ROCKY MOUNTAIN INSTITUTE®

Amory B. Lovins

Chairman and Chief Scientist, Rocky Mountain Institute

www.rmi.org, ablovins@rmi.org

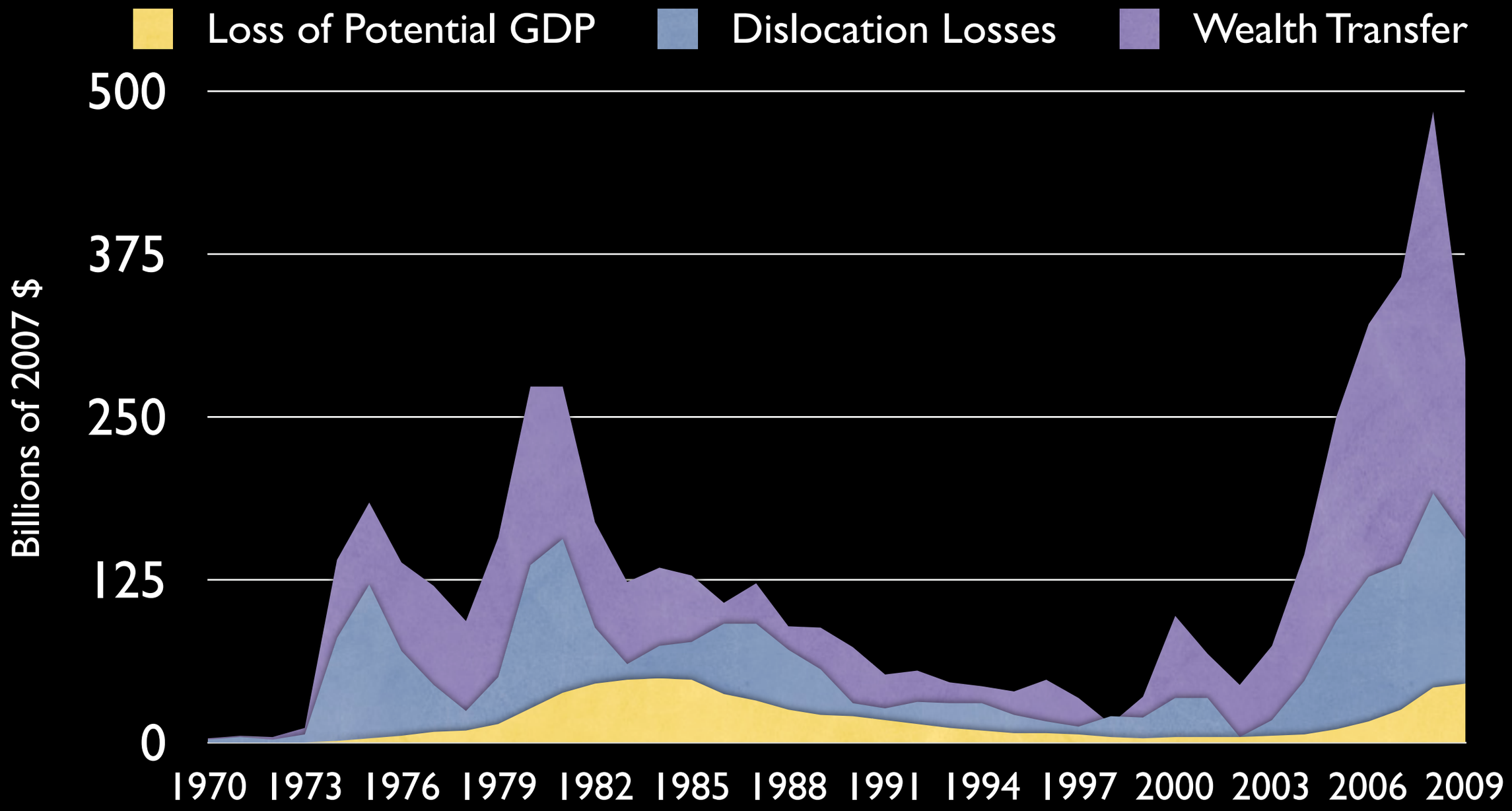
NSF CPS Program Annual PI Meeting/Conf., 2 Aug 2011 (video)

A bigger picture

	What	How
Old	Technology	Policy
New	Design	Strategy

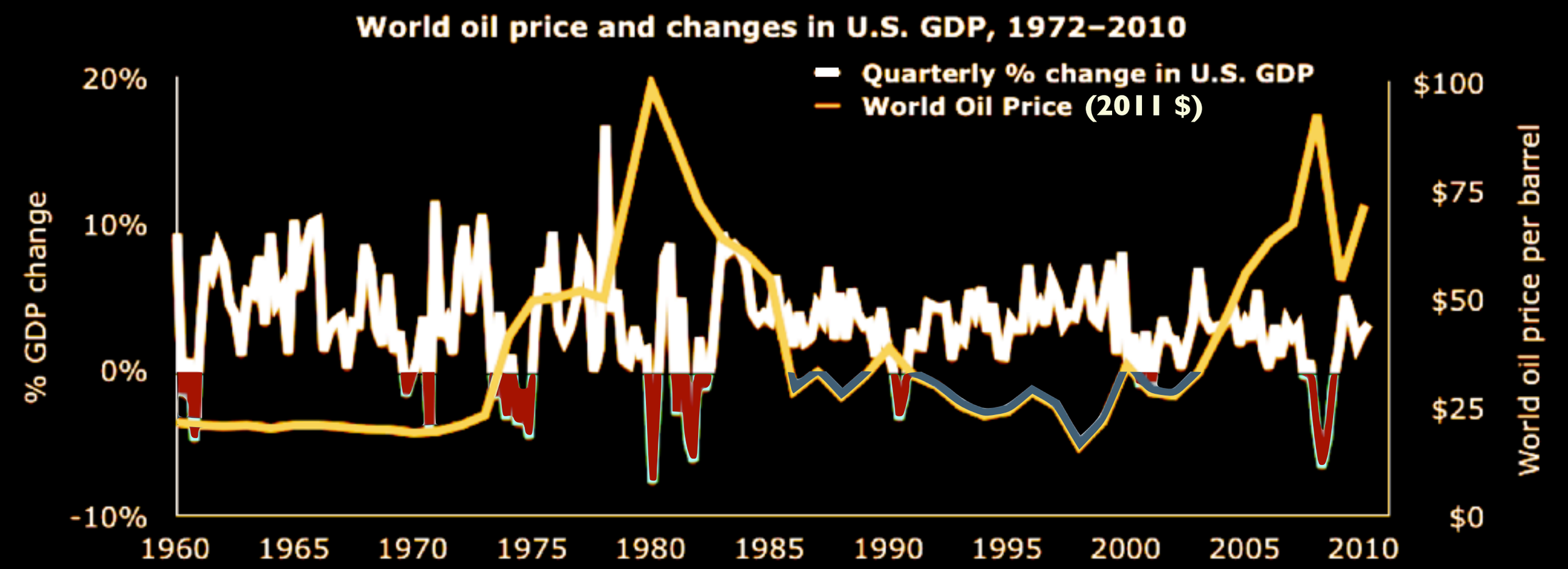
Oil: America's two-billion-dollar a day addiction

Costs of Oil Dependency to the U.S. Economy:



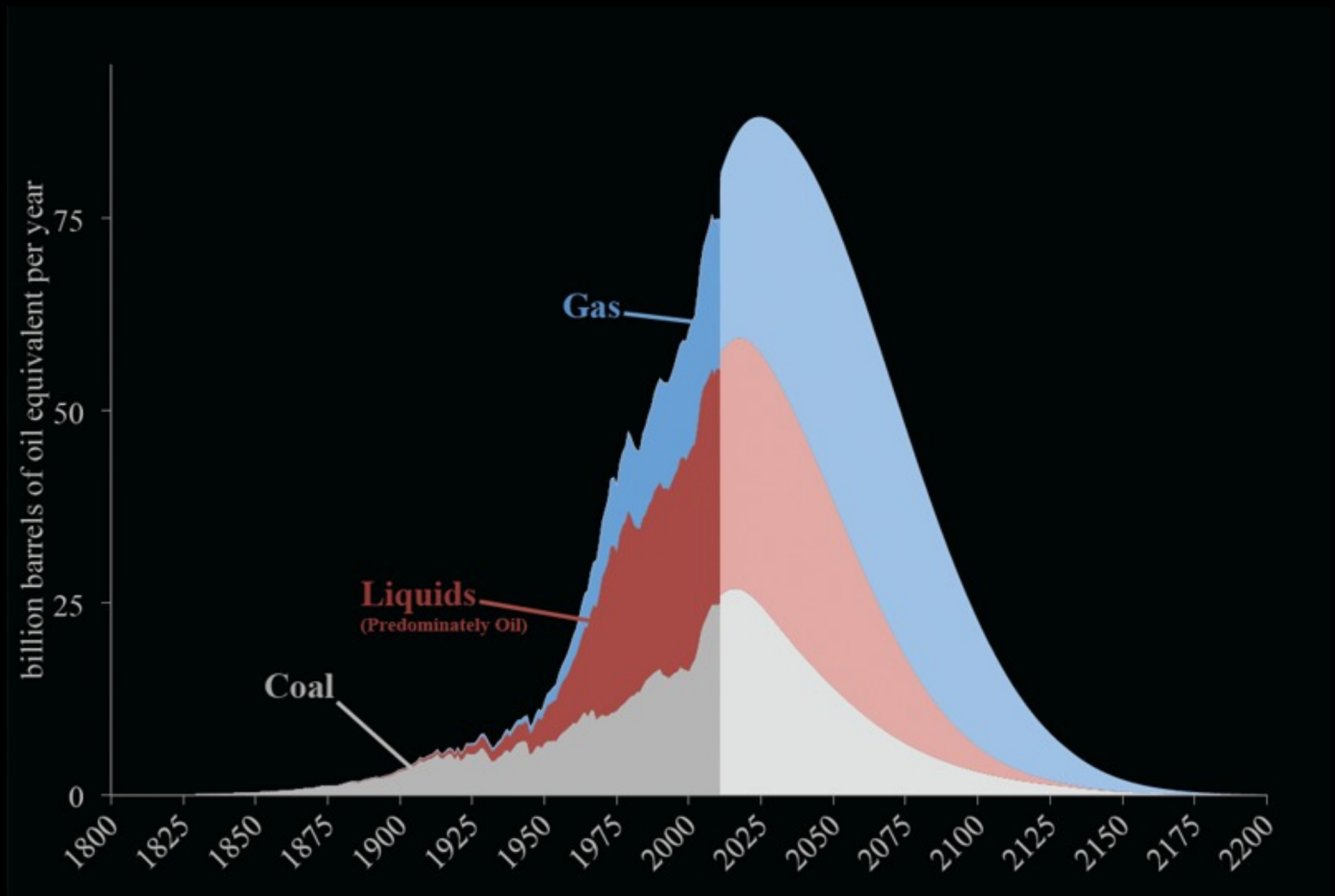
Source:
Greene, David L., and Janet L. Hopson, "The Costs of Oil Dependence 2009," Oak Ridge National Laboratory Memorandum, 2010

Oil: America's billion-dollar a day addiction



Oil: America’s billion-dollar-a-day addiction

Oil: America's billion-dollar-a-day addiction

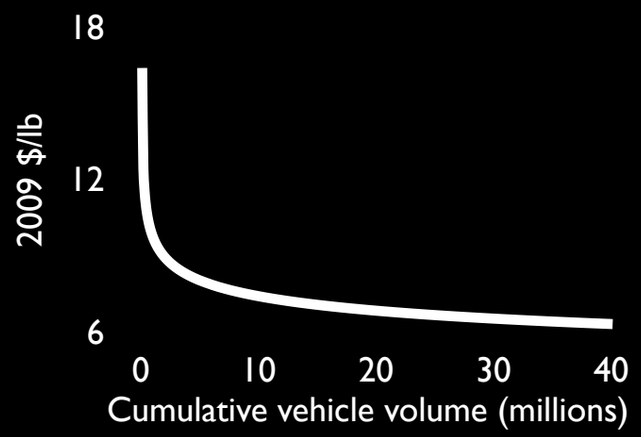


Reducing tractive load first leverages 7:1 fuel savings

Source: RMI analysis of: Sovran & Blaser, SAE 2003-01-2070; typical 2003 midsize sedan, EPA 55/45 city/highway cycle

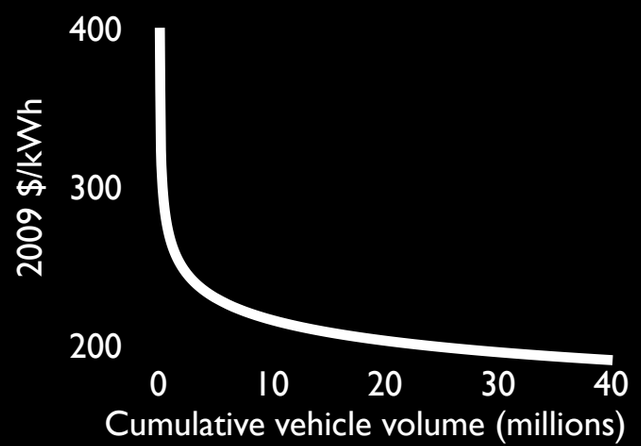
Vehicle fitness can cheaply triple efficiency—and unlock electric propulsion

Carbon fiber learning curve



Manufacturing learning curve

Battery learning curve



Vehicle fitness can cheaply triple efficiency—and unlock electric propulsion

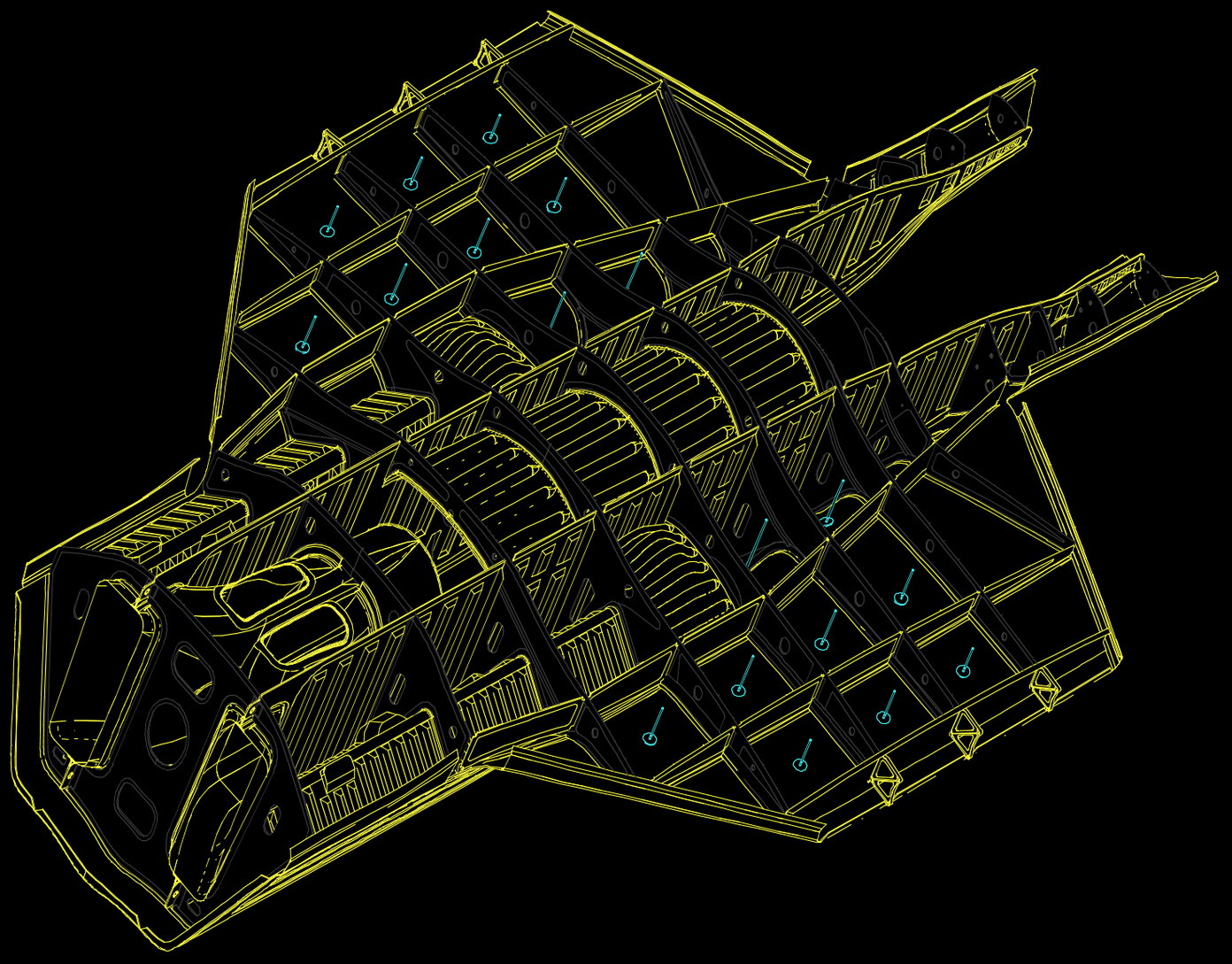
Bright *IDEA* 1-T 5-m^3 van (2009)
3–12×-efficiency plug-in hybrid, needs no subsidy

Hypercar *Revolution* SUV (2000)
67 mpg (114 w/H_2), 2-y payback

Toyota *1/X* sedan (2007)
***Prius* size, 1/2 fuel use, 1/3 weight**

VW *XL1* 2-seat plug-in hybrid (2011),
1,752 lb, 230 mpg$_{gasoline}$, 2013 production

Migrating innovation from military/aerospace to high-volume automaking

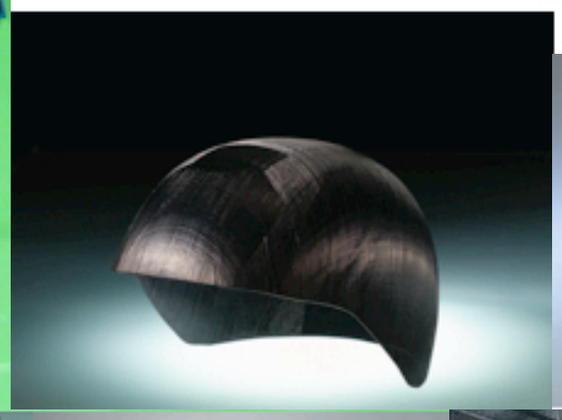


95% carbon composite, 1/3 lighter, 2/3 cheaper

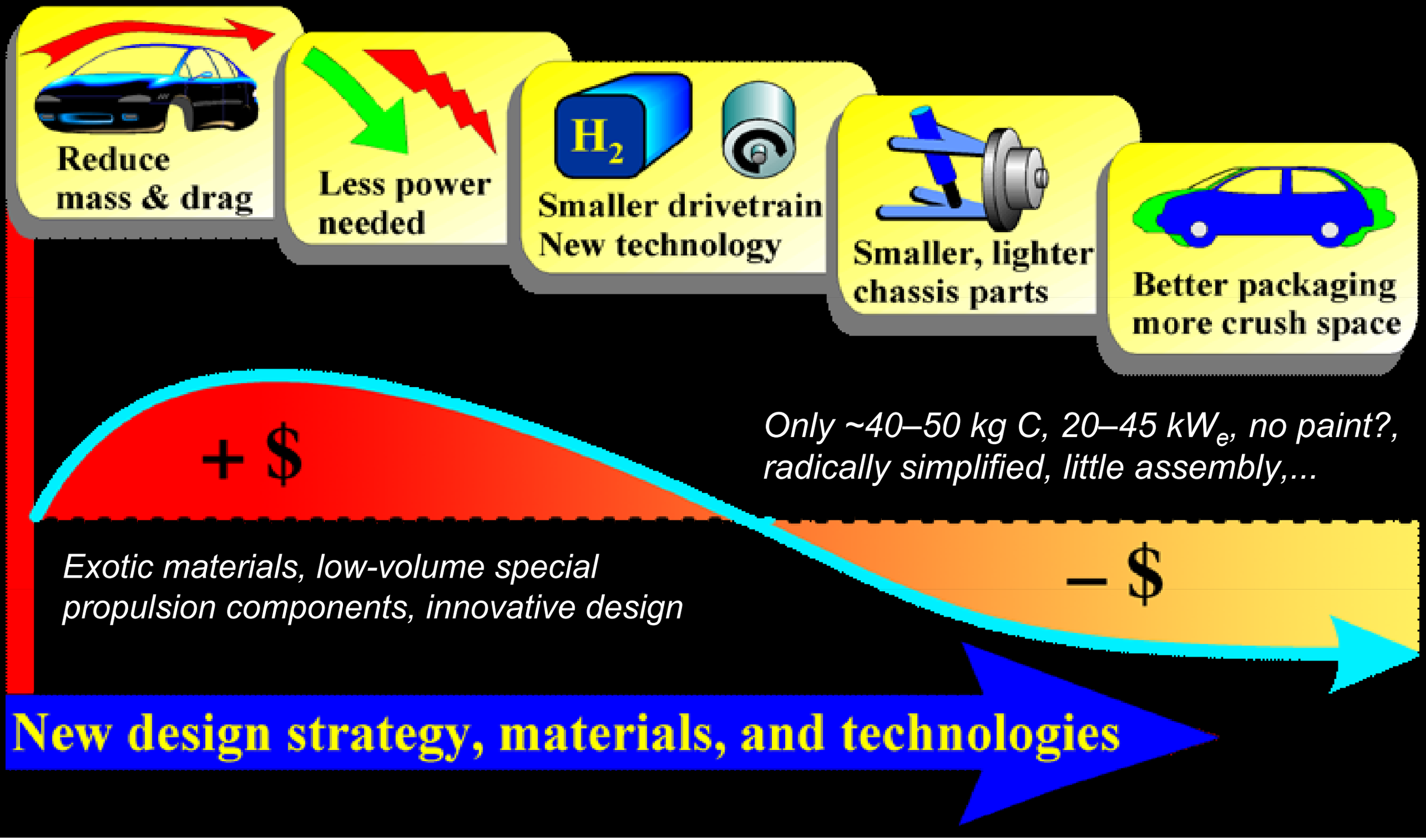
Radically simplified manufacturing

14 parts, ~99% less tooling cost
no body shop, perhaps no paint shop
2/3 smaller powertrain

New U.S. and foreign manufacturing technology can make affordable carbon-composite structures in less than one minute



Decompounding mass and complexity also decompounds cost



Design to win the future, not perpetuate the past

Present design space

New design space

Define the end point

Development targets

Risk management

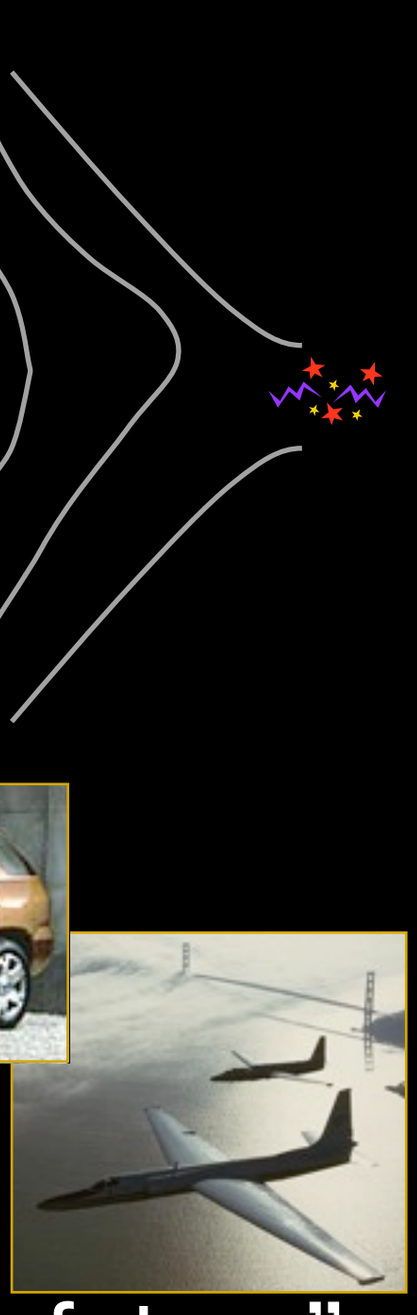
Market introduction

Economic insight

Customer relationships

Technology introduction

Integration payoff areas

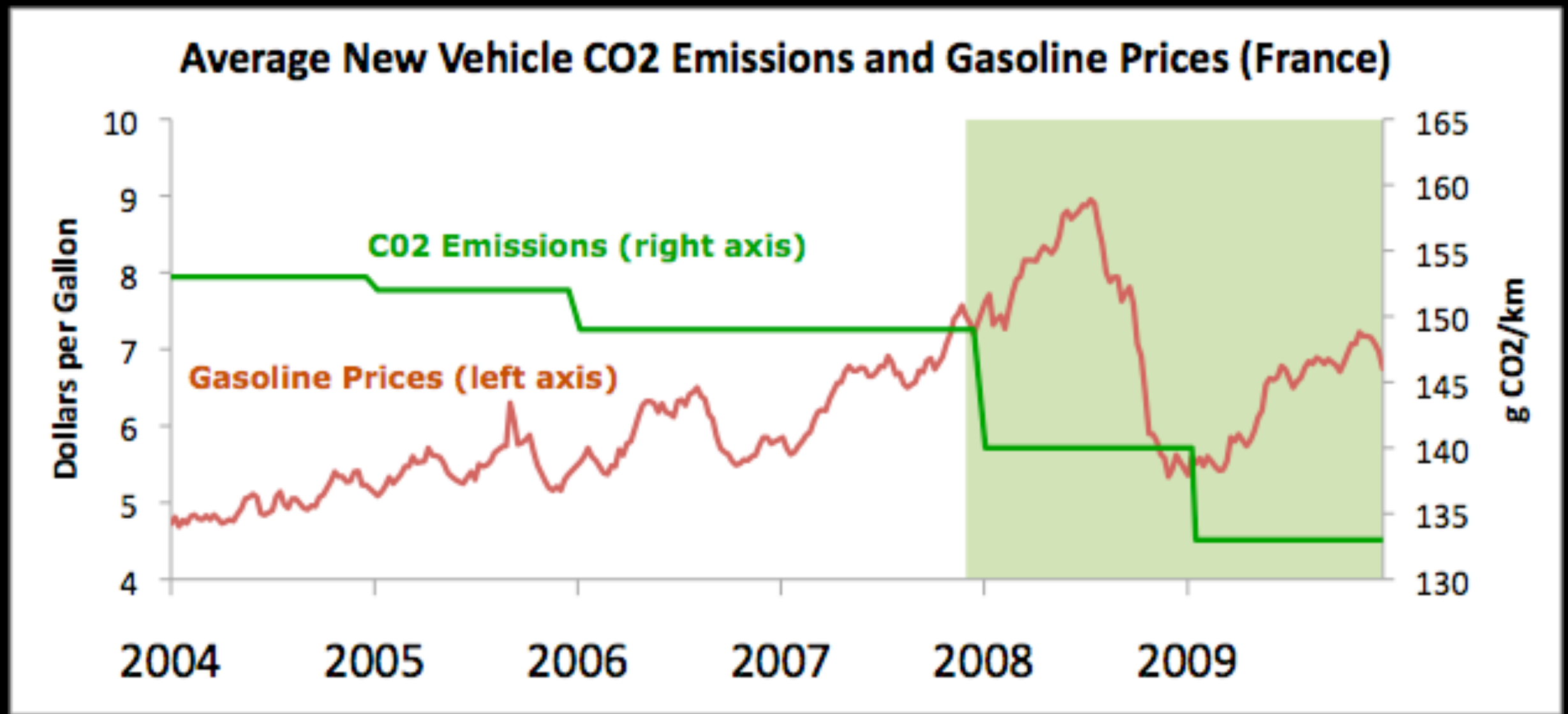


First production variant

Foundation Platform

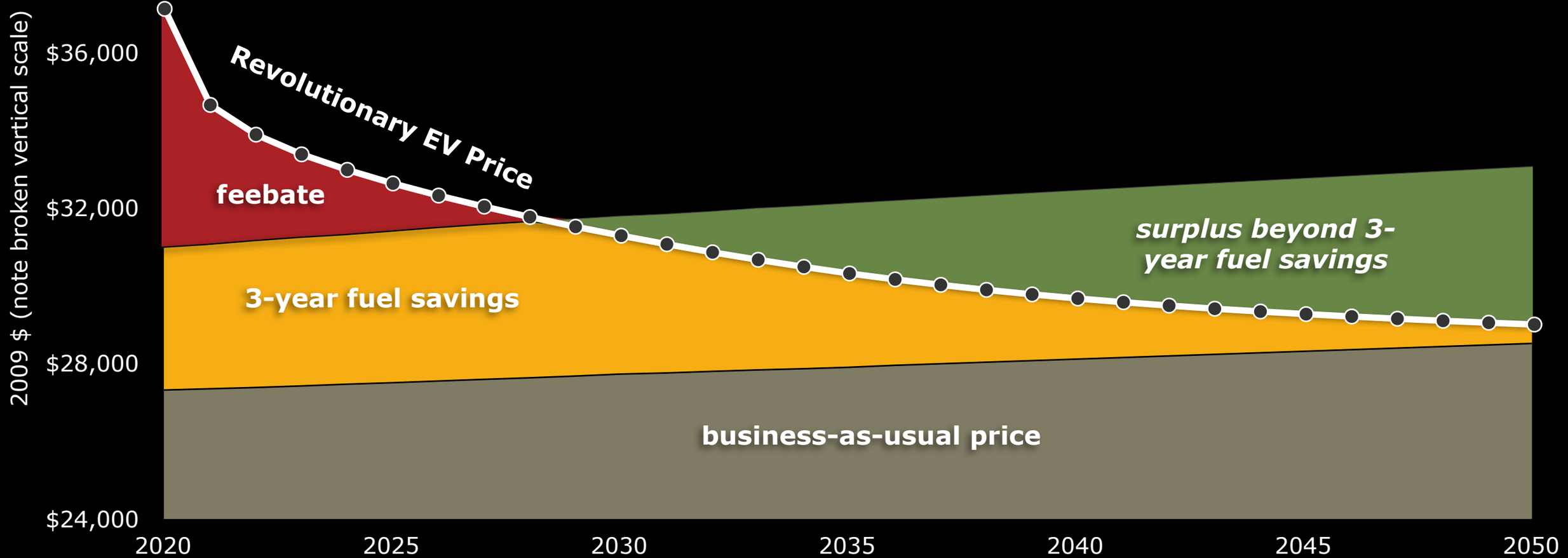
Design “in the future”

Federal, state, or regional policy can unlock this potential



Feebates provide early stimulus to preserve margins while battery and EV costs are high; after technology becomes mature, fuel savings provide surplus for OEMs, dealers, and customers to share

Revolutionary+ battery-electric vehicle price for initial purchase plus first 3 y operation vs. business-as-usual vehicles, 2020–2050 (results are similar with fuel-cell vehicles)



Tripled-efficiency trucks can also pay back quickly

Prevost (Québec) bus, Cd = 0.31

RMI, 2008, www.rmi.org/rmi/Library/T08-08_TransformationalTrucksEnergyEfficiency;
NAS/NRC, 2010, www.nap.edu/catalog.php?record_id=12845

Emerging efficient airplanes offer up to 70% lower fuel burn than today's aircraft (2010 U.S. fleet average)

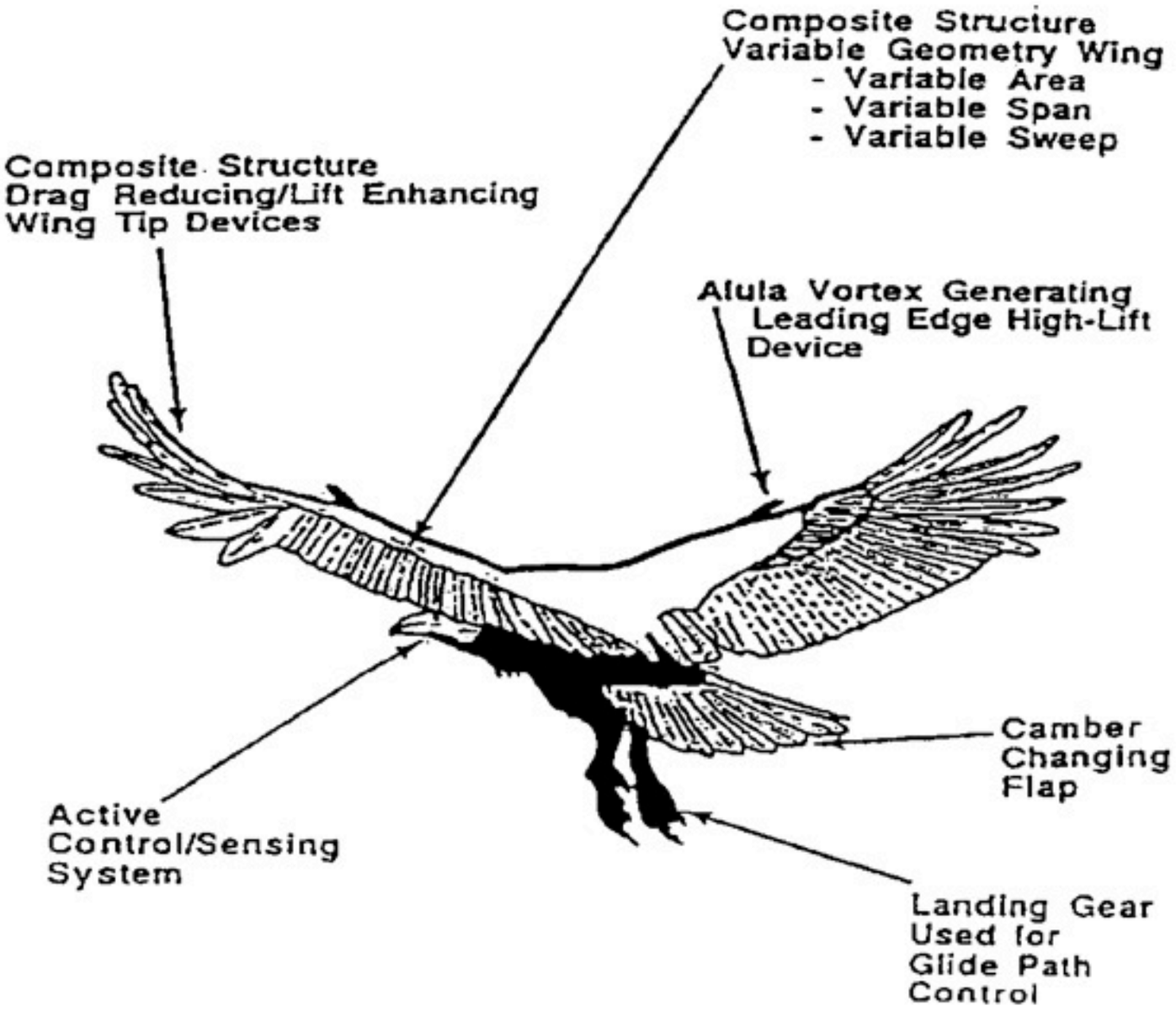
Clockwise from top: Boeing's SUGAR Volt electric-battery gas-turbine hybrid propulsion system with a strut-braced wing (–70% fuel); MIT H-Series Blended Wing Body concept with podded, actively controlled boundary-layer-inlet propulsion (–59%); Honda light jet with top-mounted engines; NASA truss-braced wing concept with buried single rear propulsor (–60–80%); winged seed of the tropical Asian climbing gourd Alsomitra macrocarpa*, which glides for hundreds of meters. Another ~2× can be saved with unducted-fan or fuel-cell LH_2 cryoplanes, well validated in several countries, and ~5–12% with morphing flight surfaces already flight-tested.*

Ultramodern aeronautical technology embodied in a gliding bird

A California Condor (*Gymnogyps californianus*)

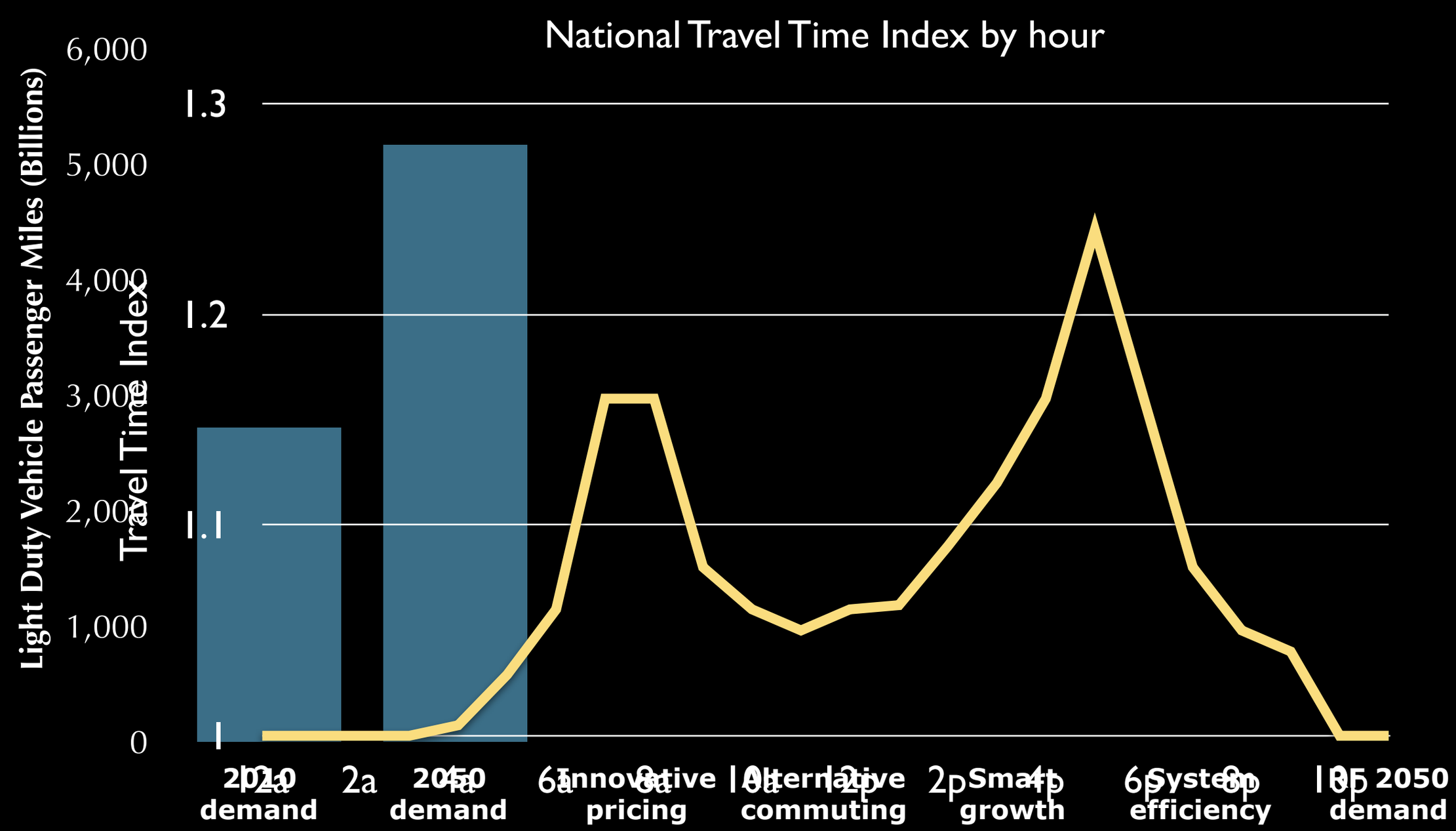
Important Aeronautical Technology Incorporated In Birds

- Mission Adaptive Wing
- Active Controls/ Control Configured Vehicles
- Composite structures
- Damage Tolerant Structures
- Fully integrated System Design
- Advanced Manufacturing Techniques

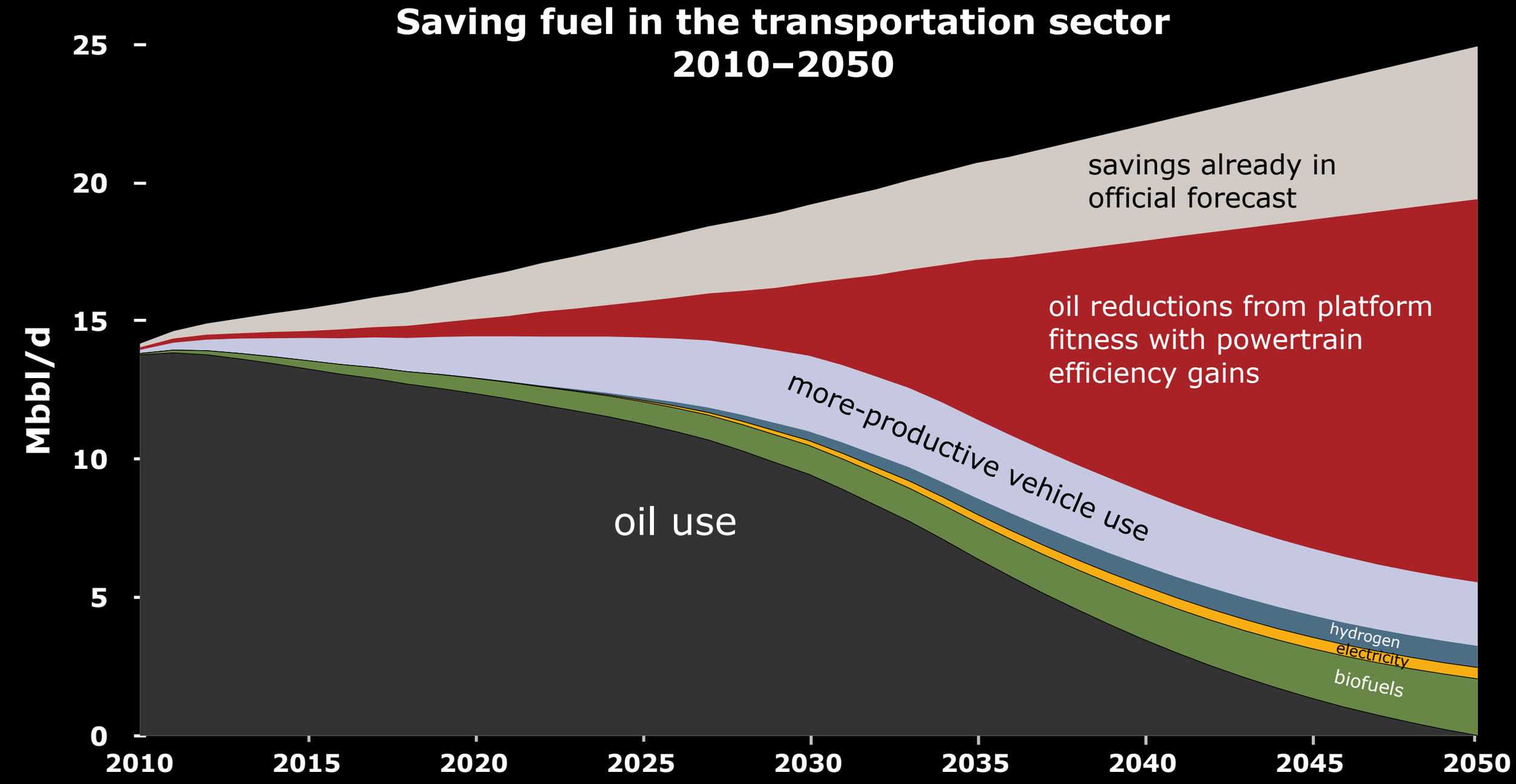


Courtesy of Dr. Paul MacCready (1925–2007)
Founder and Chairman, AeroVironment, Inc.

Revolutions in how vehicles are not just made but also *used*



The bottom line for transportation: $4 trillion net present value



“We must leave oil before it leaves us.”

—Fatih Birol, Chief Economist, International Energy Agency, 2008

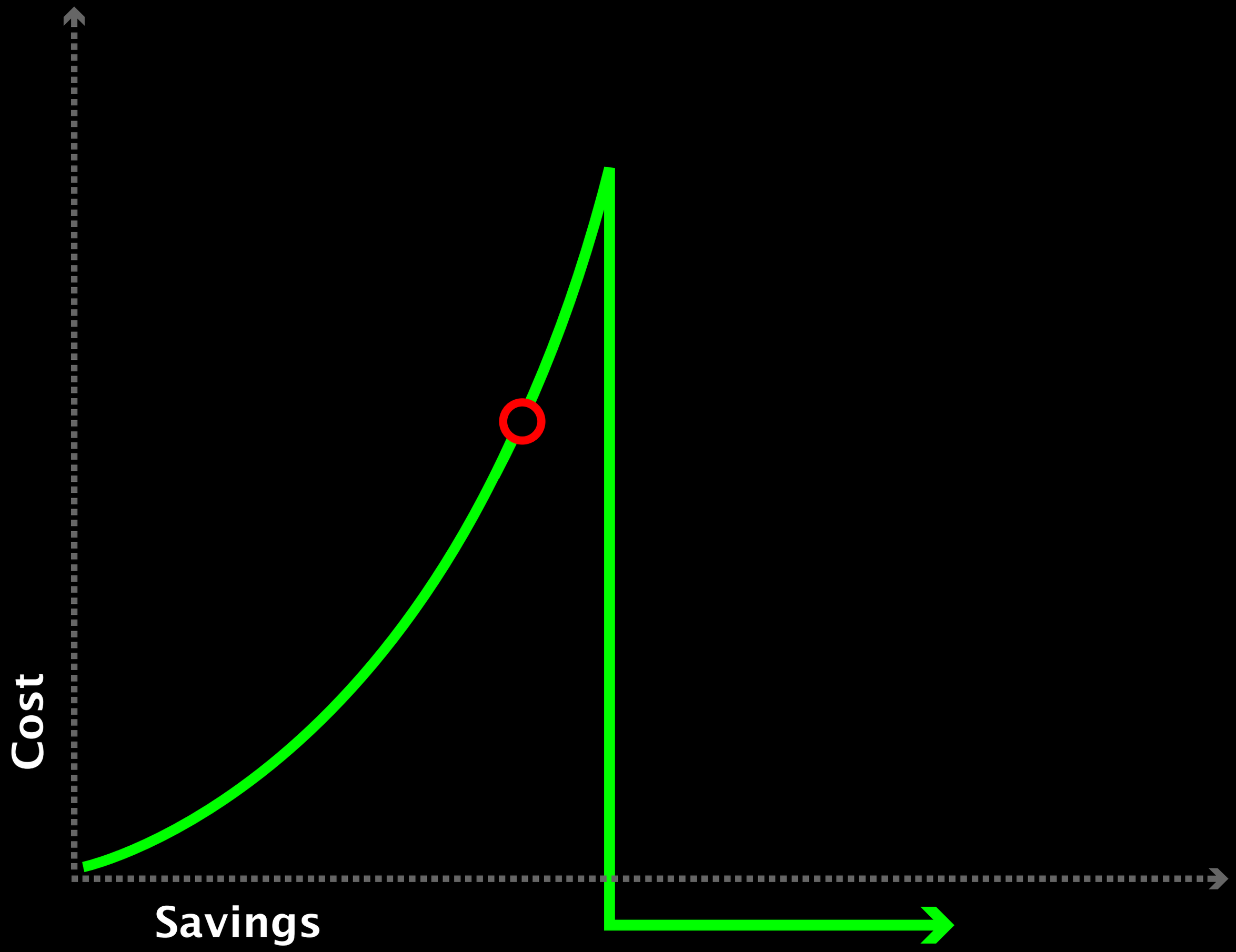
Lovins House, Old Snowmass, Colorado, 1984

–47°F with no heating/cooling equipment, yet *lower* construction cost

Inside, a >100-species tropical jungle: 36 banana crops, no furnace


Cost
Savings


Cost
Savings

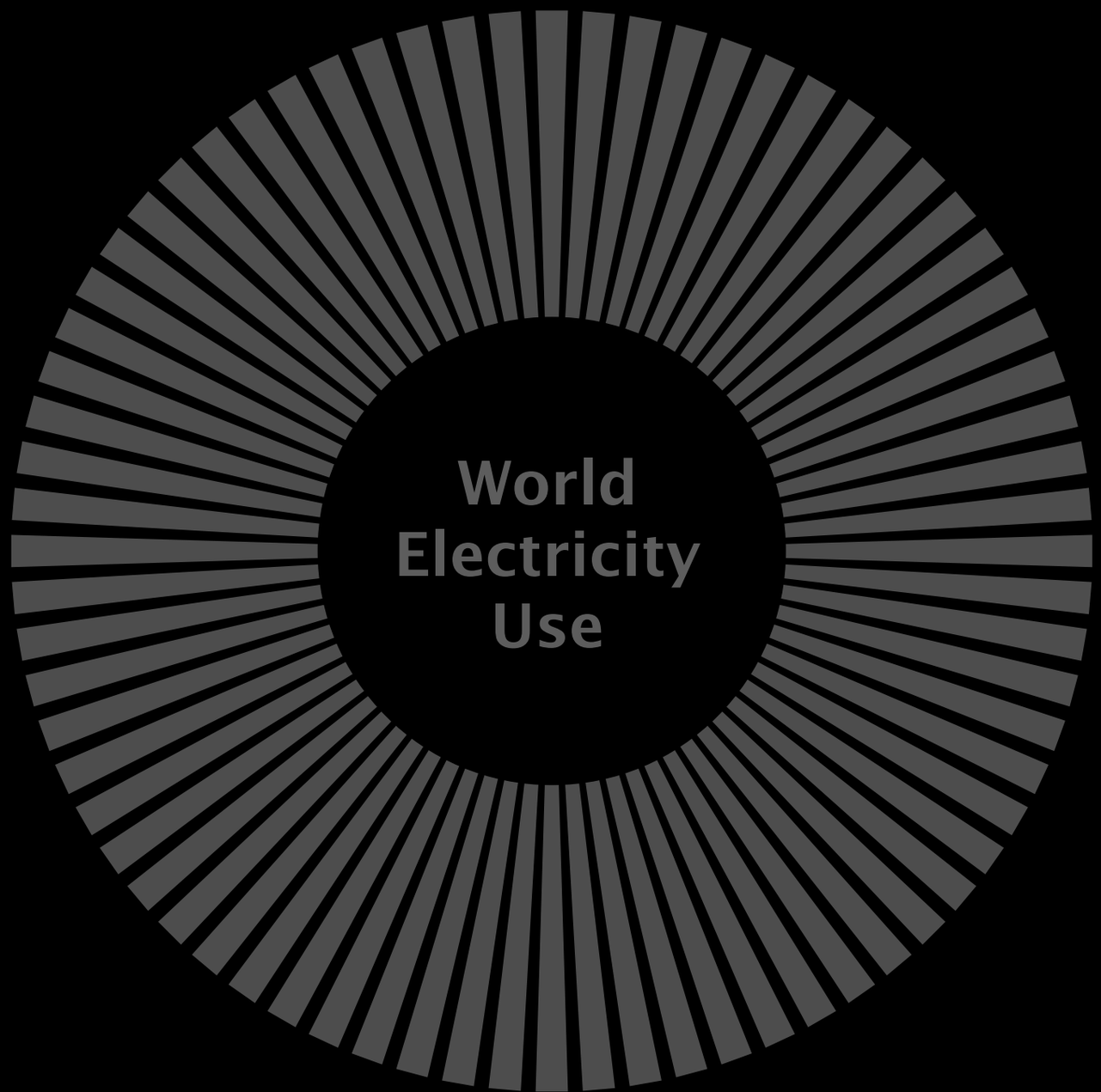

Cost
Savings

Whole-System Thinking

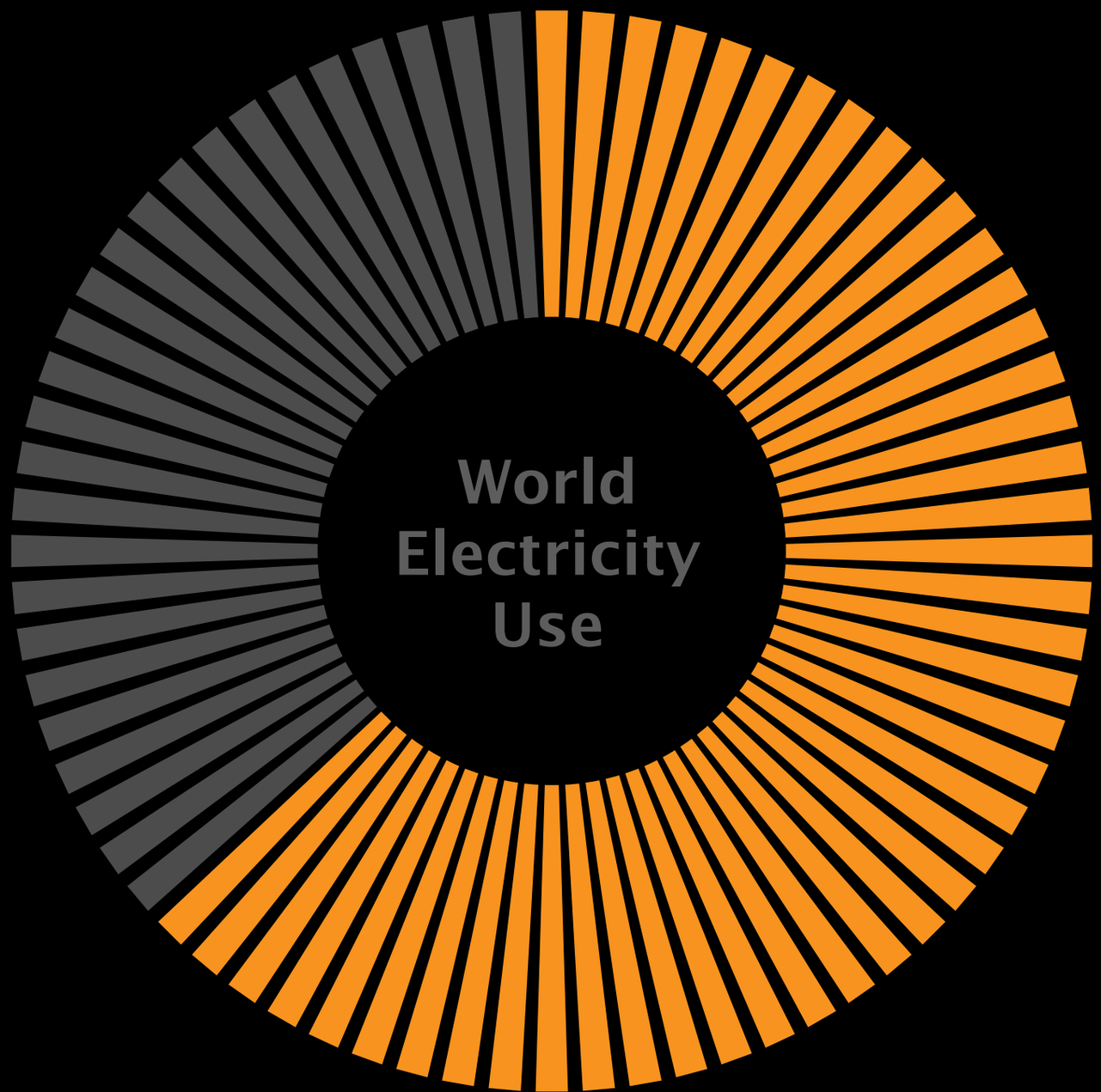
Integrative design in retrofitting the Empire State Building

ESB approach

World electricity use

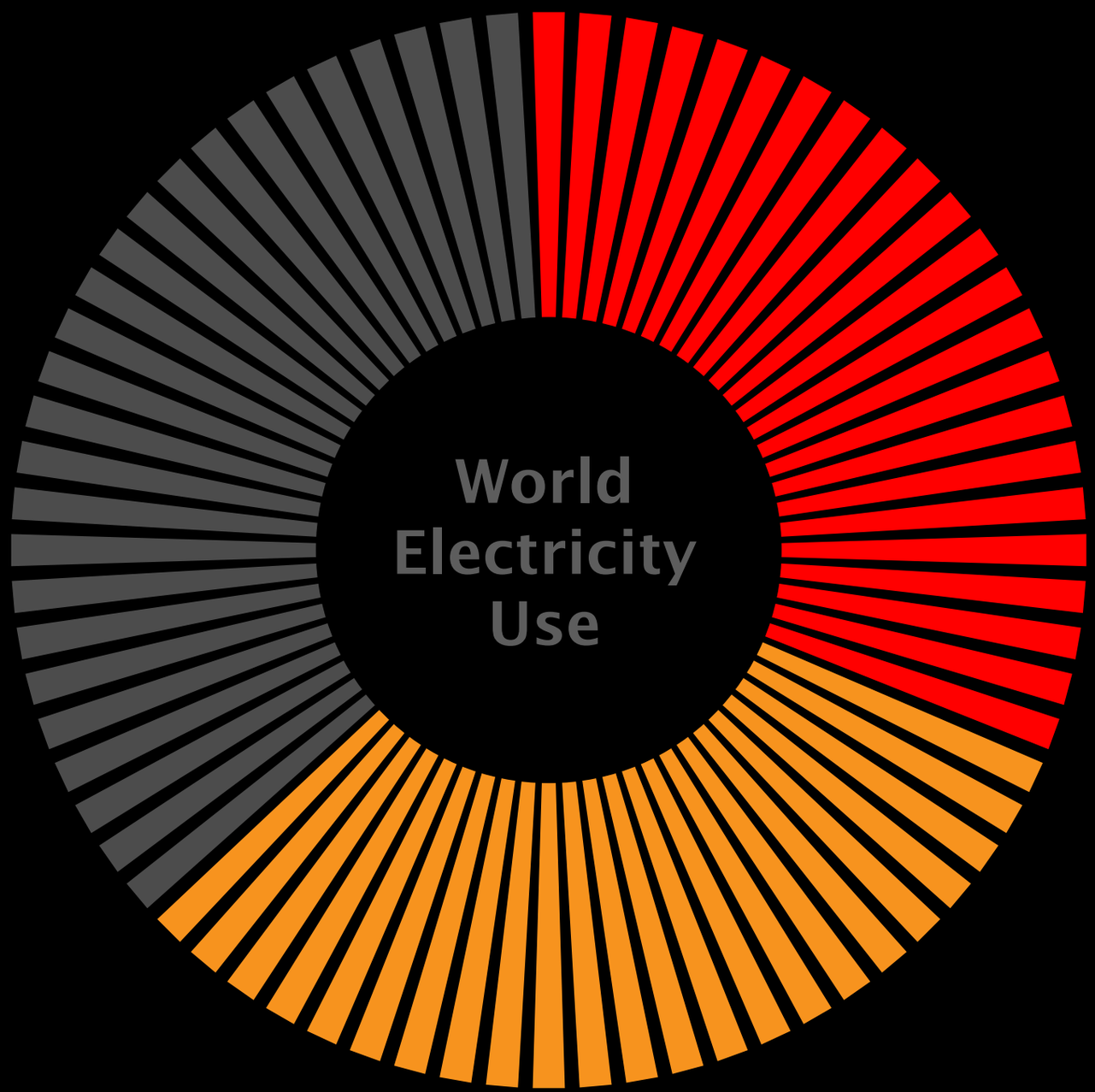


World electricity use



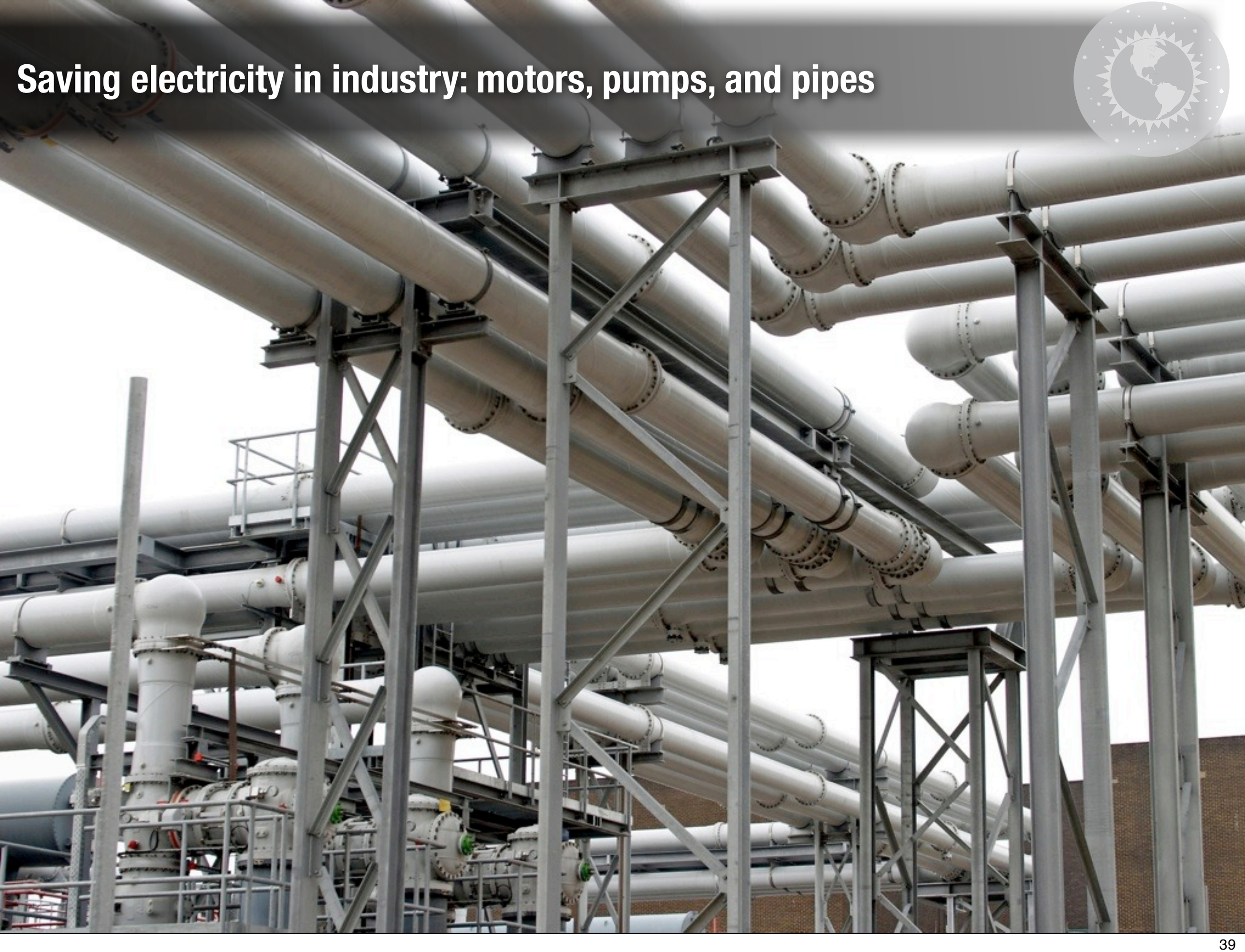
60% Motors

World electricity use



30% Pumps and Fans

Saving electricity in industry: motors, pumps, and pipes



Fat, Short, Straight Pipes

No new technologies, just two changes in design mentality

1. Big pipes, small pumps
(not the opposite)

2. Lay out the pipes first,
then the equipment
(not the reverse)

≥7x savings...then another ~4x...

Fat, short, straight pipes — not thin, long, crooked pipes!

Benefits counted

- ≥7× less pumping energy
- Lower capital cost

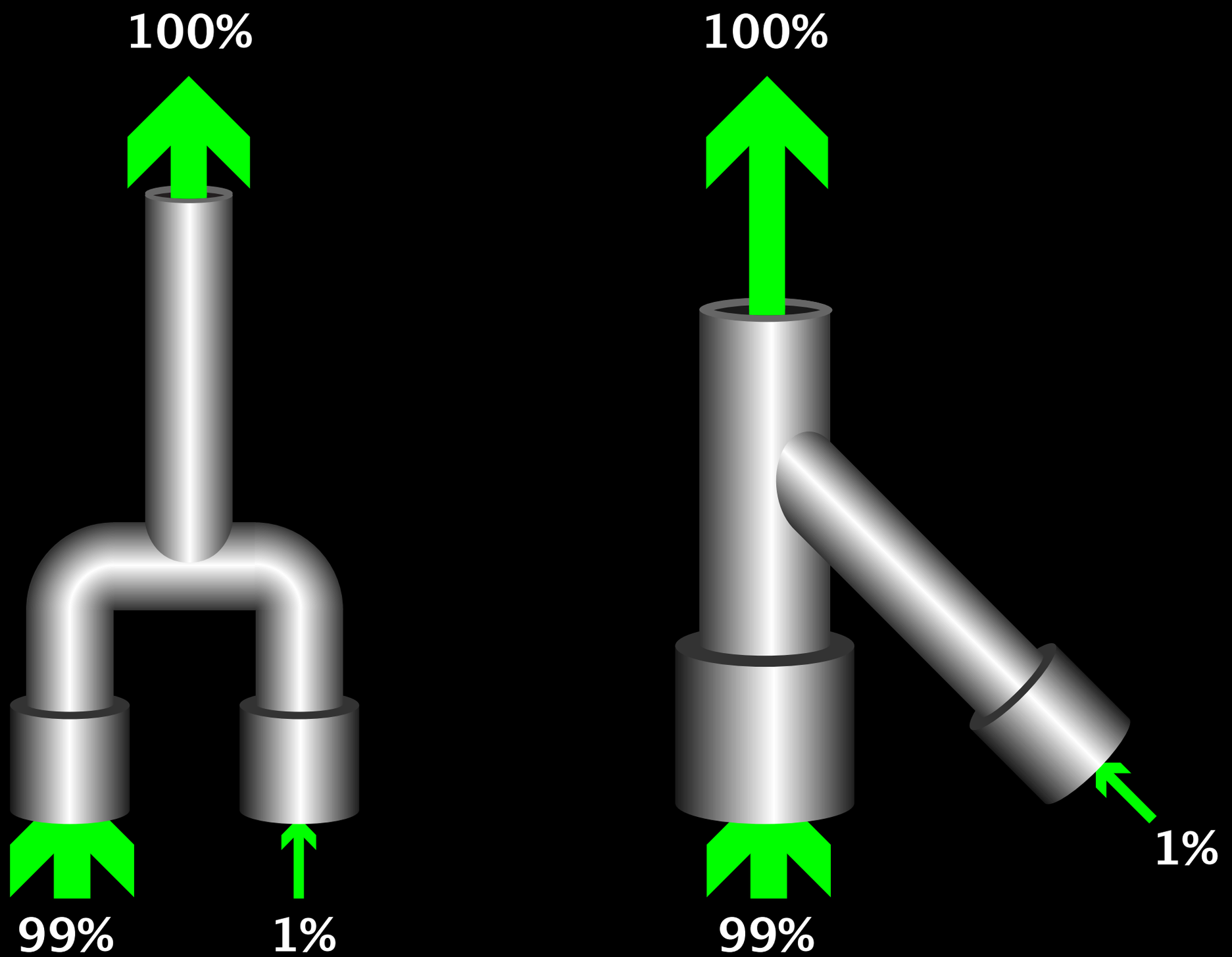
"Bonus" benefit also captured

- 70 kW lower heat loss from pipes

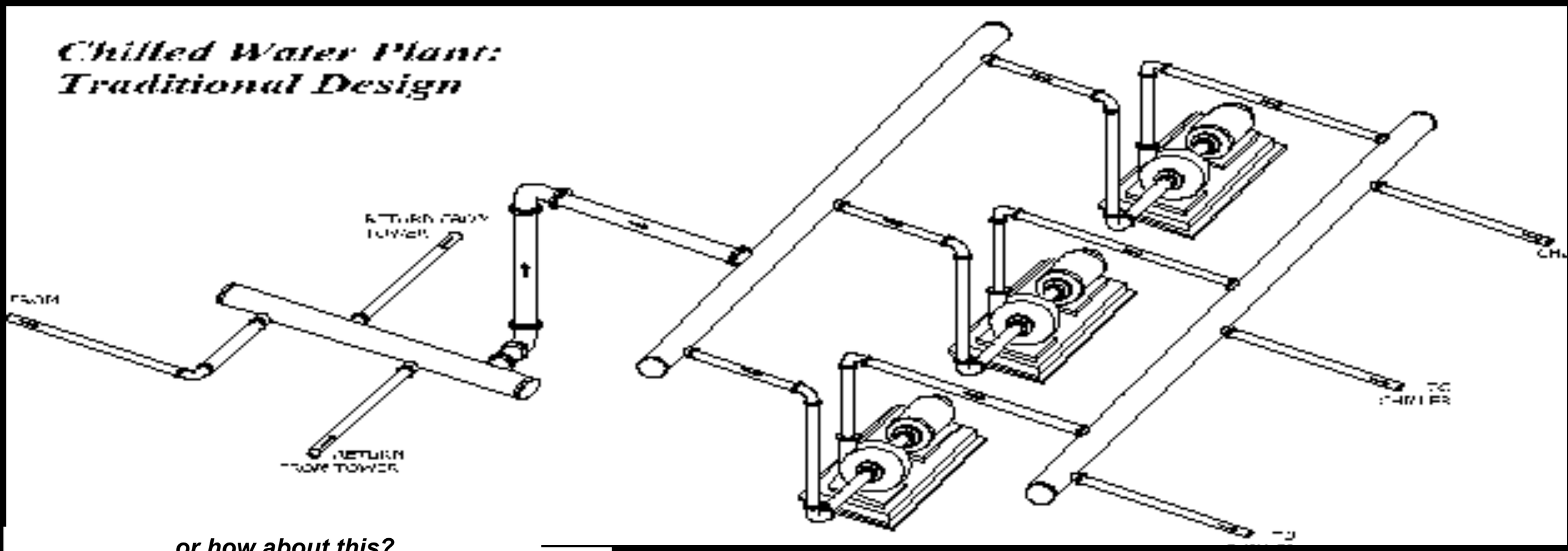
Additional benefits not counted

- Less space, weight, and noise
- Clean layout for easy maintenance access
- Needs little maintenance, yet better uptime
- Longer equipment life, more flexible capacity

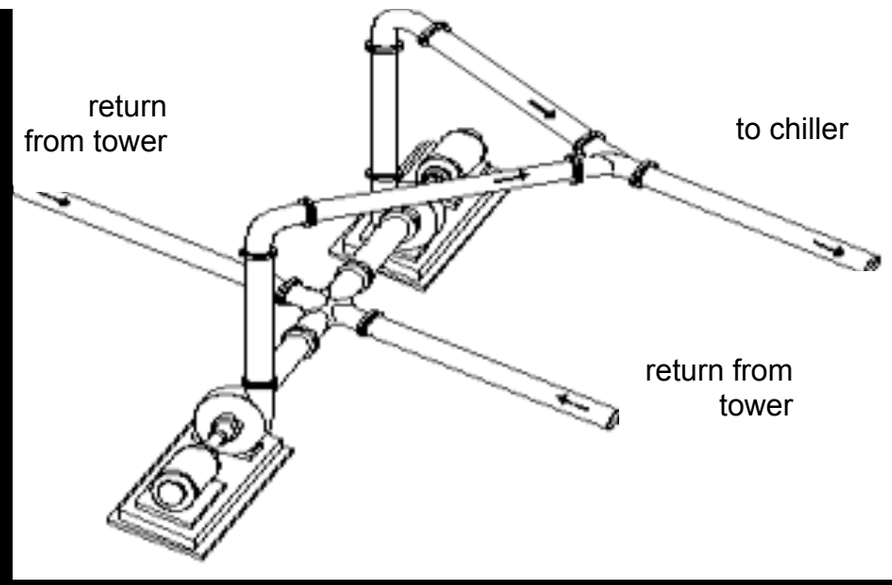
Count these too and save…>96%?


100%
99%
1%
100%
99%
1%

Which of these layouts uses less capital and energy?



…or how about this?



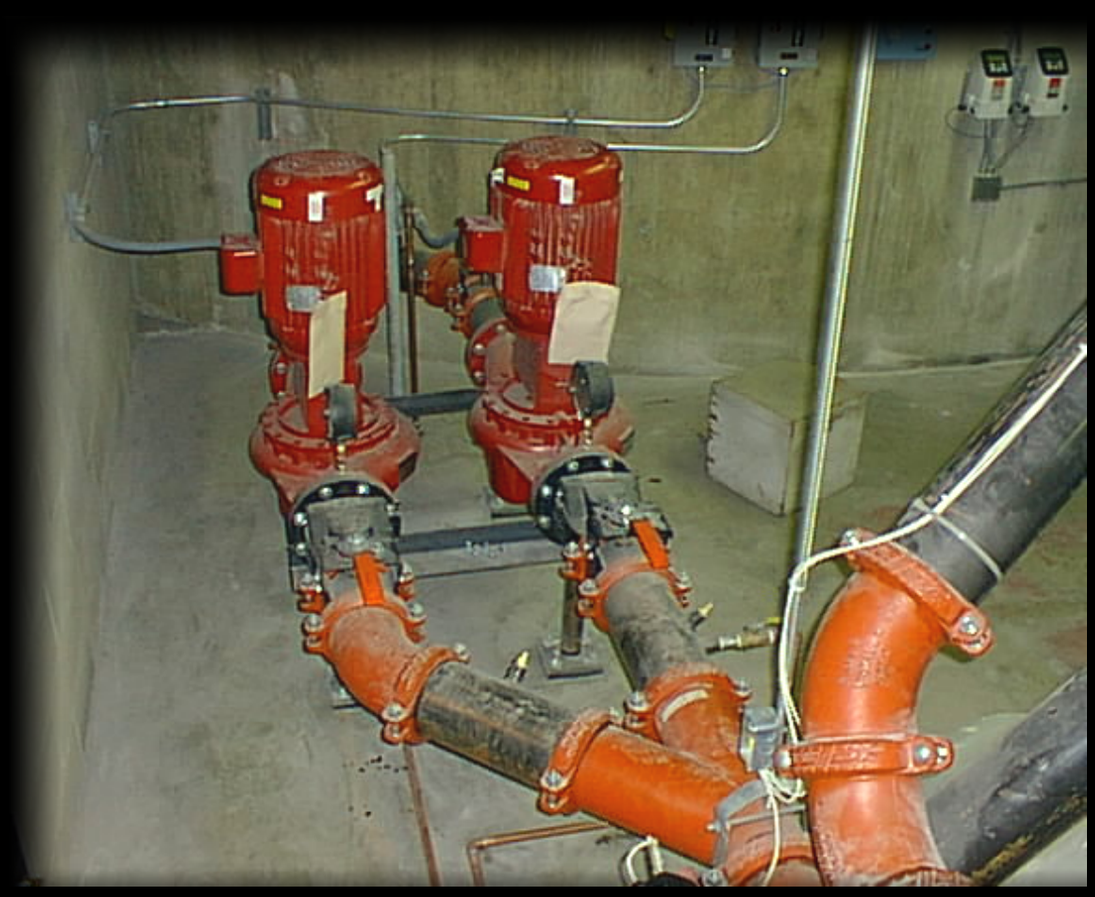
- Less space, weight, friction, energy
- Fewer parts, smaller pumps and motors, less installation labor
- Less O&M, higher uptime

69% less pumping power, lower capital cost

Changing pipes to reduce friction saves 75% of pumping energy

(Rumsey Engineers, Oakland Museum, condenser-water pumping loop retrofit)

15 “**negapumps**”



Notice smooth piping design
– 45˚s and Ys

Energy efficiency: start downstream

Energy efficiency: start downstream

100 Units

10 Units

>100× energy leverage in the EDS data center

Power Plant 67%

Transmission 10%

Cooling 33%

Lighting 4%

UPS 15%

Fans 10%

Power Supply 35%

Under-Utilization 85%–97%
- Compute
- Storage
- Bandwidth

Inefficient & Zero-Value Applications 10%–40%

Inefficient Business Processes ??%

then cut utility losses by ~50%

…then cut support overhead by 90%

…then cut IT equipment's internal losses by 75%…

First debloat software and ensure that every computation cycle is needed

100W
Energy into Power Plant

30W
Energy into Data Center

17W
Energy Into Server

9W
Energy Into Chips

.3W–1.5W
Energy into Applications

.12W-.9W
Energy into Business Process

.00?W
Energy into Customer Value

49

Start Downstream

www.10xe.org

Practical design keys to a broad and profitable efficiency revolution

- Optimize whole systems for multiple benefits
- Bust barriers, and reward what we want
- Faith, hope, clarity, and relentless patience
- This unprecedented cornucopia is the manual model: we must all actually go turn the crank!
- “Preach the gospel at all times. If necessary, use words.”

—St. Francis of Assissi

The secret of great design integration:

No Compromise!

Design is *not* the art of compromise and tradeoff—how not to get what you want

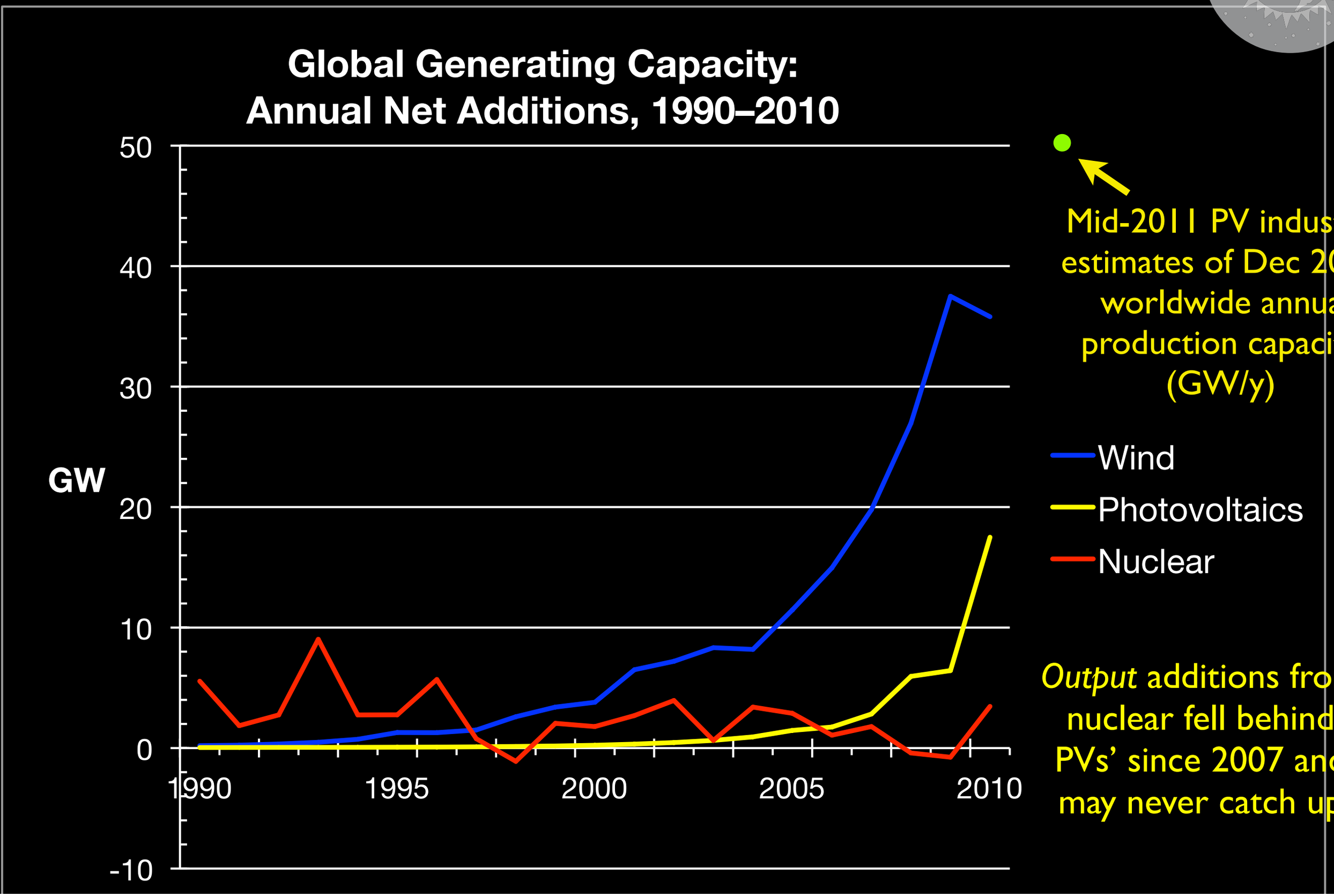
J. Baldwin: "Nature doesn't compromise; nature optimizes. A pelican is *not* a compromise between a seagull and a crow." It is the best possible pelican (so far)—and after 90 million years, that's a pretty good one

The need for compromise is generally a symptom of misstated design intent

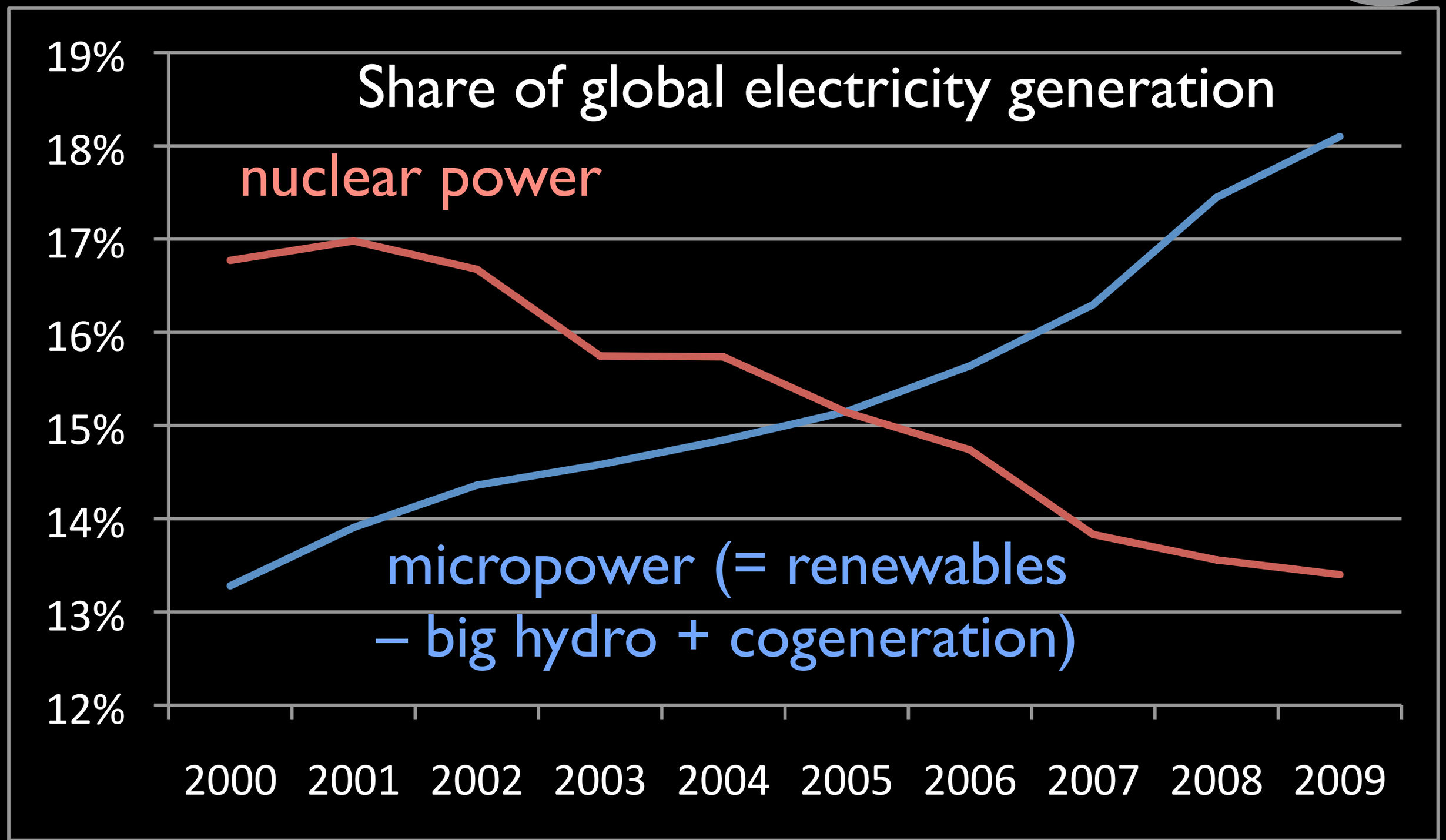
Helpful design hints

- You can only get to simplicity through complexity. *–Anon.*
- Everything should be made as simple as possible..but not simpler. *–Einstein*
- I wouldn't give a nickel for the simplicity on this side of complexity —but I'd give my life for the simplicity on the *other* side of complexity. *–Einstein*
- Perfect simplicity is not when there's nothing left to add, but when there's nothing left to take away. *–St.-Exupéry*
- How did I sculpt *David*? I just chiseled away everything that wasn't *David*. *–Michaelangelo*
- Seek the pattern that connects. *–Bateson*
- You know you're on the right track when your solution for one problem accidentally solves several others. *–Corbet*
- Avoiding problems is even better than solving them. *–Lovins*
- All the really important design errors are made on the first day. *–Anon.*

Global markets are rapidly shifting to distributed renewables

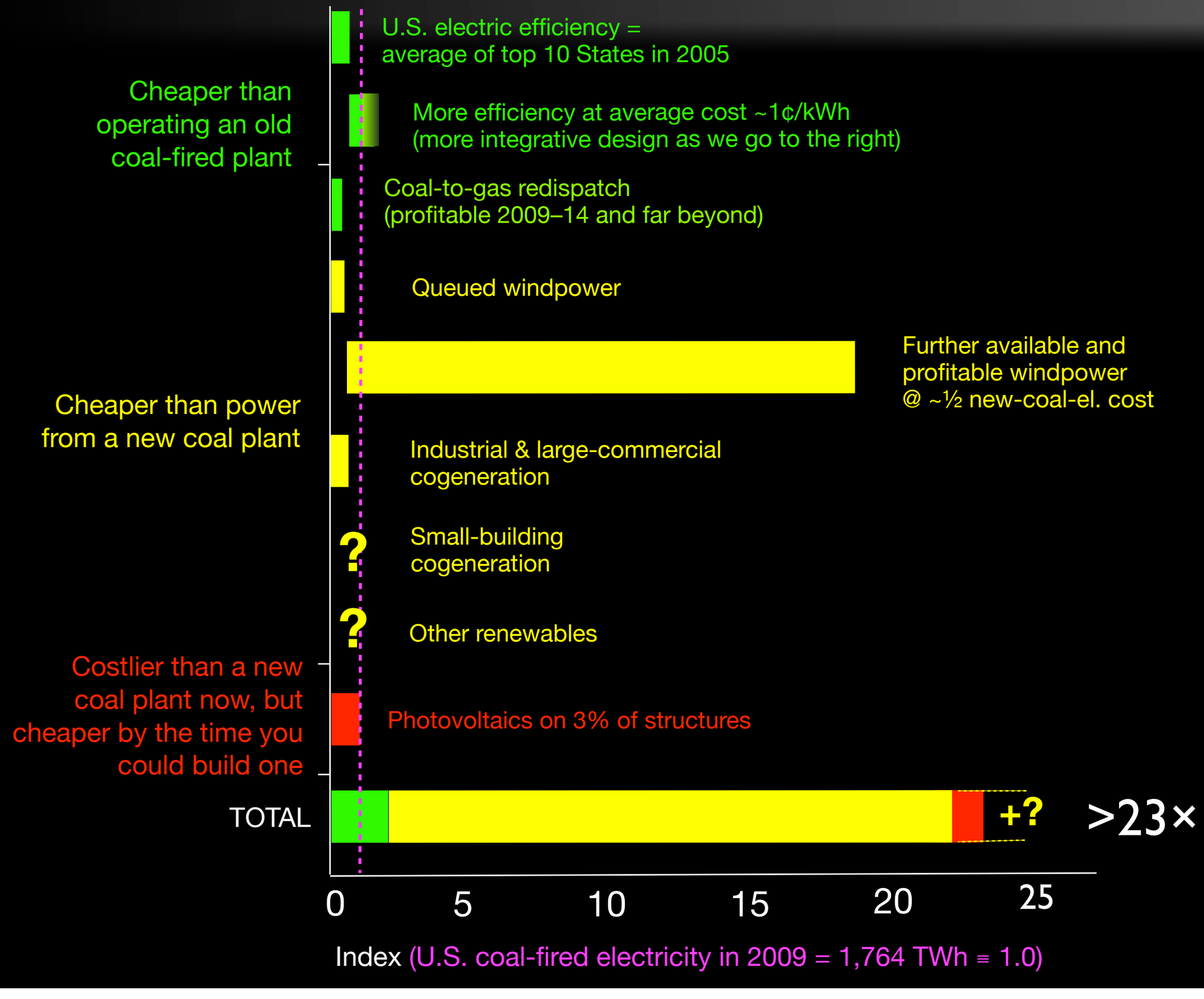


Nuclear and micropower generation have more than swapped roles, mainly due to market perceptions of their relative costs and risks



Sources: nuclear and total: *BP Statistical Review of World Energy 2010*; micropower: RMI analysis from industry sources (www.rmi.org/**rmi**/Library/2010-06_MicropowerDatabase). BP generation data are gross, renewables generally net (understating their relative share).

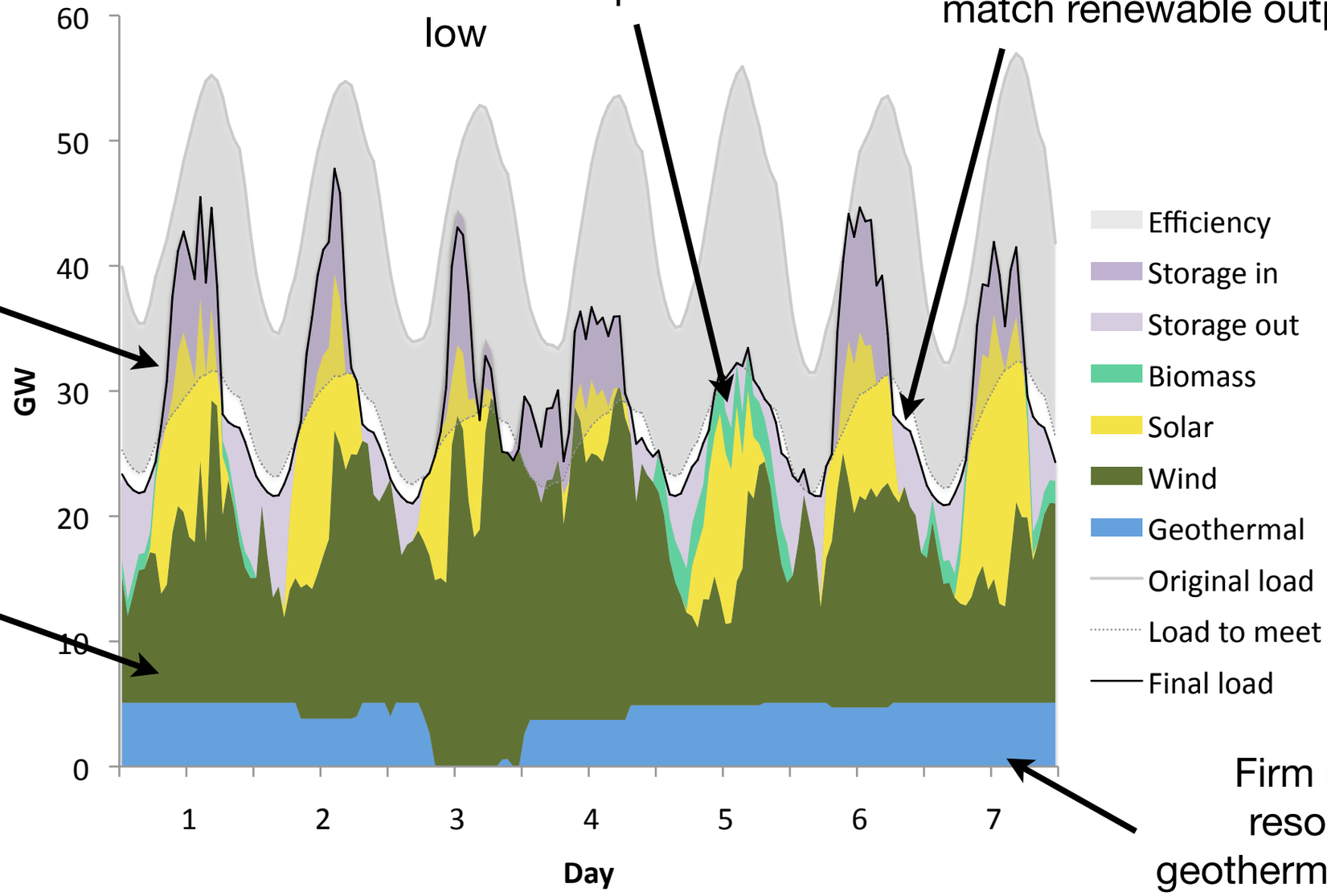
U.S. coal-fired electricity avoidable by...



Storage discharge and flexible biomass can meet peak demand when wind and solar output are low

PHEV charging and demand response can reshape the demand profile to match renewable output better

Energy efficiency can reverse peak demand growth

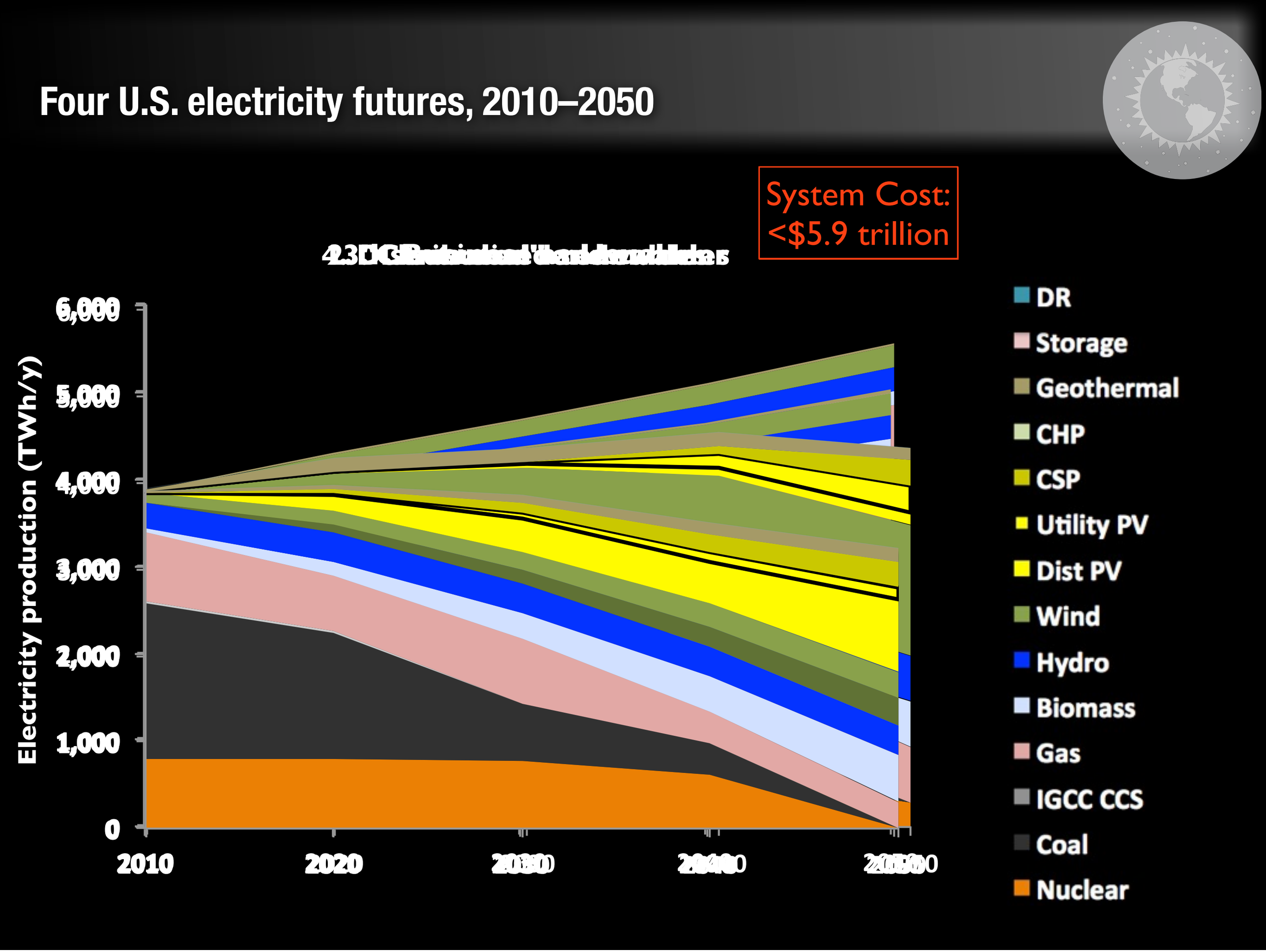


Renewables like wind and solar are not always correlated to demand

Firm renewable resources like geothermal, small hydro solar-thermal-electric, and biomass/waste-fueled power generation can be used to balance wind and solar

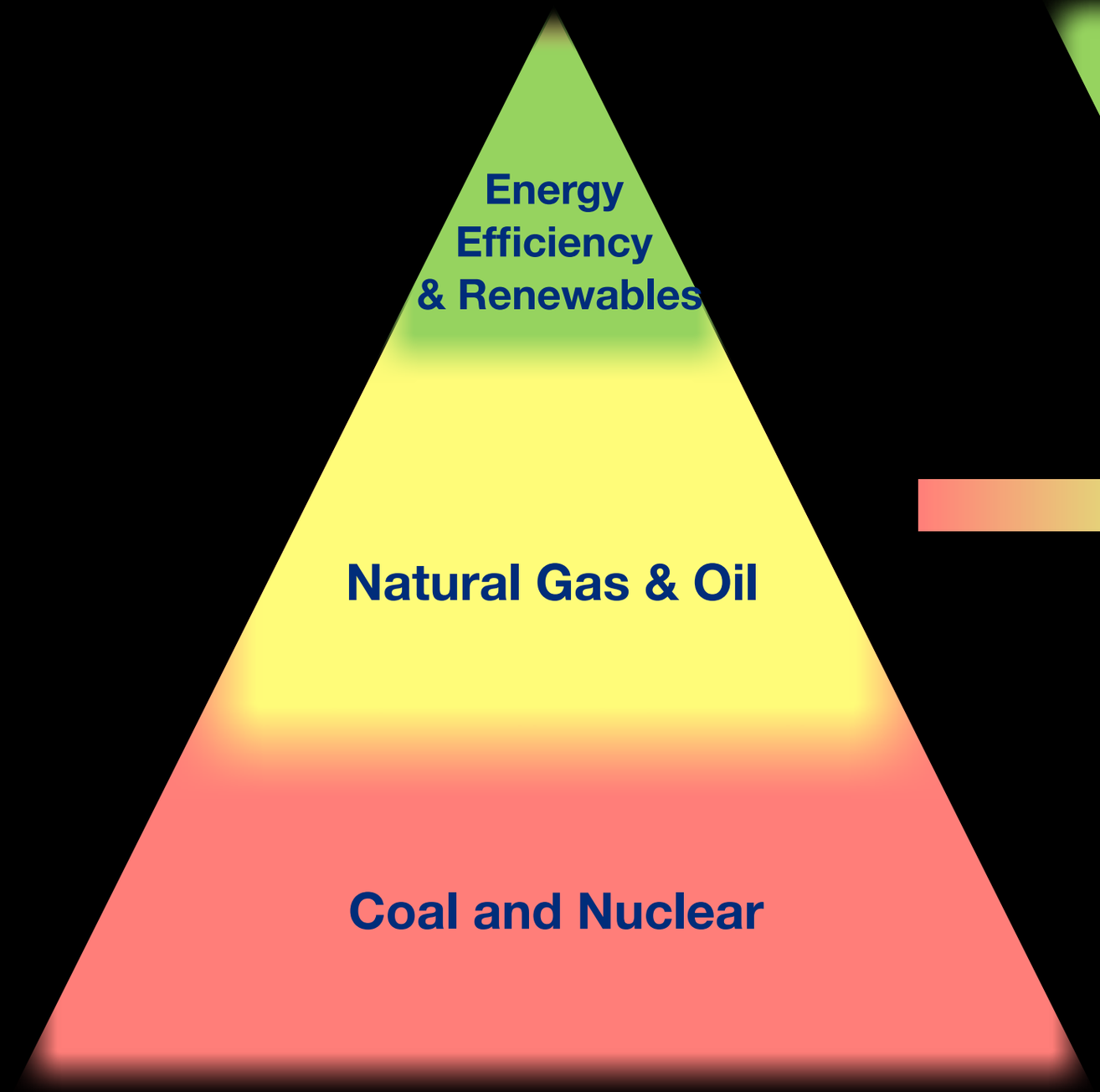
Four U.S. electricity futures, 2010–2050

System Cost:
<$5.9 trillion

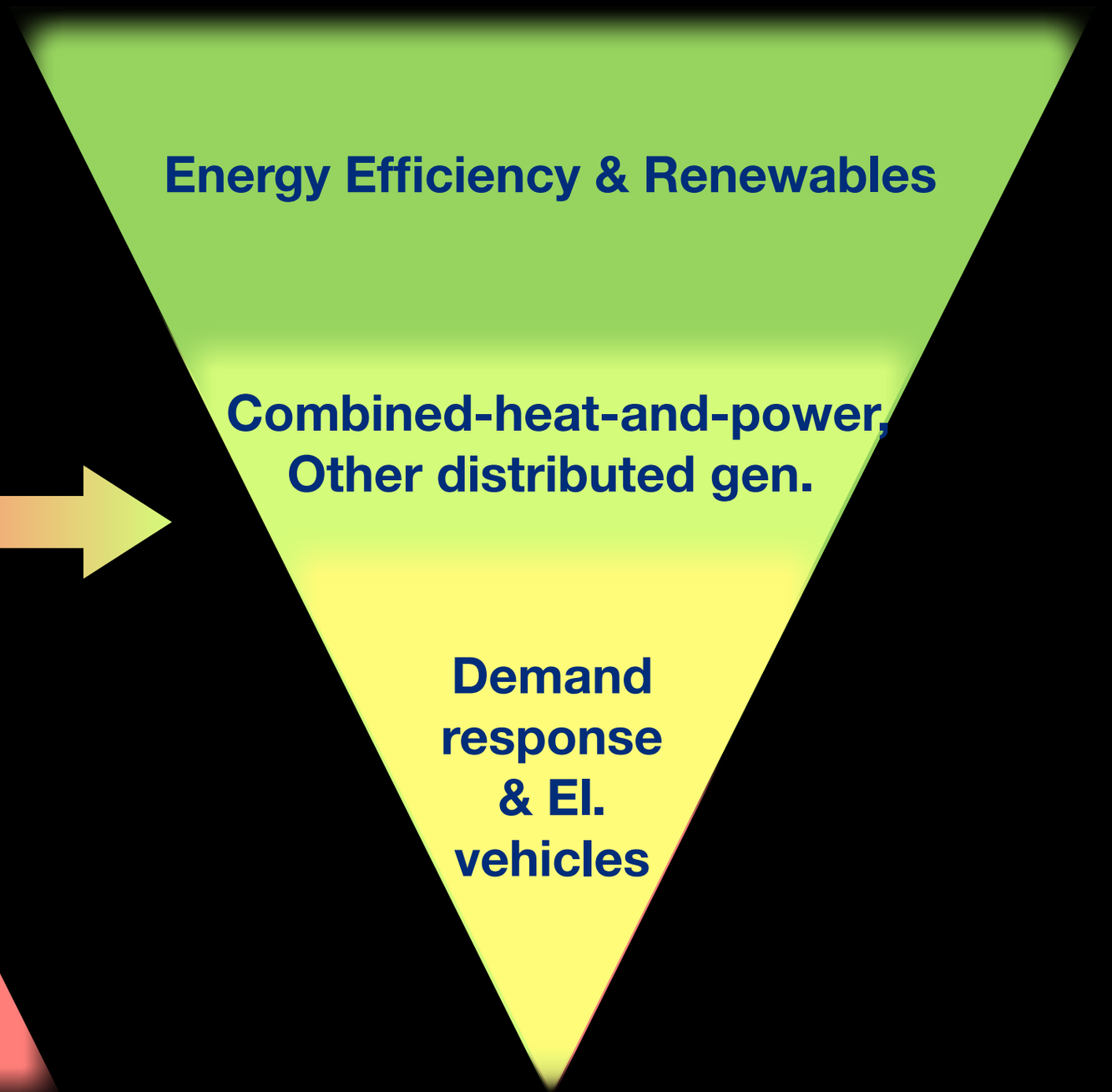


Transforming the electricity sector

Current System

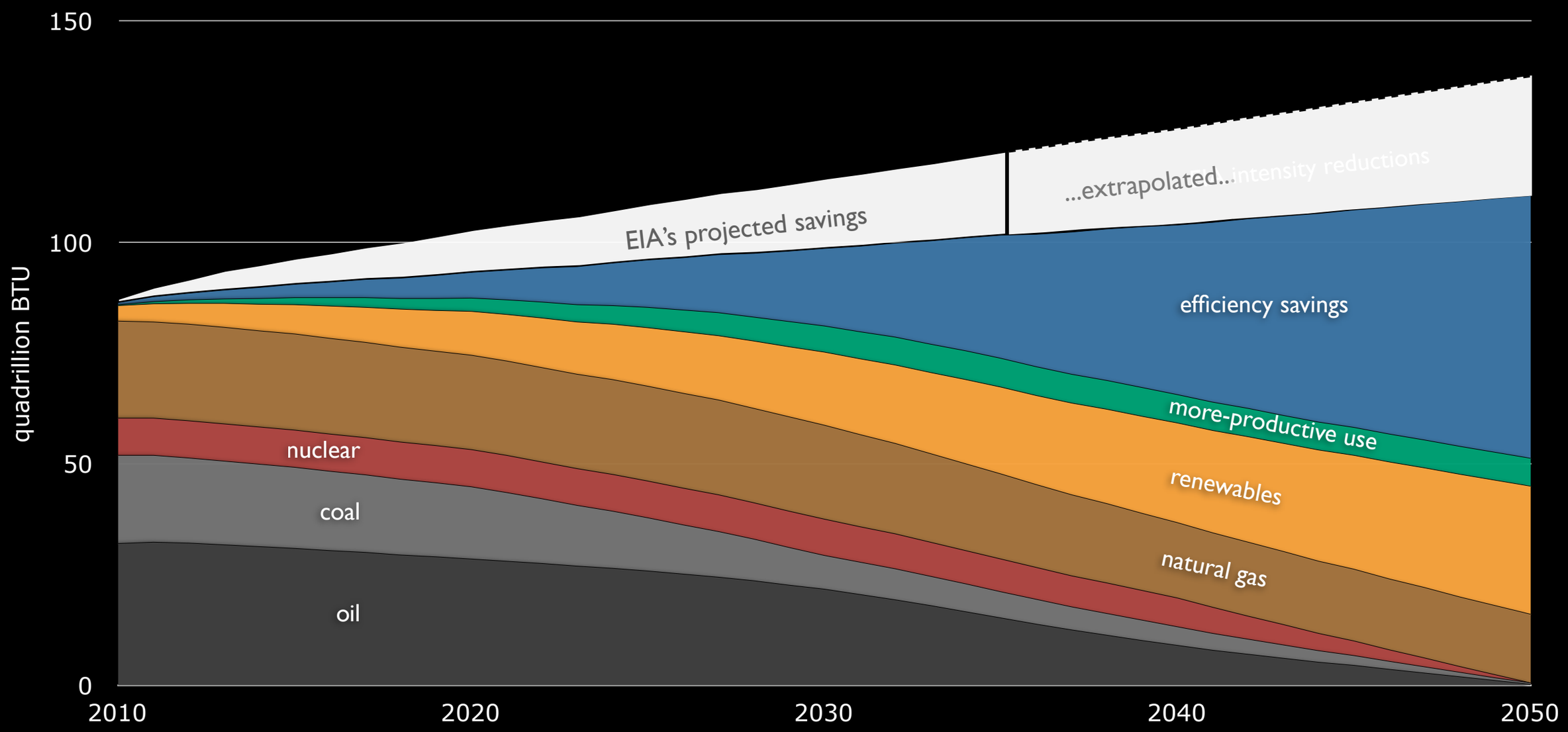


Reinventing Fire System



Reinventing Fire provides a credible vision of a U.S. economy free of oil and coal by 2050

Energy Use in the U.S. Economy, 2010–2050




REINVENTING
FIRE
www.rmi.org
ablovins@rmi.org