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30 Years of Energizing Efficiency

The Energy Efficiency Potential for a Robust Economy*

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An ACEEE 30th Anniversary Symposium:
Energy and the Economic Imperative:
The Role of Efficiency in Creating a Robust Economy

Washington, DC
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*** In the spirit and tradition of Nobel Laureate and former Caltech physicist Richard Feynman, in his 1959 visionary talk, "There's Plenty of Room at the Bottom." See, http://www.its.caltech.edu/~feynman/plenty.html.**

An Opening Commentary

- Energy efficiency may be the farthest reaching, least-polluting, and fastest growing energy success story of the last 40 years. But it is a highly invisible success story, and certainly not one that is typically reflected in policy models. . .
- We've accomplished a lot, but a deeper review suggests that efficiency gains today reflect only the tip of the needed potential.
- Stepping outside the usual modeling framework of "get the prices right," we need renewed collaborations, policies, innovations, and especially productive investments that create large systematic exergy efficiency improvements to maintain a robust economy.
- And to build on Bob and Ed Ayres' book, *Crossing the Energy Divide* (articulating the need to double the level of useful work in our economy), I pose the question: How big energy efficiency – if we choose to develop it?

Two *Working Definitions*

Working Definition: Technology

- There are two aspects of technology that specifically reflect its entirely human dimensions:
  - The cumulative human knowledge embodied in our artifacts, tools, equipment, and structures – all designed with an effort or desire to achieve a given social outcome; and
  - The rules and norms rules by which we choose to deploy that knowledge.
- The very human common denominators in this definition of technology are innovation and choice.
- To which I add this critical observation: we have yet to approach the physical frontier of possibilities.

Working Definition: Energy Efficiency Investments

- The cost-effective investment in the energy we don't use to produce our goods and services.
- Examples include:
  - New electronic ballasts and lamps, sensors, building and piping insulation, and heat recovery systems installed to primarily save energy
  - Combined heat and power (CHP) and recycled energy systems with efficiencies of 70-90 percent, or more
  - Information and communication technologies (ICT) whose secondary value increases overall energy productivity
  - Investments in the more innovative, high value-added industries and services that power structural change, but in ways that also lower our overall energy-intensity
- The common denominator in all these examples is productive investment and informed behavior.

"We shape the world by the questions we ask"

Physicist John Wheeler

A Short *Historical* Perspective

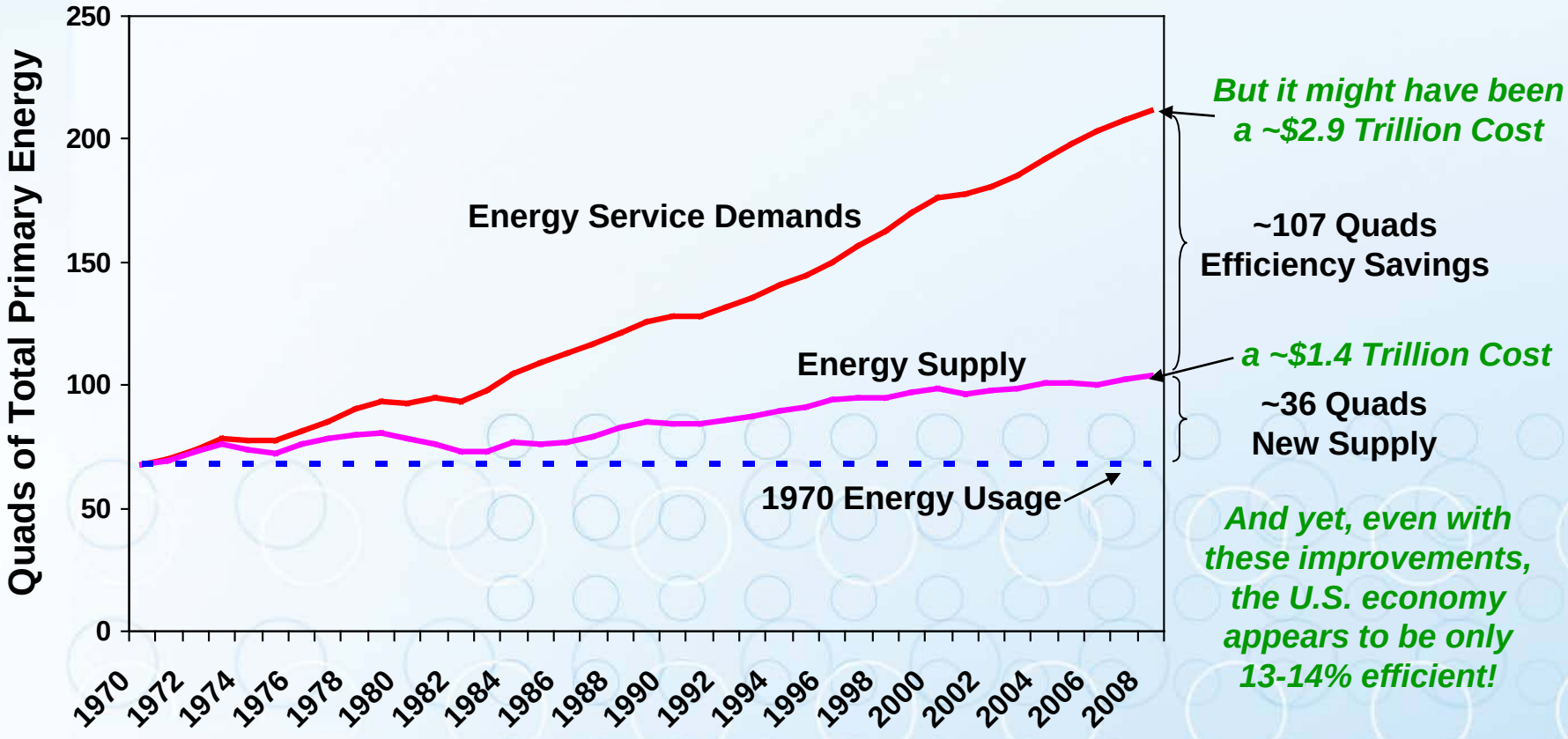
The year 1970 is not an especially important one in the history of the U.S.

- The roughly 40-year period since 1970 is about the same interval of time most scientists and policy analysts now believe we have remaining to effectively resolve the emerging energy constraints and global climate change (i.e., 2010 through 2050). This is a daunting prospect.
- With Alfred North Whitehead's admonition to look forward and backward for real insights, let's first review the historical efficiency perspective.
- In 1970 the movies "Love Story" and "M*A*S*H" drew crowds to air-conditioned theaters. The Chicago Seven were acquitted and Janis Joplin died.
- And, in 1970, teenager Frank Nasworthy actually did reinvent the wheel and it popularized skateboarding.
- But, in 1970 there were no personal computers or cellular phones. Slide rules were still used for engineering calculations rather than hand-held calculators. In 1970 fax machines did not exist other than for highly specialized uses such as weather mapping.

The year 1970 is not an especially important one in the history of the U.S.

- In 1970 there were no catalytic converters on automobiles, no VCRs or CD players in our homes. Technologies such as electronic ballasts, solid state lighting, low-emissivity windows and industrial “high-lift” heat pumps had yet to be invented.
- Intel was still a year from releasing the first commercial microchip.
- In 1970, the world had yet to hear of names like Chernobyl, Three-Mile Island and the Exxon Valdez.
- Perhaps more important, global climate change and ozone depletion were unthinkable prospects.
- FedEx was still several years away, and the Internet consisted of just four university sites that had been connected only the previous fall. Carbon nanotubes were not discovered until 1991.
- And 1970 was also the year when the U.S. Environmental Protection Agency was created, and it was about the time when I began my own career.

The Historical Efficiency Contribution*



*Assuming 1970 Technologies and Market Structure with a Growth in GDP (in $2000)

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Some Preliminary Conclusions?

- Our historical consumption of energy, or the development and pursuit of energy efficiency, has been <<< optimal;
- Public policies and informed choices in 1970 may have enabled an entirely different historical path from what we've seen; and
- Our future path will depend on the policies we choose to enact, the informed behaviors that unfold, and the scale of more productive investments that we encourage and stimulate.

The *Future* of Energy Efficiency

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Our Ultimate Energy Efficiency Resource?

- Recalling the comment of early Twentieth Century UK essayist, Lionel Strachey, who remarked: *“Americans guess because they are in too great a hurry to think.”*
- Jerry Hirschberg, founder and former CEO of Nissan Design, who noted that: *“Creativity is not an escape from disciplined thinking. It is an escape with disciplined thinking."*
- And Henry Ford once said, *“Thinking is the hardest work there is which is the probable reason why so few engage in it.”*

Reflecting on the words of economist Kenneth Boulding: "Images of the future are critical to choice-oriented behavior," let me pose *three quick questions*…

What is the Weight of the Internet?

- Each transistor on a chip requires about 40,000 electrons to charge up.*
- A typical email contains ~50 kilobytes, requiring ~8 billion electrons. One electron weighs 2×10^{-30} pounds so a typical email weighs ~2.6×10^{-18} ounces.
- But email is only ~9% of total traffic with 75% due to filing sharing. Total daily internet activity – ranging from love letters and pornography to climate studies, music files, home movies, and vacation plans – is ~40 petabytes.
- And, 40 petabytes ~ 1.3×10^{-8} pound, or on the order of ***0.2 millionths of an ounce.***
- By comparison, if all that information were on paper, it might be ~6 to 7 million tons per day.

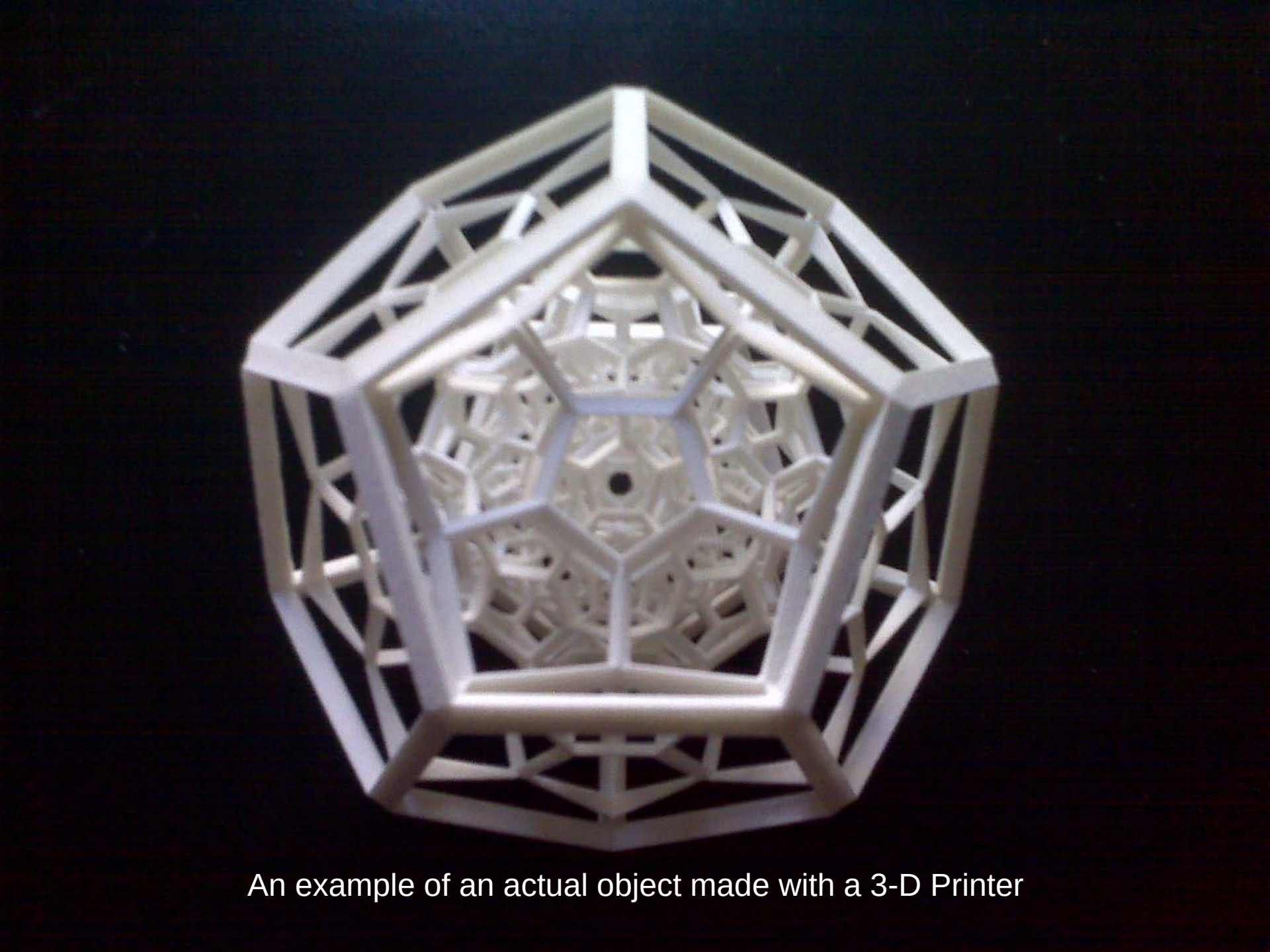
Note: Researchers today are working on a single electron transistor.

What is the Bekenstein Bound?

- Building on the foundations of information theory advanced by MIT graduate Claude Shannon in 1948, Princeton graduate student Jacob Bekenstein proved in 1973 there was a limit to the information that can be stored in any given region of space.
- Contrary to expectation, the limit to information does not depend on volume but on surface area.
- Rough calculations suggest that the Bekenstein Bound is ~10^{70} bits/square meter.
- By comparison, CD's now cram "only" 10^{13} bits/square meter.
- In other words, we're not even close to the physical limit or the technology frontier.

What is Instant, Additive, or Freeform Fabrication and Manufacturing?

- One technique? Using ink jet printers to provide the backbone of an entirely new generation of instant manufacturing technologies, producing everything from hearing aids, shoes, and cell phone covers to replacement bones and body tissue.
- How done? Selective laser sintering of materials deposited by dozens or hundreds of micro-nozzles according to a pattern embodied within a 3-D print file. With ordered parts and materials offered on-line. . . .
- Such processes may be more energy-efficient and use a greater array of basic materials; they also benefit from negligible economies of scale — which means they can rely more on local resources, and be located closer to local production needs.
- The implications for both direct and transportation energy use may be significant and beneficial.



An example of an actual object made with a 3-D Printer

Other Emerging Technology Trends

- Movement away from commodity-based ownership to service-based leasing.
- Multiple outputs from convergent technologies so that we minimize waste and maximize product.
- Decentralized generation continuing to show net social, economic, and environmental benefits.
- Information and communication technologies which reduce transaction costs, fostering more decentralized (agile) decision-making enterprises.
- Increased environmental awareness, concerns, and choices. . . all enabled by new technologies that facilitate changes in preferences, attitudes, and behaviors.

Many Untapped Efficiency Markets Within the United States – through 2030

- End-use technologies
  - Windows: (>$50 B) low-e>>photochromics>>electrochromics
  - Lighting: (>$260 B) incandescent>>fluorescent>>solid state
  - Storage: (>$420 B) batteries>>high-performance capacitors
  - Building Integrated Photovoltaic Systems (~$230 B potential)
- Semiconductor-enabled and other platform technologies
  - Information and communication technologies (~$280 B potential)
  - Electricity grid modernization
  - Building automation/control systems
- Business models
  - Project development for CHP systems (>$100 B potential)
  - Recycled energy development (> $100 B potential)
  - Performance contracting (~$5 B/yr)
  - Smart grid technologies (~$500 to $800 B potential)
  - Utility program delivery (~$3-5 B/yr)

Note: all dollars values presented here are only intended to provide working estimates of scale rather than precision. New and more reliable values to be developed by June 2010.

The *Results* of an Initial Modeling Assessment that Builds on Investment*

* From the October 2009 ACEEE report , *Climate Change Policy as an Economic Re-development Opportunity: The Role of Productive Investments in Mitigating Greenhouse Gas Emissions*. See, http://www.aceee.org/press/e098pr.htm.

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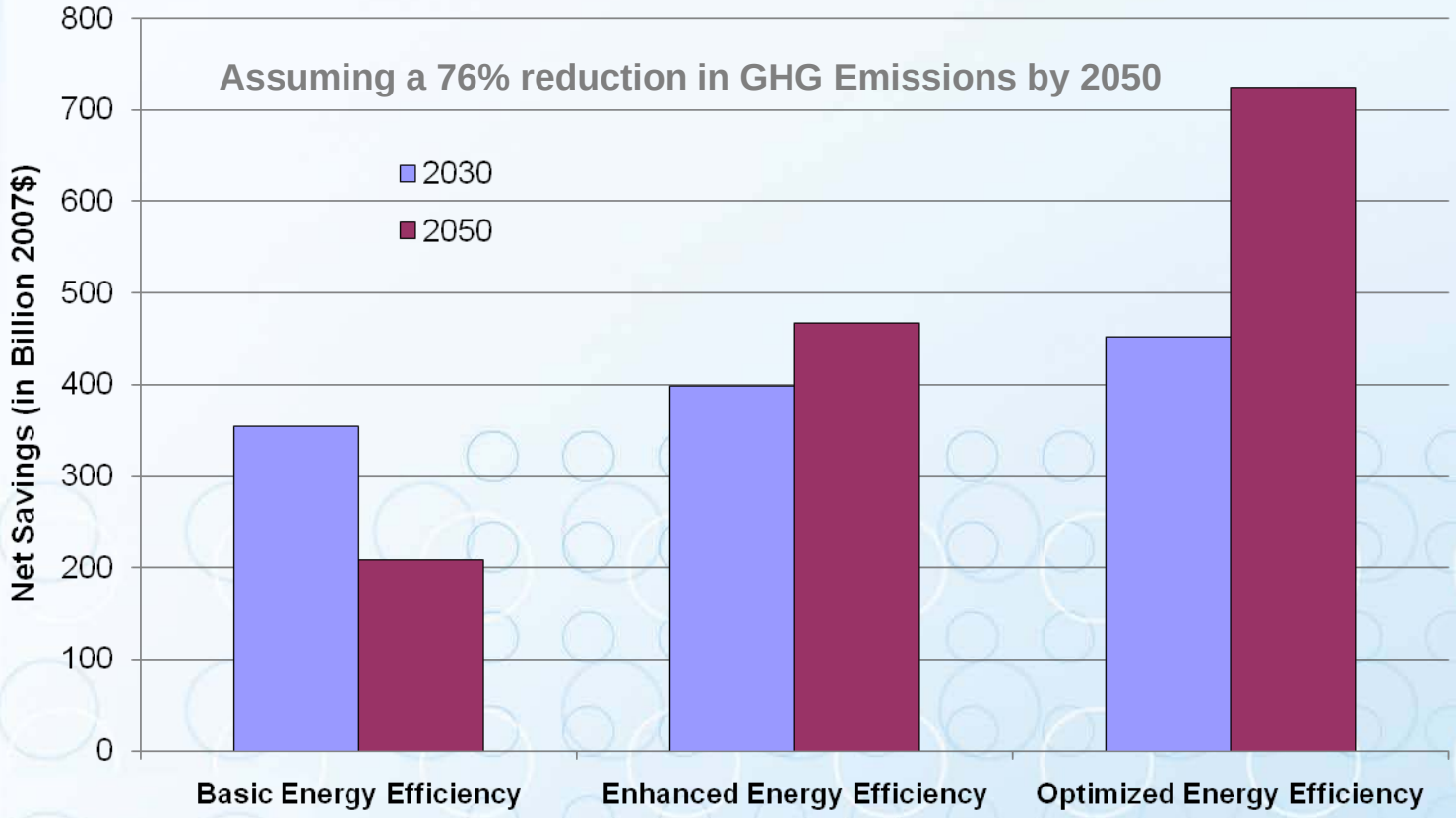
ACEEE Analysis of Climate Legislation: Net Savings from Efficiency Investments*



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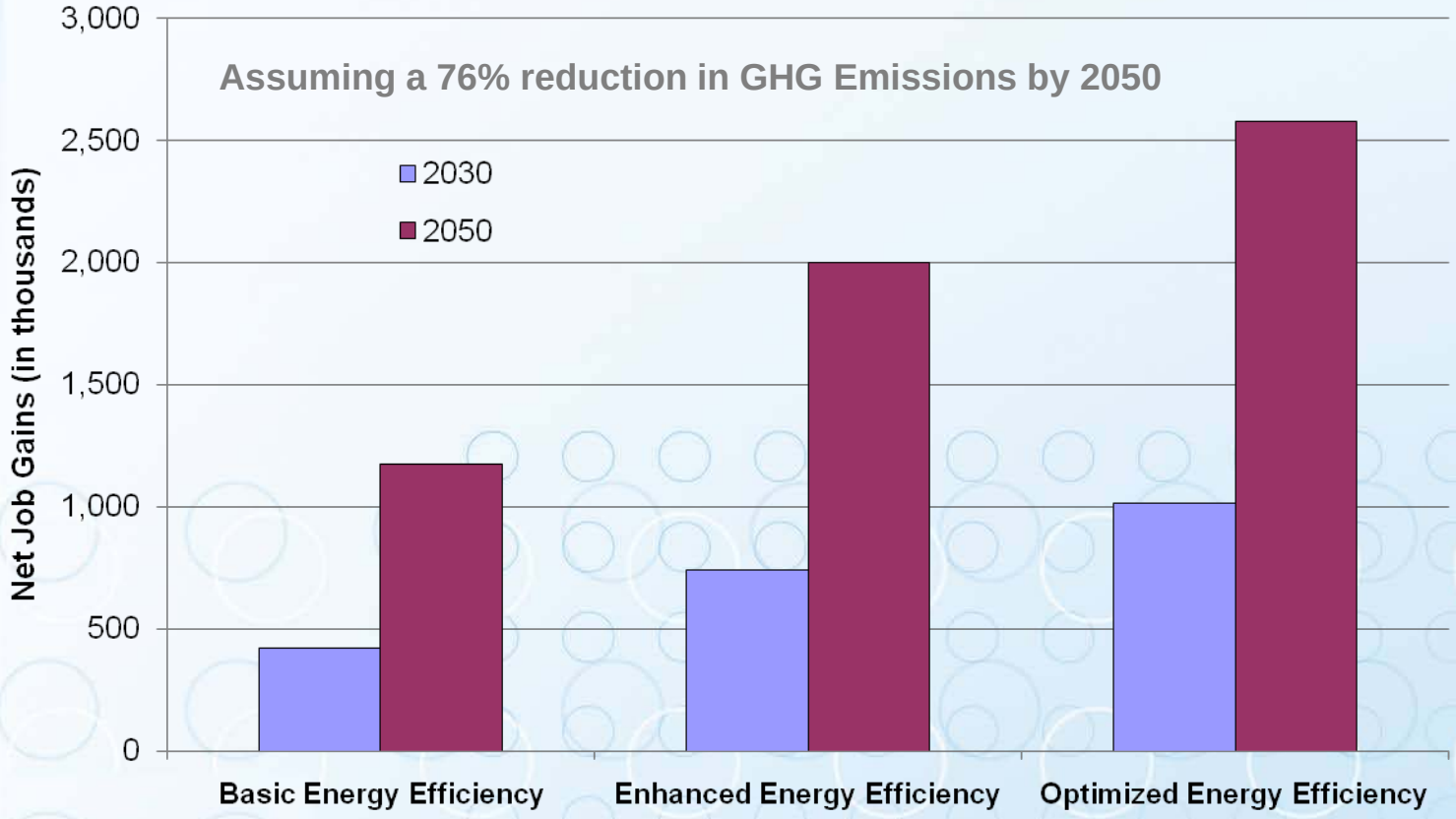

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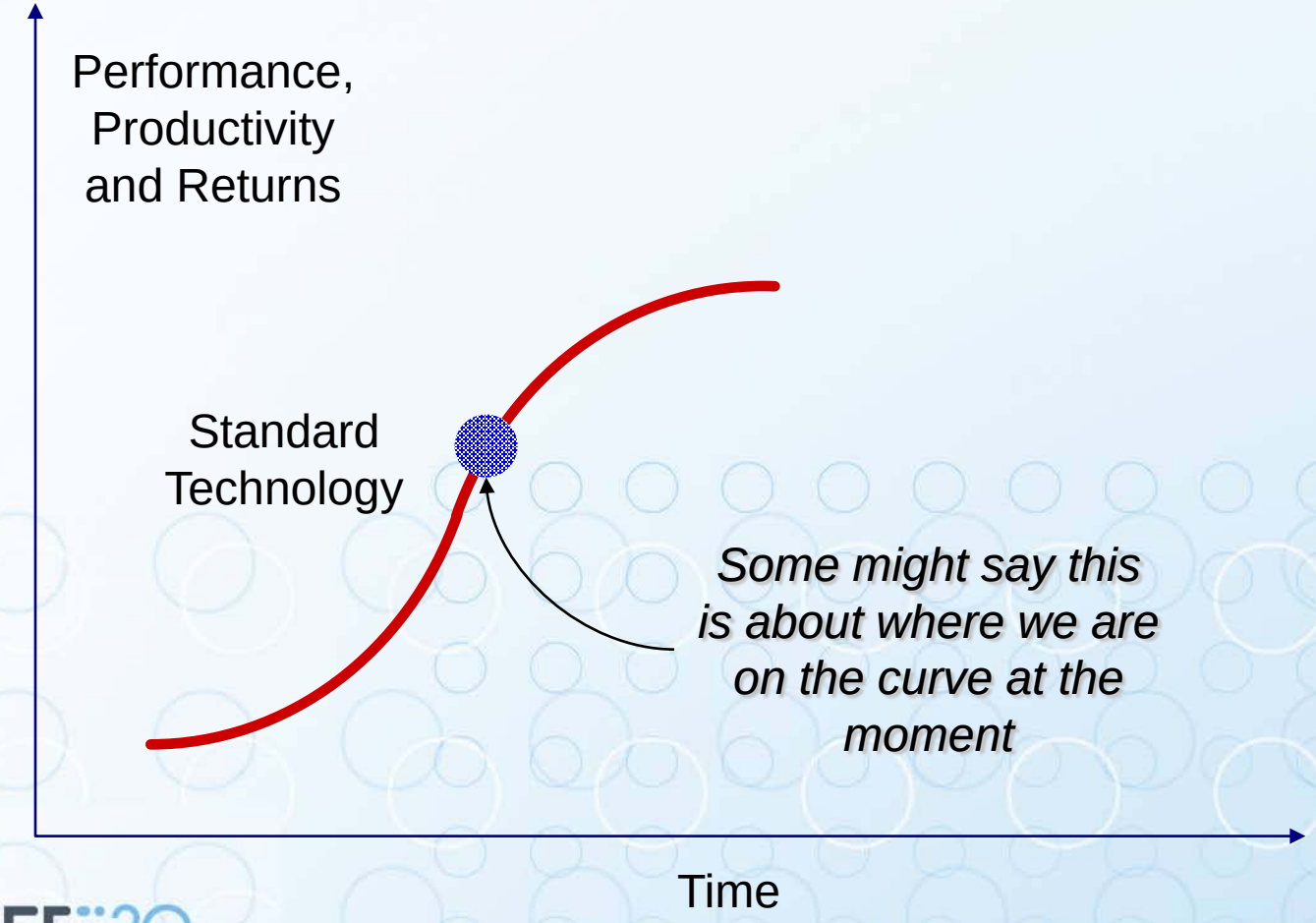
Key Insight #1: Purposeful Effort is Required if We are to Respond to the Climate Imperative



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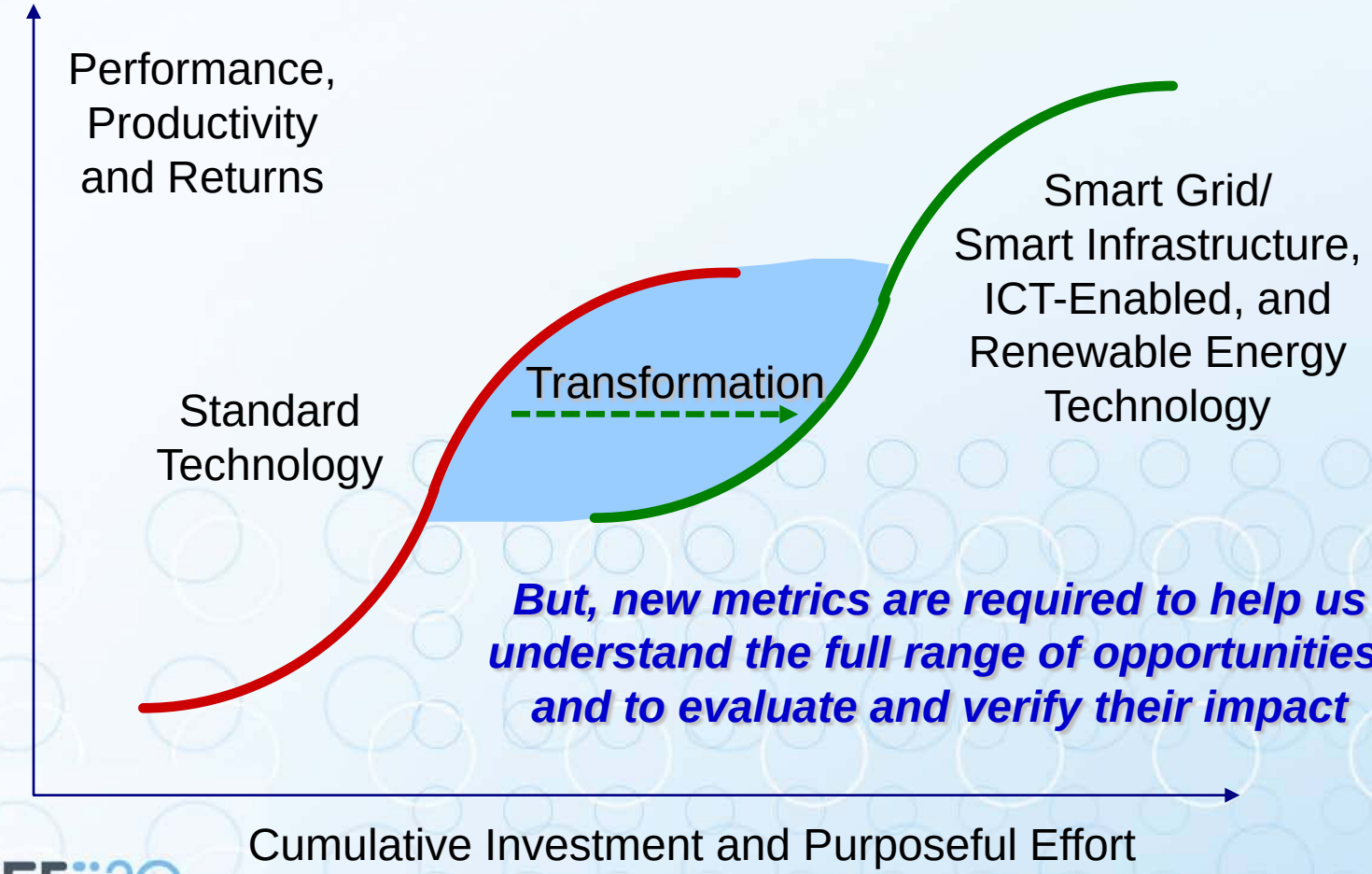
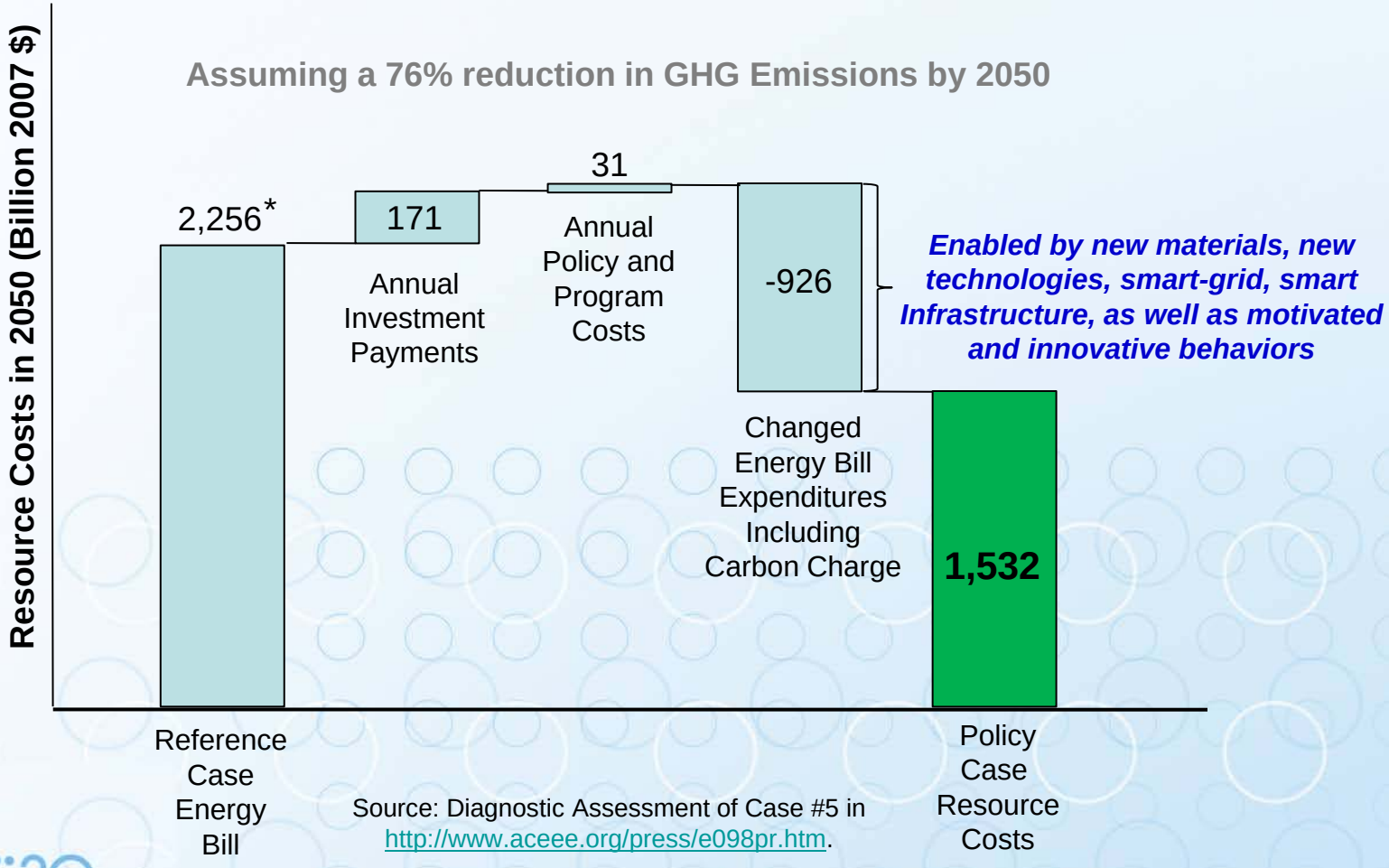


Changes in the 2050 Resource Costs from the Adoption of U.S. Climate Policies



Source: Diagnostic Assessment of Case #5 in http://www.aceee.org/press/e098pr.htm.

*Note: If Ayres and Warr (2009) are correct, the reference case may be more expensive than suggested . . .even with a diminished or less robust economy.

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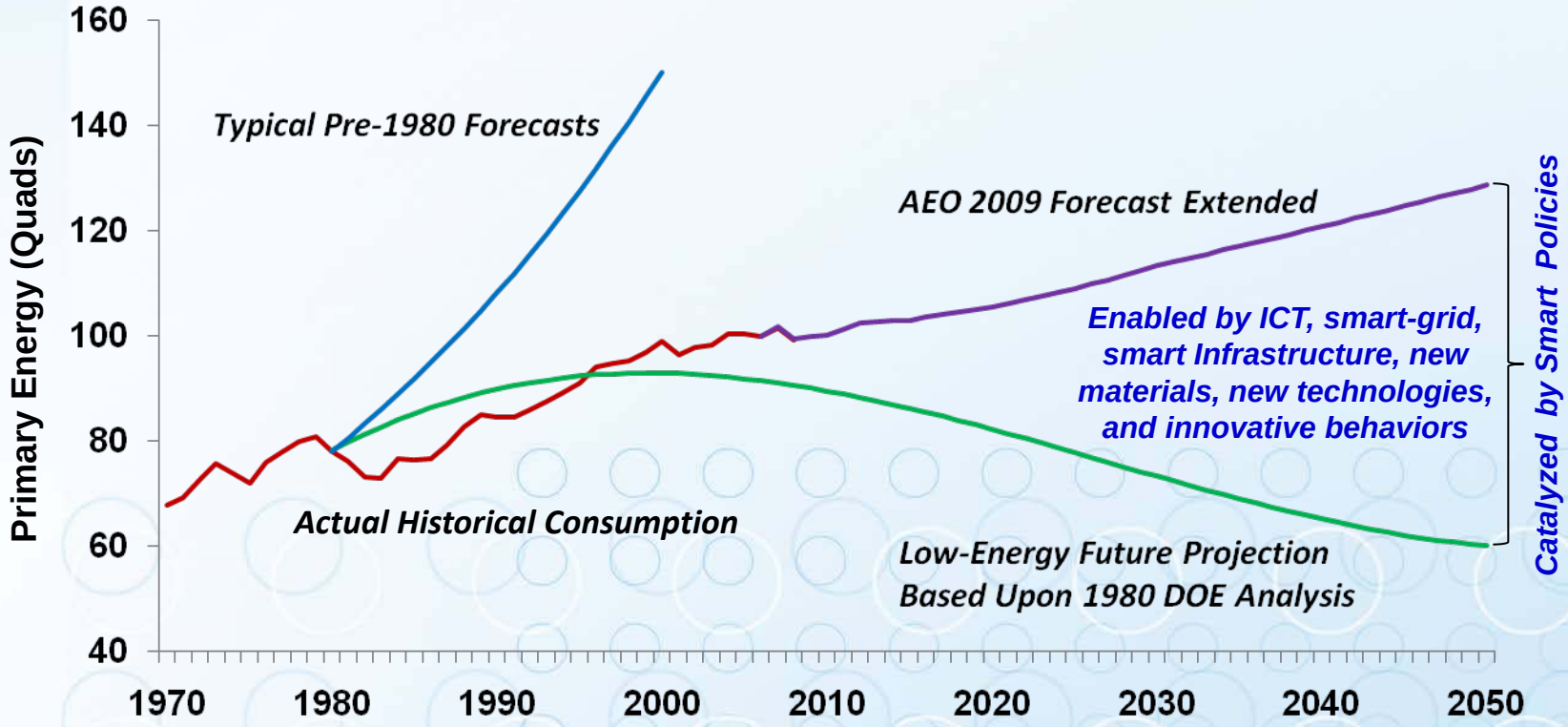
Key Insight #2: The Energy Efficiency Resource Is Larger than Generally Believed



Source: DOE 1980 Policy Analysis, AEO 2009, and a 2009 ACEEE report, "The Positive Economics of Climate Change Policies: What the Historical Evidence Can Tell Us," see: http://www.aceee.org/press/e095pr.htm.

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How Big Energy Efficiency?

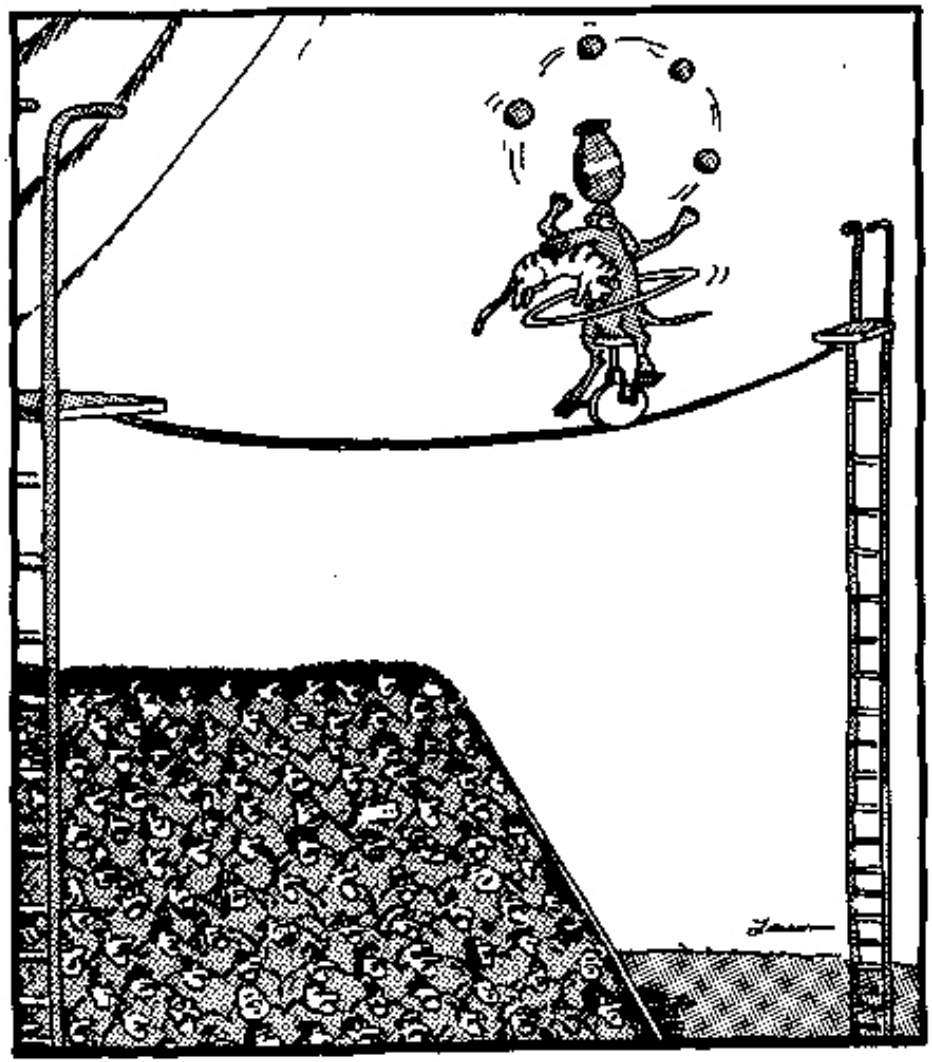
- Again, since 1970 energy efficiency – in it's various forms – has satisfied ~75 percent of our nation's increased demand for energy-related services while new energy supplies only 25 percent of the new demands.
- Preliminary estimates suggest that energy productivity can provide as much as 60 percent of the needed reductions in total greenhouse gas emissions by 2050 – if we choose to develop and invest in that resource.

Citing Just Two of the Many "Big Efficiency" Examples Usually Overlooked

- Our nation's electricity generation system is at best 32 percent efficient, a level that is essentially unchanged since 1960. What we waste in the generation, transmission and distribution of electricity is more than Japan uses to power its entire economy. There are many cost-effective solutions available to recycle this huge level of waste. ***Smart infrastructure may enable a major shift toward huge productivity improvements.***
- A 2007 DOE-sponsored study suggested that if all commercial buildings were rebuilt by applying a comprehensive package of energy efficiency technologies and practices, they could reduce their typical energy use by 60 percent. Adding the widespread installation of rooftop photovoltaic power systems could lead to an average 88 percent reduction in the use of conventional energy resources. ***Smart materials, smart designs, and again, smart infrastructure may enable this to happen.***

The Good News About Energy Efficiency Investments and Climate Change Policies

- It is does not have to be about ratcheting down our economy;
- Rather, and drawing upon the full range of ICT and other opportunities, it can be all about:
  - using innovation and our technological leadership;
  - investing in more productive technologies (including both existing and new technologies); and
  - developing new ways to make things, and new ways to get where we want to go, where we want to work, and where we want to play.
- ***Most economic policy assessments and models appear to assume the former – to the detriment of informed behavior, and smart energy and climate policy.***



High above the hushed crowd, Rex tried to remain focused. Still, he couldn't shake one nagging thought: He was an old dog and this was a new trick.

The difficulty lies not with the new ideas, but in escaping the old ones. . . .

John Maynard Keynes

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For more information and updates visit:
http://www.aceee.org/conf/30th/april26.htm

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