TITLE: "**New Technology and Market Design for Energy and Climate Security"**

4. Subject

The book is intended to provide and explain connections in more detail than ever before from the nuts and bolts of climate risks and technology solutions to the higher-level policy options and decisions. Even in the climate risks section (Part 4) it explains connections which had not been made before even within the climate sciences themselves, as the preface summarizes. The main sections (parts 2 and 3) show how we can make electricity and meet our transportation needs much more cheaply than any of the new big climate bills propose, by making better integration of the best, new technologies connecting all the way from electrons and photons to national and international energy markets. Policy makers need this new roadmap, but their advisors and investors need the paper trail all the way back to technical reality.

12. Sample Material

Table of Contents:

ANNEX A

Draft Chapter Text

The following pages provide draft text from the planned chapters of the book.

A.0 Section 0.3: Why Policy and Investment People Need What New Information (Werbos draft)

A.1. Preface (section 0.4, Ward, Wadhams, Werbos, full draft)

A.2. Section 1.2.1, draft entire chapter . **Enhancing Reliability, Resiliency, Sustainability and Affordability with Customer Centric of Wholesale and Retail Electricity Market Design Policies**, Momoh

A.3. Section 1.2.2, plan. Upgraded price and market signals, optimization and greater consumer participation in markets and transmission planning. O'Neill and Ilic.

A.4 Section 1.4.4 JTEC a competing option with no moving parts for high efficiency heat to electricity , Johnson

A.5 Section 2.1 full draft: Energy and environmental considerations -- overall summary, Rabl

A.6 Section 2.2 outline: Electric Highway Transportation -- introduction, systems issues, batteries, recharge options, Marko

A.7 Section 2.3.1 summary, **Section 2.3.2 Electric and Hybrid Electric Aircraft Systems**

A.8 Section 2.4 outline: Alternate Propulsion Options, most notably alternate liquids and balance of fuel flexibility and consumer choice on electricity, Werbos

A.9. Section 2.5.1 draft Enablers Miller and Johnson

A.10 Section 2.5.2 full draft chapter Rechargeable Lithium-Air Batteries, Johnson

A.11 Section 4 outline: Geo- and Mega- Engineering Options: Research, Development & Demonstrations to Create Quick Backup Options (Contributors: Mankins, additional contributors)

A.11 Section 5, summary, Werbos and De Hoyos

A.0 Section 0.3: Why Policy and Investment People Need What New Information

DRAFT summary, Werbos and others to be added

0.3.1. The Big Picture and Proposed Climate Strategy

The Preface (section 0.4) explains why many of us on the engineering side now believe that the worst forms of climate change are truly an “existential risk,” a threat to the very existence of the human species. And yet, from our deep studies of the technology and economics of making electricity and transportation, especially, offer new solutions far beyond what todays policy communities seem to know about yet. The main goal of this book has been to create new conversations between the real leading scientists, both on the worst climate risks, and on new technologies and new approaches to market design which could slash the risks, at a much lower cost than you would think from the climate bills and agreements we see in the media or in conventions of stakeholders.

One of us was chosen as on or two of the staffers working for Senator Specter of Pennsylvania in 2009, working with the Senate Environment and Public Works (EPW) Committee, when that Committee was assigned the task of evaluating the omnibus climate bill sent to us from the House. The cost projected by DOE and EPA was on the order of half a trillion dollars per year, but was projected to cut US CO2 by only 40% or so by 2100, in part because it left transportation virtually untouched. A huge cost, but not enough to prevent the worst case damage. That year, Senator Kerry gave a speech to his Foreign Affairs Committee, arguing that the main policy analyses he saw were misdirected in any case; the goal here, he said, was to BUY insurance -- to focus on the very worst serious risks, and find efficient ways to prevent them. That is how we developed the plan which emerges from this book.

This book does not propose an omnibus bill which tries to distribute favors or create massive 2,000 page list of new regulations, like what failed in 2009. Leading climate experts in 2009 said that we should have focused instead on *sectoral measures -- highly focused and efficient measures based on expertise in depth on the biggest sources of CO2 emission, accounting for the huge market imperfections (market failures) which real experts on those sectors know about, which make it possible to reduce costs.* Based on the new technologies we have probed for this book (with the help of a great new network of contributors, discussing how to connect the new technologies and market designs), we believe that a highly focused, scientifically driven push to advance these innovations may even make a lot of money for the world economy, at the end of the day. Above all, the book tries to tell us HOW.

The two sectors we focus on most are making electricity and transportation, areas where the IEEE Power and Energy System (and its long experience in probing but constructive technical review and crossdisciplinary projects) can draw on expertise simply not available in a connected way anywhere else on earth.

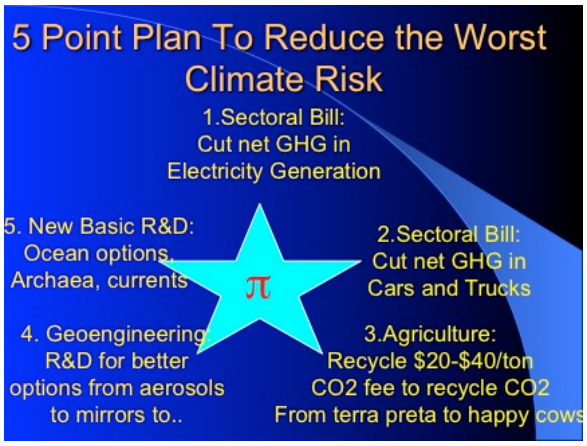
EIA once collected primary data on CO2 emissions from the US, tabulated in different ways. More than 80% of the actual primary net emissions came from making electricity (electric utilities plus electricity generated in industry) and from transportation (including off highway vehicles in industry). Lobbyists wanting to work on buildings often state that commercial and residential sectors may account for 30% of CO2, but that counts the CO2 used to generate electricity used in commercial buildings, and many other such overlaps. If we could cut just these two sectors to near zero net CO2, in an effective and efficient way, that would be far more effective than omnibus bills. We do have exciting new options to do exactly that. The main part of this book, section 2 and section 3, go into depth on exactly what we can to do that; here we will give just a few highlight, putting it together for the policy maker or investor.

In an ideal world, however, we would give equal time to another whole section, focusing on the NET reductions in greenhouse gas (GHG) emissions which could be achieved all over the world by changes in

agriculture and related areas, and could actually sequester enough GHG to offset all of the present emissions from that sector and from the core of the manufacturing sector as well. But in truth, neither PES not any other global engineering society we could find can do full justice to that sector, which involves scattered communities all over the world. Chapter 4 will give and overview of what two of us (Werbos and De Hoyos) and any further collaborators they can find can tell you, but it will not have as much depth as the rest.

Senator Specter would be disappointed by that, because the climate bills HE introduced before 2009 did full justice to the agricultural sector, and would have ben politically marketable in agricultural states whose support could have given us a climate bill in 2009, if certain stakeholder groups had not gotten in the way, as we saw very vividly first hand. Chapter 4 will briefly say a bit more.

Because of the new collaborations and dialogue which this book project has started up, the book is far deeper and more reliable than the overview which one of us spoke about in 2019 in Korea and Japan, illustrated then in this slide (posted at http://www.werbos.com/climate_extinction_risk_and_solutions.htm):



This book will try to cover all five points in the slide, and more. Geoengineering seemed as challenging as agriculture at first, for this book, but thanks to John Mankins, the book will represent a viewpoint based on unique panoramic experience covering not just geoengineering but space technologies in general.

The remainder of this summary will focus on the specific lessons for making electricity and transportation, leaving the rest to sections 3, 4 and 5.

0.3.2. How to Make Drastic Cuts in GHG from Making Electricity

The White House Smart Grid Policy of 2011 called on NSF (where I then led electric power research) to focus on developing a "4th generation intelligent grid that would us intelligent system-wide optimization to allow up to 80% of electricity to come from renewable sources and 80% of cars to be pluggable electric vehicles (PEV) without compromising reliability, at minimum cost to the Nation (Werbos, 2011, IEEE Computational Intelligence Magazine)."

Many have called for trying to cut back on the electric power grid, and moving towards stand-alone distributed generation. However, that has not been the main direction of economic progress in recent decades. In fact, the defeat of the 2009 Obama climate bill was due less to opposition by oil producers (who were protected in that bill in any case), and more to NARUC, the National Association of utility regulators, who simply were not willing to accept the high costs it would have imposed on ratepayers. In PES, we understand that the total retail cost of renewable electricity is often over $1 to the customer, if one accounts for time of day effects, intermittency, the need for backups, and other effects.

Furthermore, a major workshop by DOE and NASA, for the Climate Change Technology Program of George Bush, included calculations by the inventor of the carbon nanotube (Richard Smalley of Rice) showing that a small percentage of desert land in the US would be enough to power all the needs of the US, multiplied many times over, if the solar farms would be located in the zones of greatest sun. After all, a solar farm located in an area of twice as much sun will result in electricity generation per kwh about half what it would cost from a similar solar farm located in other areas, not even counting the problems of time-shifting costs and backup.

I am very grateful to the old NSF for allowing me to join the International Advisory Board (IAB) of the Chile Solar Energy Research Consortium SERC (http://serc.cl/en/), which helped guide a competitive market process for large solar farms and research in the Atacama desert, closely aligned to the mining industry there. In my initial work there (see www.werbos.com/Atacama.pdf) I was the one expert most excited by the promise for solar cells, PVs, in South America if the time of day problems could be solved by using long-distance transmission and intelligent grid control to make trades with Brazil. However, as new information came in, it became more and more clear that solar thermal solar farms were making more progress, and PVs were encountering problems. (www.werbos.com/E/GridIOT.pdf). In any case few large markets have the kind of hydro system which Brazil offered in that region.

Based on current information, the “A team” most dependable option for very deep reductions in renewable energy cost in most of the world is a COMBINATION of:

(1) the high quality thermal storage systems developed and proved out under SERC, must less expensive than batteries, proving power at the exact time of day of demand, better even for baseload uses.
(2) breakthrough technology, now best from GE, offering 50% efficiency in a manufacturable system, able to convert concentrated heat to electricity in a controlled fashion, usable either DIRECTLY with the heat captured in the “eye of the obelisk,” the upper chamber of a power tower, or the thermal storage system.
(3) Modern construction technology for solar farms such as the German and Spanish members of IAB have proven, compatible with major grid enhancement and new control technology and market design such as what the EU needs most urgently right now. SERC should be enhanced to strengthen these technology pipelines, up and down the line, and add more partners, such as GE, Heliogen and Siemens.
(4) More modern market design, to make it as easy to build interregional transmission as it is already for gas pipelines in the US, using modern intelligent control to optimize the time of day and load tracking and ancillary services required.

RD&D is needed immediately, perhaps even with major new integrated prototype projects using the most advanced technology in all four sectors, to make large scale affordable all-renewable electricity deployed and ready for expansion as soon as possible, with no unnecessary paperwork or regulatory delays.

The most efficient (optimal, as in RLADP) overall strategy would combine this “A Team” bird-in-hand effort with major parallel backup efforts. Above all, these would involve the kind of more efficient Brayton conversion which does appear possible, scientifically, which Brayton Energy is promising in a contract with the solar energy office of US DOE. Another factor of 50% or so in reducing cost would be well worth the R&D cost, despite the time and risk. The same may also be said for JTEC, a promising new approach which theoretically might do even better, which we investigated in great detail at NSF, and funded. Previous work on advanced Stirling strongly supports the kinds of thermodynamic hopes which Brayton energy is counting on, without the issues of scaling in thermal storage which constrains Stirling.

In addition, chapter 4, on geoengineering and megaengineering, will also review RD&D options and strategy

for e=generating energy in space for use on earth, reflecting many of the best sources, such as Mankins' own seminal book The Case for Space Solar Power and the many debates which have crystallized since then.

0.3.3 How to Make Massive Cuts in Net GHG From Transportation

Many policy makers around the world are now fully committed to electric transportation as a way to zero out net GHG in that sector. But despite that, present policies are missing two very large and real immediate economic improvements:

(1) Technology and market design to make pluggable EVs more affordable and user-friendly;
(2) Market design to allow fair competition and rational incentives for alternate liquid fuels, especially, to create greater balance and security, and open the door to a transition much faster than EVs alone would allow (with greater fairness to many segments of the fossil fuels industry).

See www.werbos.com/oil.htm for a bill which Senator Specter sent to the Senate Office of General Counsel, which he intended to bring to the floor of the Senate in 2009, but which was blocked by people who made certain promises to certain stakeholders (who will not benefit by forcing the world to enforce a monopoly for electricity). That web page also contains an IEEE USA white paper on transportation fuel security, which took pains to specify a balanced, rational market-based approach.

Nevertheless, electricity is more and more our best hope for the long term, especially as new technologies for batteries, for recharge, for power electronics and for integrated multi-level control become available and ready for accelerated RD&D. One of the great benefits of this book has been developing the initial network of new communications between the leading experts in the most advanced batteries, power electronics, control, and the grid issues best known by authors for section 1. The annexes for section 2 of the book include many technical details and policy conclusions on how to accelerate better use of electricity in transportation, as well as section 2.4 on alternate fuel options and balanced markets.

ANNEX A.1

Draft **Preface** text

Worst Case Climate Risk

By Peter Ward, Peter Wadhams and Paul Werbos

How could world access to newer better information on new IEEE technologies be a matter of urgency, of life and death importance to us all?

When Kumar asked us to organize a new book, to connect the real science, climatology, engineering and economics to address the worst risks coming to us from climate change, even we did not realize how much we had to learn by putting the pieces together, even in the study of climate risks themselves. We did not realize just how serious and near-term the biggest threats actually are. We did not yet know how many critical pieces need to be connected together in ways they have never been connected before, both to understand and reduce the threats.

In August, 2021, Metta Spencer (https://en.wikipedia.org/wiki/Metta_Spencer), a leader of Canadian futurist groups, asked what we really know from the very most solid science about the risk that climate change might actually become serious enough to endanger the existence of the human species. The key challenge was to bring together people who had never put the relevant pieces together to assess how bad the risk might be. This discussion, at https://www.youtube.com/watch?v=SMp9a0PwL3o, was a great eye-opener to us. But it was only just an opening.

Section 3 of this book will review new work solidly proving the large risks due to methane emissions and changes on ocean currents, established in the work of Wadhams.

But our personal motivation here is driven more by a much larger risk, which has yet to be fully proven, which cries out for more and deeper R&D, but which now seems convincing enough that we feel we are part of a struggle for our very lives (or at least our childrens' lives).

We now know that the most important mass extinctions of life on earth in past history were caused by outgassing of H2S (a poison twice as potent per ppm as hydrogen cyanide) from the oceans. The H2S was mainly produced by a type of microbe which has different names in different scientific communities, but resulted from two conditions in deep ocean waters: (1) low oxygen; and (2) a high concentration of certain nitrates, such as phosphates, which need to be studied in greater depth.

We are now much more worried than we were at the start of this project, in part because of what Ward and Werbos learned from Wadhams about changes in ocean currents (in the youtube video!), but in part because of new information about mass extinctions in the past and data on nutrient flows in the ocean today:

(a) Cui, Y., Kump, L.R. and Ridgwell, A., 2013. Initial assessment of the carbon emission rate and climatic consequences during the end-Permian mass extinction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *389*, pp.128-136. (Use "advanced search", the "hamburger" three lines at scholar.google.com, to see this and other important papers by Kump. See also the explanation in chapter 12 of

https://www.amazon.com/New-History-Life-Discoveries-Evolution-ebook/dp/B00OZM4AN2/, the best integrated history of life on earth now available.)

(b) https://www.aoml.noaa.gov/ocd/ocdweb/nutrients.html

THE GEOGRAPHIC DISTRIBUTION OF the danger levels of relevant nutrients happens to coincide exactly with the source of the Humboldt current, which is also a place where the thickness of oxygen containing deep water is shrinking rapidly (e.g. see the map from NOAA at werbos.com/Atacama.pdf). Next most dangerous is the "Arctic tongue" at the origins of Gulf Stream currents.

The "coincidence" of locations seems strange at first, but it is not surprising that regions of the ocean which contain more oxygen also contain more of our kind of life, which can digest nutrients and excrete them to the ocean bottoms.

Again, more research is needed to pin down exactly where the risks may be, and to answer the many obvious questions, but such research should be one of highest priorities in climate policy all over the world. When Guterres and Kerry both proposed a new climate security office under the UN Security Council, we strongly hoped hat such an office could be created, and managed under the highest standards of review and integrity (and funding) ever seen in the example of NSF.