engineering and public policy

Preparing Technical Leaders to Address Policy Issues that Involve Science and Technology.

CEDM

"Muddling Through" is Good Climate Policy…but Not Enough

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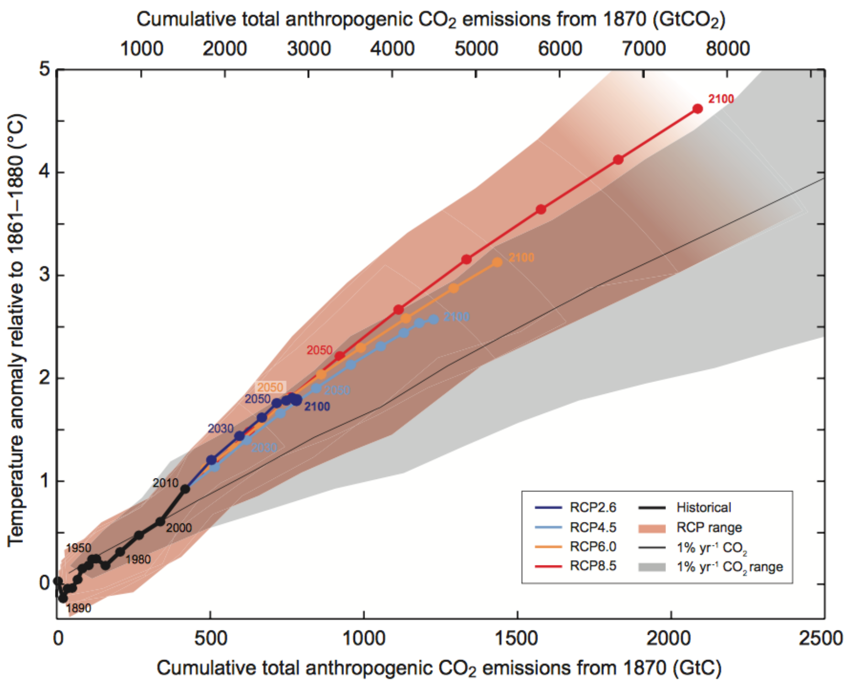
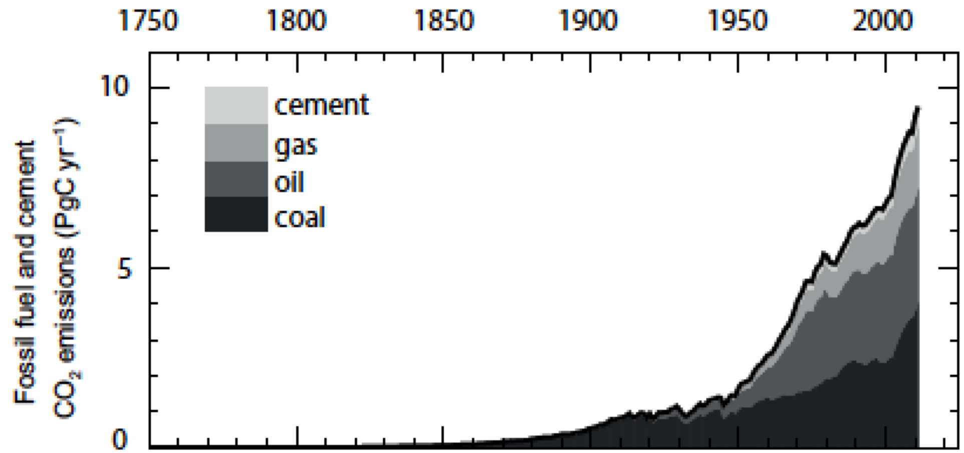
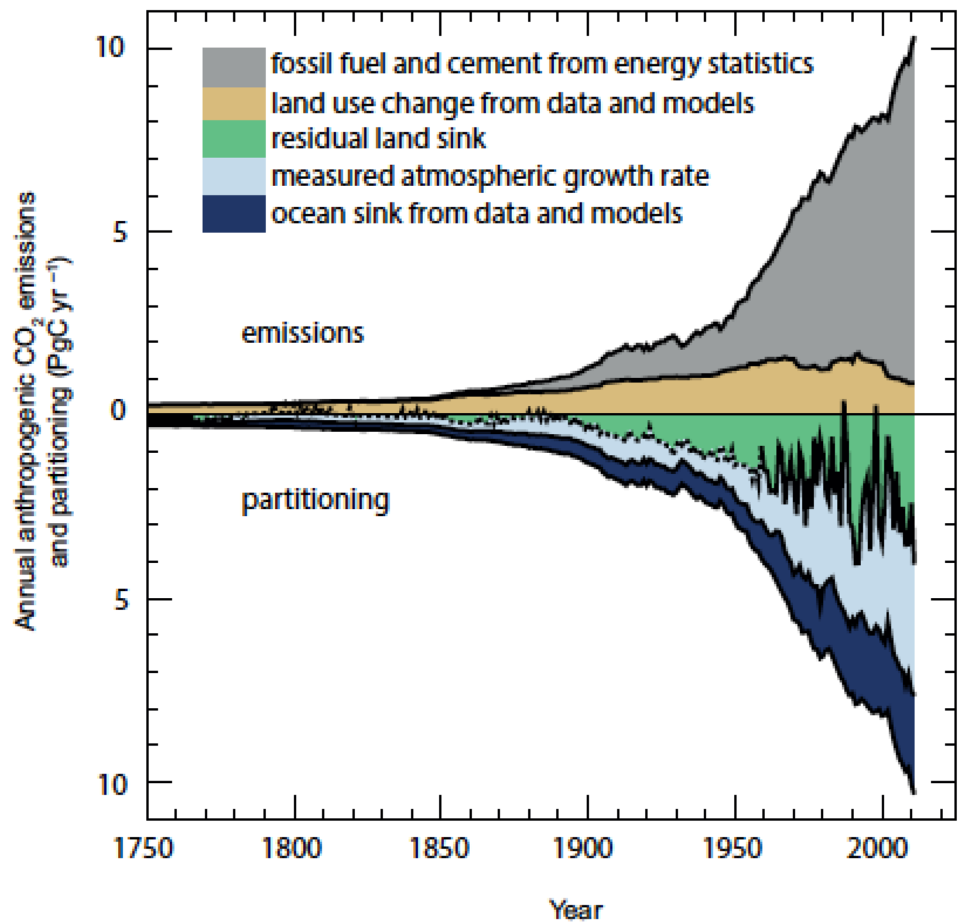
To zeroth order.

…the climate problem
is the energy problem



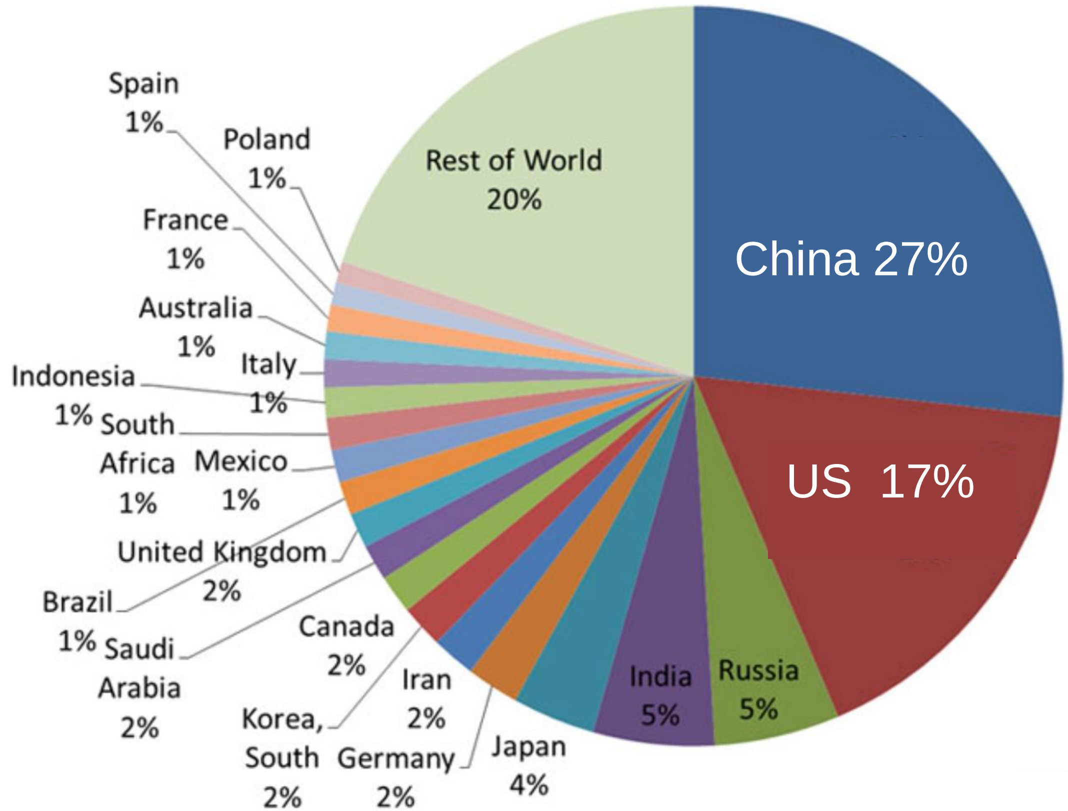




Source: IPCC AR5 WG1

So…how are we going to decarbonize the world's energy system?

International negotiations among ~180 nations are all well and good but what we really need is serious reductions by half a dozen nations or regions.



Source: UCS from EIA 2011 data

Managing carbon from the bottom up

POLICY FORUM: CLIMATE CHANGE

Managing Carbon from the Bottom Up

M. Granger Morgan

The world needs to get serious about managing the exponential growth of atmospheric carbon dioxide (CO_2). However, because uncertainties about climate science provide convenient political cover for economic interests that favor delay, the United States is unlikely to sign any comprehensive international agreement in the near future. Whether Europe and others can muster the political will to unilaterally implement the Kyoto protocol is an open question. Even if they do, the Kyoto agreement is at best a modest first step toward the essential goal of stabilizing atmospheric concentrations. Although they may be prepared to take symbolic steps, China, India, Brazil, and other large industrializing states will certainly not agree to serious constraints on their emissions in the near future. Diplomats will put a good face on things, but for at least the next decade, it is unlikely that all the world's major states will simultaneously agree to a serious program to curtail emissions of CO_2 and other greenhouse gases (*1*, *2*).

Fortunately, a universal top-down framework is not the only route to a global regime for managing CO_2. Norway (*3*), the Netherlands (*4*), and others have begun to take unilateral action. Although dismissed by some as limited and self-serving, such efforts reflect genuine moral and political commitment by the citizens of these states. The history of international environmental protection shows that effective regimes start slowly. The diplomatic community should work to encourage the growth of local and regional regimes and to promote their coordination, so that they can ultimately coalesce into a comprehensive set of global arrangements.

An evolutionary bottom-up strategy has several benefits. It can start today. As early adopters try different strategies, the world can evaluate and learn from alternative approaches. Early adopters can provide the inspiration, and proof of concept, to inspire or shame citizens in other regions, such as the United States and Canada, to take action. Some will argue that a bottom-up approach can never work, because nobody will go first, fearing competitive disadvantage.

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However, environmental policies are more often determined by broad considerations of public values than by any narrow calculus of benefit-cost. Growing numbers of people believe that the world must act and are willing to assume some extra burden to do the right thing and to provide an example.

The prospects for success with a bottom-up strategy would increase substantially if the diplomatic community softened its single-minded preoccupation with Kyoto and began to provide greater support and encouragement to early adopters. For example, some states or regions may impose a domestic carbon emissions tax. To avoid disadvantaging their own industry in domestic markets, they may want to impose nondiscriminatory border adjustment tariffs on the CO_2 releases that are implicit in imports. Similarly, states may wish to provide subsidies to cover the incremental cost to firms of adopting low-emission technologies. For example, it is rapidly becoming practical to separate hydrogen from hydrocarbon fuels and to sequester the CO_2 in geological formations at depths of several kilometers. In contrast to electric power from photovoltaics, which currently costs about 10 times as much as conventional fossil electric power, carbon separation and sequestration may cost as little as 20 to 30% more than a conventional coal plant (*5*–*6*). That makes it economically attractive, but wide adoption would still require a regulatory requirement or a subsidy.

Today, border adjustment tariffs and subsidies to support carbon management activities would likely encounter difficulties with World Trade Organization rules (*7*). But, trade rules are always in flux, and multilateral agreements are treated more favorably than unilateral initiatives. With some effort, the diplomatic community might find ways to allow border adjustment taxes and subsidies designed to address global pollutants, even if such policies continued to be disallowed for states addressing local or regional environmental problems.

The diplomatic community could also help by developing forums to address a number of the problems that must be resolved in a bottom-up strategy. These include the following:

- How can the international community speed adaptive learning based on a sharing of experiences of early adopters?
- How might different carbon management strategies, such as emissions taxes and trading regimes, best be harmonized?
- What problems will multinational firms operating in several jurisdictions face? How can such problems be eased? How can more such firms be encouraged to become agents for early action and learning?
- How can the safety and reliability of geological sequestration be assured so that early actions of single states do not create long-term problems for all?
- What international oversight is needed of other geoengineering strategies, such as deep ocean disposal of CO_2, ocean fertilization, and strategies to modify the earth's overall reflectivity or albedo, which, while they can be adopted by individual states, could have global consequences?
- What additional steps can be taken for the equitable transfer of clean energy technologies to the industrializing world?
- How can the world's industrialized states cooperate to dramatically increase their support for basic energy-technology research?

Free markets are great for inducing efficient allocation of scarce resources and for commercializing existing knowledge. However, if the world is going to make a major transition to a more sustainable energy system, it will need to develop cleaner, low cost, energy systems by dramatically increasing current investments in basic energy-technology research.

A single international accord is not the only starting place from which to move toward serious global management of CO_2 and other greenhouse gases. If we act now to encourage initiatives by individual states and regions, the world can learn from these efforts and begin to move, in a progressively more coordinated way, toward a more sustainable future (*8*).

References and Notes

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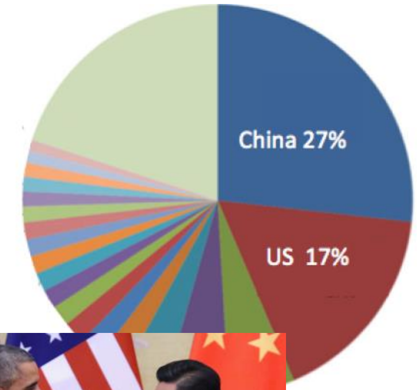
9. I thank H. Dowlatabadi, A. Farrell, H. Jacoby, D. Keith, G. Skolnikoff, and D. Victor for helpful discussions. This work is supported by NSF grant SBR-9521914 and by Carnegie Mellon University Academic Funds.

Source: *Science*, 2000 Sep 29.

In that light…



…because it covers close to half the worlds CO_2 emissions, the recent bilateral agreement with China is a very important step forward.

Photo by Feng Li/Getty Images

It may involve incremental "muddling" but for the first time it gets the two nations that produce the most CO_2 emissions discussing concrete steps.

Chinese emissions are to peak by 2030 *and not grow thereafter* (i.e., exponential growth in CO_2 emissions will end).

EDF reports that at present China has carbon trading programs in five cities and two provinces that cover >2000 sources (16% of total GHG emissions).

Here in the U.S….

…while the Waxman-Markey Bill was not perfect, clearly it would have offered a better way forward than using Section 111 of the CAC. However, it's better to get started with something than continue to doing nothing.

111TH CONGRESS
1ST SESSION

H. R. 2454

AN ACT

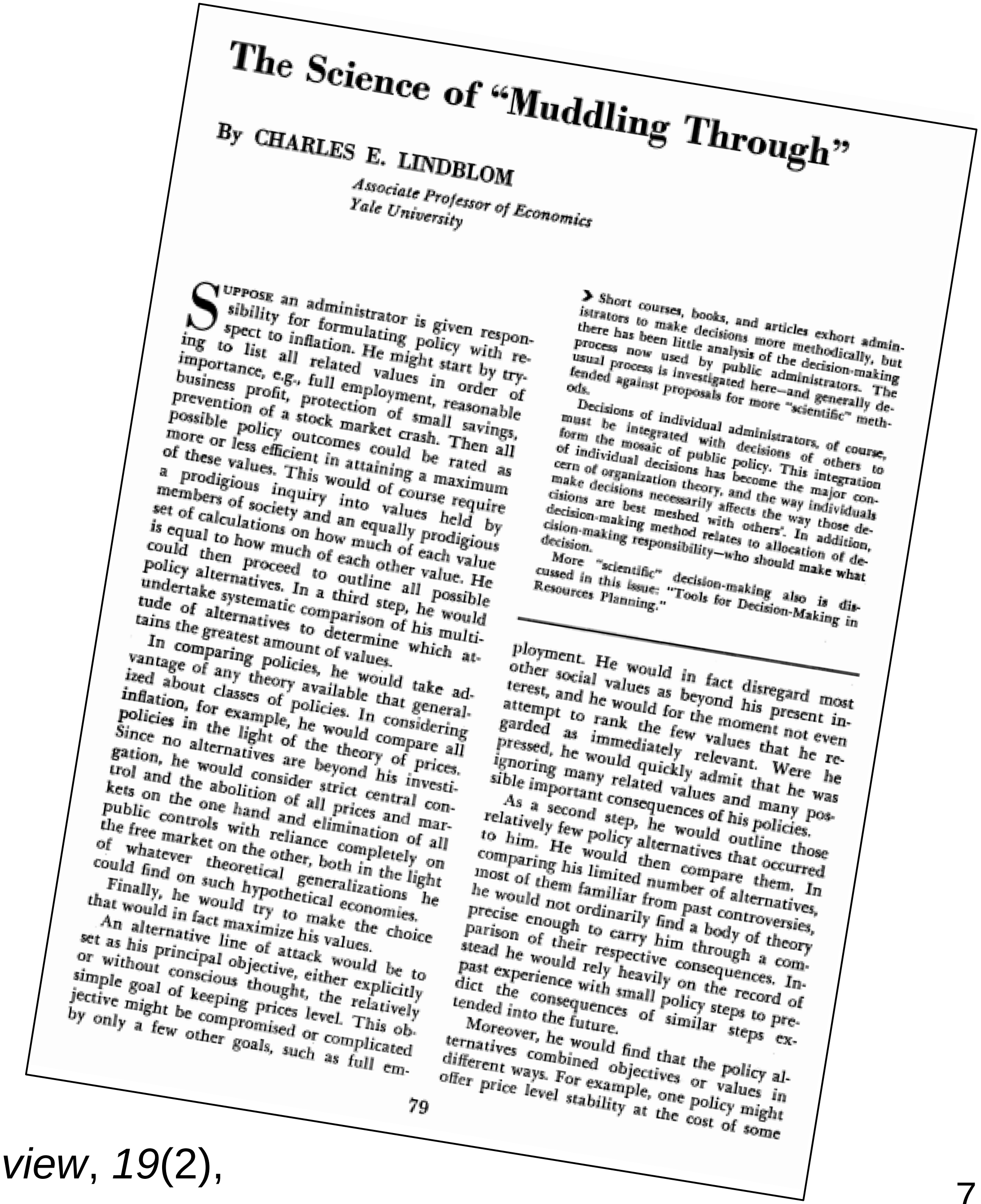
To create clean energy jobs, achieve energy independence, reduce global warming pollution and transition to a clean energy economy.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Source: U.S. GPO.

The Science of Muddling Through

More than half a century ago political scientist Charles Lindblom argued that such “muddling through” with incremental steps is frequently superior to attempting to design and implement comprehensive policy solutions.



The Science of "Muddling Through"

By CHARLES E. LINDBLOM

Associate Professor of Economics
Yale University

SUPPOSE an administrator is given responsibility for formulating policy with respect to inflation. He might start by trying to list all related values in order of importance, e.g., full employment, reasonable business profit, protection of small savings, prevention of a stock market crash. Then all possible policy outcomes could be rated as more or less efficient in attaining a maximum of these values. This would of course require a prodigious inquiry into values held by members of society and an equally prodigious set of calculations on how much of each value is equal to how much of each other value. He could then proceed to outline all possible policy alternatives. In a third step, he would undertake systematic comparison of his multitude of alternatives to determine which attains the greatest amount of values.

In comparing policies, he would take advantage of any theory available that generalized about classes of policies. In considering inflation, for example, he would compare all policies in the light of the theory of prices. Since no alternatives are beyond his investigation, he would consider strict central control and the abolition of all prices and markets on the one hand and elimination of all public controls with reliance completely on the free market on the other, both in the light of whatever theoretical generalizations he could find on such hypothetical economies.

Finally, he would try to make the choice that would in fact maximize his values.

An alternative line of attack would be to set as his principal objective, either explicitly or without conscious thought, the relatively simple goal of keeping prices level. This objective might be compromised or complicated by only a few other goals, such as full employment. He would in fact disregard most other social values as beyond his present interest, and he would for the moment not even attempt to rank the few values that he regarded as immediately relevant. Were he pressed, he would quickly admit that he was ignoring many related values and many possible important consequences of his policies.

As a second step, he would outline those relatively few policy alternatives that occurred to him. He would then compare them. In comparing his limited number of alternatives, most of them familiar from past controversies, he would not ordinarily find a body of theory precise enough to carry him through a comparison of their respective consequences. Instead he would rely heavily on the record of past experience with small policy steps to predict the consequences of similar steps extended into the future.

Moreover, he would find that the policy alternatives combined objectives or values in different ways. For example, one policy might offer price level stability at the cost of some

> ➤ Short courses, books, and articles exhort administrators to make decisions more methodically, but there has been little analysis of the decision-making process now used by public administrators. The usual process is investigated here—and generally defended against proposals for more "scientific" methods.
>
> Decisions of individual administrators, of course, must be integrated with decisions of others to form the mosaic of public policy. This integration of individual decisions has become the major concern of organization theory, and the way individuals make decisions necessarily affects the way those decisions are best meshed with others'. In addition, decision-making method relates to allocation of decision-making responsibility—who should make what decision.
>
> More "scientific" decision-making also is discussed in this issue: "Tools for Decision-Making in Resources Planning."

Source: *Public Administration Review*, *19*(2), pp. 79-88, Spring 1959.

However…

…if climate policy is ultimately to be successful, "muddling" will need to be combined with some longer-term "visioning."

Modest first steps that reduce emissions of greenhouse gases are wonderful, but to stabilize the climate the world must reduce emissions of greenhouse gases by at least an order of magnitude.

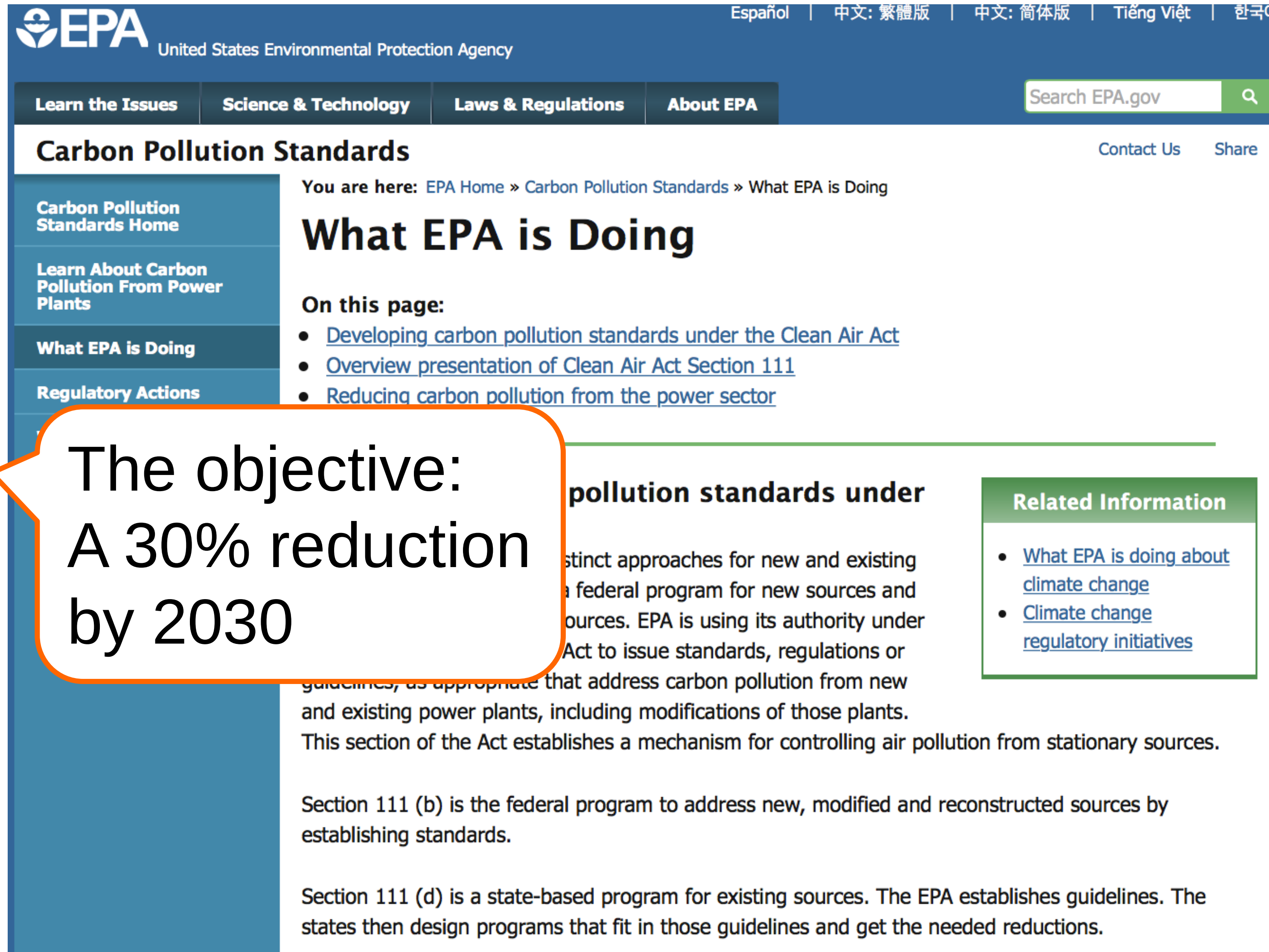
It is not too soon to start thinking about how to avoid getting stuck with policies that do not scale up – how to avoid regulatory lock-in and to move past early incremental steps to achieve deep reductions.

The U.S. is finally getting serious

Under 111(b)
New sources:
1,000/1,100
lb CO_2/MWh

Under 111(d)
Four blocks:
1) Increase coal boiler heat rate efficiency
2) Re-dispatch to lower CO_2 emitting sources
3) Create low/zero carbon generating sources
4) Improve electricity efficiency

AND ~20 states and ~1000 city mayors have their own plans, with CA clearly the most serious.



The objective:
A 30% reduction by 2030

This will be implemented…

…differently in each state. Groups of states can also cooperate to come up with regional solutions.

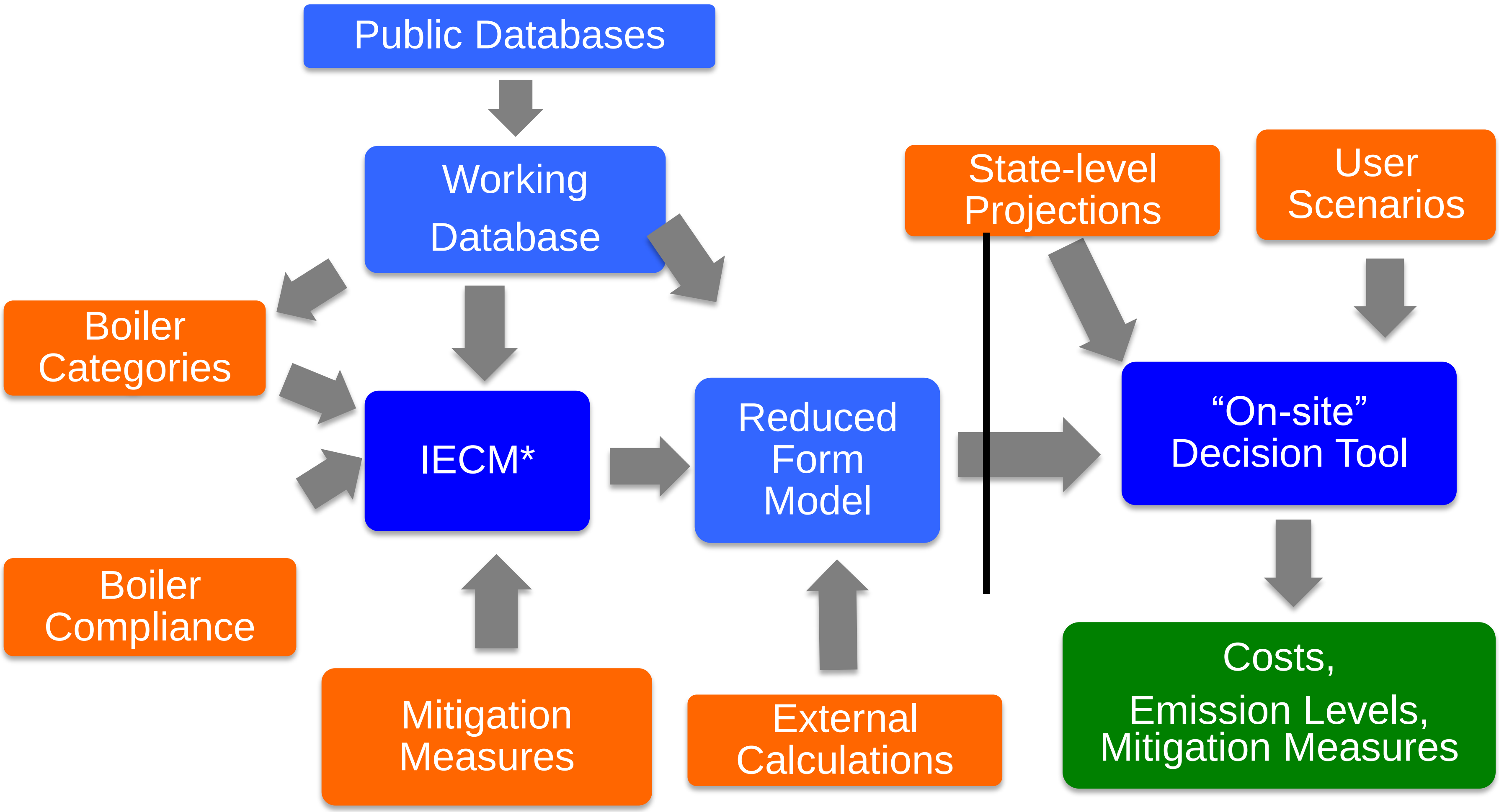
To assist in this process my colleagues Paul Fischbeck, Haibo Zhai and Jeffrey Anderson have developed a model that characterizes every coal-fired boiler in the U.S.

Paul

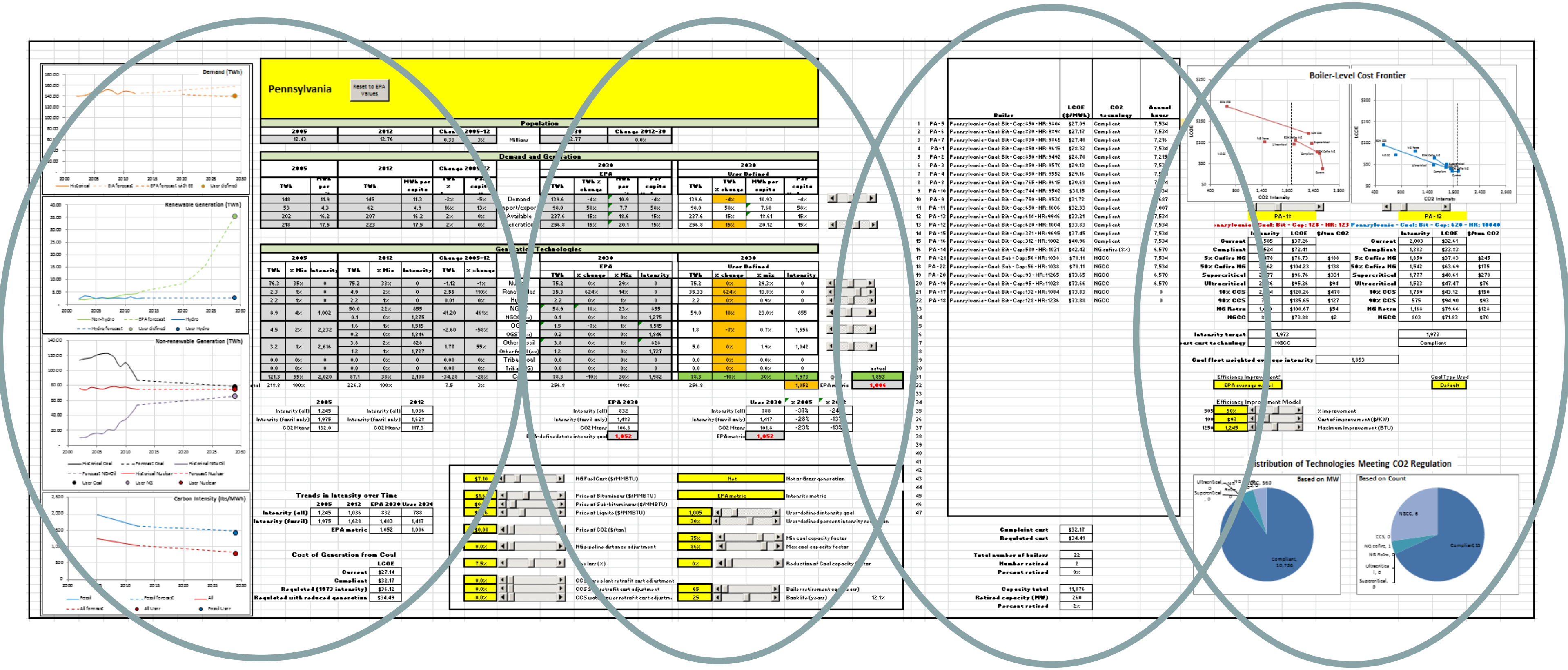
Haibo

Jeff

Decision Tool Task Structure



User interface



Historical Context

2030 Forecast

State-level details

Boiler-specific details

However…

…there is a risk that a plethora of different state and other strategies that result in some limited reduction in CO_2 emissions will not readily scale-up to larger future reductions.

While I will not talk about it today, there may be similar international risks (e.g., ICAO on CO_2 from airlines).


Images from: Lymedisease.org; coolfunpics.com;clicker.com

Hopefully…

…litigation will not derail the present U.S. effort under CAC Section 111, and the U.S. will achieve the EPA's goal of reducing power sector emissions to 30% below 2005 levels by 2030.

But 30% is only a less than a third of what will ultimately be needed. Moving beyond the resulting complex patchwork of state-by-state regulatory solutions will likely pose big challenges.

We should applaud…

…incremental progress on emissions reductions in the face of implacable political opposition. But there is no escaping the need for an order of magnitude reduction in global emission of greenhouse gases.

Changing complex regulatory systems once they become firmly established can be *extremely* difficult.

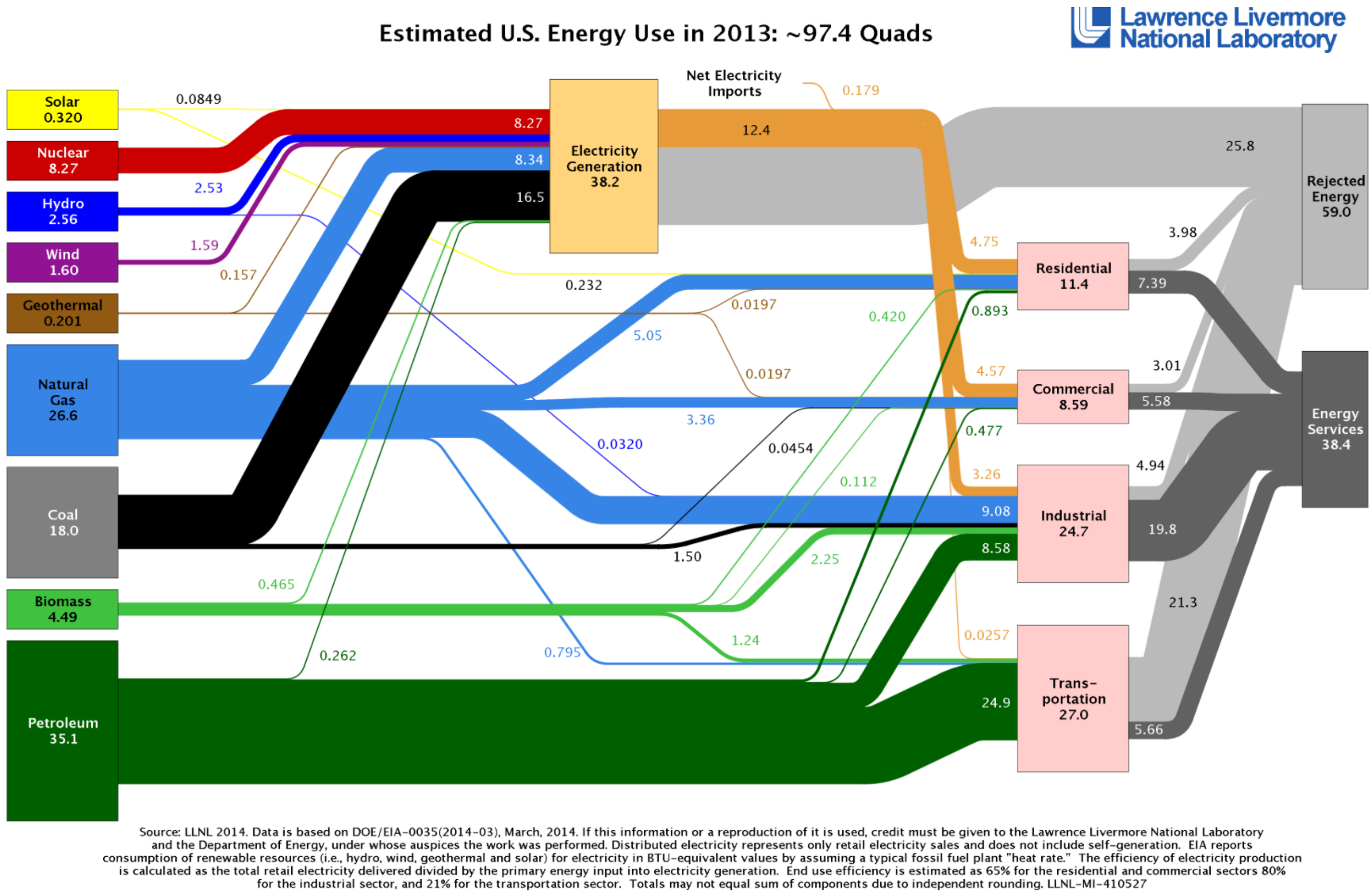
Hence I believe that for…

…each piece of incremental progress, the policy research community must start *now* to ask how best to avoid technical or policy lock-in or dead ends, and identify strategies that will readily allow a scale up to larger future reductions.

The resulting challenges in regulatory and policy design will be daunting. However, without those designs, progress could stall.

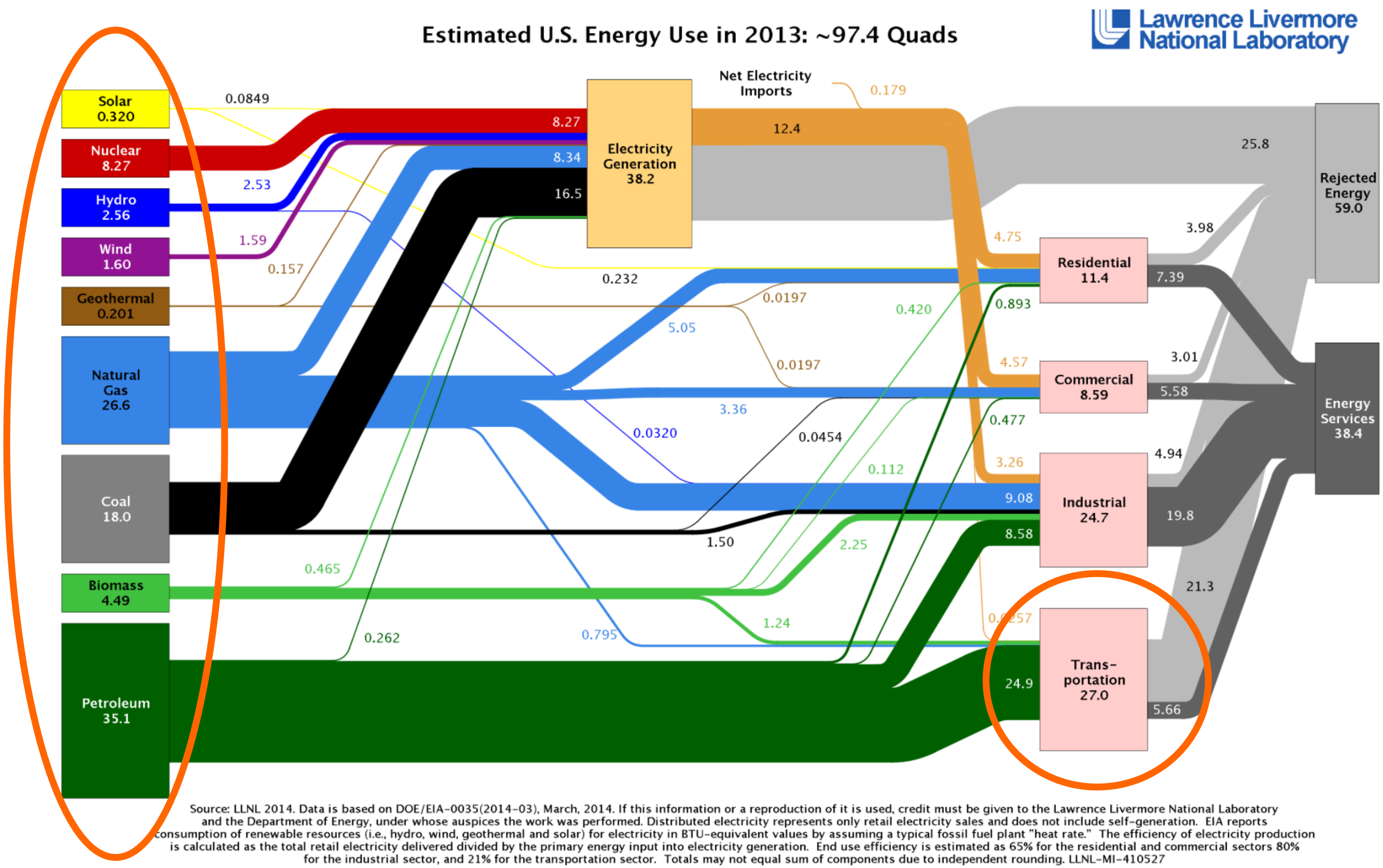
The success of today should not become the burden of tomorrow.

The U.S. Energy System



Source: https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2013.png

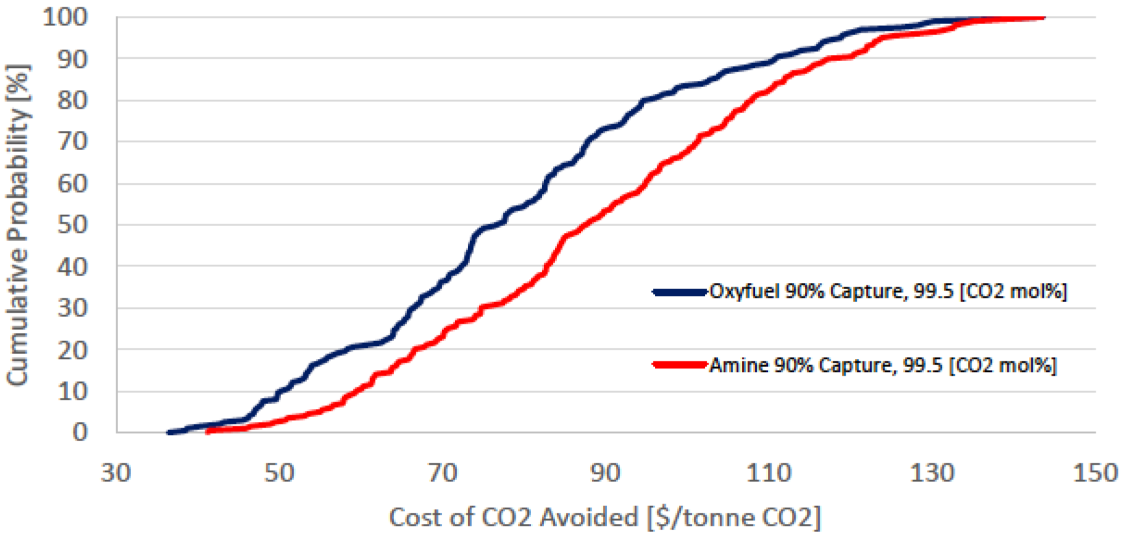
Promote low/zero CO_2 energy



Source: https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2013.png

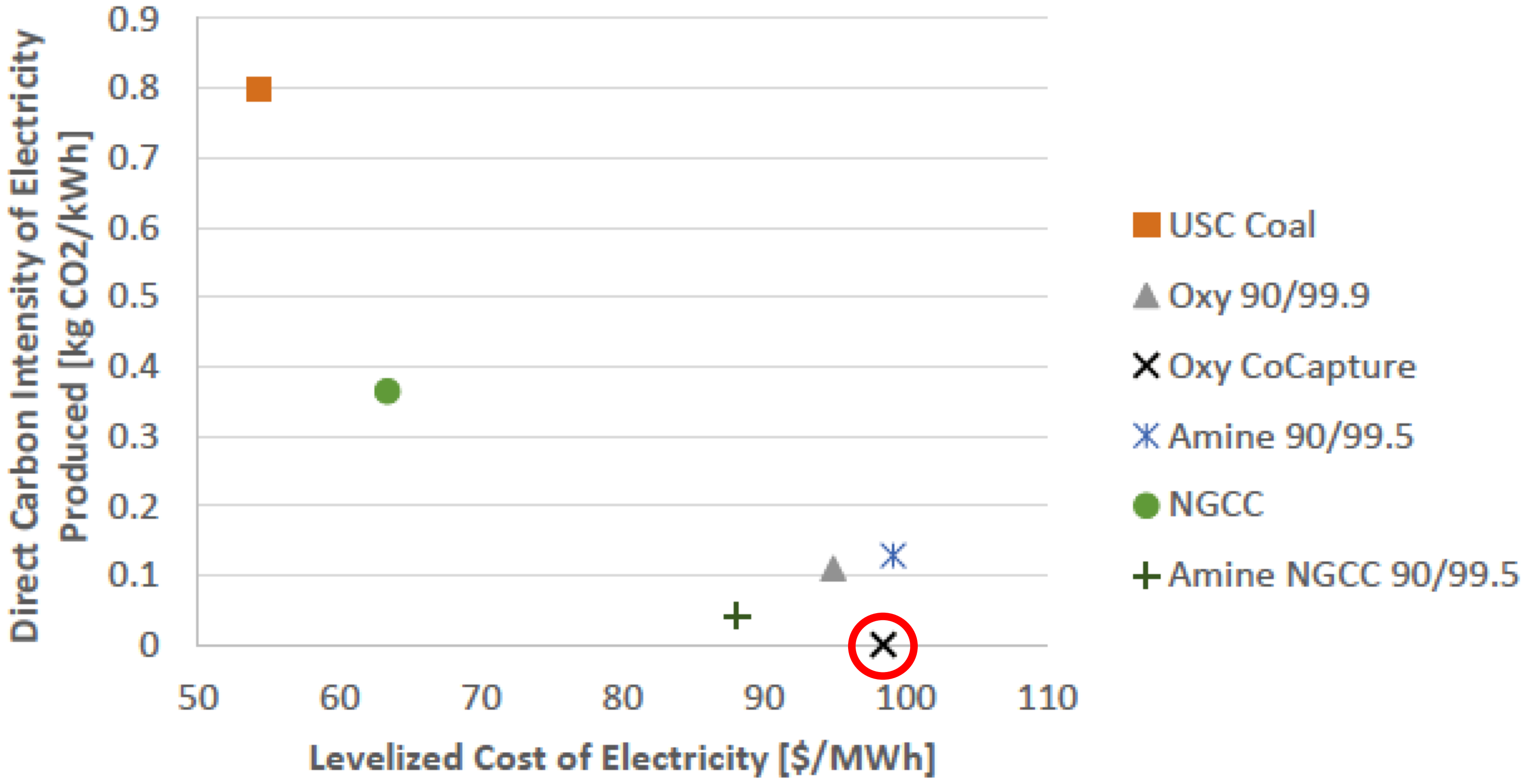
Four examples of strategies

1. DoE should mount a program to coordinate with States and/or utilities and IPPs that want to meet part of their CAA Sec111 obligations with CCS by providing subsidies for commercial scale CCS. Such a program should pay special attention to strategies such as Oxifuel that can reach 100% capture



Source: Kyle Borgert, Oxyfuel Carbon Capture for Pulverized Coal, EPP PhD, 2015.

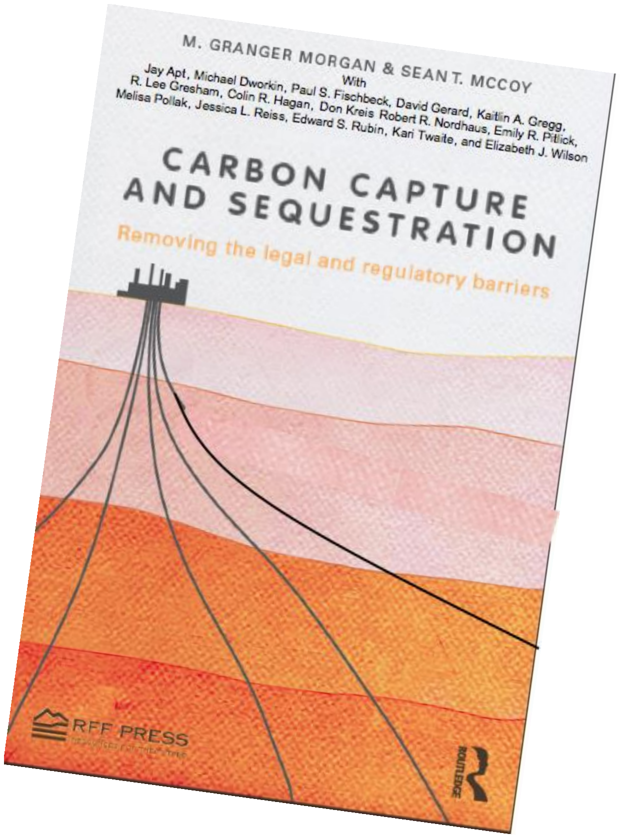
Comparison of CCS technologies



Source: Kyle Borgert, Oxyfuel Carbon Capture for Pulverized Coal, EPP PhD, 2015.

Four examples of strategies

2. Congress should adopt a regulatory framework that is similar to the one developed in draft legislation by the CCSReg Project for the underground sequestration of carbon dioxide.



At the moment…

…the regulatory situation is different in different states. (EPA rules don't address issues like ownership, liability, long-term stewardship.)

The CCSReg project developed an adaptive performance-based approach that would yield a more uniform national regulatory strategy for sequestration and developed a 50-pager draft bill to show how it could be implemented.

A BILL

To establish a comprehensive system for the safe and effective transport and geologic sequestration of carbon dioxide.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Carbon Capture and Sequestration Regulatory Act of 2012".

SEC. 2. TABLE OF CONTENTS.

The table of contents for this Act is as follows:

Four examples of strategies

3. States, regions and the federal government should develop strategies to sustain the present fleet of nuclear plants in the face of low-cost natural gas and other competitive pressures.

Images from http://insideclimatenews.org/slideshow/14-us-nuclear-plants-closing-or-risk—-photographs-and-text

Low natural gas prices

Several plants have recently closed. It is my understanding that the closure of Kewaunee was entirely economic (i.e., gas prices). Vermont Yankee and San Onofre both needed investment that owners considered unattractive…again largely I think as a result of low gas prices.

Recently a senior executive at PJM told one of my colleagues that he thinks five more nuclear plants are at risk as a result of low natural gas prices.

While this is the result of the short-term economic focus imposed by restructuring, it is nuts given that soon the nation is going to have to get serious about decarbonizing our energy system.

Source:www.infomine.com/investment/metal-prices/natural-gas/all/

Four examples of strategies

4. DoE and NRC should reinvigorate the U.S. effort to support the development of advanced and small modular power reactors.


PNAS

Expert assessments of the cost of light water small modular reactors

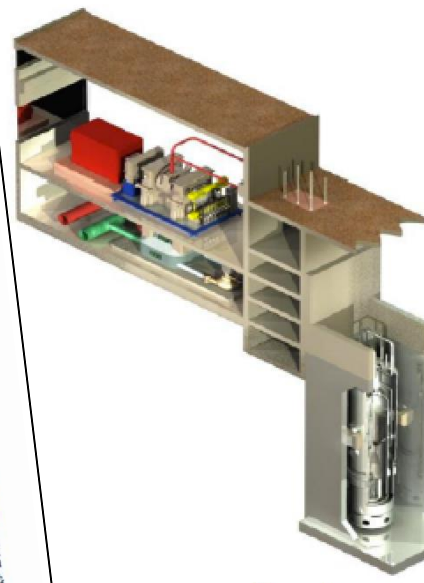
Ahmed Abdulla[1], Inês Lima Azevedo, and M. Granger Morgan

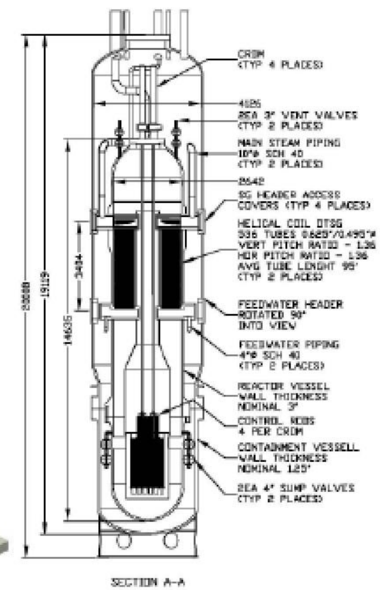
Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213

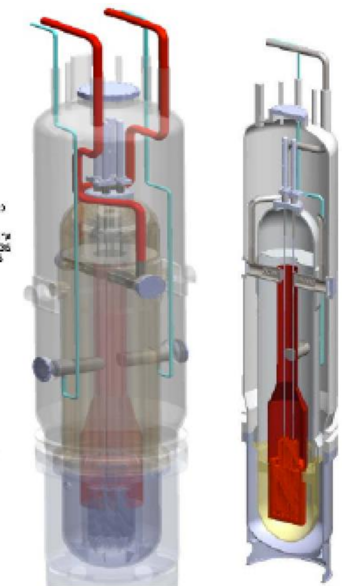
Edited by William C. Clark, Harvard University, Cambridge, MA, and approved April 26, 2013 (received for review January 9, 2013)

Analysts and decision makers frequently want estimates of the cost of technologies that have yet to be developed or deployed. Small modular reactors (SMRs), which could become part of a portfolio of carbon-free energy sources, are one such technology.

Our brains are not well-equipped to make decisions that involve considerable uncertainty. As extensive empirical research has now shown, we make such judgments using a variety of cognitive heuristics that, although they serve us adequately in many day-to-day settings, can result in overconfidence and bias that leads both lay people and experts astray when they address more complex and unusual problems (2, 3). Decision science (4–8) offers a set of strategies for improving how we make important decisions in the face of uncertainty.







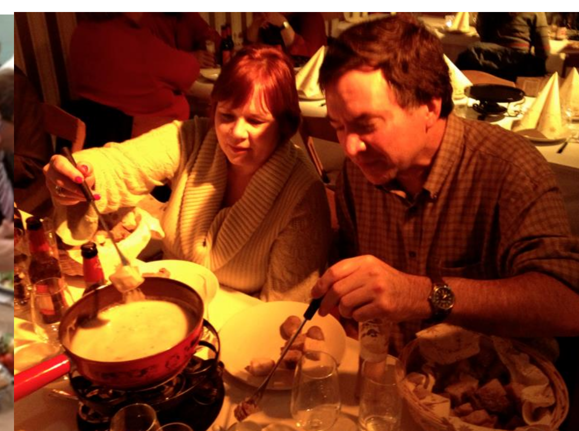
Sourse: Abdulla, Azevedo and Morgan, *PNAS*, *110*(24), 9686-9691, 2013.

A Workshop we ran in Switzerland on Small Modular Reactors

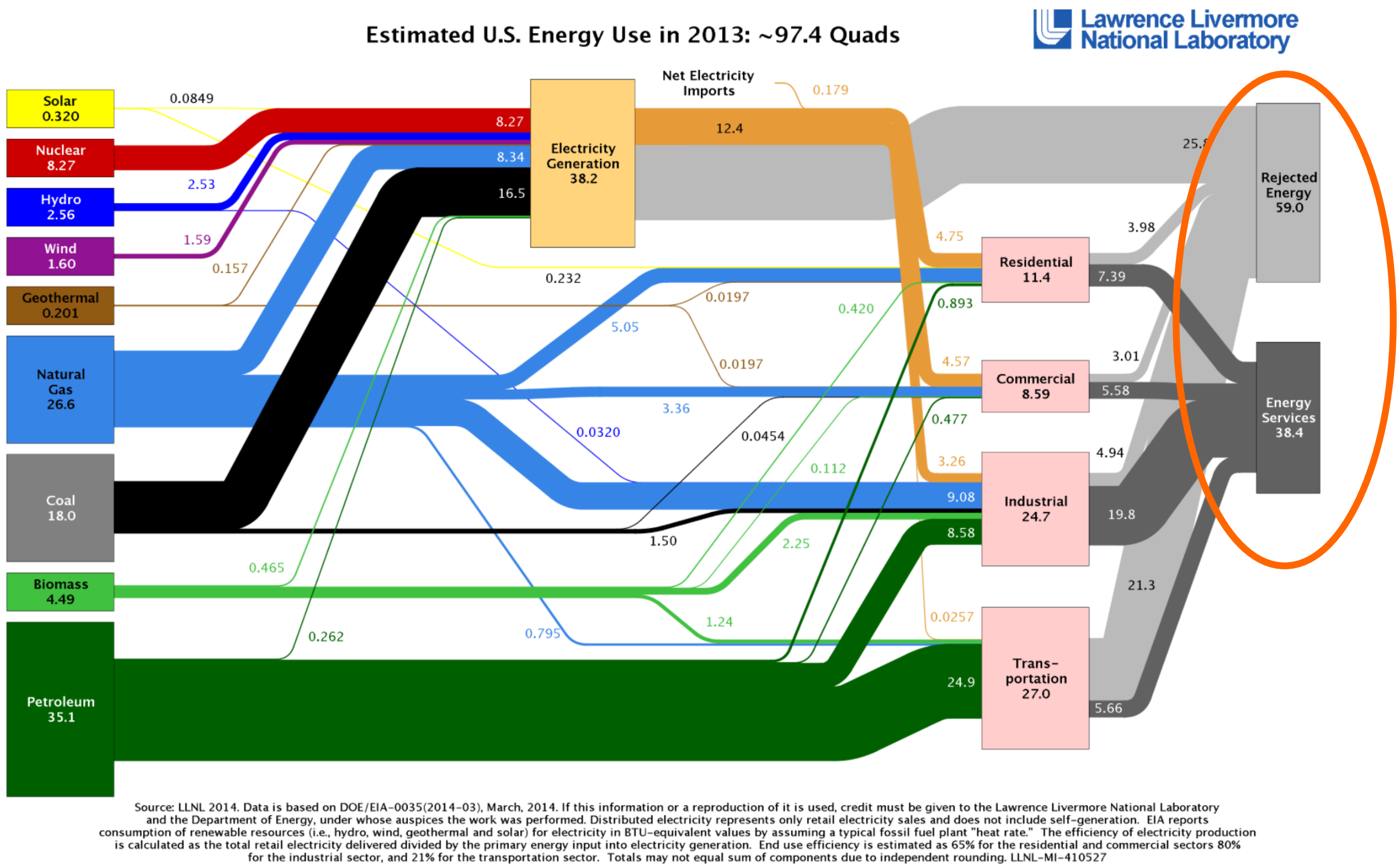
CARNEGIE MELLON UNIVERSITY · PITTSBURGH PENNSYLVANIA 1900

irgc international risk governance council

PAUL SCHERRER INSTITUT PSI



Promote greater end-use efficiency



Source: https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2013.png

Three examples of strategies

1. To improve overall energy conversion efficiency states should promote DG with CHP.

BUT, in parallel, DoE should work to develop:

- gas from biological sources (Germany got 10% of its electric power in 2014 from bio sources)
- distribution systems for H_2

so that wide adoption of DG with CHP doesn't lock us in to continued use of CH_4

AND we need to find ways around state laws that grant distribution utilities exclusive service territories so as to promote the growth of small micro-grids.

2. Empirical assessment is essential

The Hawthorne effect and energy awareness

Daniel Schwartz[a,1], Baruch Fischhoff[a,b], Tamar Krishnamurti[b,c], and Fallaw Sowell[c]

Departments of [a]Social and Decision Sciences and [b]Engineering and Public Policy, and [c]Tepper School of Business, Carnegie Mellon University, Pittsburgh, PA 15213

Edited by Thomas Dietz, Michigan State University, East Lansing, MI, and accepted by the Editorial Board August 2, 2013 (received for review February 1, 2013)

The feeling of being observed or merely participating in an experiment can affect individuals' behavior. Referred to as the Hawthorne effect, this inconsistently observed phenomenon can both provide insight into individuals' behavior and confound the interpretation of experimental manipulations. Here, we pursue both topics in examining how the Hawthorne effect emerges in a large field experiment focused on residential consumers' electricity use. These consumers received five postcards notifying, and then reminding, them of their participation in a study of household electricity use. We found evidence for a Hawthorne (study participation) effect, seen in a reduction of their electricity use—even though they received no information, instruction, or incentives to change. Responses to a follow-up survey suggested that the effect reflected heightened awareness of energy consumption. Consistent with that interpretation, the treatment effect vanished when the intervention ended.

environmental decision making | energy conservation | electricity consumption | behavioral decision research

How to substitute human responsibility for futile strife and hatred—this is one of the most important researches of our time.

Elton Mayo, in Roethlisberger and Dickson (1)

Beginning in 1924, the Western Electric Company Hawthorne plant was the site of some of the most influential studies in the formative years of the social sciences: the illumination experiments, examining the effects of artificial lights on worker behavior. Although workers seemed to increase their productivity when lighting regimes changed, the researchers eventually concluded that those changes actually reflected psychological factors, such as workers' responses to receiving special attention or being aware of the experiment. Subsequent studies at Hawthorne reached similar conclusions (1). Such changes came to be called Hawthorne effects (2, 3), although, ironically, secondary analyses concluded that there was no effect in the original studies or, more precisely, that the studies' design was too flawed to establish whether the effect was, in fact, observed there (4–7).

The mythical status of the initial observation notwithstanding, the Hawthorne effect is a fundamental concern for scientists studying any program designed to change human behavior, who must distinguish the effects of the program from the effects of being in the study. As a result, the Hawthorne effect has been examined in many areas, including worker performance (8), education (9, 10), health (11), and voting (12). The evidence from these studies is mixed. Some of the variability in their results may reflect differences in how they operationalized the concept of "being in a study." At one extreme lie such minimal manipulations as telling people no more than that they are in a study. At the other extreme lie treatments known to have their own effects, such as directly monitoring specific behaviors (13), providing performance feedback (14), inadvertently communicating research hypotheses (15), and providing new resources or instruction (16). Here, we add to the relatively small set of experiments that have examined the effects of study participation per se, with a field experiment examining electricity use of several thousand consumers. Our results reveal evidence of a pure Hawthorne effect, the psychological mechanisms shaping its size, and its implications for field studies of policy interventions.

In addition to its obvious economic and environmental importance, household electricity consumption offers several attractive features as a research domain. It is routinely measured for many households. It is such a small part of most Americans' budgets that it typically receives little attention, meaning that participating in a study might be enough to make it salient. Finally, most people know how to save electricity—even if they do not always know which ways are most effective (17, 18). Thus, if participating in a study increases the salience of electricity consumption, people should know what to do without further instruction—which could confound the pure participation manipulation.

Although there are many studies of interventions seeking to affect energy consumption, few have assessed the impact of Hawthorne (study participation) effects on their results (19). Among those few, some used an opt-in design eliciting a commitment to participate (hence confounded the mere-participation manipulation), had small samples, used weak manipulations, or omitted essential details in the research report, making it hard to tell what they did and found (20–22). As a measure of the importance of even small changes in energy consumption, states have set goals ranging from 0.1% to 2.25% annual savings (23).

Our experiment sent five weekly postcards to a random sample of electricity customers, notifying them about their participation in a study about household electricity use. Monthly electricity use was collected before, during, and after the experimental period for the treatment group and for a similarly selected control group. One month after the last postcard was sent, we surveyed a random sample of participants, asking about their response to the study.

Experimental Design

Participants were randomly selected from residential customers of a mid-Atlantic electricity utility to be in treatment or control groups. Households in the treatment group received their first notification a few days before the start date through a postcard stating that they had been selected to be in a 1-mo study about electricity use in their home and that no action was required on their part. They then received four additional weekly postcard reminders about the study. Thus, the study's sole stated goal was measuring electricity consumption. The control group received nothing. The observation period approximately spanned the interval between successive monthly readings. Table 1 summarizes household characteristics for the treatment and control groups. A subsample received a survey 1 mo after the end of the study period. *Methods* provides details on the postcards, survey, sampling, and data structure.

Results

The main dependent variable was households' electricity use. Although meter readings are scheduled for monthly intervals, there is some variability in when they are actually performed. To

Author contributions: D.S., B.F., and T.K. designed research; D.S. performed research; D.S. and F.S. analyzed data; and D.S., B.F., T.K., and F.S. wrote the paper.

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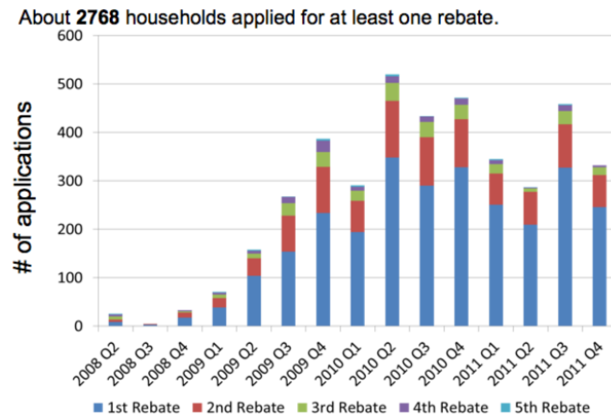
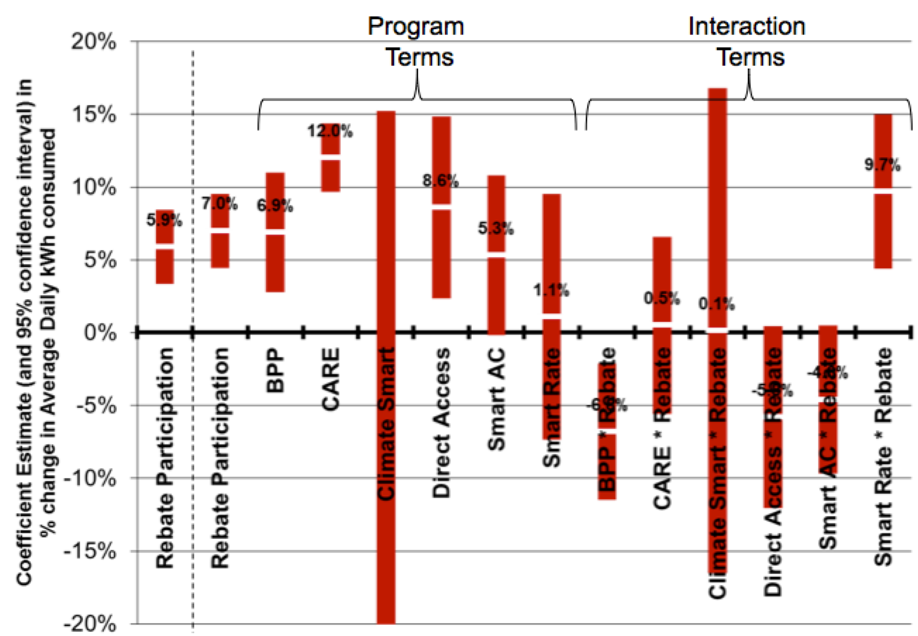


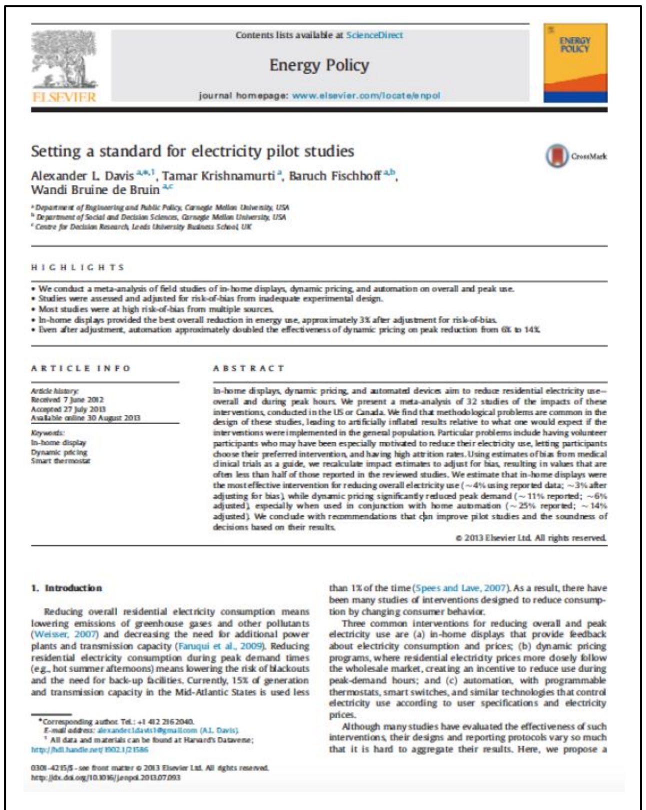
Azevedo and Meyer, 2015.



Source: Schwartz et al., "The Hawthorne effect and energy awareness," *PNAS, 110(38), 15242-15246, 2013.*

Three examples of strategies

3. Strategies designed to promote consumer adoption of technologies and behaviors that promote improved end-use efficiency should be carefully designed using empirically-based modern behavioral social science.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Setting a standard for electricity pilot studies

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HIGHLIGHTS

- We conduct a meta-analysis of field studies of in-home displays, dynamic pricing, and automation on overall and peak use.
- Studies were assessed and adjusted for risk-of-bias from inadequate experimental design.
- Most studies were at high risk-of-bias from multiple sources.
- In-home displays provided the best overall reduction in energy use, approximately 3% after adjustment for risk-of-bias.
- Even after adjustment, automation approximately doubled the effectiveness of dynamic pricing on peak reduction from 6% to 14%.

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ABSTRACT

In-home displays, dynamic pricing, and automated devices aim to reduce residential electricity use—overall and during peak hours. We present a meta-analysis of 32 studies of the impacts of these interventions, conducted in the US or Canada. We find that methodological problems are common in the design of these studies, leading to artificially inflated results relative to what one would expect if the interventions were implemented in the general population. Particular problems include having volunteer participants who may have been especially motivated to reduce their electricity use, letting participants choose their preferred intervention, and having high attrition rates. Using estimates of bias from medical clinical trials as a guide, we recalculate impact estimates to adjust for bias, resulting in values that are often less than half of those reported in the reviewed studies. We estimate that in-home displays were the most effective intervention for reducing overall electricity use (~4% using reported data; ~3% after adjusting for bias), while dynamic pricing significantly reduced peak demand (~11% reported; ~6% adjusted), especially when used in conjunction with home automation (~25% reported; ~14% adjusted). We conclude with recommendations that can improve pilot studies and the soundness of decisions based on their results.

1. Introduction

Reducing overall residential electricity consumption means lowering emissions of greenhouse gases and other pollutants (Weisser, 2007) and decreasing the need for additional power plants and transmission capacity (Faruqui et al., 2009). Reducing residential electricity consumption during peak demand times (e.g., hot summer afternoons) means lowering the risk of blackouts and the need for back-up facilities. Currently, 15% of generation and transmission capacity in the Mid-Atlantic States is used less than 1% of the time (Spees and Lave, 2007). As a result, there have been many studies of interventions designed to reduce consumption by changing consumer behavior.

Three common interventions for reducing overall and peak electricity use are (a) in-home displays that provide feedback about electricity consumption and prices; (b) dynamic pricing programs, where residential electricity prices more closely follow the wholesale market, creating an incentive to reduce use during peak-demand hours; and (c) automation, with programmable thermostats, smart switches, and similar technologies that control electricity use according to user specifications and electricity prices.

Although many studies have evaluated the effectiveness of such interventions, their designs and reporting protocols vary so much that it is hard to aggregate their results. Here, we propose a

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[1] All data and materials can be found at Harvard's Dataverse; http://hdl.handle.net/1902.1/21586

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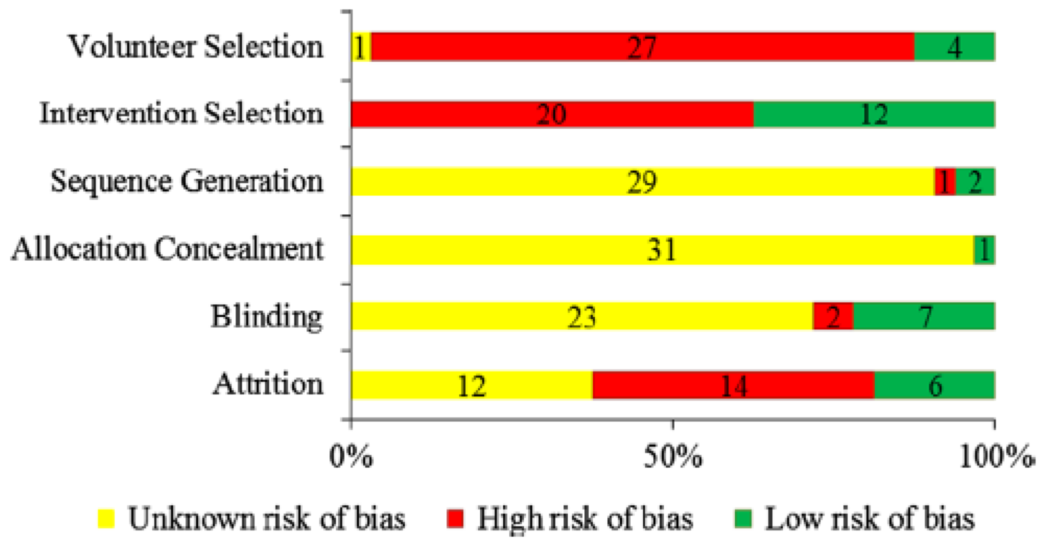
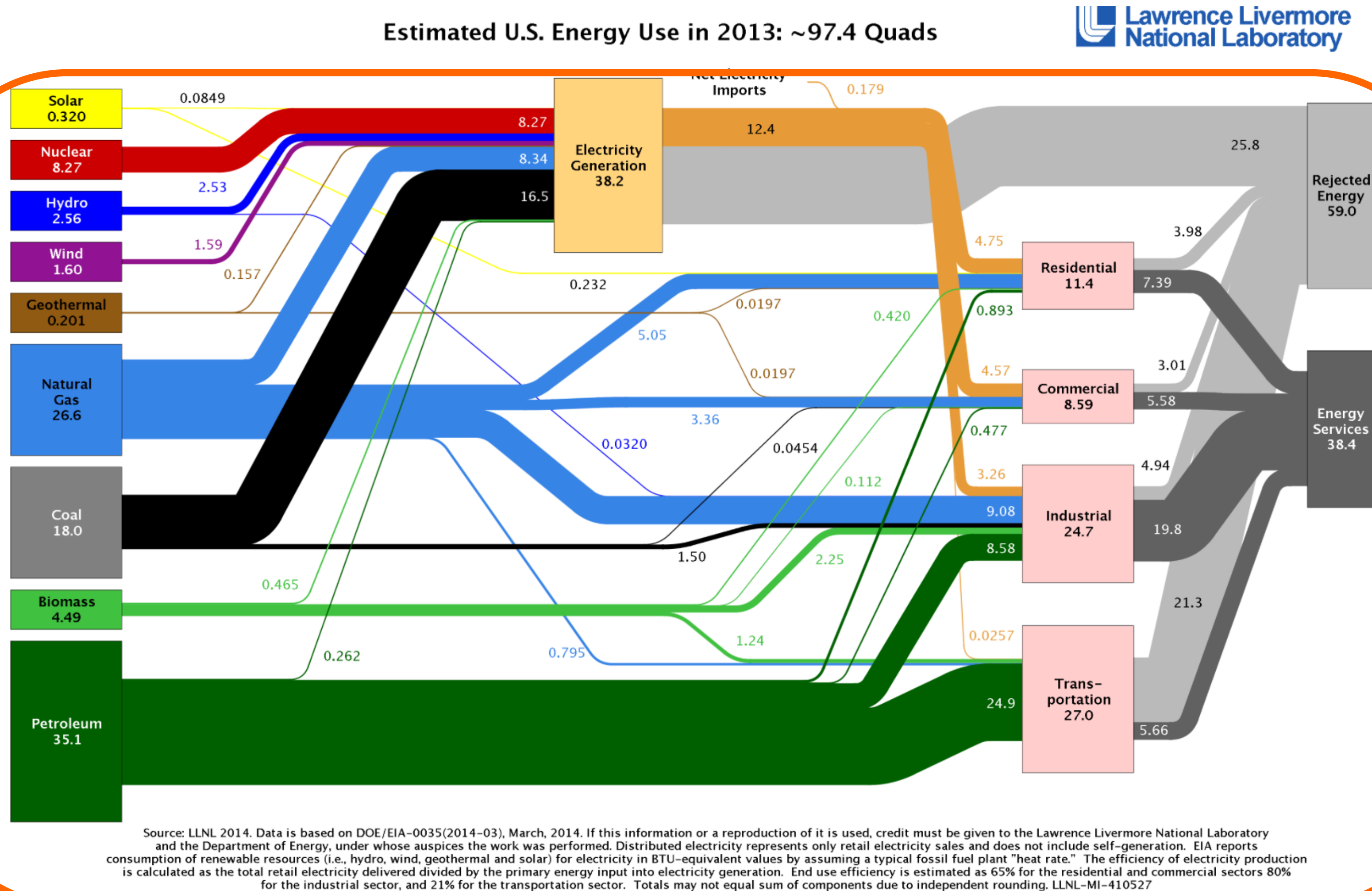


Fig. 1. Distribution of studies that meet the criteria for high, low, or unknown risk-of-bias updated to reflect author responses.

Source: Davis, et al., "Setting a standard for electricity pilot studies," *Energy Policy, 62, 401-409, 2013*

Focus on GHGs and adopt strategies that scale



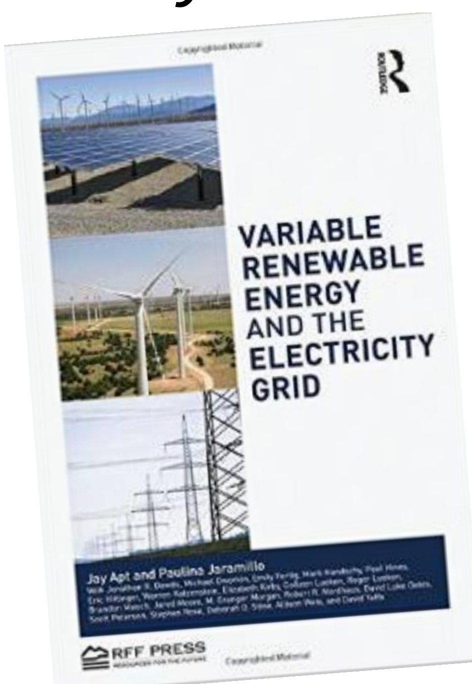
Source: https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2013.png

Two examples of strategies

1. State legislatures should substitute carbon portfolio standards for renewable portfolio standards. Analysis groups should lay the groundwork for support easy adoption.

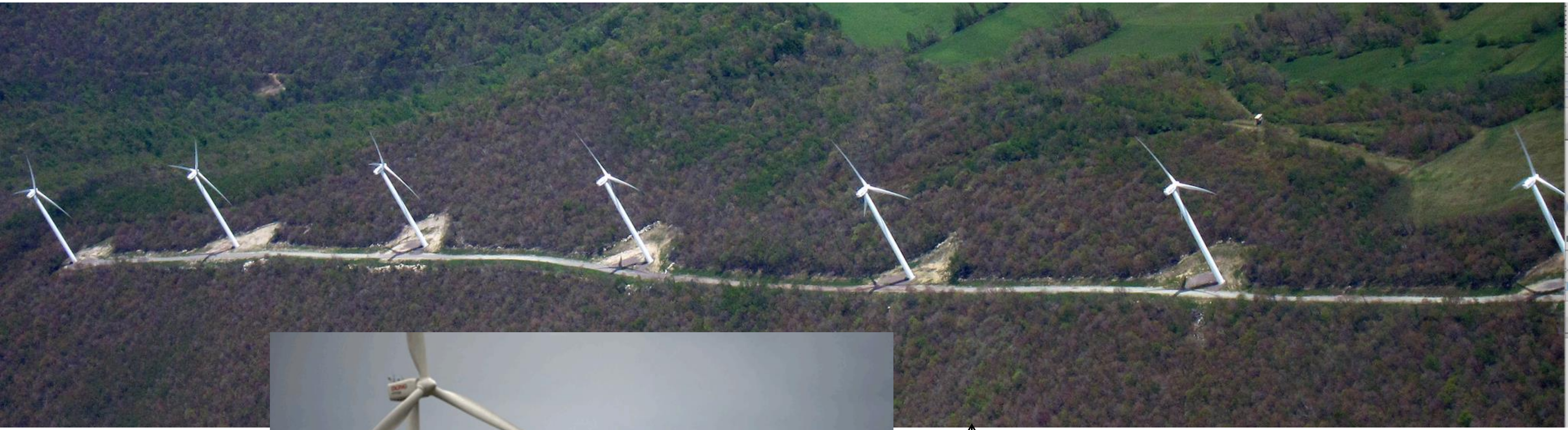
renewable portfolio standards → Carbon/GHG portfolio standards

If what we care about is reducing emissions of greenhouse gases, then we should focus on that *directly*.



Wind, solar and hydro have strengths, but they also have large environmental impacts (land use, stream flow, etc.).

Examples of impacts from wind



Source: https://thenaturaleye.wordpress.com

Photos by Jay Apt

On Appalachian ridges wind arrays result in habitat fragmentation. Bird and bat kills are also a serious issue.

More generally:

Ausubel argues:

Renewables are not green. To reach the scale at which they would contribute importantly to meeting global energy demand, renewable sources of energy, such as wind, water and biomass, cause serious environmental harm. Measuring renewables in watts per square meter that each source could produce smashes these environmental idols.

Int. J. Nuclear Governance, Economy and Ecology, Vol. 1, No. 3, 2007 229

Renewable and nuclear heresies

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Abstract: Renewables are not green. To reach the scale at which they would contribute importantly to meeting global energy demand, renewable sources of energy, such as wind, water and biomass, cause serious environmental harm. Measuring renewables in watts per square metre that each source could produce smashes these environmental idols. Nuclear energy is green. However, in order to grow, the nuclear industry must extend out of its niche in baseload electric power generation, form alliances with the methane industry to introduce more hydrogen into energy markets, and start making hydrogen itself. Technologies succeed when economies of scale form part of their conditions of evolution. Like computers, to grow larger, the energy system must now shrink in size and cost. Considered in watts per square metre, nuclear has astronomical advantages over its competitors.

Keywords: decarbonisation; electricity; environmental impact; nuclear power; renewable energy.

Reference to this paper should be made as follows: Ausubel, J.H. (2007) 'Renewable and nuclear heresies', *Int. J. Nuclear Governance, Economy and Ecology*, Vol. 1, No. 3, pp.229–243.

Biographical notes: Jesse Ausubel spent the first decade of his career in Washington DC working with the National Academy of Sciences and National Academy of Engineering. On behalf of the academies, he was one of the main organisers of the first UN World Climate Conference in Geneva in 1979. He was also the main author of the 1983 report *Changing Climate*, the first comprehensive review of the greenhouse effect. In 1989 he moved to Rockefeller to establish a research programme on the long-term interactions of technology and the environment, patterns of technological diffusion, and means for a large, prosperous society that spares nature.

1 Introduction

Heretics maintain opinions at variance with those generally received. Putting heretics to death, hereticide, is common through history. In 1531 the Swiss Protestant heretic Huldreich Zwingli soldiering anonymously in battle against the Catholic cantons was speared in the thigh and then clubbed on the head. Mortally wounded, he was offered the services of a priest. His declination caused him to be recognised, whereupon he was killed and quartered, and his body parts mixed with dung and ceremonially burned. Recall that the first heresy against the Roman Church in Switzerland in 1522 was the eating of sausages during Lent, and the signal heresy was opposition to the baptism of

Two examples of strategies

2. Analysis groups (e.g., RFF, EPP at CMU, ERG at Berkeley, etc.) should help states develop ways to avoid or minimize the use of point-source control strategies that are not easily superseded in the future by simple pricing of emissions or by cap and trade.

On the other hand…

While emissions taxes or cap and trade are sensible for point sources like large power plants…

Source: USA Today.com

…performance standards (e.g., CAFE) make more sense for sources like motor vehicles since \$1/ton CO_2 ≈ a penny a gallon at the pump.

My bottom line:

Muddling through may be the best we can do in the short-term in order to get started on policy to reduce CO_2 emissions.

However, to avoid dead ends, the community of policy analysts should begin to work NOW on identifying and avoiding strategies that might lead to dead ends and find ways to promote strategies that will scale up to the $\gtrsim$90% emission reduction we need.

End

In developing the ideas discussed in this talk, I have been fortunate to have generous support from the National Science Foundation (SES-9209783; BCS-9218045; SES-034578; SES-0949710 and others), the Electric Power Research Institute, the Gordon and Betty Moore Foundation, the Doris Duke Charitable Foundation, the MacArthur Foundation, the IRGC, Carnegie Mellon University and a number of others. Thanks also to my many colleagues and students, who have worked with me in these projects especially to Jay Apt, Inês Azevedo, Wändi Bruine de Bruin, Hadi Dowlatabadi, Baruch Fischhoff, Max Henrion, David Keith, Lester Lave and Ed Rubin.