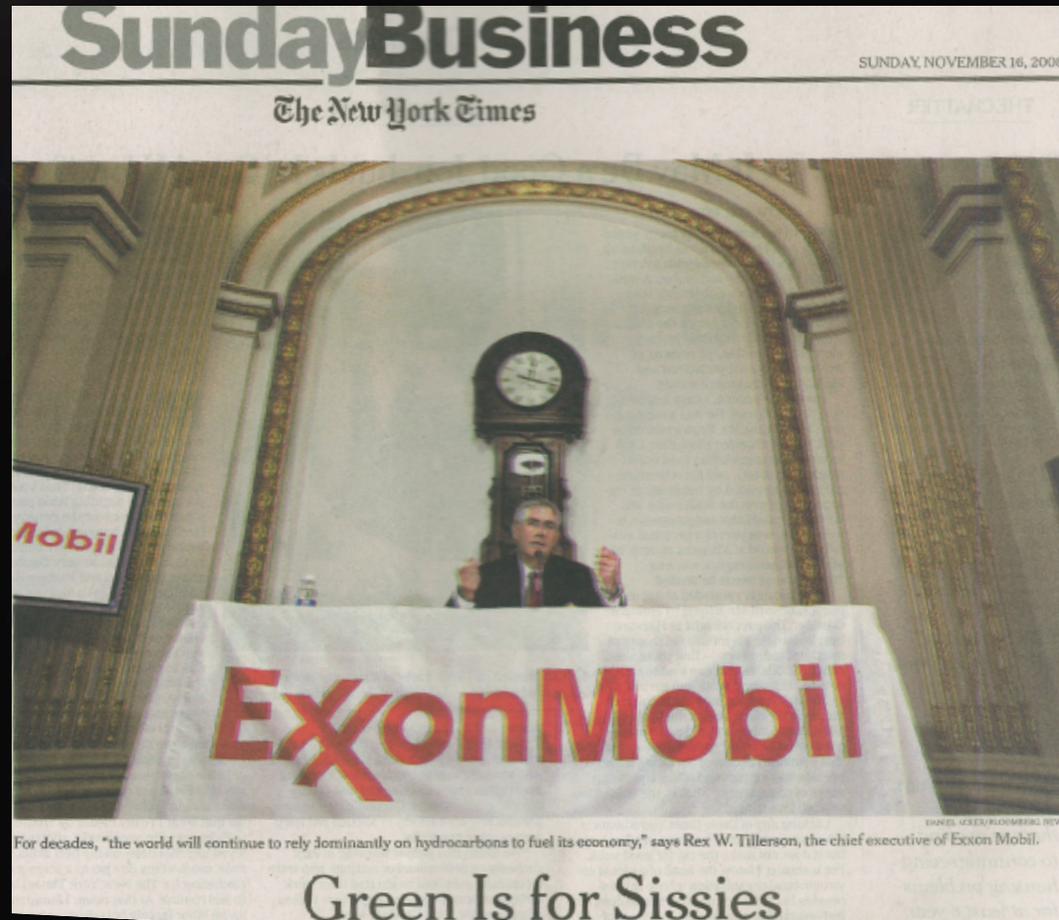
VS.

“environmental everything”

VS.

praggmentalists

T00rational ideas: the “Exxon view”?



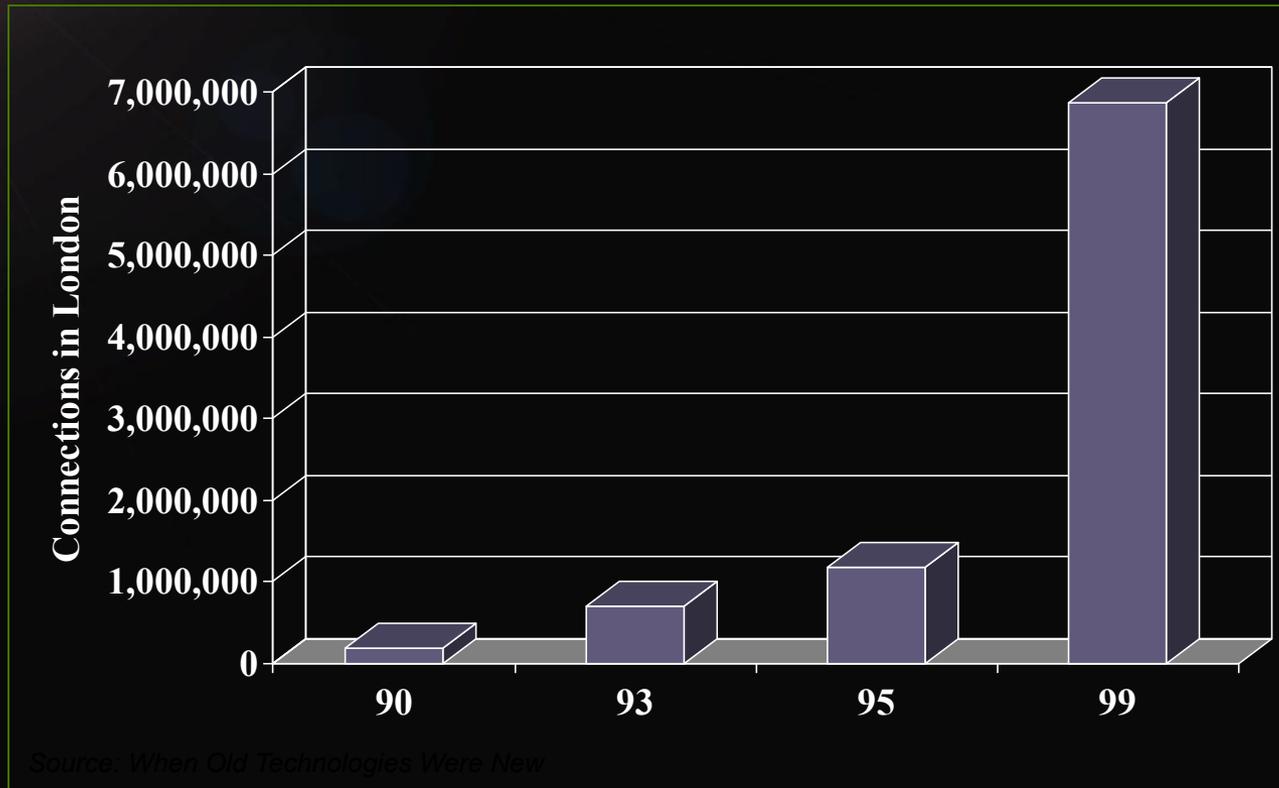
- Discipline, Patience, Vision ≠ Green!

...technology expands the “Art of the Possible”

...today’s “unimaginable” or tomorrow’s “conventional wisdom”

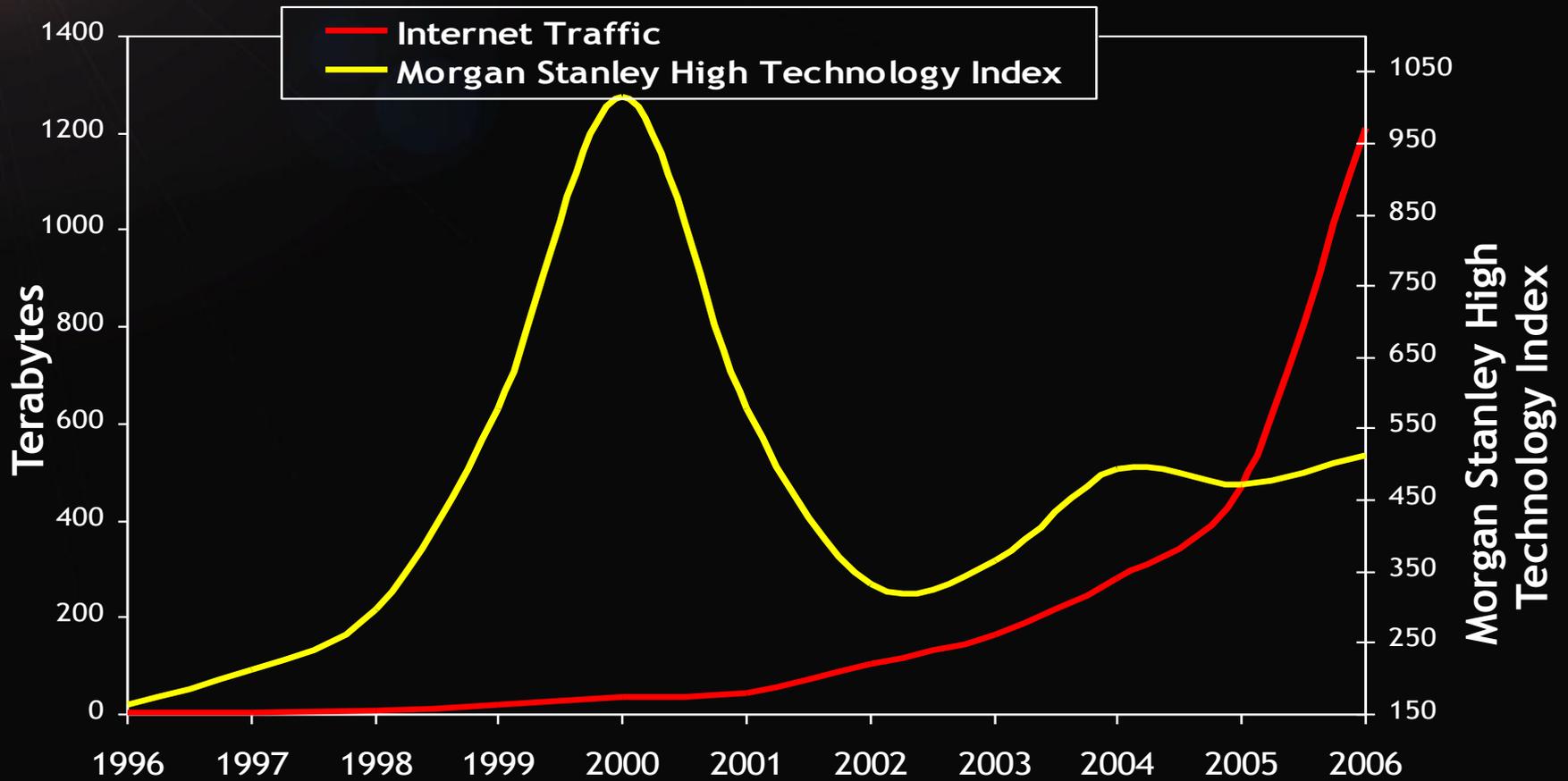
and remember....

New Technology Has A History ...



“In 1885, Yale students who were getting ‘more light than they relished’ chopped down an electric pole erected at the corner of the campus...”

Dotcom bubble but ... net “traffic” growth continued

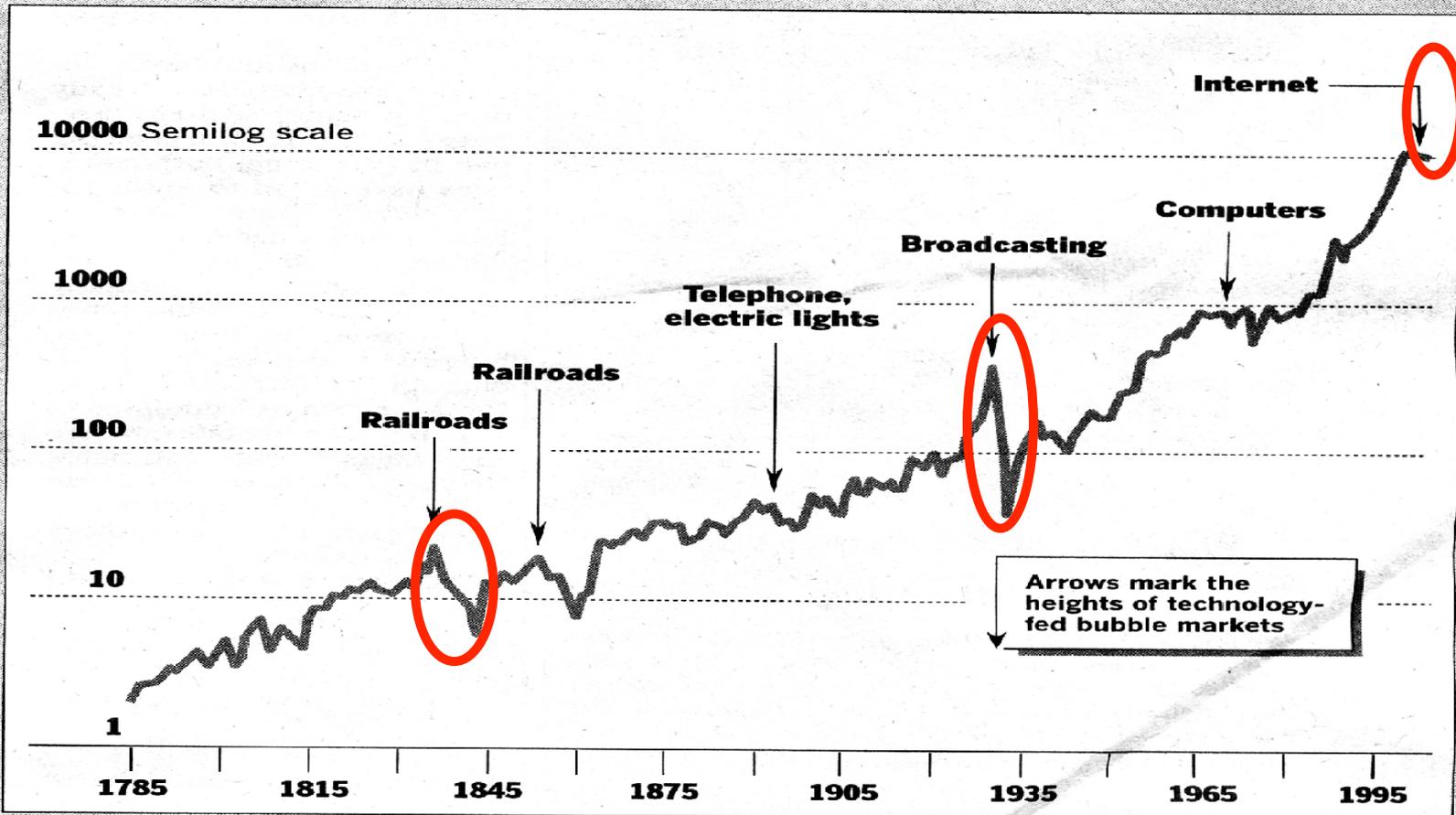


200yrs of Technology Speculation

“Triumph of the Optimists: 101 Years of Global Investment returns”

Speculation marches on

Market peaks that coincided with technology breakthroughs.
Annual average prices for U.S. stocks, 1785-2002.



SOURCES: Elliott Wave International; "Triumph of the Optimists: 101 Years of Global Investment Returns"



...our **renewable** portfolio

Not Your Niche Markets Anymore!

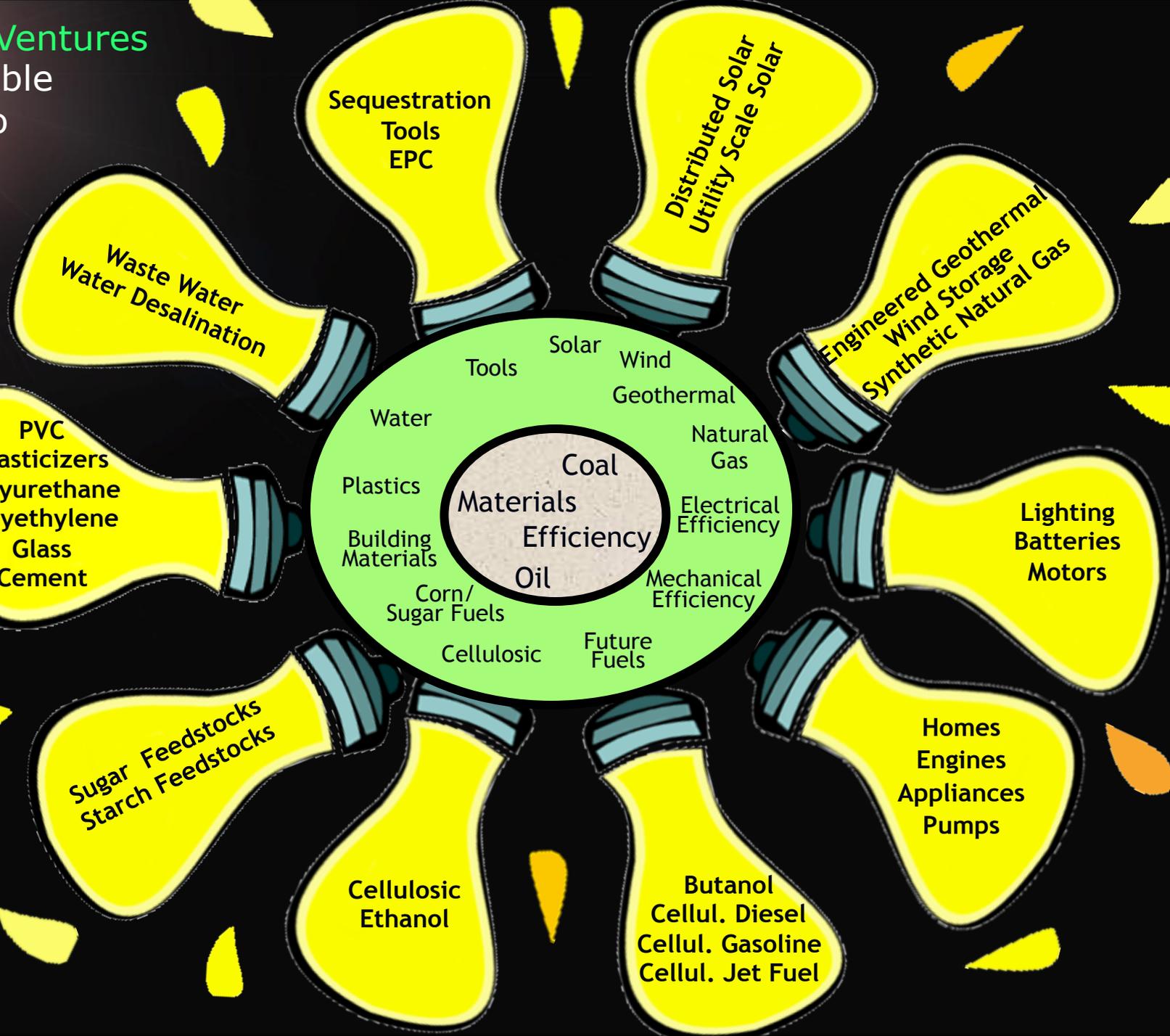
The New Green: Maintech not Cleantech

The Markets You Think Of

- > Engines (\$200B)
- > Lighting (\$80B - US)
- > Appliances (\$10'sB+)
- > Batteries + Flow Cells (\$50B+)
- > Gasoline (\$500B+)
- > Diesel (\$500B+)
- > Jet Fuel (\$100B+)
- > Cement (\$100B+)
- > Water (\$500B+)
- > Glass (\$40B)
- > Home Building (!!!)
- > BioPlastics (\$10'sB+)
- > Solar Thermal
- > EGS
- > Clean Coal
- > New Nukes

Generation - \$250B - US

Khosla Ventures
Renewable
Portfolio



Khosla Ventures
Renewable
Portfolio

NanoH2O

Nanostellar
Codon

Stion
Ausra
Infinia
PVT

AltaRock
Great Point Energy

Draths
Segetis
Soladigm
Calera

Solar
Wind
Geothermal
Natural Gas
Coal
Oil
Efficiency
Mechanical Efficiency
Future Fuels
Cellulosic
Corn/Sugar Fuels
Building Materials
Plastics
Water
Tools

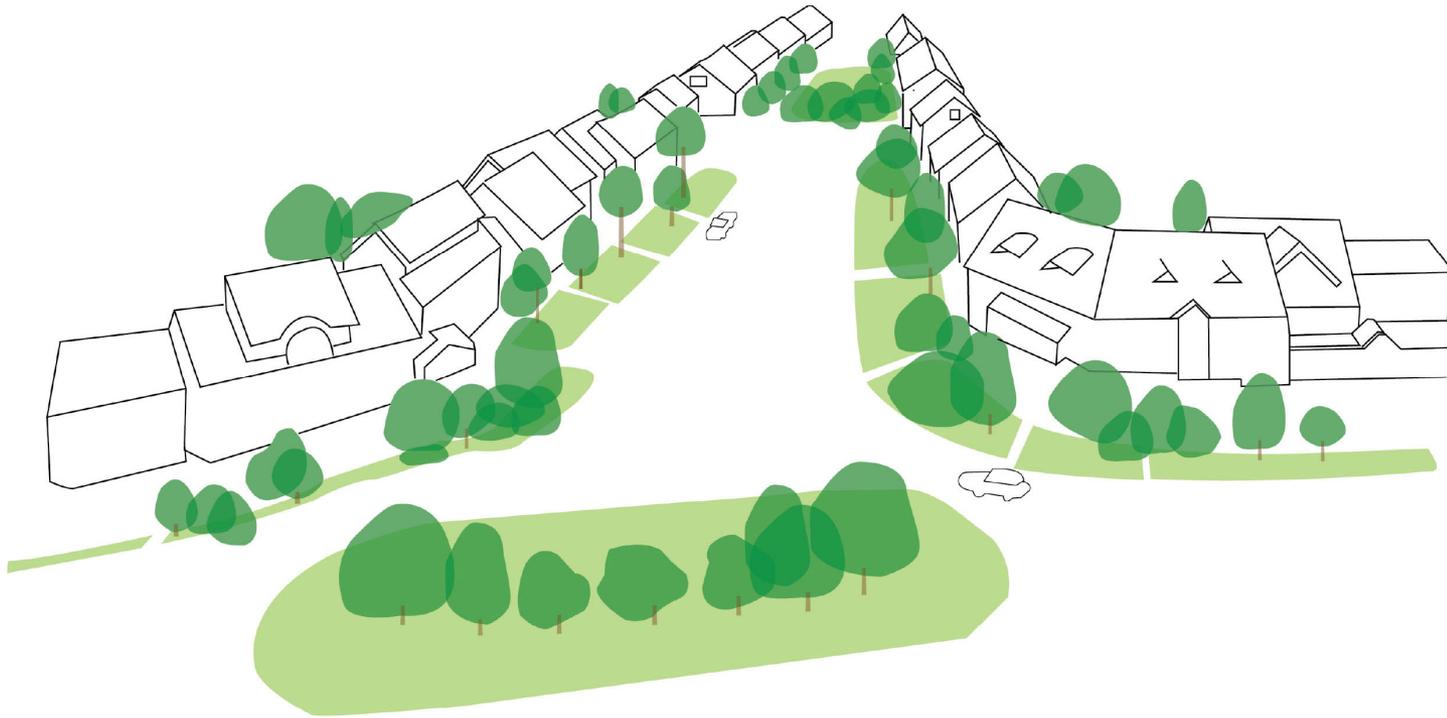
Seeo
Kaai
Sora
Lumenz
Topanga
GIV
Gridshift

Cilion

Mascoma
Range
Coskata
Lanza

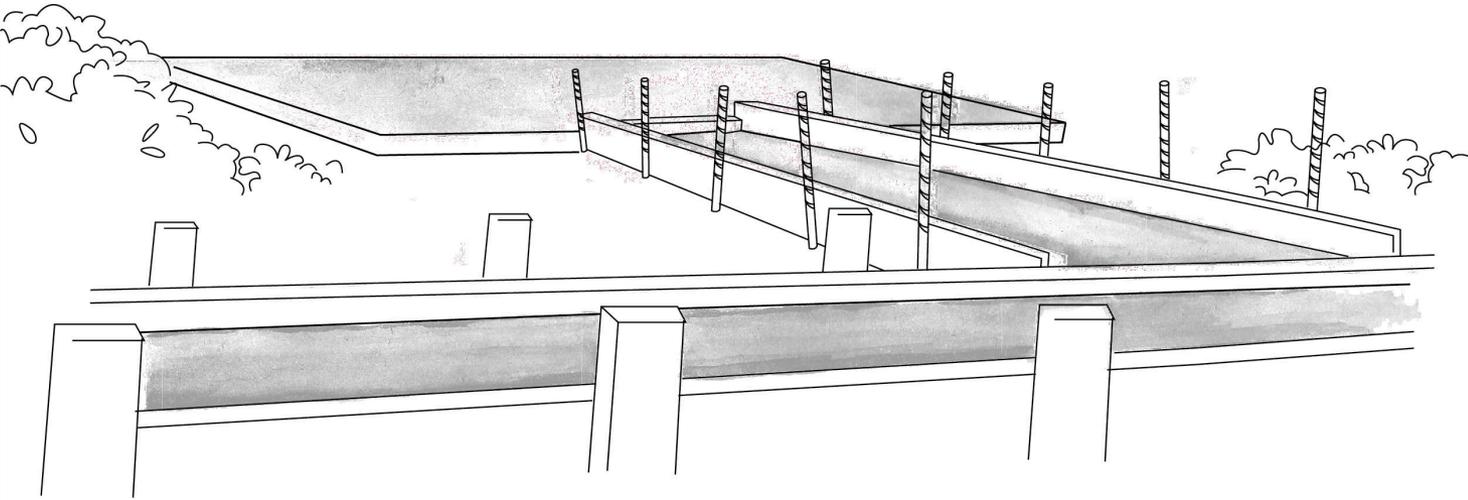
Amyris
LS9
Gevo
KiOR

PAX Streamline
EcoMotors
Trasonic
Tula
Hybradrive



Together, our products will improve the way all people live

Calera Corporation



Built on carbon negative cement

Living Homes



And prefabricated, environmentally friendly, cheaper, LEEDS homes

Soladigm



Using electrochromatic windows

Companies

Amyris

LS9

Gevo

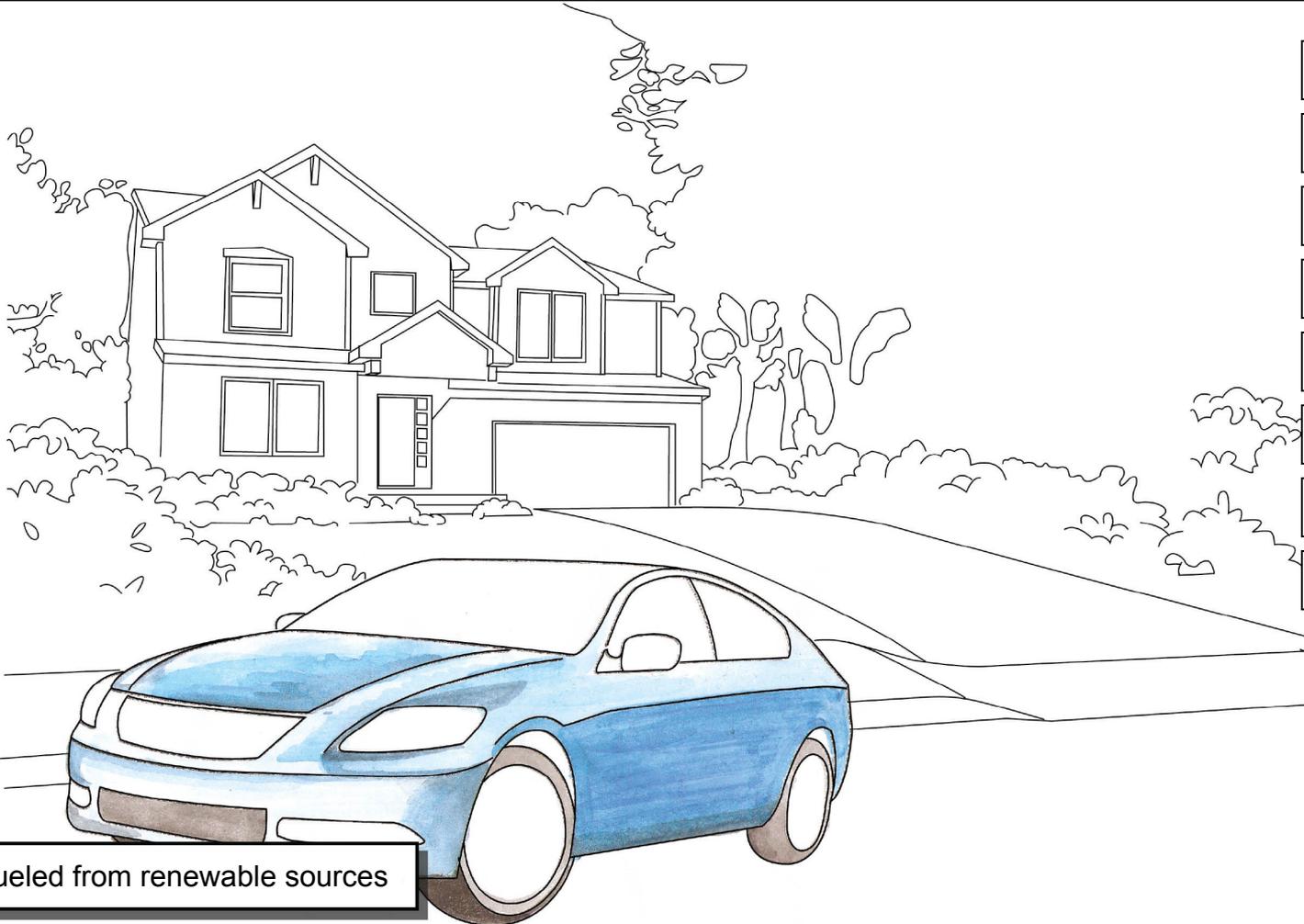
Kior

Mascoma

Range Fuels

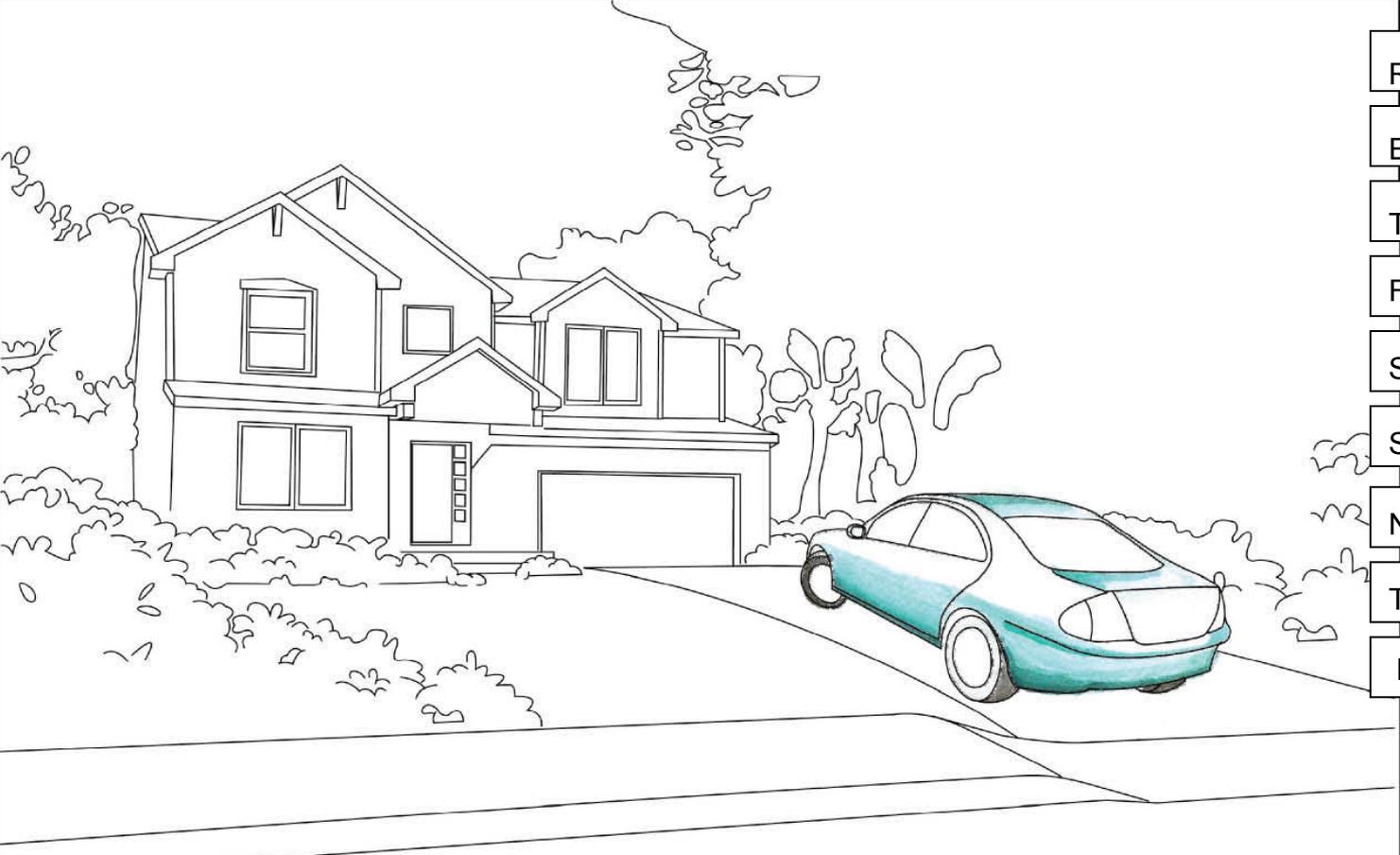
Coskata

LanzaTech



Fueled from renewable sources

Companies



Ramu

EcoMotors

Transonic

Firefly

Seeo

Sakti3

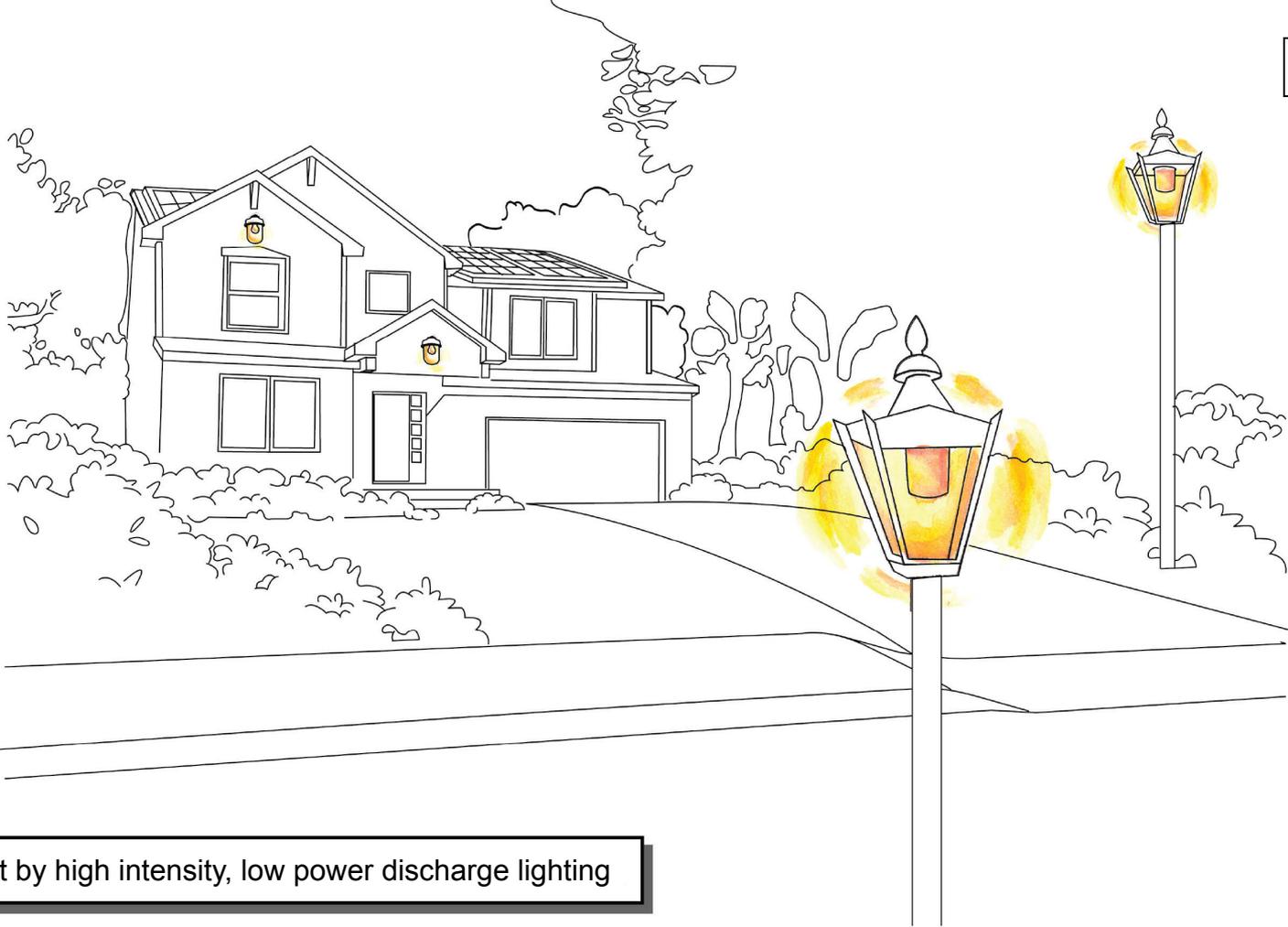
Nanostellar

Tula Technologies

Hybradrive

With reduced fuel consumption and CO₂ emissions

Topanga



Lit by high intensity, low power discharge lighting

Companies

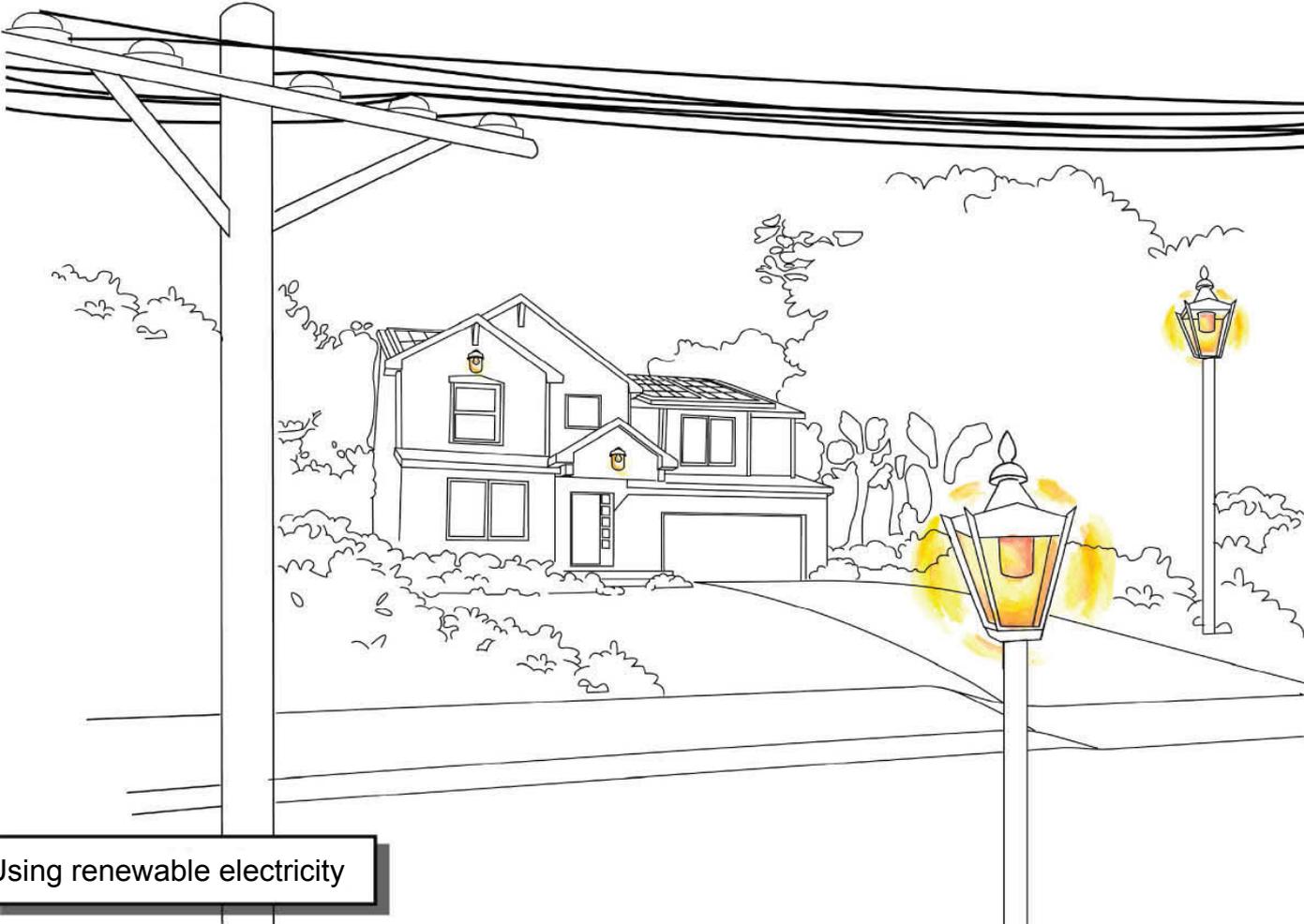
Ausra

Altarock

Infinia

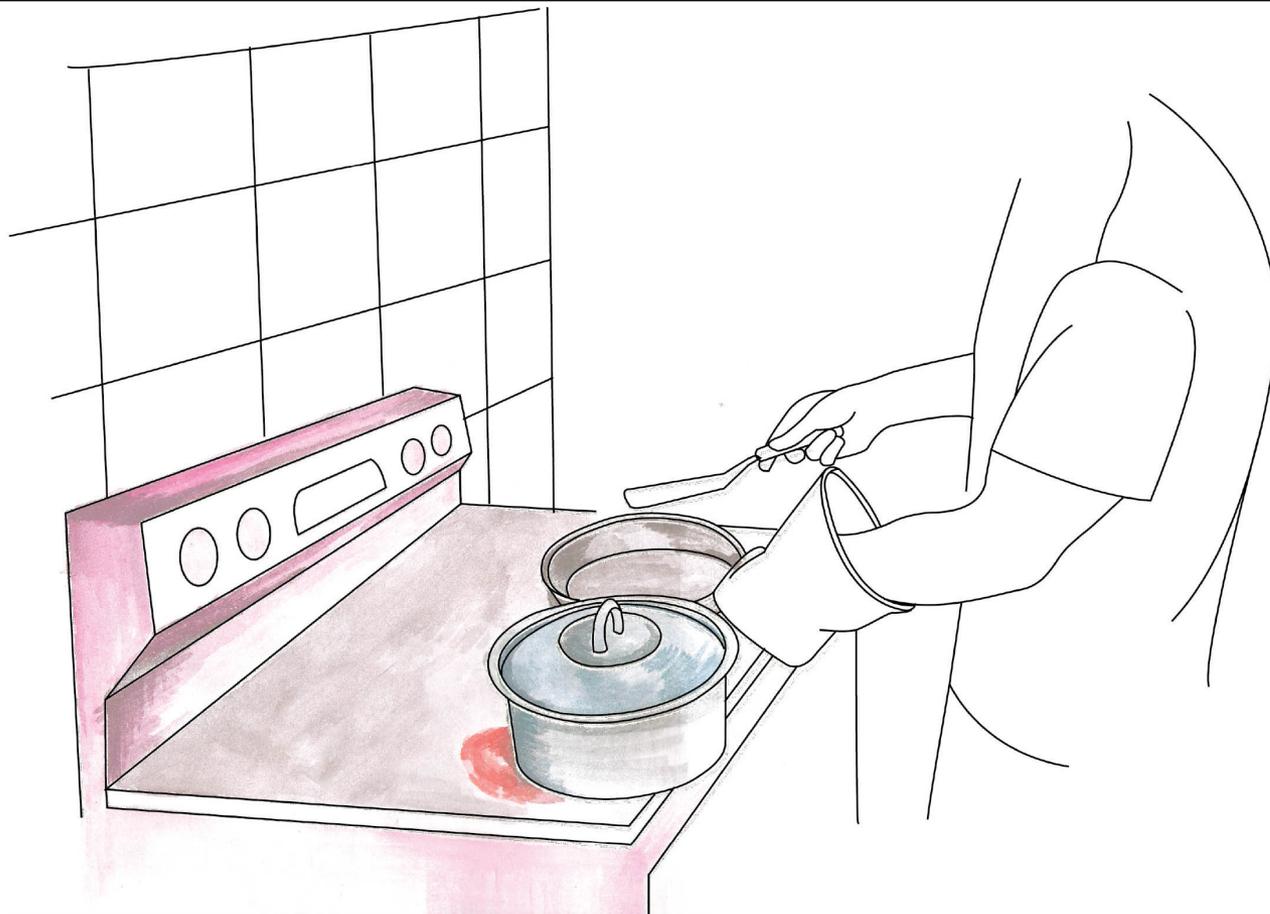
Stion

PVT Solar



Using renewable electricity

Great Point Energy



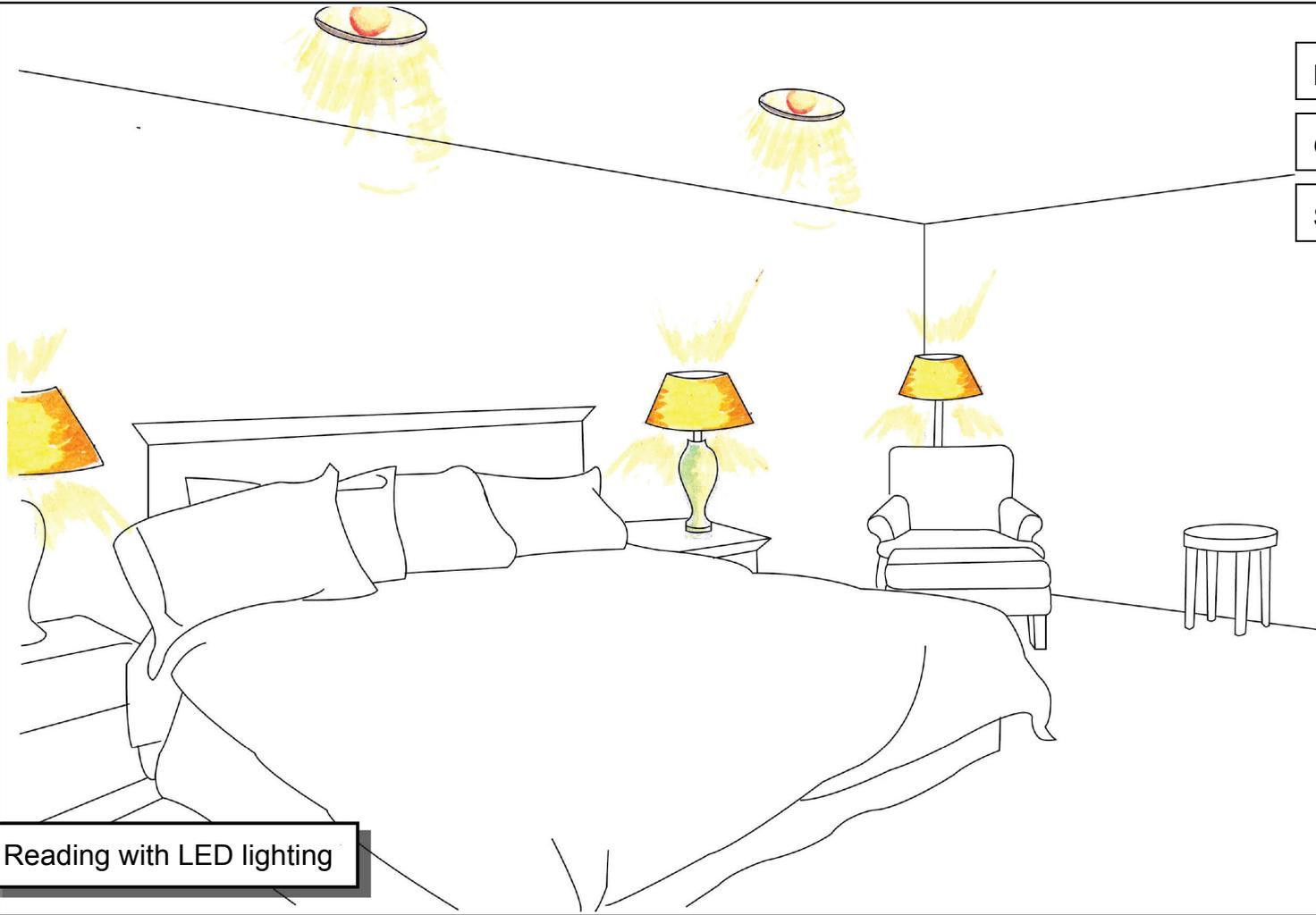
Cooking with natural gas from clean coal & biomass

Companies

Lumenz

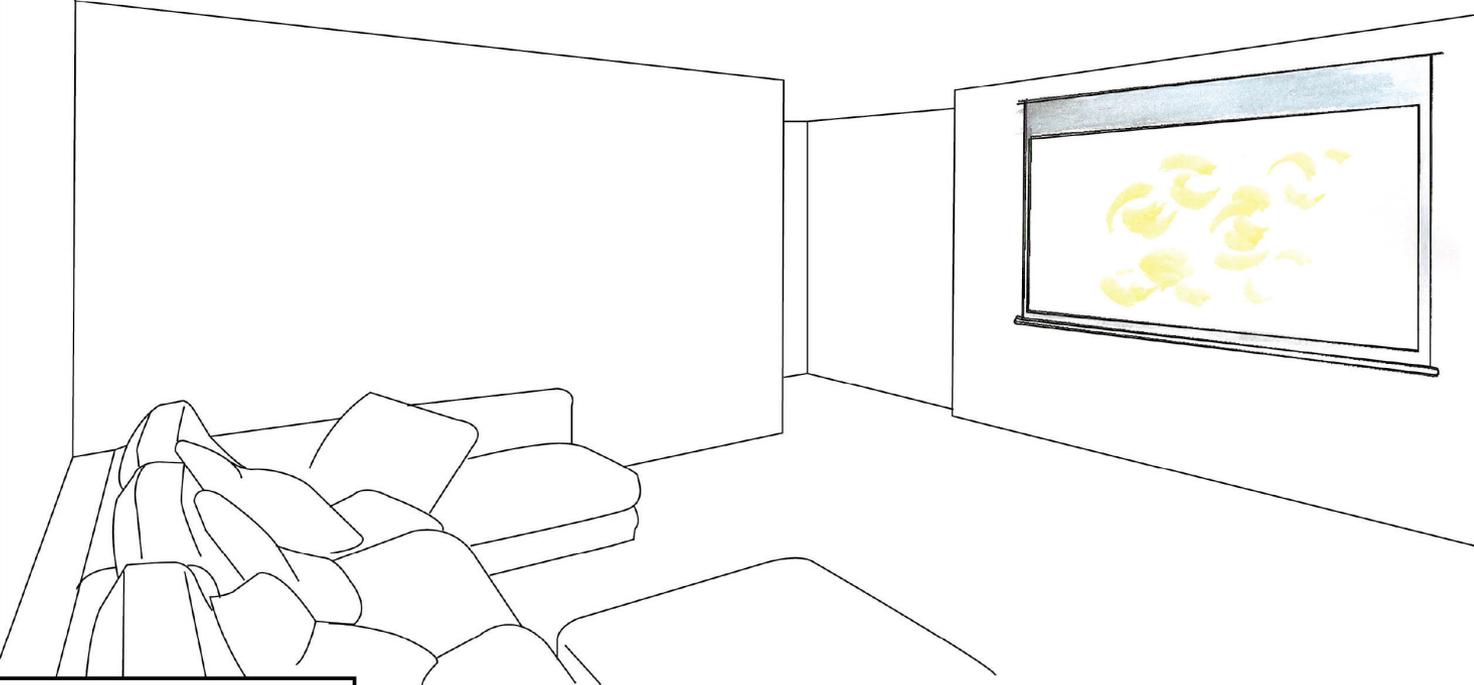
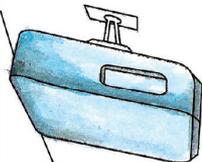
Group IV

Soraa



Reading with LED lighting

Kaai



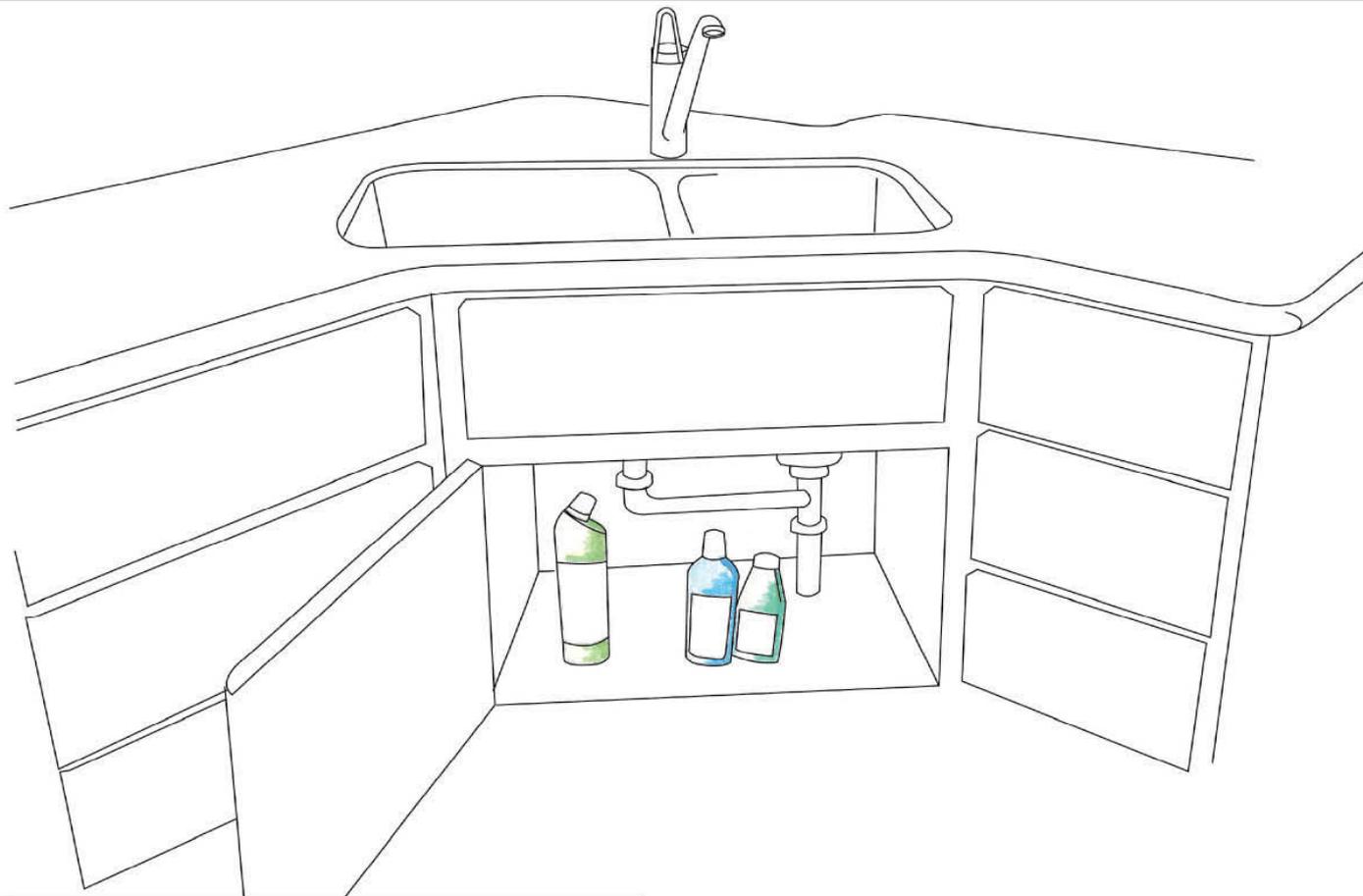
Watching HD laser TV

NanoH2O



Drinking desalinated water

Segetis



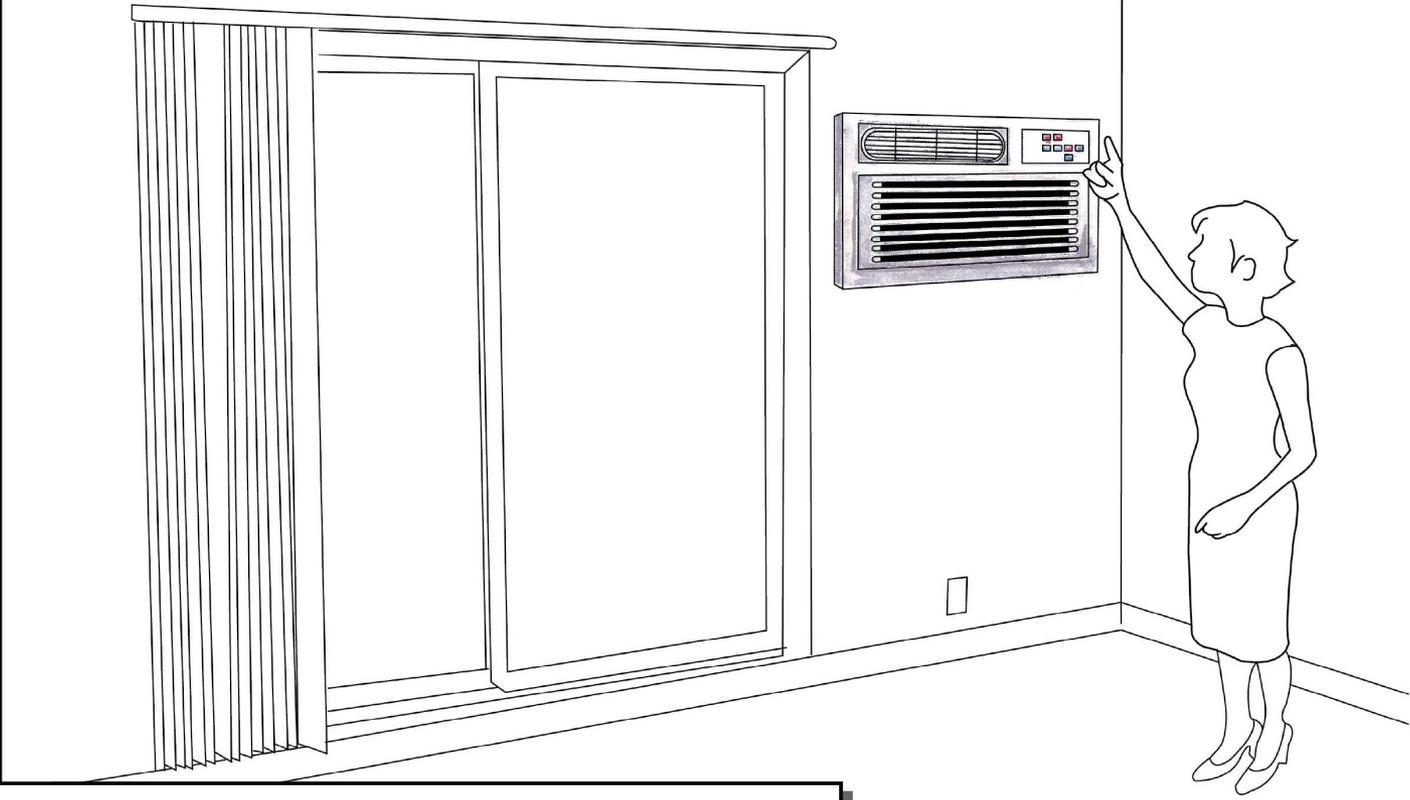
Safely using biobased plastics and chemicals

Draths

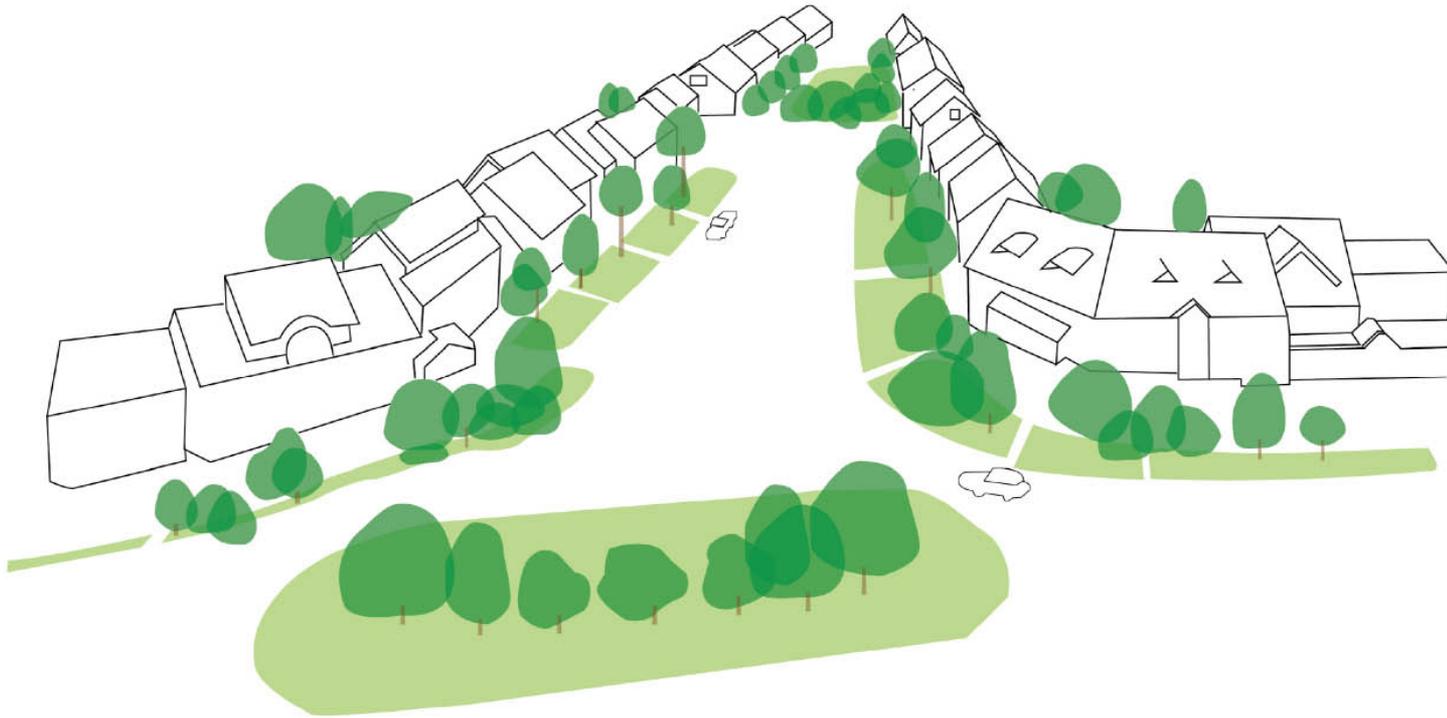


Biobased materials for your home

Pax Streamline



Staying comfortable with more efficient air conditioning



Change every aspect of daily living

to predict the future, **invent it!**

Forecast 2015:

New “cheaper than fossil” technologies proven

Forecast 2030 :

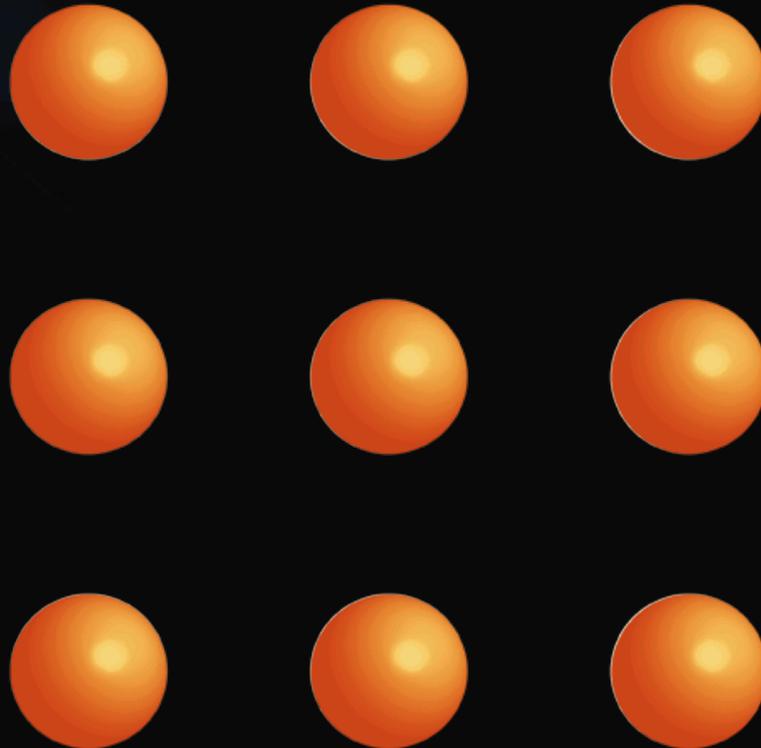
How will oil compete?

“In my view for the United States, it is the greatest economic opportunity we've had since we mobilized for World War Two. If we do it right, it will produce job gains and income gains substantially greater than the 1990s.”

Bill Clinton on the “green economy”

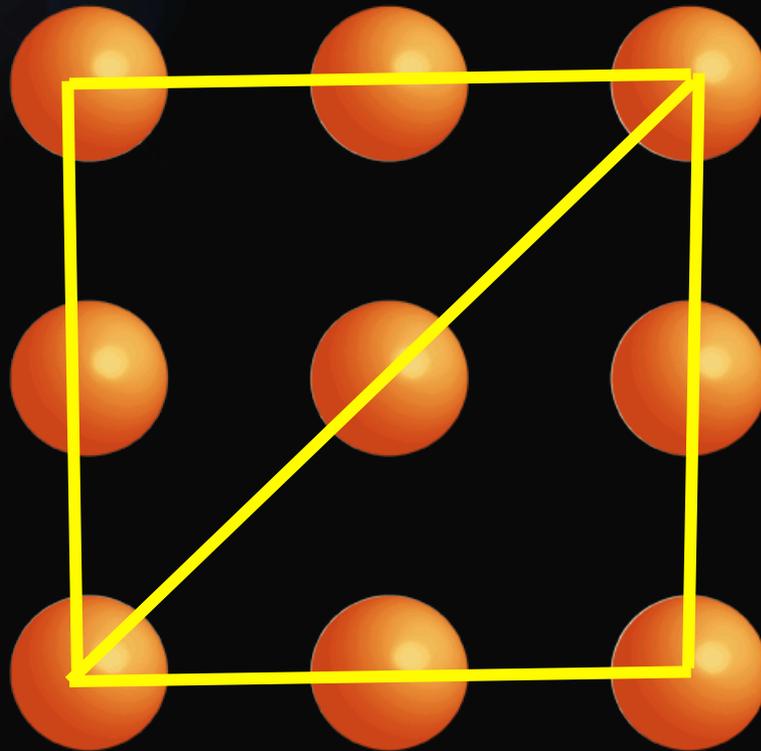
Challenge conventional solutions...

The nine dots problem



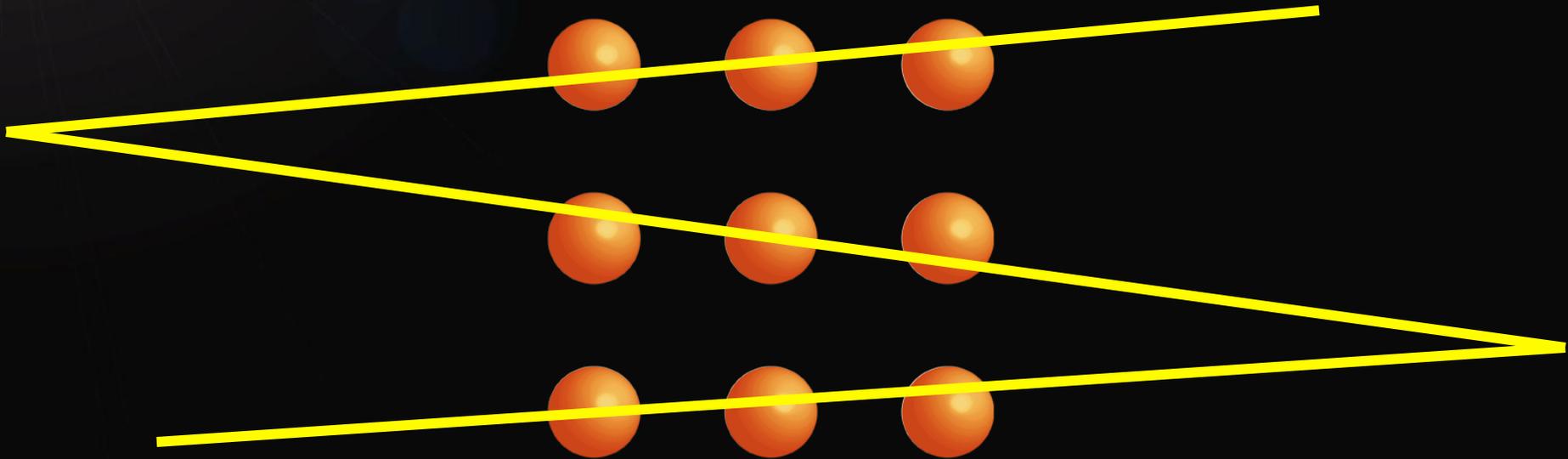
Source: Amory Lovins, RMI

Standard nine dots solution



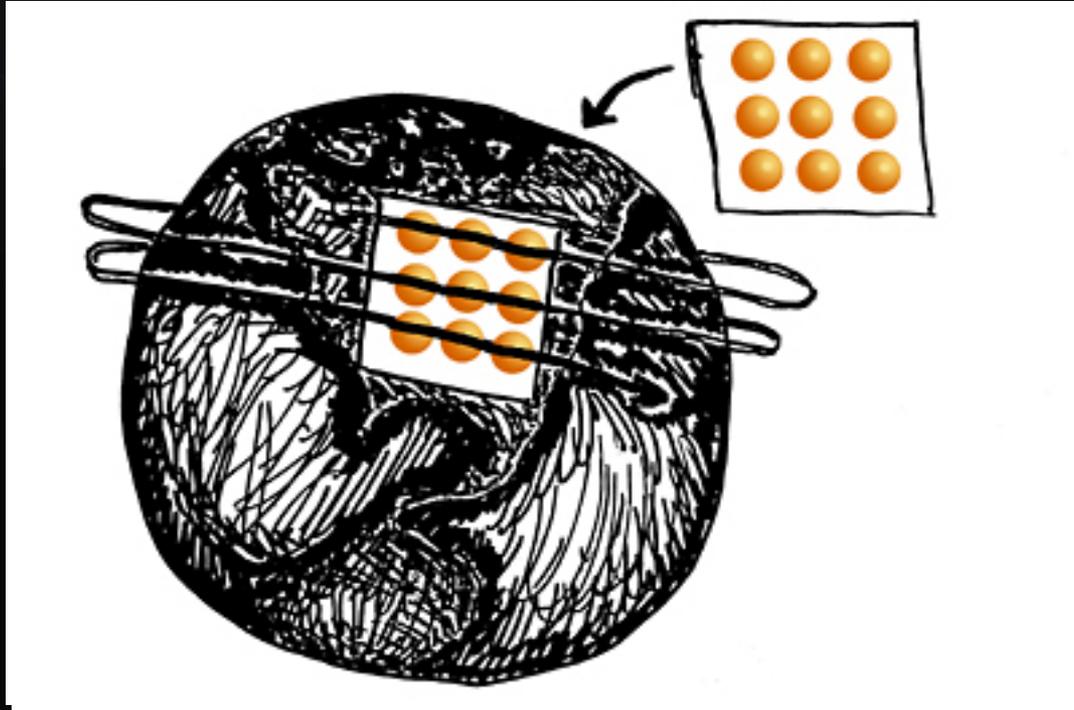
Source: Amory Lovins, RMI

Better: use just three lines



But...how about just *one* line?

Geographer's Solution

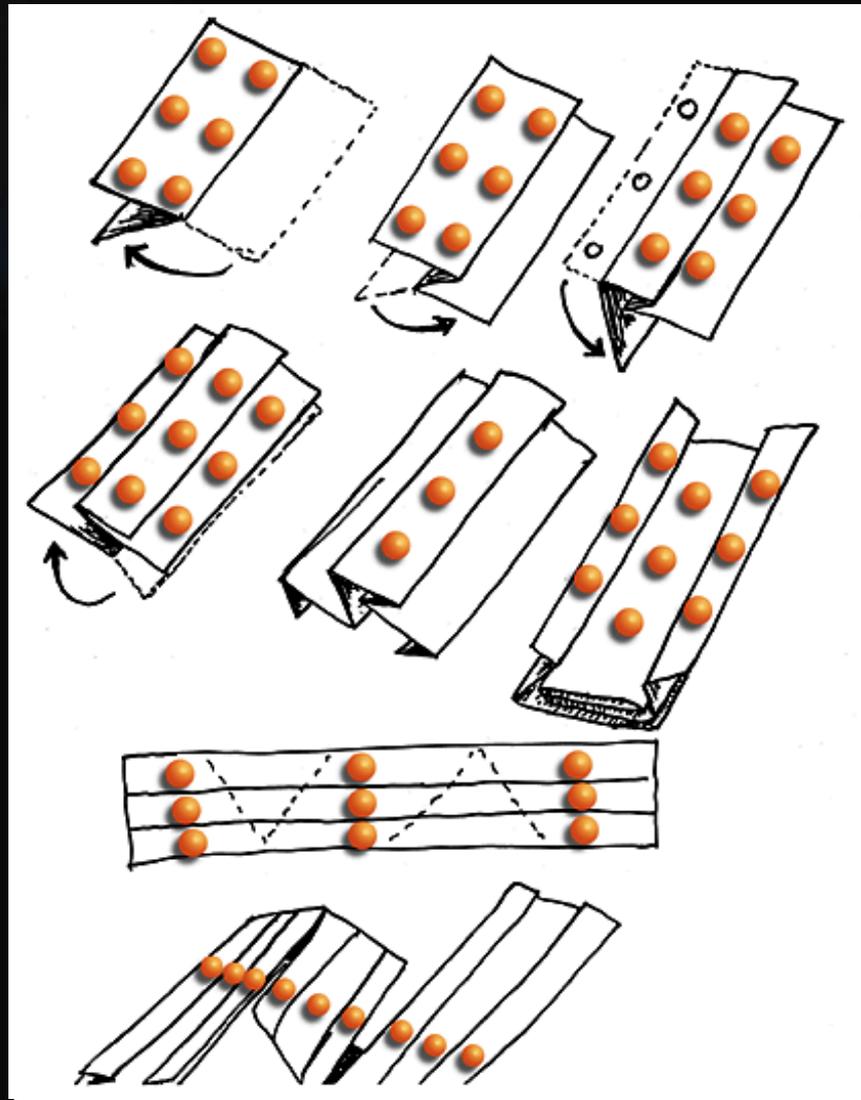


Mechanical Engineer's Solution

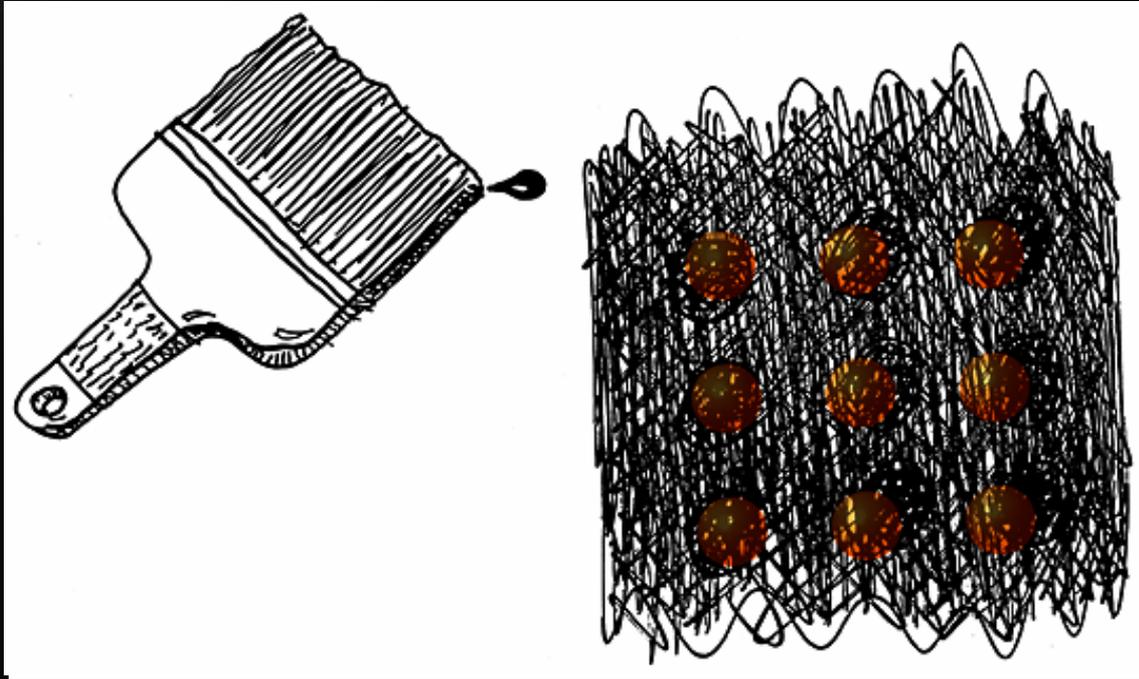


Source: Amory Lovins, RMI

Origami Solution

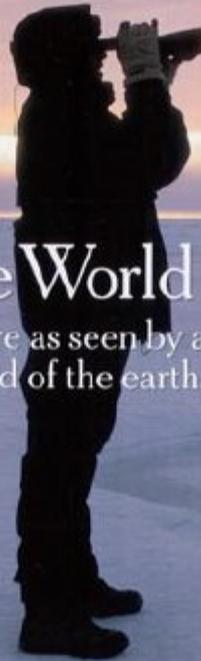


Wide Line Solution



The New York Times Magazine

JANUARY 4, 2009 / \$10 US



Watching the World Melt Away

The future as seen by a lonely
scientist at the end of the earth. By Darcy Frey

Beverly Sills's Frustrating Last Act, by Frank Bruni • America's Go-To Warlord, by Peter Maass

|...or get to **work**

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khoslaventures.com/resources.html