Long-term Energy Forecasts: Is Useful Learning Possible?

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Introduction

- Changes in the energy system take decades, so forecasting is necessary
- Long-term forecasting models, while useful in some circumstances, are almost always inaccurate
- What must we learn to make models more useful?

Definition of Learning

- The American Heritage Dictionary defines learning as
  - the act, process, or experience of gaining knowledge or skill
- Ask.com defines it as
  - any relatively permanent change in behavior that occurs as a result of experience
- In this talk, focus on learning that helps us to accomplish goals more effectively

Can we learn to do better forecasts?

- What do we mean by better?
  - more mathematical or theoretical?
  - more empirical?
  - more accurate?
  - more useful?
- The quest for greater accuracy in long term forecasting is ultimately futile
- Focus on making forecasts more useful
  - Empirical data most helpful, theory less so.

Forecasting Accuracy: The Models Have Done Badly

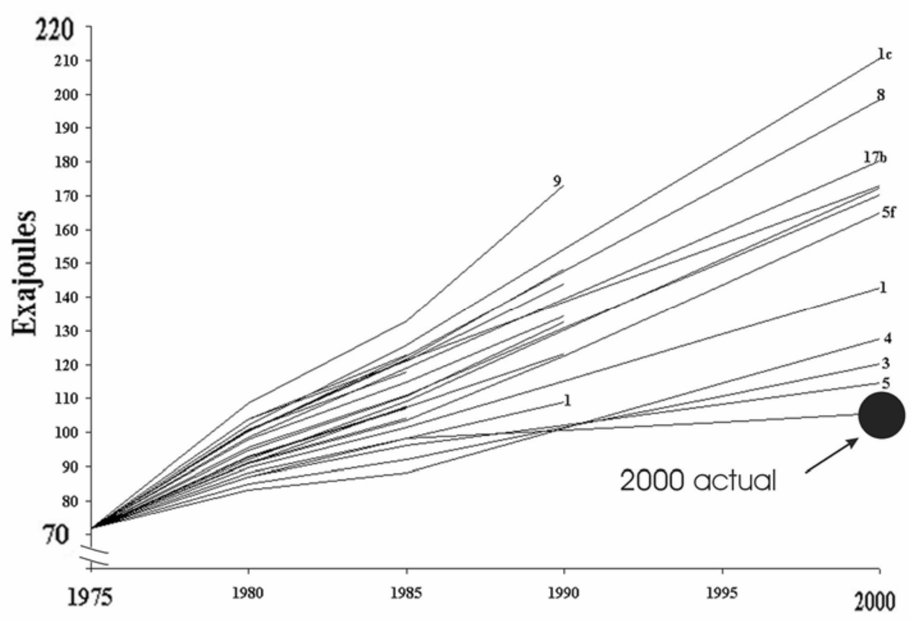
- Energy forecasting models have little or no ability to accurately predict future energy prices and demand (Craig et al. 2002)
- Even the sign of the impacts of proposed policies is a function of key assumptions (Repetto and Austin 1997)
- The dismal accuracy and inherent limitations of these models should make modelers modest in the conclusions they draw (Decanio 2003)

Craig, P., A. Gadgil, and J. Koomey (2002). "What Can History Teach Us? A Retrospective Analysis of Long-term Energy Forecasts for the U.S." *Annual Review of Energy and the Environment 2002*. R. H. Socolow, D. Anderson and J. Harte. Palo Alto, CA, Annual Reviews, Inc. (also LBNL-50498). **27:** 83-118.

Repetto, R. and D. Austin (1997). The Costs of Climate Protection: A Guide for the Perplexed. Washington, DC, World Resources Institute.

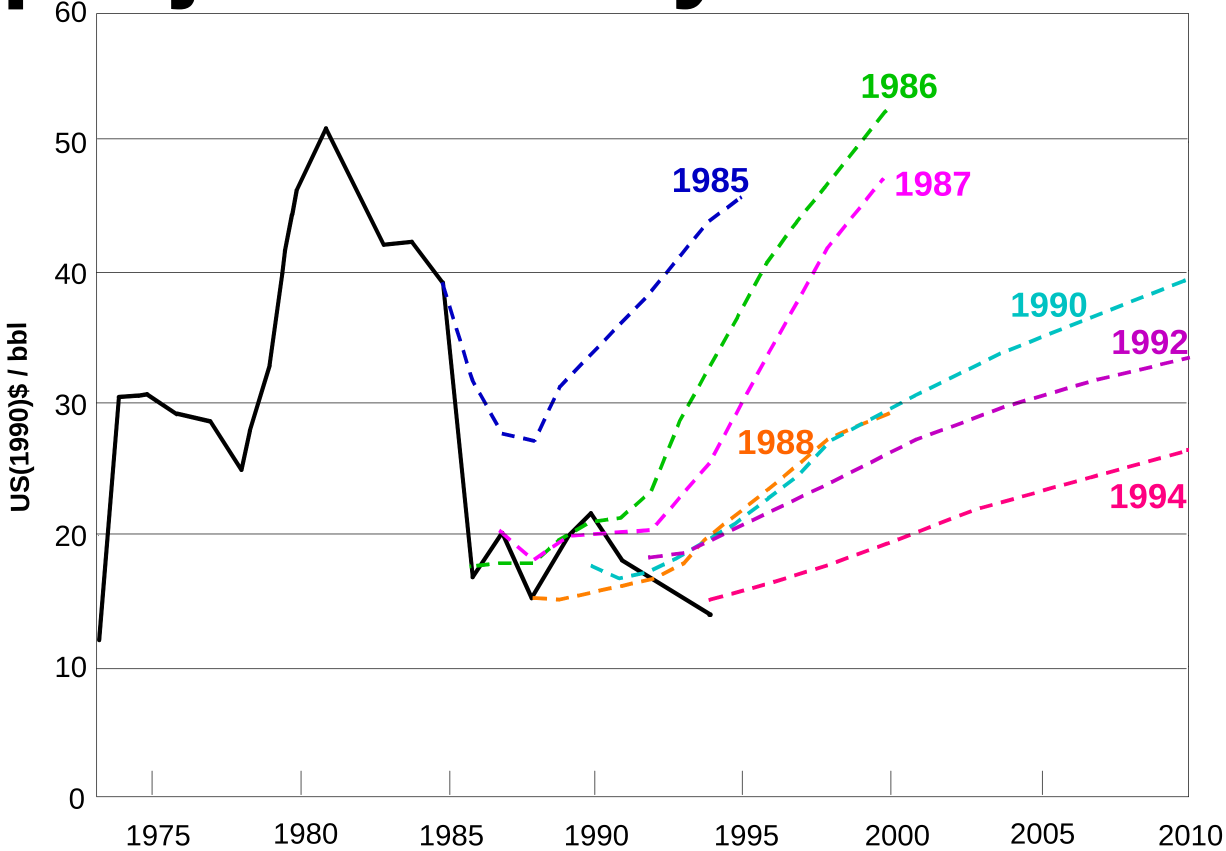
DeCanio, S. J. (2003). *Economic Models of Climate Change: A Critique*. Basingstoke, UK, Palgrave-Macmillan.

One example: 1970s projections of year 2000 U.S. primary energy



Source: Craig, Paul, Ashok Gadgil, and Jonathan Koomey. 2002. "What Can History Teach Us?: A Retrospective Analysis of Long-term Energy Forecasts for the U.S." In *Annual Review of Energy and the Environment 2002*. Edited by R. H. Socolow, D. Anderson and J. Harte. Palo Alto, CA: Annual Reviews, Inc. (also LBNL-50498). pp. 83-118.

Another example: Oil price projections by U.S. DOE



Source: BGR, 1998 (graph supplied by Arnulf Grubler, IIASA)

Why Are Long-term Energy Forecasts Almost Always Wrong?

- Core data and assumptions, which drive results, are based on historical experience, which can be misleading if conditions change
- The exact timing and character of pivotal events and technology changes cannot be predicted

Laitner, J.A., S.J. DeCanio, J.G. Koomey, A.H. Sanstad. (2003) “Room for Improvement: Increasing the Value of Energy Modeling for Policy Analysis.” *Utilities Policy*, 11, pp. 87-94.

Conditions for Model Accuracy

- Hodges and Dewar: models can be accurate when they describe systems that
  - are observable and permit collection of ample and accurate data
  - exhibit constancy of structure over time
  - exhibit constancy across variations in conditions not specified in the model

Source: Hodges, James S., and James A. Dewar. 1992. *Is it you or your model talking? A framework for model validation*. Santa Monica, CA: RAND. ISBN 0-8330-1223-1.

Implications for Forecast Results

- Forecasting models describing well-defined physical systems using correct parameters can be accurate because physical laws are geographically and temporally invariant
- Economic, social, and technological systems do not exhibit the required structural constancy, so models forecasting the future of these systems are doomed to be inaccurate. Three big sources of inconstancy
  - Pivotal events (like Sept. 11th or the 1970s oil shocks)
  - Technological innovation
  - Policy choices

Inaccurate forecasting models can still be useful

- As bookkeeping devices
- To help sell ideas or achieve political ends
- In training, communication, and education
- To clarify bounding cases
- To aid thinking and hypothesizing (e.g. scenarios, limited policy analyses)

Promoting Learning: Questions to Ask

1. Does the model represent technologies explicitly or does it rely solely on macroeconomic relationships?
2. Does the model assume perfect markets?
3. Is the model clearly documented and are the inevitable buried assumptions revealed?
4. Are the underlying data and algorithms reflective of the latest data and theory?
5. Have the forecasters conducted retrospective analyses to validate assumptions?

Promoting Learning: More Questions to Ask

6. Does the modeling exercise include a complete technology portfolio?
7. Does it include a complete policy portfolio?
8. What does it mean when a modeler says her scenario “includes” a technology or policy?
9. Are the modelers making “the big mistake” by using historical data that are inconsistent with the forecasted future?

Question 1: Does the model represent technologies explicitly or does it rely solely on macro-economic relationships?

- Without explicit technology representation
  - models cannot analyze resource potentials derived from physical principles
  - models cannot assess effects of policies that directly affect the efficiency of equipment purchases
  - models will overestimate costs
- Macroeconomic regression relationships are fine for short term forecasts, but are inadequate for forecasts of any duration longer than a few years

Question 2: Does the model assume perfect markets?

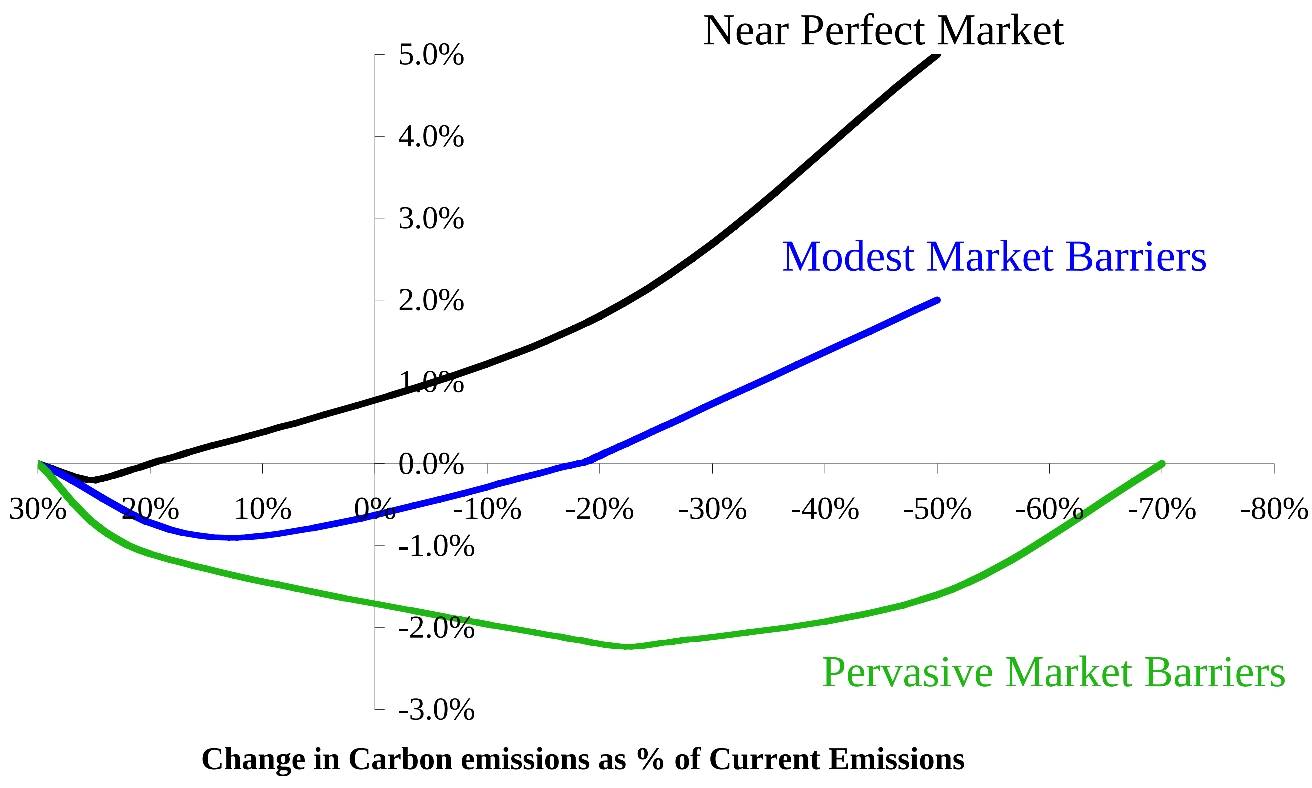
- Some widely recognized imperfections
  - Externalities (e.g. pollution)
  - Public goods (e.g. R&D)
  - Imperfect competition (e.g. natural monopoly)
  - Principal-agent problems
- Other real imperfections
  - Misplaced incentives (e.g. landlord/tenant, no separate prices on lighting just one total bill)
  - Imperfect/asymmetric/costly information (Arrow)
  - Transaction costs (Coase, Williamson)
  - Bounded rationality (Simon)
  - Institutional failures (eg utility bills in telecom)
- The big unaddressed issue: increasing returns

Increasing returns to scale and path dependence

- Economic models assume constant or decreasing returns to scale to ensure a single unique equilibrium and path independence, BUT
- Most real industries are characterized in important ways by increasing returns (implies path dependence and opportunities for simultaneously achieving environmental goals and improving economic growth)

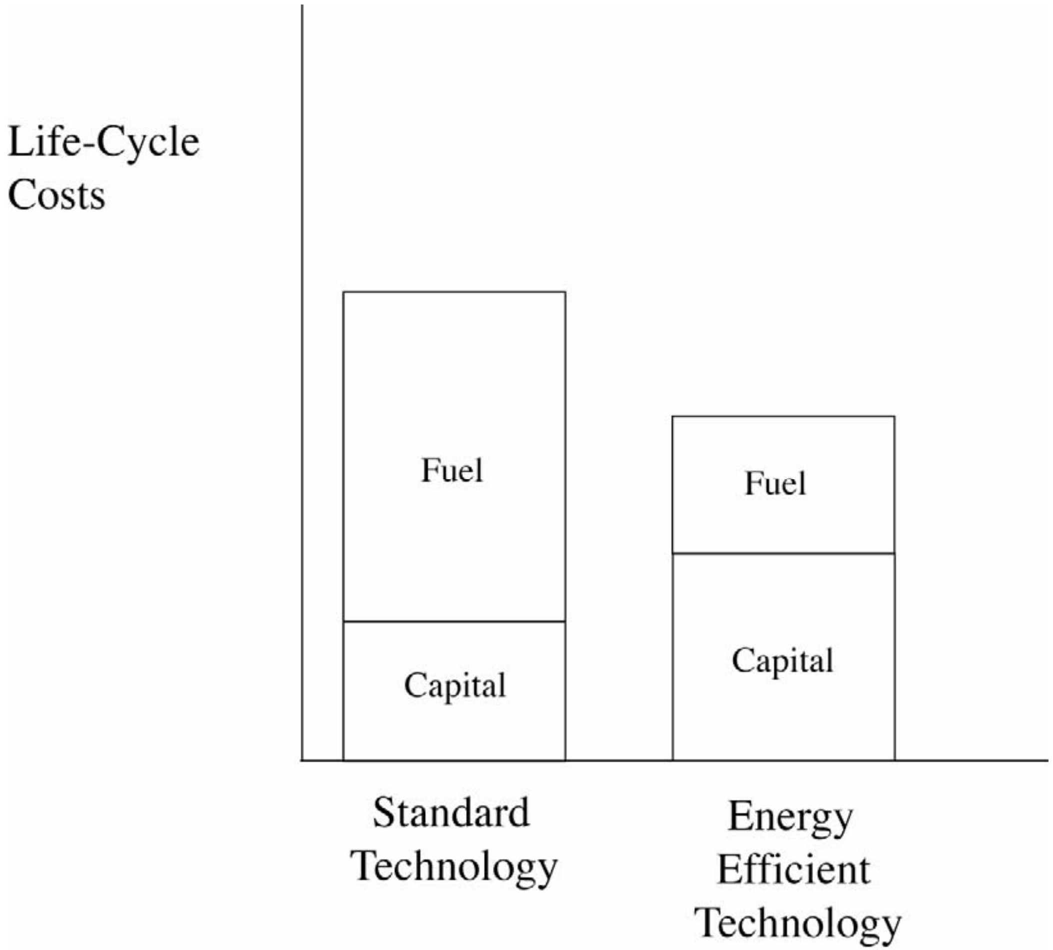
For details, see Brian Arthur, "Positive Feedbacks in the Economy," *Scientific American*, February 1990 pp. 92-98.

Three views of the costs of reducing GHG emissions

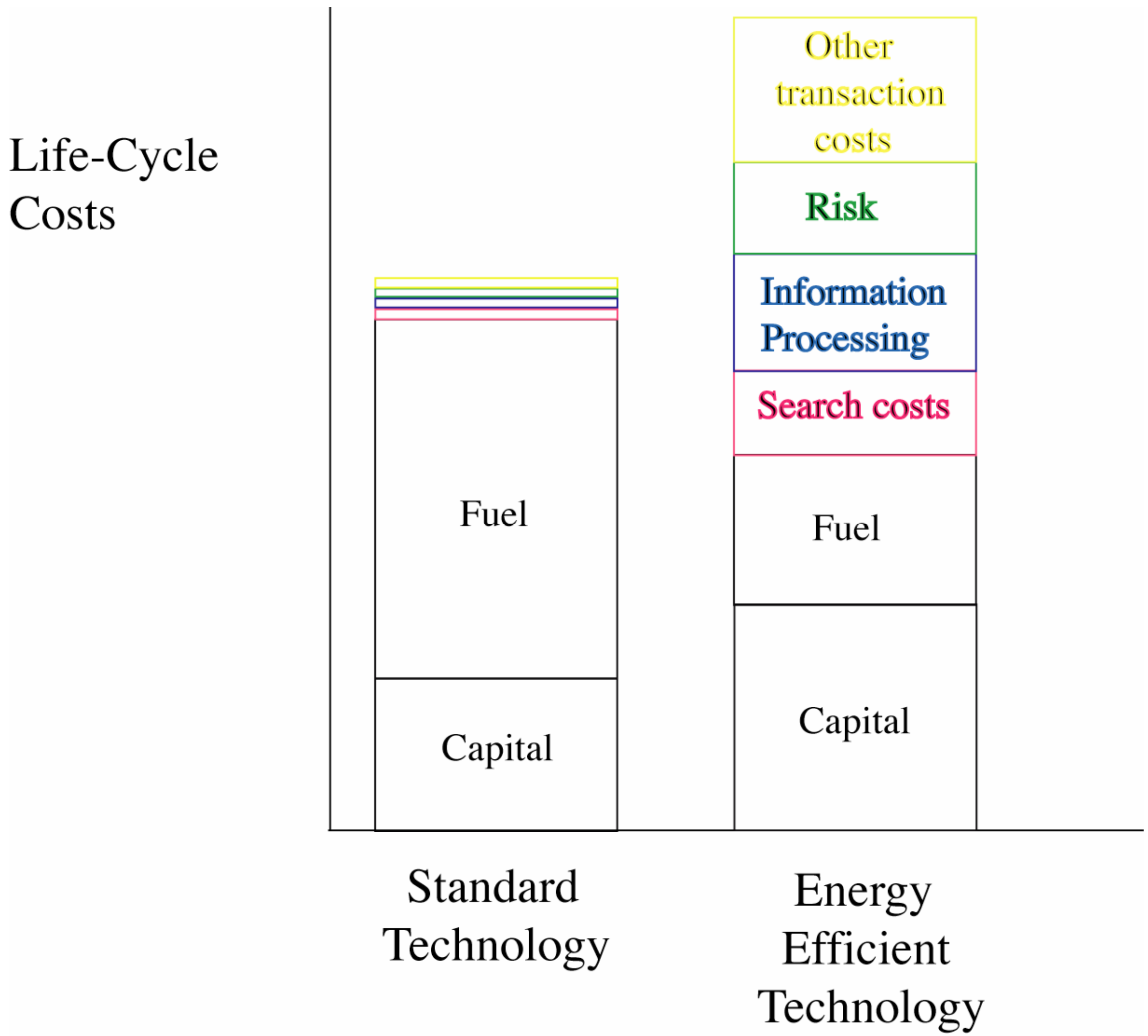


Imperfect markets: If efficiency is such a good idea, why don't people do it anyway?

Standard Engineering Economic Analysis

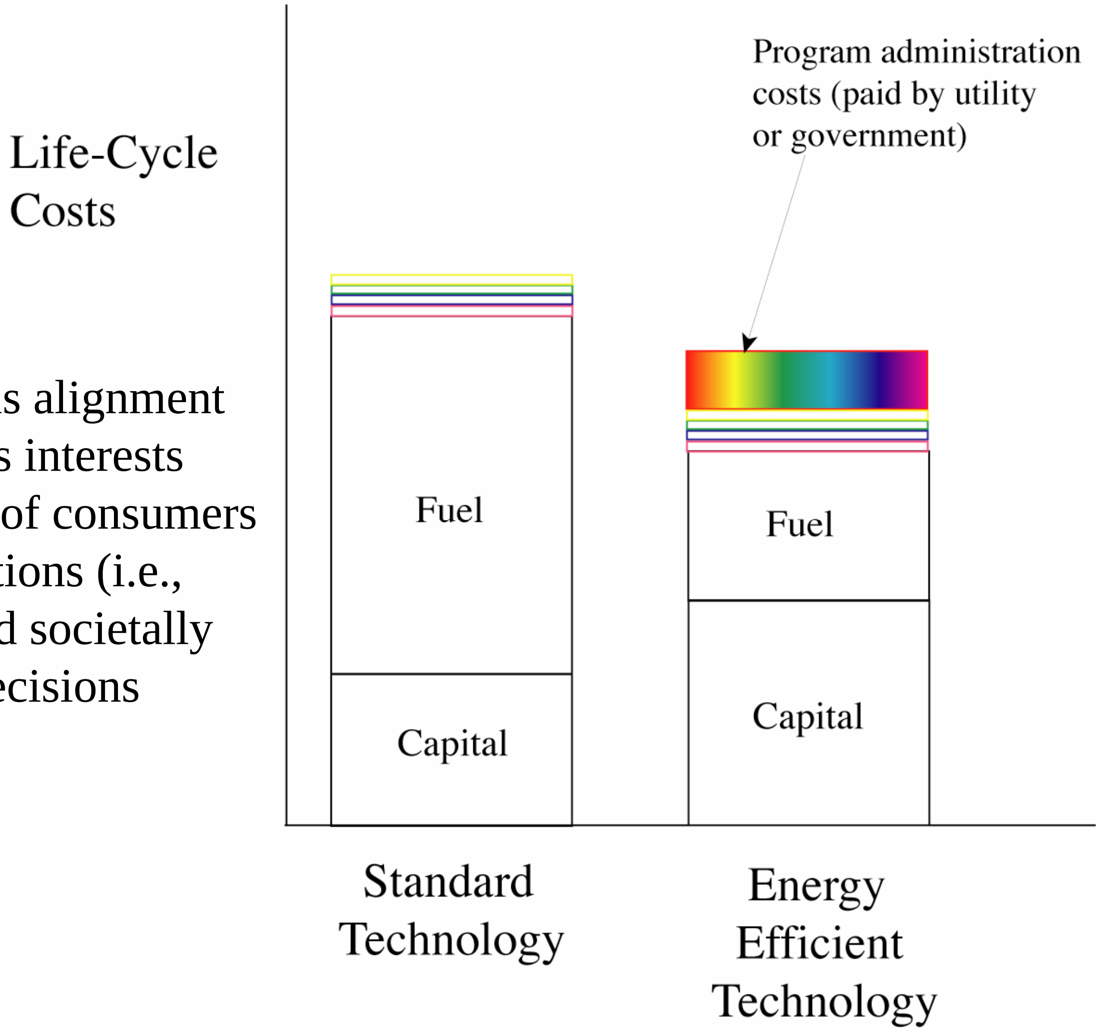


Imperfect markets: Consider transaction costs, risk, information processing, & search costs

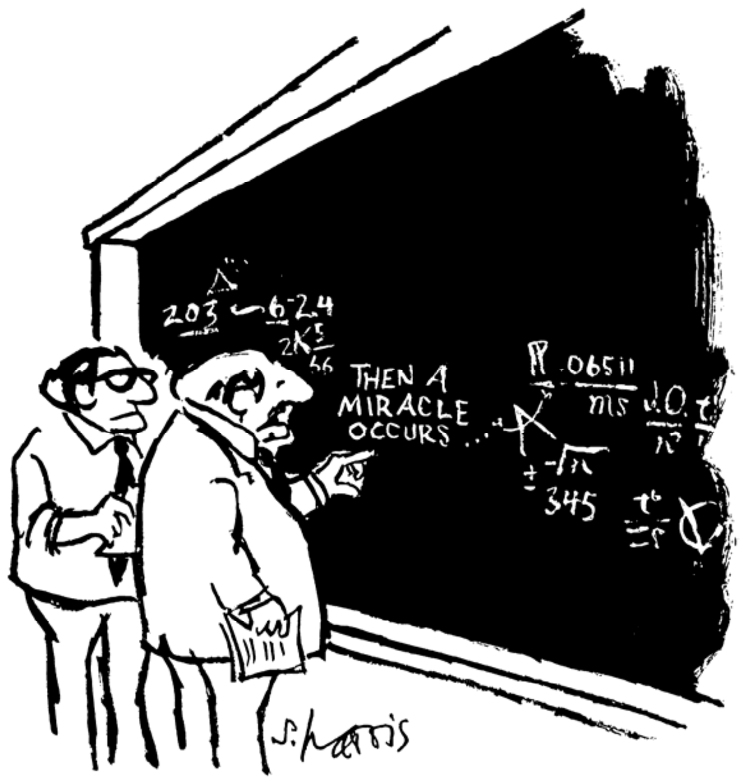


Imperfect markets: Some costs are reducible by utility and government programs

Net result is alignment of society's interests with those of consumers and institutions (i.e., rational and societally efficient decisions coincide)

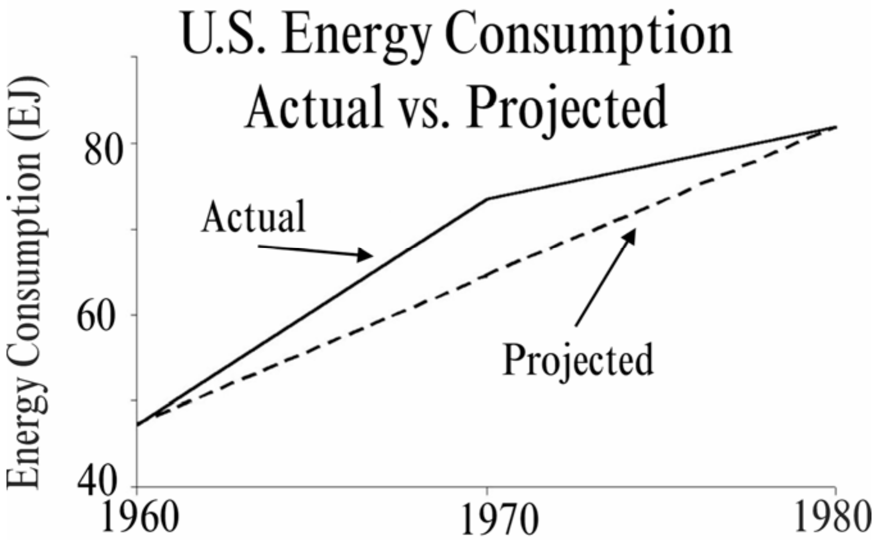


Question 3: Is the model clearly documented? Are the inevitable buried assumptions revealed?



"I think you should be more explicit here in step two."

Question 4: Have the forecasters conducted retrospective analyses?



Source: Landsberg, Hans H. 1985. "Energy in Transition: A View from 1960." *The Energy Journal*. vol. 6, pp. 1-18.

Also see Koomey, Jonathan G., Paul Craig, Ashok Gadgil, and David Lorenzetti. 2003. "Improving long-range energy modeling: A plea for historical retrospectives." *The Energy Journal (also LBNL-52448)*. vol. 24, no. 4. October. pp. 75-92.

Question 5: Are the underlying data and algorithms reflective of the latest program experience, data, and theory?

- Because of the time and expense to update them, model data and structures always lag reality
  - Example: 1990s model with 1970s data
- Economic theory has advanced greatly since the 1970s, but energy forecasting models generally don’t reflect that progress

William Ascher on data and methods

After reviewing the accuracy of dozens of different forecasts in his 1978 book, Ascher wrote "The core assumptions underlying a forecast…are the major determinants of forecast accuracy…When the core assumptions are valid, the choice of methodology is either secondary or obvious. When the core assumptions fail to capture the reality of the future context, other factors such as methodology generally make little difference; they cannot 'save' the forecast."

The Primacy of Data

- Data usually drive the results
- Models always lag behind theory, which lags behind reality

THEREFORE

- Data should be treated as more important than theory or models for robust planning and policy making

Question 6: Does the modeling exercise include a complete technology portfolio?

- Most models have poor representations of the most interesting technologies because these are new and/or difficult to model
  - Cogeneration
  - Efficiency
  - Wind
  - Biomass
  - Photovoltaics
  - Carbon capture and storage (sequestration)
- An incomplete technology portfolio overestimates mitigation costs

Question 7: Does exercise include a complete policy portfolio?

- Market reforms/technology programs
  - labeling and efficiency standards
  - feebates/fees/fuel taxes
  - marginal cost pricing
  - elimination of perverse incentives
  - golden carrots
- International allowance trading
- Tax shifts
- R&D
- An incomplete policy portfolio overestimates mitigation costs

Question 8: What does it mean when you say a technology or policy is "included" in the forecast?

- The conversation usually stops after the analyst assures the policy maker that the model "includes" the policy or technology
- Included doesn't necessarily mean it is handled correctly

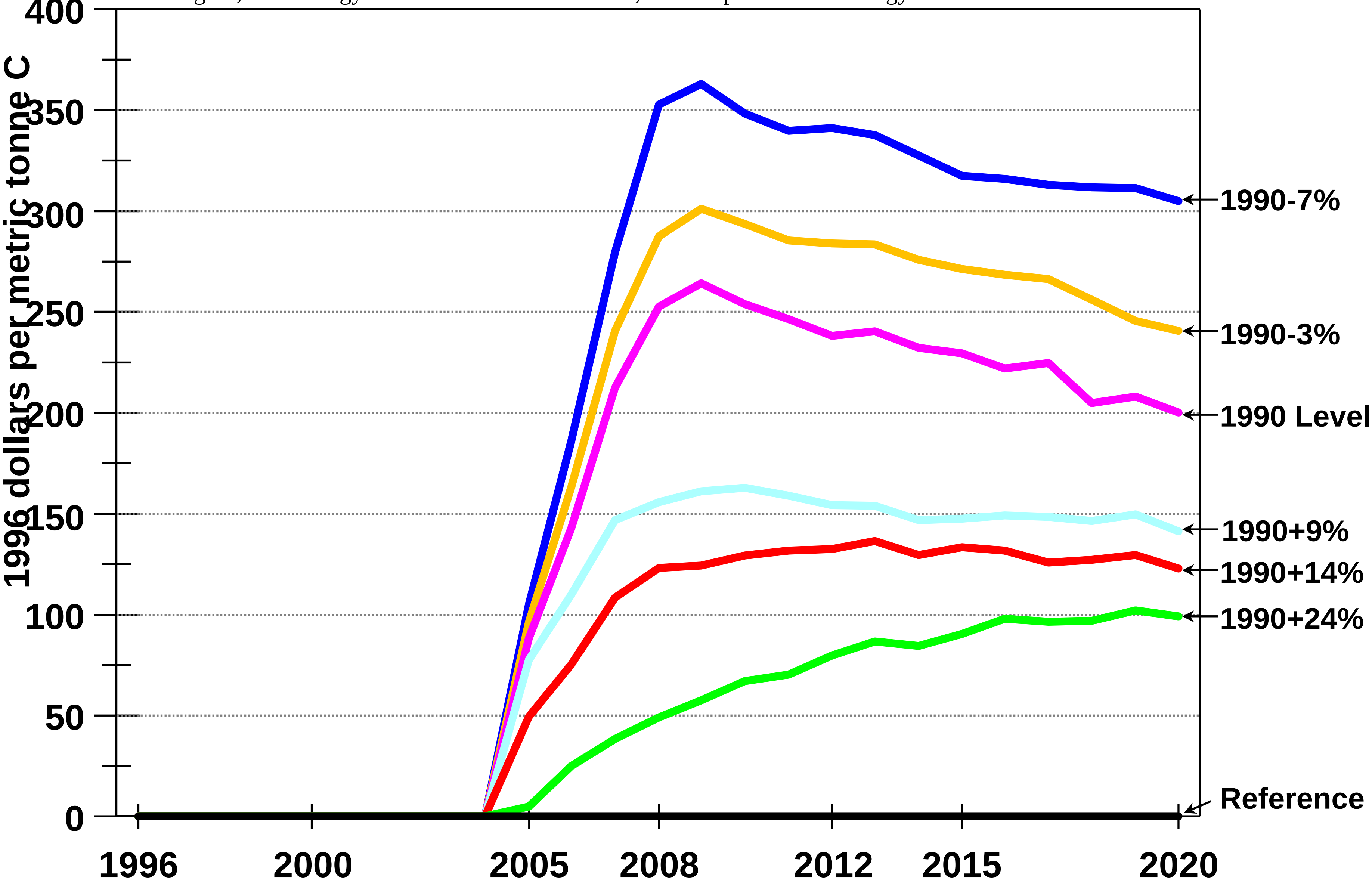
Question 9: Are the modelers making "the Big Mistake"?

- "The big mistake" occurs when modelers use historical data that are inconsistent with the forecasted future
  - Example: applying a $300/tonne carbon charge in a model but not changing the model's behavioral parameters. These parameters are almost always estimated based on history that didn't include such a large carbon charge, so any forecasting results are necessarily suspect.

Koomey, Jonathan. 2002. "From My Perspective: Avoiding "The Big Mistake" in Forecasting Technology Adoption." *Technological Forecasting and Social Change*. vol. 69, no. 5. June. pp. 511-518.

Making the Big Mistake: Carbon Prices 1996-2020

Source: US DOE. 1998. *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*. Washington, DC: Energy Information Administration, U.S. Department of Energy. SR/OIAF/98-03. October.



Conclusions

- Solving climate and oil dependence problems require reliance on long-term forecasting models, BUT the results of such models are notoriously unreliable
- Inaccurate forecasts can still be useful
- Core assumptions drive the results
  - Compiling accurate data is more important than refining complex algorithms (e.g., non-fossil resource potential data in assessments of the costs of carbon reductions)

Conclusions (2)

- Energy modelers’ claims should
  - be more modest
  - be informed by retrospectives
  - avoid the word “optimal”
- Disruptive innovations and other surprises can’t be predicted but can be anticipated
  - use scenario analysis
  - develop robust scenarios and think them through
- Many emphasize uncertainties in the scientific models but take as gospel the results of economic models that are far less reliable than those based on physical science

Some Key References

- Craig, Paul, Ashok Gadgil, and Jonathan Koomey. 2002. "What Can History Teach Us?: A Retrospective Analysis of Long-term Energy Forecasts for the U.S." In *Annual Review of Energy and the Environment 2002*. Edited by R. H. Socolow, D. Anderson and J. Harte. Palo Alto, CA: Annual Reviews, Inc. pp. 83-118.
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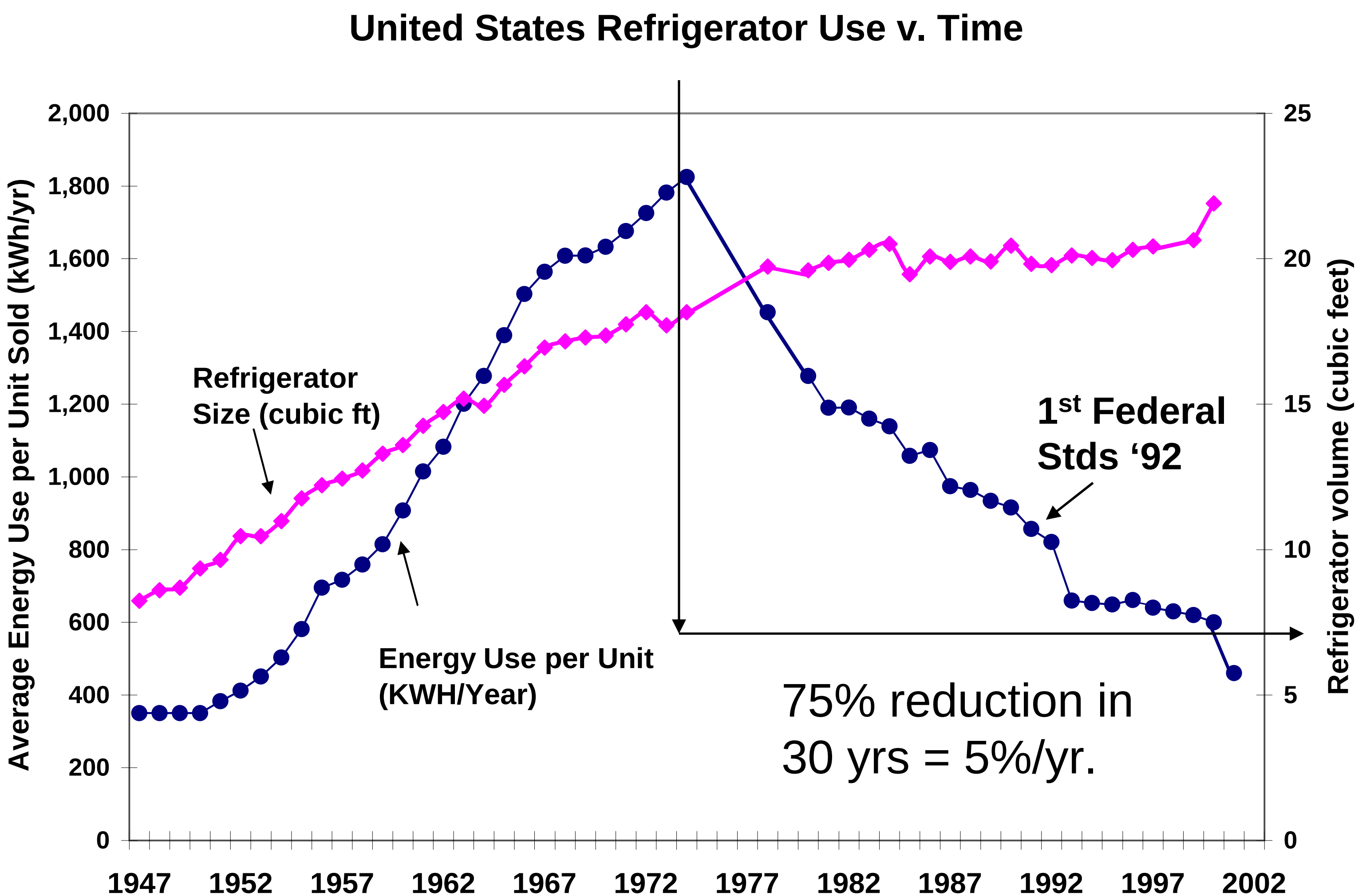
Extra slides

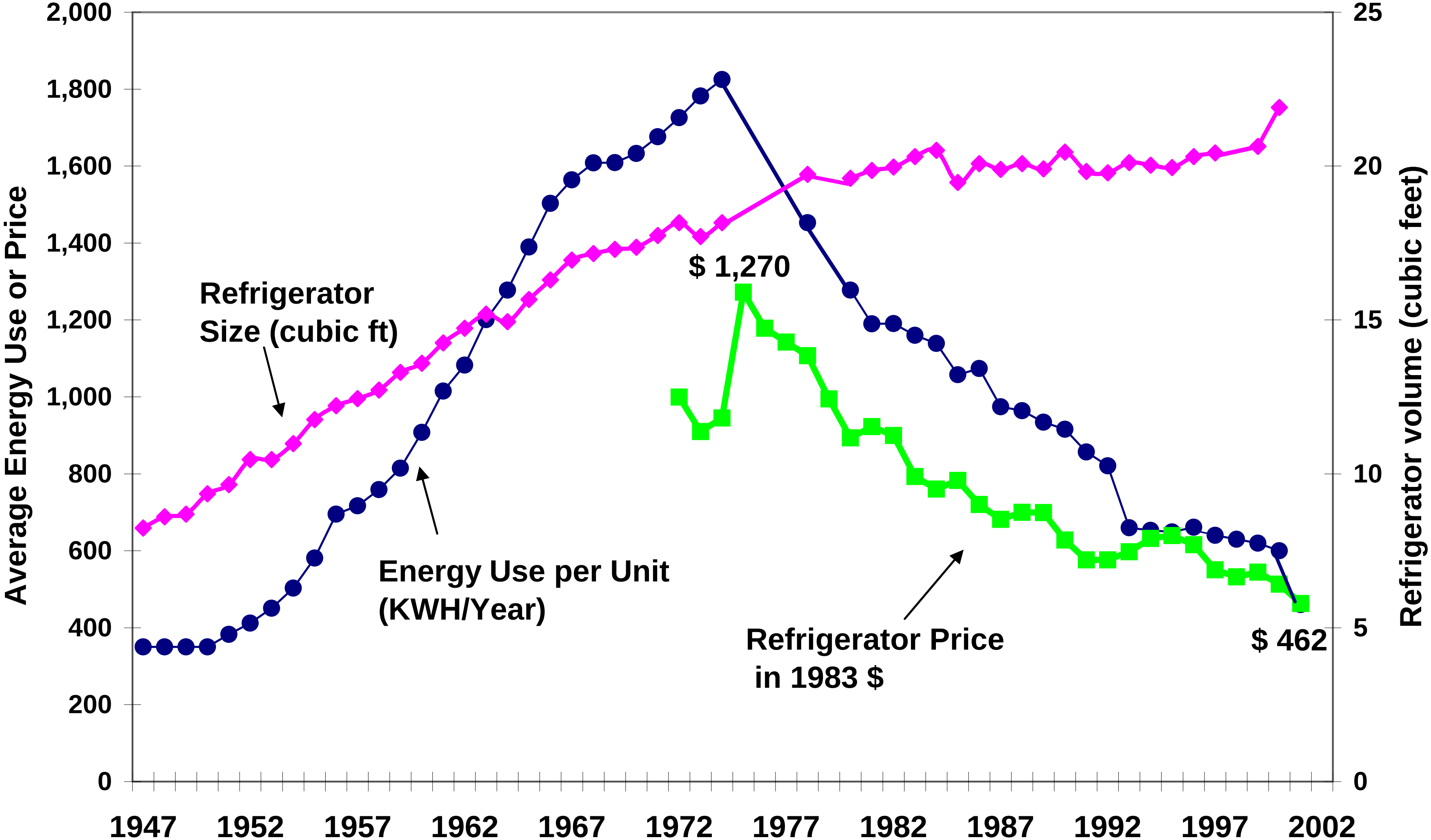
Market imperfections = efficiency opportunities in U.S. refrigerators



Source of Data: David Goldstein

Slide courtesy of Art Rosenfeld, California Energy Commission

Market imperfections = efficiency opportunities in U.S. refrigerators (2)



Source: David Goldstein

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