UNLOCKING ENERGY INNOVATION
Our Goal: “Expanding the Menu”

- Techies: More money for R&D
- Visionaries: A new Manhattan/Apollo Project
- Economists: Get prices right
- Policy wonks: Reform government
- Culture warriors: Change behavior
We’re Not Joking

“To a first approximation, raising the price of carbon is a necessary and sufficient step for tackling global warming. The rest is largely fluff.”

William Nordhaus, 2007
Our Big Question

What kind of innovation system does the U.S. need to build in order to accelerate the transition to an affordable, reliable, low-carbon energy economy?
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Fact

Jan-Dec Global Mean Temperature over Land & Ocean

Anomaly (°C) relative to 1901-2000

NCDC/NESDIS/NOAA
## Getting To “80 in 40”

<table>
<thead>
<tr>
<th>Percentage reduction rate in carbon intensity</th>
<th>Percentage reduction rate in energy intensity</th>
<th>Percentage rate of decarbonization of energy supplies</th>
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</thead>
<tbody>
<tr>
<td>((-7%/year))</td>
<td>((-3%/year))</td>
<td>((-4%/year))</td>
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Where Innovation Is Tradition
The Last 25 Years vs. the Next 40

Figure 1.2
Rates of decarbonization and energy intensity reduction in the United States: (a) from 1984 to 2009; (b) for an illustrative scenario, 2009–2050.
Some Other Notable Assertions

Electricity is the “central front”

Shale gas and “second generation” biofuels:
  • Could reduce CO$_2$ emissions in the short run
  • But in the long run, their emissions are still too great
  • And there is a danger that they could become a “bridge to nowhere”

Focusing on the climate goal will (at a minimum) not worsen capacity to achieve other goals (security, jobs, local pollution, etc.)
Four Stages of Energy Innovation

Phase 1: Option Creation
- 'Ideation'
- Concept development
- Seed stage
- Scale: $100K-100M

Phase 2: Demonstration
- Market testing
- Debugging
- System integration
- Risk reduction
- Demonstration
- Scale: $10M - 18

Phase 3: Early Adoption
- Market/regulatory development
- Limited competition
- Learning-by-doing/using
- Economies of scale
- Complementary infrastructure deployment
- Scale: up to $10s of billions

Phase 4: Improvements-in-Use
- Continued cost reductions
- Unrestricted competition
- Carbon pricing
- Evolutionary advances
- Scale: Up to $100s of billions

Where Innovation Is Tradition

PHILOXENIA UNIVERSITY
‘Design Criteria’ for the Energy Innovation System

Accelerate all stages: option creation, demonstration, early adoption, and improvement-in-use.
Create space for new entrants.
Competition at each stage.
Rigorous and timely down-selection at each stage
Scale of the system should match the scale of the task
Accommodate and exploit diversity (regional, organizational, technological, etc.)
‘Design Criteria’ for the Energy Innovation System

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The current energy innovation system satisfies none of these criteria.
Three Waves of Innovation

First wave: 2010-2020+
- Mostly energy efficiency
- Innovation in financing and business models

Second wave: 2020–2050+
- Reduce the costs and risks of existing low-carbon electricity supply technologies (nuclear, wind, solar, CCS, etc.) and infuse ICTs into the grid (“smart grid”)
- Large-scale deployment of these systems

Third wave: >2050 (?)
- Fruits of basic research
- Entirely new concepts, materials, etc. (e.g., artificial photosynthesis, fusion, etc.)

All three waves must be pursued simultaneously and immediately.
4 Stages x 3 Waves

“Wave 1” 2010-2020
Option creation
Demonstration
Early take-up
Improvement-in-use

“Wave 2” 2020-2050
Energy Efficiency
Energy Efficiency
Low-carbon electricity supply
Low-carbon electricity supply

“Wave 3” 2050--
Energy breakthroughs
All Three Waves:
Structural Reform of the Power Sector

The electric power industry today is less an innovator than an obstacle.
Structural reform in the electric power industry is a prerequisite for building a new energy innovation system
“Smart integrator” utility:
• Would own and operate transmission and distribution networks
• Would maintain a grid architecture that is open to all sources and types of generation and energy management services
• Would not be responsible for devising/refining innovative generation/energy management technologies, nor scaling them up
• New entrants and economic competition, not regulation, would drive innovation in power generation and energy management services
### 4 Stages x 3 Waves: Wave 1

<table>
<thead>
<tr>
<th>Wave 1</th>
<th>Option creation</th>
<th>Demonstration</th>
<th>Early take-up</th>
<th>Improvement-in-use</th>
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<tbody>
<tr>
<td>“Wave 1” 2010-2020</td>
<td>Energy Efficiency</td>
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<tr>
<td>“Wave 2” 2020-2050</td>
<td>Low-carbon electricity supply</td>
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<tr>
<td>“Wave 3” 2050--</td>
<td>Energy breakthroughs</td>
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The First Wave: Energy Efficiency in Buildings

An enormous and immediate opportunity
“Green shoots” are evident and must be nurtured:

• Energy codes for new buildings enacted and enforced
• Sustain the drive to tighten appliance EE standards
• Expand and simplify incentives for building retrofits
  – Financial innovation: Green Bank, PACE, on-bill finance, etc.
  – Building labeling
  – Continued investments in building design and technology
4 Stages x 3 Waves: Wave 2

“Wave 1” 2010-2020
Option creation

“Wave 2” 2020-2050
Demonstration
Energy Efficiency
Low-carbon electricity supply

“Wave 3” 2050--
Early take-up
Energy Efficiency
Low-carbon electricity supply
Energy breakthroughs

Improvement-in-use
The Second Wave – Part 1: Low-Carbon Electricity Supply

A federally-mandated innovation surcharge on retail electricity sales
State-appointed trustee organizations would allocate revenues to . . .

. . . . regionally-based innovation investment boards (RIIBs) which would fund, through a competitive process, demonstration or early take-up projects certified by . . .

. . . a federal ‘gatekeeper’ organization, representing the public interest, which would ensure that candidate projects would advance the goals of the energy transition by offering the potential of significant reductions in carbon emissions
Electricity users  
State-based trustees  
Regional Innovation Investment Boards  
Demonstration projects and early deployment programs

Federal “gatekeeper”

State A  
State B  
State C  
State D  
Region 1  
Region 2  
Region 3  
P1  
P2  
P3  
P4  
P5  
P6  
P7
The Second Wave – Part 2:
The Rest of the Electricity System

There are major technological opportunities beyond central station power

But they will not be realized without organizational and institutional innovation, such as:

- Open architecture
- Dynamic pricing
- Cost recovery for hard-to-price services
- Public support for demonstration and early adoption
4 Stages x 3 Waves: Wave 3

<table>
<thead>
<tr>
<th>Wave 1</th>
<th>Wave 2</th>
<th>Wave 3</th>
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<tr>
<td>2010-2020</td>
<td>2020-2050</td>
<td>2050-</td>
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- **Option creation**
- **Demonstration**
- **Early take-up**
- **Improvement-in-use**
- **Energy Efficiency**
- **Low-carbon electricity supply**
- **Energy breakthroughs**
The Third Wave: Creating Breakthrough Options

“History will not end in 2050”

To address new challenges and seize opportunities that will emerge between now and then:

• More and more sustained investments in option creation, including through ARPA-E

• Pluralistic funding and open information exchange, globally as well as domestically
A 10-point framework for building a new U.S. energy innovation system

- New innovators, start-ups and entrants from elsewhere
- Expanded competition in electric power markets
- ‘Smart integrator’ transmission and distribution utilities
- An invigorated energy efficiency marketplace
- Regional Innovation Investment Boards (RIIBs)
- State Energy Innovation Trustees
- A federal ‘gatekeeper’ agency
- Dynamic pricing
- Open grid architecture and customer control
- A much larger and more diverse federal energy research structure