Securing a Clean Energy Future

Opportunities for States in Clean Energy Research, Development, & Demonstration

A Report for the National Governors Association as part of the
Securing a Clean Energy Future Initiative

National Governors Association
1908 - 2008

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Foreword

—Minnesota Governor Tim Pawlenty
NGA Chair, 2007-2008

For the better part of the past century, America has enjoyed the benefits of an energy system that has been relatively inexpensive and easy to use. But our continued reliance on this system—dominated by finite and carbon-intensive resources—has made us increasingly vulnerable to unstable countries that house vast amounts of the world's energy supplies and has jeopardized our relationship with the environment.

Our country is too dependent on foreign sources of energy. By 2030, we will be providing only 65 percent of our own energy needs—35 percent will come from foreign sources, mostly oil. Our total energy-related carbon dioxide (CO_2) emissions are projected to increase more than 25 percent by 2030. Continuing down this dangerous pathway risks our economic well-being, energy security, environmental future, and quality of life.

America is at a tipping point. As has happened at other key moments in our nation's history, the public is ahead of policymakers; citizens are seeking strong leadership for a new direction. As governors, we have a unique opportunity to lead the United States toward a cleaner, more independent, and secure energy future. That's why as 2007-2008 chair of the National Governors Association, I launched a yearlong initiative—*Securing a Clean Energy Future*—to enlist the efforts of all governors to make our nation a global leader in energy efficiency, clean technology, energy research, and the deployment of alternative fuels.

I believe we can and must craft a new comprehensive and multi-faceted energy future that does not require sacrificing our prosperity. Our new energy future can increase our national security, improve our environment, and bring economic benefits to our communities.

Record numbers of governors discussed initiatives to develop alternative sources of energy or to promote conservation in their 2007 and 2008 State of the State Addresses. *Securing a Clean Energy Future* draws on these and other efforts to benefit every state—and the nation. The initiative focuses both on what we can do immediately and on what we must do in the future to reduce overall energy demands while keeping our economy strong. A bipartisan task force, comprised of forward-looking governors who share a common desire to advance clean energy ideas and who represent a cross-section of the country, guides the initiative's efforts.

The *Securing a Clean Energy Future* gubernatorial task force will identify and implement approaches that:

- Improve the use of our energy resources through efficiency and conservation;
- Promote nonpetroleum-based fuels, such as ethanol and biodiesel;
- Take reasonable steps to reduce greenhouse gas emissions; and
- Accelerate research and development of advanced clean energy technologies.

Achieving these goals will require a new devotion to conservation, research, new energy technologies, and a clean fuels infrastructure. Changing our current practices—reducing our current dependencies through the development, adoption, and use of new technologies and infrastructure—is a long-term commitment. States have shown they are willing to lead the way. Together, we can find and follow a pathway to a better, cleaner, more independent energy future.

The *Securing a Clean Energy Future* Task Force

Minnesota Governor Tim Pawlenty—*Co-Chair*
Kansas Governor Kathleen Sebelius—*Co-Chair*
Connecticut Governor M. Jodi Rell
Florida Governor Charlie Crist
Hawaii Governor Linda Lingle
Montana Governor Brian Schweitzer
Pennsylvania Governor Edward G. Rendell
Washington Governor Chris Gregoire

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States can play a key role in the research, development, and demonstration that is essential to clean energy innovation.

Executive Summary

The transition to clean energy is one of the greatest challenges of the 21st century. The goals of this transition—which are both economic and environmental—can only be realized with technical innovation. States will play a key role in the research, development, and demonstration (RD&D) processes that drive this innovation. In the coming years, states will be making crucial decisions to advance clean energy RD&D. Such decisions will play a key part in helping America secure a clean energy future.

Clean energy encompasses not only renewable energy sources (e.g., wind, solar, biomass, geothermal, and tidal), but also cleaner fossil fuel technologies (such as carbon capture and storage), energy efficiency, and advanced energy storage technologies. Clean energy is already a major economic force: In 2007, an estimated $71 billion was invested in new renewable energy capacity worldwide. However, many of these technologies are still often more expensive than mainstream alternatives. One of the main goals of RD&D is to reduce the costs of clean and renewable energy technologies so their benefits can be fully realized.

Technological innovation is traditionally viewed on a linear timeline in which universities and laboratories conduct basic and applied research—often with federal dollars—and private firms undertake development, demonstration, and deployment. While this model varies, states can play an important role at each stage.

Broadly speaking, states that know their overall energy system and energy users are best positioned to implement clean energy opportunities. These states typically have the following capacities to undertake clean energy RD&D:

- A detailed understanding of their own resources and needs;
- An ability to respond quickly to a changing environment; and
- A capacity to seize opportunities missed by private or federal institutions.

States planning a clean energy RD&D program should first take stock of their existing resources—which usually fall into the following categories—to determine any competitive advantages:

- Natural resources, both renewable and nonrenewable;
- Industrial resources, including existing infrastructure and expertise; and
- Intellectual resources, such as universities and national laboratories.

Funding of clean energy RD&D programs must be invested strategically to make use of limited financial resources. Many states have successfully sought funding from federal agencies, such as the U.S. Department of Energy (U.S. DOE) or various national and industry laboratories. But private funding for clean energy RD&D has skyrocketed in recent years, and states can attract these dollars through matching grants, as well as by improving their infrastructure and intellectual capital.

States using their own funds are advised to seek a portfolio of projects likely to effectively leverage their monies. States should also consider collaborating with other entities within their state, such as utility organizations, state associations, and with other states, to leverage funding and manage risk. In general, state funding spent on a portfolio of clean energy research is likely to achieve results in short, medium, and long time frames.

Drawing on the innovation literature and the experiences of specific states, the following principles will help states create successful clean energy RD&D programs:

1. **Create demand push alongside market pull.** The creation of a technology does not ensure its success; ultimately it must find a market. States have many different methods to stimulate markets for clean energy technologies, including standards (such as a Renewable Portfolio Standard), taxes, incentives, and subsidies. In addition, broad policy initiatives—including overall goal setting, regulation, and consumer education and outreach—can help spur clean energy markets.

2. **Ensure a consistent time frame.** The benefits of RD&D are realized over a horizon—at least 5 to 10 years, and as long as 20 to 30 years. States can and should contribute to the RD&D process at all stages, providing targeted assistance when it is most needed. Because energy projects are capital-intensive, they are especially vulnerable to what's known as the "Valley of Death"—the funding gap between development and deployment that can halt initiatives before they get off the ground.

3. **Catalyze collaboration between academia, industry, nonprofits, and other states and governments.** State governments are strategically positioned to facilitate these collaborations. Groups of states can also achieve great benefits through regional communication, coordination, and collaboration.

4. **Enlist expert advice to reach the wisest possible investment decisions.** Making strategic investment decisions in clean energy RD&D requires not only academic expertise, but also input from industry and business, as well as nonprofits. A balance of opinions should be sought through the creation of diverse advisory boards and peer-reviewed grant programs.

5. **Create metrics of success for the funded RD&D programs.** Although the benefits from RD&D can be defined differently, program evaluation is an important step toward improving future investment decisions. Metrics include journal citations, patents filed, new jobs created, and value of new businesses. Efforts to quantify energy savings and pollutant reductions can also be valuable indicators of success.

The process of creating a clean energy economy is well underway across the United States, and the contributions made by individual state RD&D initiatives so far are very encouraging. States can continue to play a key role in the research, development, and demonstration that is essential to technological innovation.

Introduction

State governments face great opportunities and considerable challenges in the transition to a clean energy future. The necessity of this transition is now widely recognized by scientists and policymakers alike, but many questions remain: Which clean energy sources can best offset the demand for fossil fuels? How can energy be used more efficiently, saving money and reducing carbon emissions simultaneously? Can the new energy economy stimulate economic growth and revitalization? And how can new energy technologies reconcile economic, environmental, and energy goals? States will play—and already have played—a key role in the research, development, and demonstration (RD&D) to solve these problems.

The goal of this report is to inform and guide states in the crucial decisions they will have to make about clean energy RD&D in the years ahead. It aims to establish and clearly document a set of principles for investing in clean energy RD&D that all states can apply regardless of their unique circumstances. Moreover, with demand for energy growing, states need to consider a broad energy portfolio, including energy efficiency, renewable energy, nuclear power generation, and clean fossil fuels, when looking at their long-term energy needs. This calls for greater investment throughout the clean energy RD&D continuum.

While states should make efforts to understand and utilize their own energy resources, this report also contains examples of actions that states have already taken, as well as actions at other levels of government from which states can draw inspiration. The report discusses a variety of clean energy technologies, illustrating possibilities rather than providing a detailed explanation of each. It is designed to serve as a useful starting point for states seeking to invest in their future—and in the future of the nation—by developing a new generation of energy technologies that can sustain America throughout the 21st century.

Why Clean Energy RD&D?

By fully understanding exactly what is meant by clean energy RD&D, states can better prioritize these investments among other competing demands. This section defines what is meant by clean energy RD&D, discusses the benefits of clean energy RD&D programs, and explains why states are well-positioned to act.

What is RD&D?

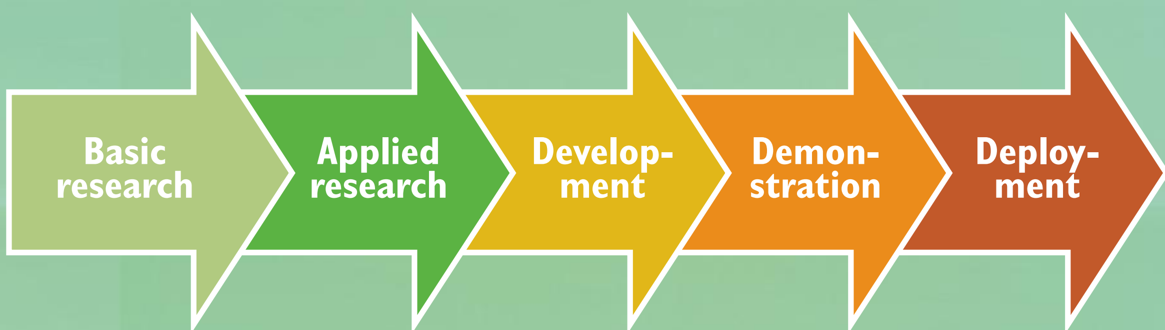
Understanding the process of technological innovation in a technology-driven industry like clean energy is crucial. Helping states to aid this understanding is a set of innovation-related terms used throughout the report, and an explanation of how innovation is applied in clean energy policy decisions.

What follows is a brief description of this process, definitions of innovation-related terms used throughout the report, and an explanation of how innovation is applied in clean energy policy decisions.

Definitions

The standard “linear” innovation model **(Figure 1)** provides a useful starting point for defining and discussing aspects of technological innovation. In this view of the technology development pipeline, basic laboratory research is evolved and adapted for the market, and is then simply commercialized. The real world, of course, is more complicated, includes a wide variety of stakeholders, and technologies do not necessarily follow this progression from beginning to end.

Figure 1. Technical innovation timeline: From basic research to commercial success



Stage 1 Basic Research: Research seeking to understand fundamental scientific principles and to add to the overall knowledge base.

Stage 2 Applied Research: Research intended to meet knowledge needs in a particular area, which can include fulfilling a societal need.

Stage 3 Development: Design and creation of a new marketable product.

Stage 4 Demonstration: Use of a new technology to evaluate its performance and prove its effectiveness.

Stage 5 Deployment: Large-scale, commercially sustainable use of a new technology.

The term *R&D* has traditionally referred to the first three stages of this process; however, it is now more common to talk about *RD&D* in a way that emphasizes that the innovation process does not stop at development. The second "D" is sometimes used to mean "demonstration" and sometimes "deployment" (or, similarly, "dissemination"). The term *RD³* is an even more inclusive term that covers every element in the timeline (research, development, demonstration, and deployment).

In this report, the acronym RD&D is used to mean research, development, and demonstration. These three topics comprise a coherent whole, since they cover all the steps in the creation of a new technology *before* it enters the marketplace. However, this discussion emphasizes that deployment is also of critical importance, even though it is not the focus of this report.

Guiding the RD&D process

The linear model on page 4 assumes that basic scientific research will lead to applied research in new technologies (usually funded by the public sector). The model then assumes that once the technology has been proven in the laboratory, if it offers commercial promise, it will receive private funding for product development and demonstration and ultimately be sold as a commercial product.

However, new technologies are not destined to advance through this timeline, but rather face substantial risks for failure at every step along the way. For example, a common explanation of the breakdown between knowledge acquisition and application is that the development of a technology is driven by scientific interest rather than user need. It is for this reason that government policy can play an essential role in steering RD&D efforts to improve existing technologies or develop new ones that fill a clear need, thus resulting in a positive outcome (i.e., product deployment).

This important sector of research that does not fit neatly into this categorization is termed "use-inspired" basic research, in which fundamental scientific questions must be answered to solve a specific technological problem.[1] This is discussed in more detail later in this report.

Although this report will emphasize applied research as a more effective leverage point for state involvement than basic research, this is not always the case. Much clean energy RD&D falls into this category; for example, with regard to the materials science behind solar power and the biology behind biofuels.

What is "clean energy"?

For the purposes of this report, "clean energy" is used as a general term to include the following components:

- **Renewable energy sources**—Such as solar, wind, tidal, biomass, and small hydro and geothermal power;
- **Clean, nonrenewable energy technologies**—Such as clean coal plants with carbon capture and sequestration, but also including co-generation and district heating;
- **Efficiency technologies**—Such as compact fluorescent lights, efficient water heaters, improved refrigerators and freezers, advanced building control technologies; advances in heating, ventilation, and cooling (HVAC); and advanced solid state lighting; and
- **Advanced energy storage technologies**—Including lithium-ion batteries for hybrid and electric vehicles; load leveling and peak shaving for electric power, and electrochemical devices, such as supercapacitors.

Not discussed in this report are established fossil fuel technologies (such as combined-cycle gas turbines, even though they can be comparatively clean). Nor does this report talk about nuclear fission, a technology that, because of the massive capital investments required as well as the complex implementation issues, is outside the scope of achievable RD&D efforts for most states.

Clean energy is already a major economic force. As noted earlier, worldwide investments in new renewable energy capacity reached an estimated $71 billion in 2007, up from $55 billion in 2006 and $40 billion in 2005.[2] Most of the increase went to new investments in solar photovoltaics (PVs) and wind power. In 2007, the technologies with the largest share of investment were wind (43 percent), solar PVs (30 percent), and solar hot water (10 percent), followed by lesser shares of small hydropower, biomass power and heat, and geothermal power and heat.

Clean technologies investments are predicted to grow. *The Clean Edge Clean Energy Report 2008* estimates that the total revenue for four clean energy technologies (PVs, wind, biofuels, and fuel cells) may increase to more than $250 billion by 2017.[3] The revenues from technologies like geothermal, tidal, small hydro, solar thermoelectric, biomass, clean coal, and advanced batteries add billions more to that figure.

However, with the exception of hydro and sometimes wind, electricity generation with these technologies usually results in higher costs than with conventional coal and gas plants.[4] One of the main goals of increased RD&D is to substantially reduce the costs of clean energy technologies so that their full benefits can be realized. The benefits of undertaking RD&D on clean energy technologies are discussed below.

Benefits of a clean energy RD&D program

Research and development is not an end goal, but is an essential step toward reaping the benefits of new industries. RD&D benefits fall into two categories:

1. The direct benefits from RD&D activities.

2. The follow-on benefits from the emergence of new clean energy industries.

Direct benefits of clean energy research and development

Advantages from clean energy industries are derived from the entire spectrum of activity that goes into a high-technology industry, including the research and development itself. Through clean energy RD&D, states can:

1. **Build an intellectual workforce and attract top talent.** Investment in RD&D generates high-skilled, high-paying jobs.

2. **Create spinoff benefits in other industries.** For example, the Apollo Space program is credited with returning roughly $13 to the economy for each dollar invested, with only a small portion of that return directly from the Moon landing program itself.

3. **Produce intellectual property (e.g., patents).** Intellectual property continues to pay dividends to the creators, such as universities or laboratories, independent of the industries that emerge within the state itself.

Benefits from the emergence of clean energy industries

While RD&D itself can certainly benefit a state's economy, the greatest economic payoffs of renewable and efficient energy technologies are only realized when the technologies are built and used on a large scale. Accelerating the deployment of clean energy is expected to have a number of benefits, which can be divided into the following three primary categories:

1. **Benefits for citizens.** The public gains include living in a cleaner environment, and, over the long-term, lower electricity costs and insulation from fossil fuel price volatility and increases.

2. **Benefits to the state's scientific and technology enterprise.** Positives include expanded RD&D funding, an influx of scientists and engineers, the promotion of lucrative technology clusters, and the advancement of technologies necessary to support a clean energy economy.

3. **Economic growth.** Fiscal rewards stem from the creation of new businesses and jobs, expansions of existing firms, attraction of investment capital to the state, improvements in the economic competitiveness of the state, and the stimulation of new clean energy markets.

It goes without saying that environmental benefits—including greenhouse gas reductions—are an important motivation for pursuing clean energy, which is an issue that has been covered extensively in other reports.[5] But this report focuses on items two and three above to explore the extensive evidence that suggests that clean energy technologies can not only help in the quest to improve the environment, but can also generate positive economic returns to states.

Additional benefits of clean energy jobs

The issue of job creation in clean energy industries is of great interest to states. Although numerical estimates vary, clean energy may create significantly more jobs than fossil energy per dollar invested. In a 2001 study,[6] the Renewable Energy Policy Project calculated that wind and solar energy produce 40 percent more jobs per dollar than does coal. A 2004 study[7] by the Renewable and Appropriate Energy Laboratory found that investment in renewable energy created three to five times as many jobs as the same investment in fossil-fuel energy systems. **Figure 2** shows the expected impact of Renewable Portfolio Standards (RPS), which could yield more than 348,000 jobs by 2025.

Furthermore, "clean tech" creates a spectrum of different types of jobs, from technical and engineering to sales to research and development. As an example,[6] the jobs created by the wind industry include manufacturing of parts (40 percent), turbine servicing and installation (31 percent), and blade manufacturing (26 percent). For the solar PV industry, the largest job categories are module assembly (30 percent), systems wiring (18 percent), and contracting and installation (15 percent). The fact that clean energy systems have low or no fuel costs means that a greater proportion of funds can be allocated to train and pay workers.

Another important aspect of clean energy jobs is that a certain percentage will be community-based.[8] These jobs can become drivers of economic redevelopment and have the potential to replace "blue collar" jobs with "green collar" jobs. For example, renewable-energy-based green collar jobs can create new demand for manufacturing equipment, installation, and the maintenance necessary to build and operate wind turbines or PV solar panels. **(Box 1)**.

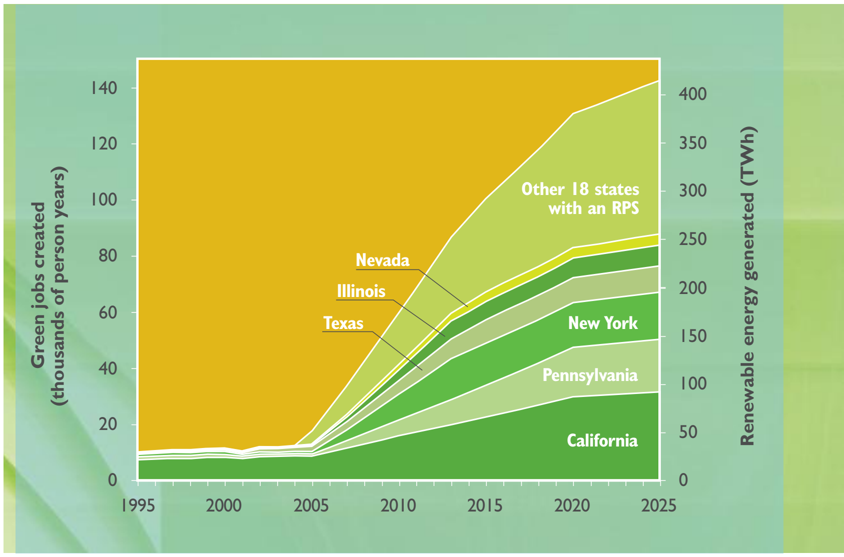
States are well-positioned to take action

Despite the many benefits of clean energy industries, the question still arises: Why should *state* governments play a role in clean energy research and development? Should that be the role of the federal government or of private industry? There is no single answer to this question. There are some aspects of clean energy RD&D on which states are ideally situated to act (discussed later in this report) and other areas that may best be left to private industry or the national government. Below are some of the general advantages of carrying out clean energy RD&D at the state level.

States know their own resources

Each state has an opportunity and a role to play in the clean energy economy, both for the nation as a whole to make the best use of its resources and for states to make the most of the opportunities given to them. States with abundant clean energy resources, such as wind or solar, can benefit from helping to commercialize the technology to utilize these resources. Even in the absence of natural resources, states with a strong knowledge-based economy are positioned to contribute to clean energy technology development. By recognizing their unique strengths and needs when it comes to energy policy, states can set their own clean energy RD&D priorities and, in so doing, reap the greatest benefits for their individual economies.

Figure 2. Projected job creation from state Renewable Portfolio Standards to 2025



Source: Kammen, D. M. (2007). Testimony on "Green Jobs Created by Global Warming Initiatives," United States Senate Committee on Environment and Public Works, September 25, 2007.

Box 1: Growing the Green Energy Economy

With an eye toward accruing benefits from clean energy, several states see investment as a way to meet broader economic development goals. **Washington's** legislature recently passed a bill establishing the Green Economy Jobs Growth Initiative to increase clean energy jobs by a total of 25,000 by 2020.

Other states are using job creation as a selling point for investments in clean energy RD&D or for working toward clean energy and carbon standards. **Utah** plans to invest $973 million in the clean energy RD&D effort—dubbed USTAR—through 2035 in the hopes of creating more than 20,000 new jobs. **Connecticut** loaned a local company $4 million to expand a fuel cell plant that would create an additional 100 jobs in the state.

Some states are also working on new "green" workforce training efforts; for instance, the **New York** State Energy Research and Development Authority has announced a $6 million clean energy workforce training initiative.

States can act as policy laboratories

States have already become energy innovators by introducing a range of policies and programs that can be replicated in other states or at the regional or national level in support of clean energy. They have the ability to pursue a range of options that best fit their state's natural resources, industrial and technological base, and available funding. California's Global Warming Solutions Act provides a prime example **(Box 2)**. Technology development and policy do not always follow a steady path, but can present opportunities for action. States have the agility to take advantage of those windows.[9]

States can take advantage of unrealized opportunities

Over the past few decades there has been a trend away from investment in energy technology—both by the federal government and by the private sector, which largely follows the federal lead.[14,15,16] Today, the United States invests about $1 billion less in energy RD&D annually than it did a decade ago. The decline is pervasive; it is seen across almost every energy technology category and at multiple stages in the innovation process. Moreover, this decline has occurred while overall U.S. RD&D has grown by 6 percent per year.

The upside is that there is a wealth of opportunities that can be captured by quick and effective state action. For example, because of the lack of strong federal drivers, the U.S. clean energy industry lags Europe and Asia in terms of export capacity. However, states can significantly impact this with local industry development and are poised to profit from exporting to a global community rapidly deploying low carbon energy systems. Countries such as Germany, Spain, and Denmark, which are global leaders in the development and construction of wind turbines, are already realizing this profit. They have multiyear waiting lists for foreign orders.

Box 2: California Global Warming Solutions Act of 2006

California's 2006 Global Warming Solutions Act (AB 32) regulates greenhouse gas emissions from major industries, calling for emissions to be cut to 1990 levels by 2020, a 25 percent[10] reduction. AB 32 is also part of a longer term state plan, enacted by Governor Arnold Schwarzenegger as Executive Order S-3-05, to reduce emissions by 80 percent below 1990 levels by 2050.

The benefit of such a program lies not only in the greenhouse gas reductions themselves, but in the impetus they provide for technological innovation. California's development and deployment of clean technologies will place it in a strategic position to export this expertise to the rest of the nation and to the world. By one estimate, the AB 32 emissions goals will actually increase the gross state product by $60 billion and create 17,000 jobs.[11]

AB 32 provides the framework through which a number of California initiatives are linked and coordinated. State efforts to spur development and deployment of both solar thermal and PV technologies, new "zero energy" residential and commercial building standards, as well as efforts to achieve wider deployment of combined heat and power (CHP) systems are all coordinated by AB 32.

In addition, the state commissioned two studies—the Market Advisory Report[12] and the Economic and Technology Advancement Advisory Committee (ETAAC) report[13]—to assess policies and programs that could accelerate both the development and deployment of clean energy technologies needed to achieve the goals of AB 32.[i]

[i] ETAAC was formed by AB 32 to advise the California Air Resources Board (ARB) on "activities that will facilitate investment in and implementation of technological research and development opportunities including, but not limited to, identifying new technologies, research, demonstration projects, funding opportunities, developing state, national, and international partnerships and technology transfer opportunities, and identifying and assessing research and advanced technology investment and incentive opportunities that will assist in the reduction of greenhouse gas emissions. The committee may also advise the ARB on state, regional, national, and international economic and technological developments related to greenhouse gas emission reductions."

Leveraging a State's Existing Resources

Every state has an abundance of resources that can be harnessed in support of clean energy industries, from sunlight and fertile soil to advanced manufacturing industries to skilled workforces. For states to implement a successful RD&D strategy, they must identify and objectively assess their resources, with a focus on those that offer the greatest returns or a competitive advantage over other states or regions. While in some cases states can effectively develop expertise in new areas, RD&D strategy should be based first and foremost on the state's indigenous strengths.

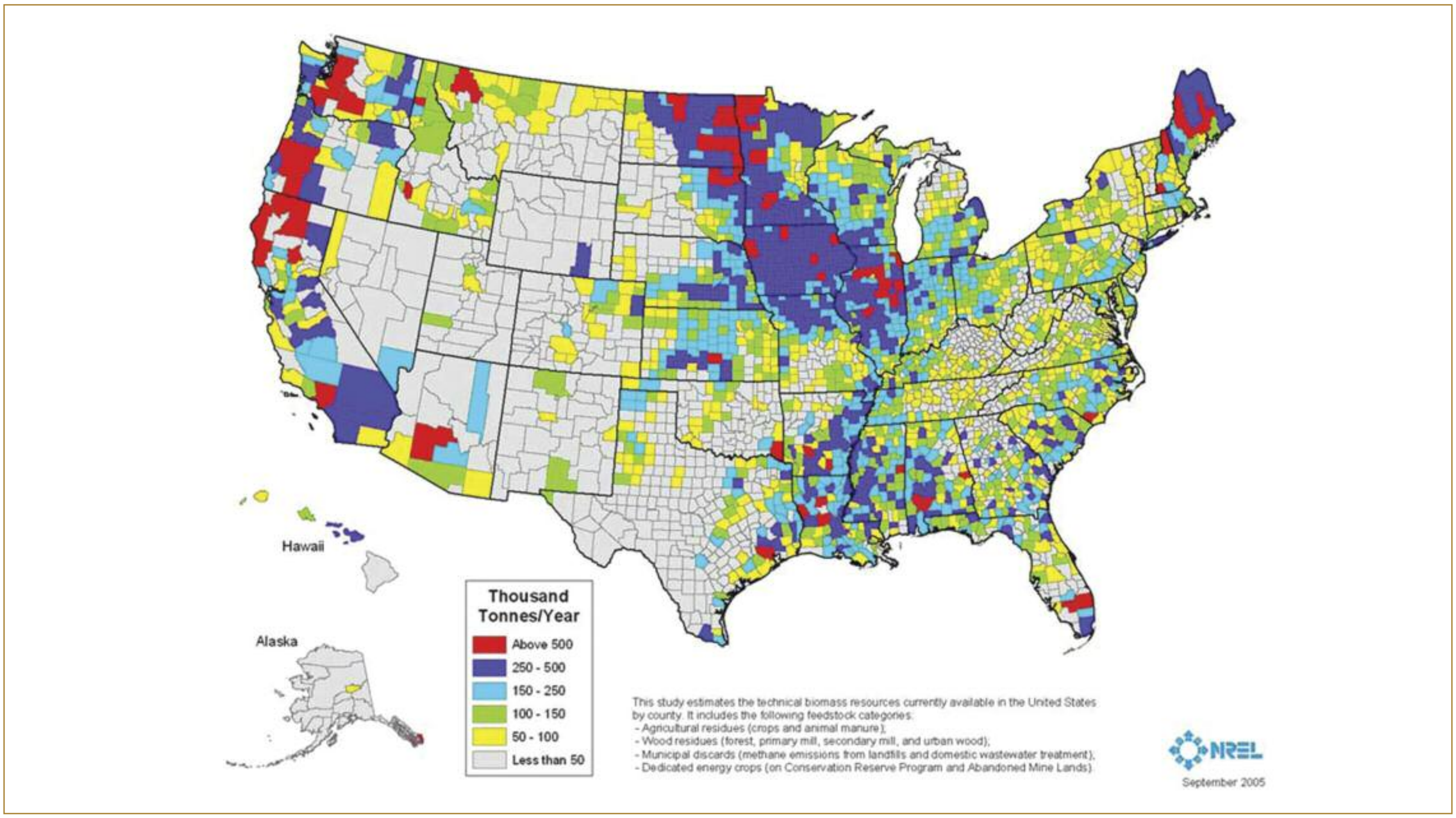
The unique combination of resources in each state argues for pursuing clean energy RD&D at the state level. States are in the best position to assess their resources and craft policy to support the most promising opportunities, in ways that national policies or market forces may not.

The resources that are most relevant to clean energy RD&D are natural resources, industrial resources, and intellectual resources. This section will discuss how states can best use their resources in each of these categories.

Natural resources

For clean energy industries, especially the development of renewable energy, natural resources play a critical role. In the absence of natural resources, many of the clean energy technologies are not worthwhile investments. In contrast, the emergence and continued evolution of the information economy relies on industrial and intellectual resources that are free from the need for ample sunlight, wind, or fertile soil. This constraint on clean energy industries makes strategic investments especially important. Within environmental, fiscal, and other limits, states are looking to take full advantage of their natural resources.

Figure 3. Biomass resources in the U.S. (courtesy NREL)



Renewable resources

Renewable resources are defined as non-fossil fuel energy sources that can never be completely consumed.[17] In 2006, America used renewable energy sources—water (hydroelectric), geothermal, wind, sun (solar), and biomass—to meet about 7 percent of its total energy needs.[18] In standard usage, the following energy sources are considered renewable:

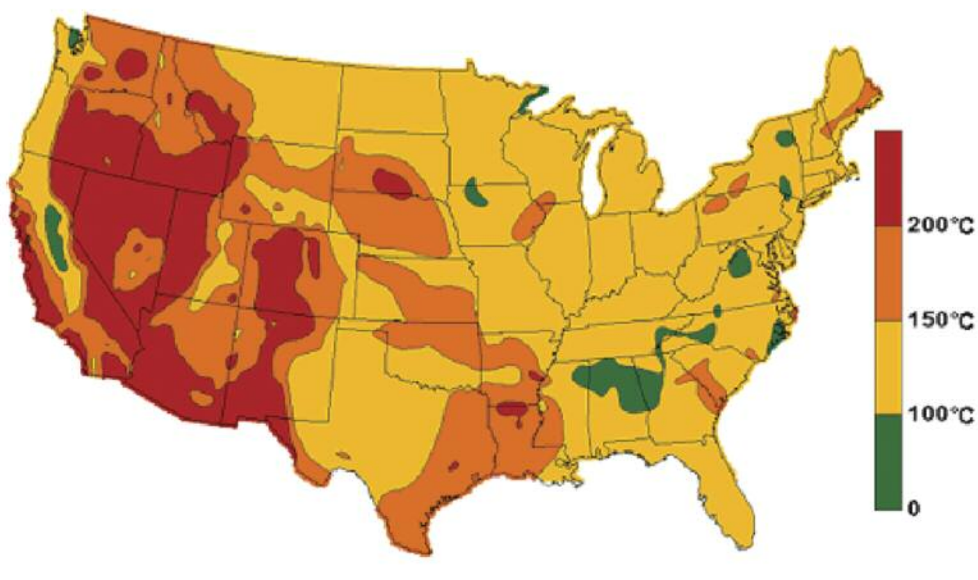
- Solar radiation
- Geothermal [ii]
- Wind
- Tidal power
- Biomass
- Wave power
- Hydropower [iii]
- Ocean thermal gradients

Renewable resources offer long-term economic benefits that combine the prospect of increasing employment and economic growth on the one hand [7] and providing energy security and stability on the other. They also reduce greenhouse gas emissions and other pollutants.

Renewable energy resources are broadly distributed throughout the country. Biomass resources **(Figure 3)** are concentrated in northern New England, the northern Midwest, the South, the Southwest, and the West Coast. Geothermal resources in the U.S. **(Figure 4)** are largely concentrated in the western states, with some areas of the Midwest also offering opportunities. Most U.S. solar resources **(Figure 5)** are concentrated in the western and southwestern states, but with sufficient sunlight value found throughout most of the Midwest and the Southeast. Wind resources **(Figure 6)** lie in coastal areas, including the Great Lakes region, with lesser concentrations throughout most of the Midwest.

Some states have substantial renewable resources that can be combined with a variety of other technologies, while others have fewer choices. The U.S. DOE Office of Energy Efficiency and Renewable

Figure 4. Geothermal resources in the U.S. (courtesy of EERE)



The map above shows geothermal resources in the continental United States. Estimated subterranean temperatures of 200 degrees Celsius (C) and above are shown in red, estimated subterranean temperatures of 150 to 200 degrees C are shown in orange, estimated subterranean temperatures of between 100 and 150 degrees C are shown in yellow, and estimated subterranean temperatures of 0 to 100 degrees C are shown in green.

[ii] Geothermal can be used for electricity generation (geothermal power) or for heat (geothermal heat pumps).

[iii] It is worth noting that certain types of renewable resources can be theoretically exhausted or are disputed as renewable. For example, geothermal power can be locally depleted. Large hydropower projects may harm ecosystems and human communities; for this reason, some states and organizations only count small hydro (<30 MW capacity) under their renewable energy standards.

Figure 5. Solar resources in the U.S. (courtesy NREL)

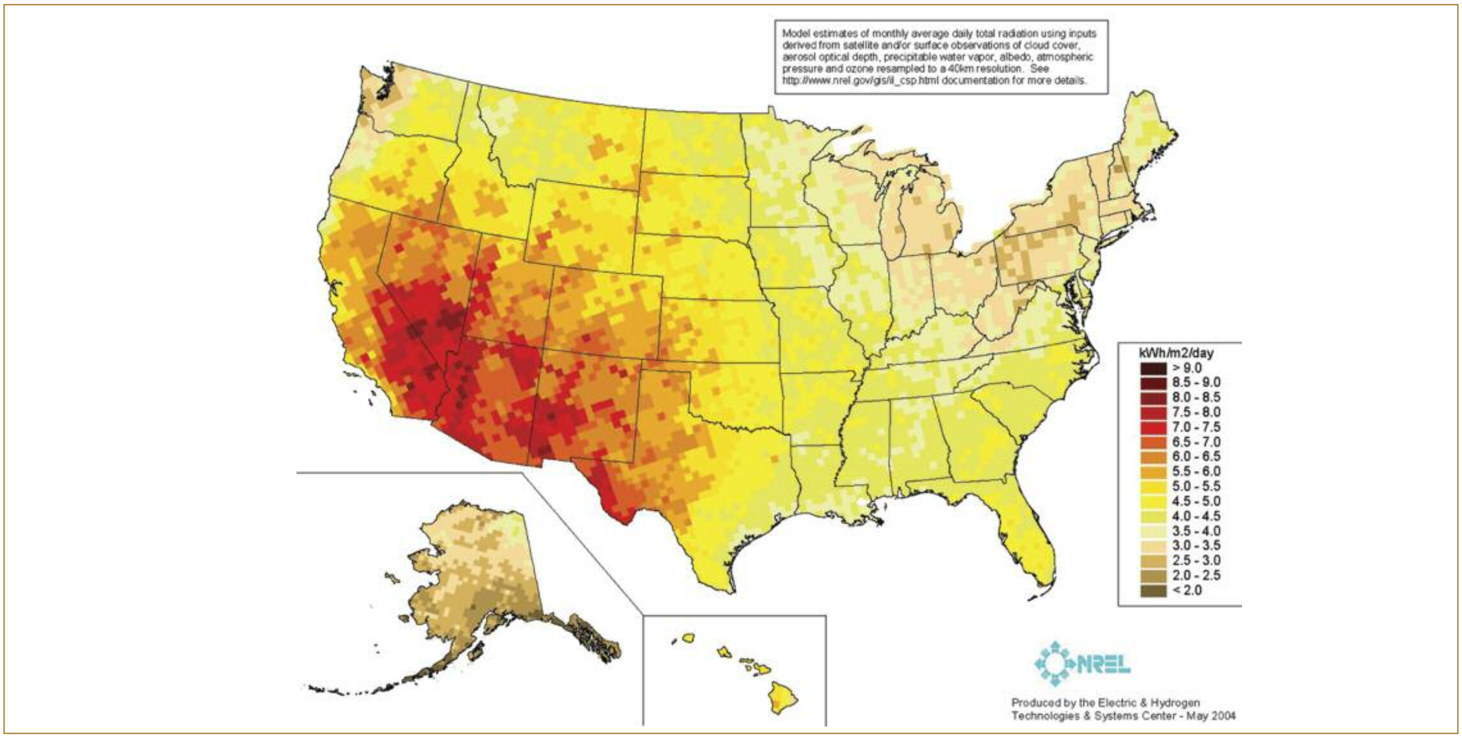
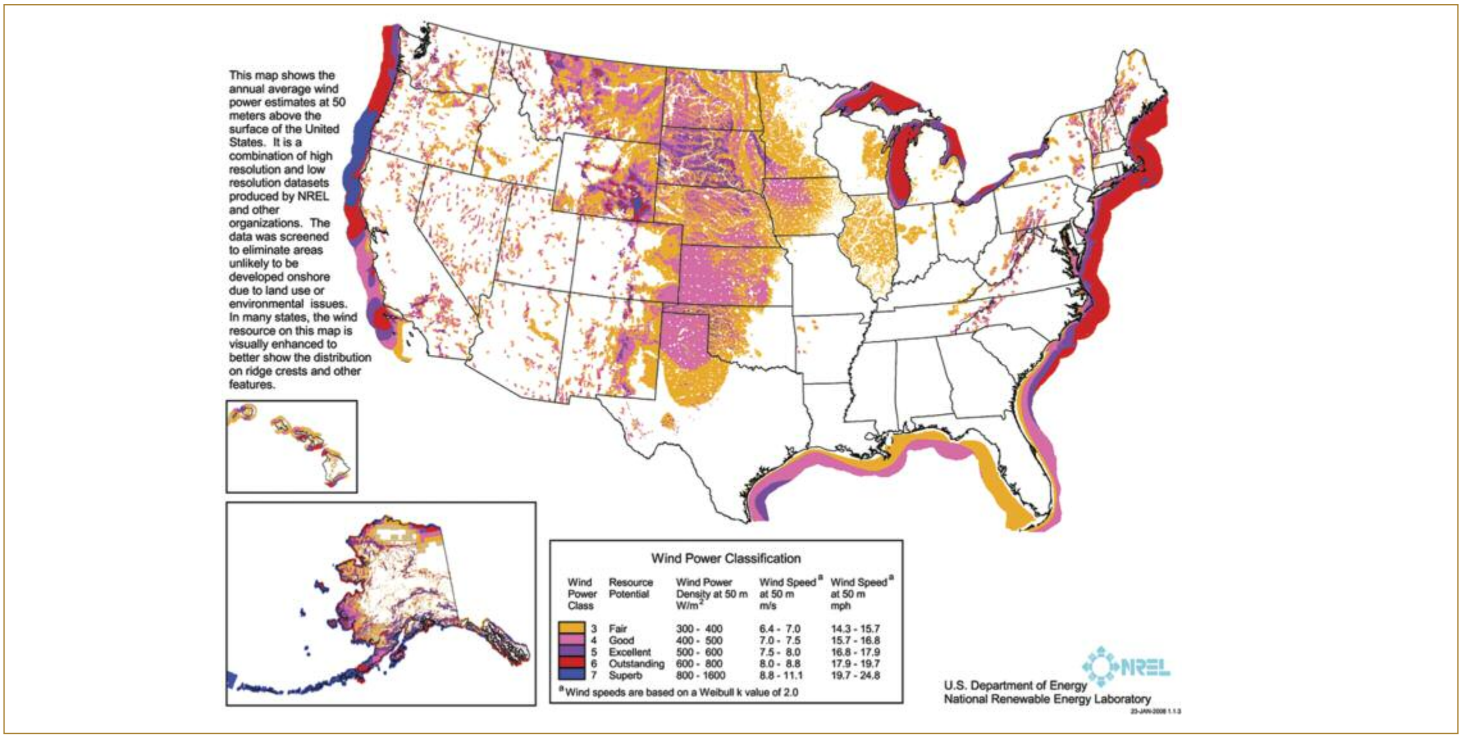


Figure 6. Wind resources in the U.S. (courtesy NREL)



Energy (EERE) summarized this information with an online tool identifying the most promising alternative energy resources in each state.[19] Nevada **(Box 3)** provides an interesting example of a state with several different renewable energy options.

Box 3: Nevada's Renewable Energy Resources

Nevada's primary renewable energy resources are solar, wind, and geothermal power. The state, thus far, has most extensively tapped its geothermal resources, though both solar and wind offer greater capacity. Many of the areas that offer the greatest potential are sparsely populated, making potential deployment of solar and wind farms more feasible. Its geothermal potential is the largest in the country.[20] The abundance and variety of these renewable resources served as an impetus for Nevada to introduce a Renewable Portfolio Standard for electricity generation,[21] which has been revised upward and now calls for 20 percent of electricity to come from renewable sources by 2015.

Nevada	Geothermal (Electricity)[22]	Geothermal (Heat)[22]	Solar[23]	Wind[23]
Installed Capacity	276.4 MW[iv]	64 MW	n/a	n/a
Potential Capacity	2,600-3,700 MW	2,400 MW	10,600 MW	6,300 MW

Nonrenewable resources

Despite recent increases in the price of fossil fuels, they continue to be cheaper sources of electricity than renewables and available in significantly greater capacity, although prices are beginning to converge. However, while new wind farms can often provide power at 4 to 8 cents a kilowatt hour (kWh), comparable to fossil fuel generation rates, the transmission grid is geared toward nonrenewable power, and often better suited for fossil base load generation that does not face intermittent power generation and/or storage challenges.

On the transportation side, gasoline and diesel remain the most convenient transportation fuels, although record-setting oil prices are likely to make efficient vehicle technologies like plug-in hybrids, fuel cells, and alternative fuels more attractive to consumers.

Given the structure of the energy and transportation industries, it is expected that states will continue using nonrenewable resources for years to come, but more efficient and less polluting technologies are greatly needed. For states with extensive supplies of nonrenewable resources, such as coal or natural gas, investing in RD&D to improve efficiency and reduce pollutants or carbon emissions could be an attractive option. The coal industry in Illinois provides a good example of this **(Box 4)**.

Box 4: The Illinois Clean Coal Institute

Illinois has extensive coal reserves, which, if used in an environmentally sound manner, offer significant economic opportunities. Coal is an important industry for Illinois and is anticipated to remain so. In 2006, nearly 33 million tons of Illinois coal was mined, generating almost $1 billion in state revenues. By investing in clean coal research, the state of Illinois is building on its natural strengths.

The Illinois Clean Coal Institute (ICCI)[v] was established in 1982 by the Office of Coal Development, part of Illinois's Department of Commerce and Economic Opportunity (DCEO). Its mission is to promote development and use of technologies that reduce environmental impacts from the use of coal for power generation. The ICCI research program covers the life cycle of coal, from mining methods and business practices to coal preparation to clean combustion to management of the residuals. One of its major emphases is reduction of sulfur and mercury emissions, though ICCI is beginning to fund projects relating to reduction of greenhouse gases.

The ICCI coordinates the state's coal research program and brings together private companies, universities, and other interests. Since 1982, the DCEO has invested roughly $46 million in coal RD&D through the ICCI, while attracting about $1 million from Illinois coal companies for research and more than $14 million from industry and other government agencies.

Industrial resources

Industrial resources include physical infrastructure (such as manufacturing plants) as well as related expertise in the industrial workforce. Industries that are positioned to provide expertise relevant to clean

[iv] Electrical power is usually measured as a kilowatt (kW) or megawatt (MW). According to the American Wind Energy Association, 1 MW of wind-generated power can supply electricity to approximately 240 to 300 households per year. Regional variations exist, however, depending on time of year and climate conditions.

[v] More information is available at http://www.icci.org.

energy include automotives, pharmaceuticals, agriculture, electronics and computer chips, and pulp and paper production. Their techniques and processes are similar to those necessary for a number of clean energy industries.

Utilizing existing industrial resources

Strengthening state economies through the development of clean energy industries can be best accomplished by using existing resources and expertise rather than starting from scratch. State funding or technical assistance can make it easier for firms to expand into clean energy technologies, providing them with flexibility while preserving current jobs. Incentives such as tax breaks or matching funds can allow firms to expand into new areas that they otherwise may have avoided as too risky. **New York** is a prime example of using existing resources **(Box 5)**.

Box 5: New York's Transportation Research Programs

States can capitalize on their existing industrial strengths by supporting R&D that provides continued advances in the environment and energy performance of otherwise "mature" products. For example, **New York** is not only North America's largest user of electrified commuter and transit rail products, it is also one of North America's premier rail products manufacturers. Through programs such as the New York State Energy Research and Development Authority's (NYSERDA) Advanced Transportation Products R&D program, New York State is supporting economic growth in clean energy transportation products manufactured in New York and sold to the rest of the world.

State support can also be especially important if existing firms are challenged by economic changes. In particular, state support may enable companies to focus on new, promising clean energy technologies. **Ohio** has implemented a program to focus on transitioning existing manufacturing capacities to advanced clean energy production **(Box 6)**.

Box 6: "Building Ohio Jobs" with Clean Energy

As part of Building Ohio Jobs, a $1.57 billion initiative proposed by Governor Ted Strickland and adopted by the **Ohio** General Assembly in May 2008, the state will invest $150 million in advanced and renewable energy.[24] Rising demand and costs for energy—combined with the state's manufacturing strength—has created opportunities for the state. The investment in energy is designed to nurture and attract firms in energy production, delivery, storage, and supply chains.

The RD&D focus of Building Ohio Jobs is in solar and wind manufacturing, advanced coal technologies, biofuels and bioproducts, and energy conservation and efficiency. The initiative will support Ohio companies as they expand and retool to provide components for advanced energy technologies ranging from clean coal to renewables like solar and wind.

Most states incorporate industrial and technology policies into their economic development programs, including their plans for clean energy industries. For instance, they can identify the workforce skills needed for emerging industries, and expand state university and junior college programs to provide these employees. An important component of **Colorado**'s new Climate Action Plan[25] is a focus on education and workforce development. Colorado has created a "Jobs Cabinet" in its executive branch to align the state's education goals with the need to "develop an adequate and well-trained workforce for the New Energy Economy."

In addition to supporting existing firms, states can also target RD&D programs to firms with relevant technological expertise. States may be able to preserve their existing industrial bases by encouraging firms to expand into clean energy industries. The following examples demonstrate how expertise developed in one industry can be adapted for clean energy:

- **From windshields to solar power.** Automotive industry suppliers concentrated in **Michigan** and **Ohio** developed an expertise in technology for thin-film coatings to lessen glare on automotive windshield glass. This industrial expertise has spawned a host of successful regional companies in Ohio producing thin-film PV products, including Xunlight Corporation, United Solar Ovonic, and First Solar LLC.

These commercial success stories were propelled with resources from the Ohio state government and the University of Toledo, which houses the Wright Center for Photovoltaics Innovation and Commercialization. The center received $26.6 million in state grants to establish and develop its thin-film research programs **(Box 7)**.

- **From computer chips to solar cells.** In Silicon Valley, **California**, semiconductor designers and manufacturers have turned their silicon expertise toward the development and manufacturing of solar PVs. An outstanding example is SunPower Corporation, which currently employs 3,500 people and has a market capitalization of approximately $8 billion. SunPower started rapid growth in 1999 with public funding from the National Institute of Standards and Technology's (NIST's) Advanced Technology Program, among other sources.[26] By 2005, SunPower went public, following an investment from Cypress Semiconductor. SunPower's success likely would not have been possible without the investment and expertise from Cypress, which allowed the company to engage in high-volume manufacturing.[27] Although in this case the initial funding was from a federal rather than a state agency, SunPower exemplifies how strategic investments can be made in clean energy technologies that synergize with a state's existing industries.

- **From oil drilling to geothermal and wind power.** Two key capabilities of the oil industry—drilling and building offshore platforms—can play important roles in the advancement of geothermal power and offshore wind power. Accessing the natural heat of the Earth requires drilling to depths that are frequently reached by the oil industry—and by few others. Offshore oil drilling platforms require the same stability and endurance that are needed for offshore wind installations.

  In fact, existing offshore oil platforms can be converted to wind turbine platforms with minimal modification, as shown in a project currently underway off the coast of Galveston, **Texas**. This 150-MW project by Galveston Offshore Wind (a division of Wind Energy Systems Technology) will be the first offshore wind farm in the United States, and came about directly as a result of oil industry expertise.[28] Although the Galveston project did not benefit from state assistance, it provides an example of a cross-industry synergy that states can seek out.

Box 7: Michigan and Ohio's Innovation in Solar Photovoltaics

United Solar Ovonic, a company previously focused on producing automotive products, now manufactures and sells thin-film solar laminates that convert sunlight to energy. United Solar is a wholly owned subsidiary of Energy Conversion Devices, a company with a market value of more than $1 billion. United Solar recently chose Greenville, **Michigan**, as the location for a new $129 million solar cell manufacturing facility. The Michigan Economic Development Commission approved a Single Business Tax credit valued at $5.7 million to win the company's business. The city of Greenville also received a $5 million federal Community Development Block Grant to fund infrastructure improvements around the new plant. With additional funding for job training, the state and local incentive package totals approximately $37 million, and yet the project is projected to increase net state revenue by $22.9 million and create approximately 550 new jobs.

Ohio's Third Frontier Project was initiated in 2002 to expand the state's high-tech research capabilities. The 10-year, $1.6 billion initiative was designed to build world-class research capacity, support early stage capital formation, and finance advanced manufacturing technologies to help existing industries become more productive. A beneficiary of this state program, the University of Toledo, has become a leading center for thin-film solar technology RD&D, and numerous companies have blossomed as a result. Moreover, a new joint venture between the Third Frontier and the Ohio Board of Regents, called the Ohio Research Scholars Program, recently awarded the University of Toledo and Bowling Green State University more than $8 million to support expanded thin film PV RD&D.

Xunlight Corporation, a technology spin-off from the University of Toledo, provides an excellent example of the value created by access to RD&D funding. The company develops thin-film, silicon-based PV products, based on research originally funded by the following federal, state, and private grants:

- National Renewable Energy Laboratory (U.S. DOE)—$3,094,907
- Ohio Department of Development Program—$2 million
- Air Force Research Lab, Kirtland Airforce Base—$1,247,000
- National Science Foundation - Partnership for Innovation—$600,000

Box 7 (continued)

- Small Business Innovation Research Program (U.S. DOE)—$100,000
- General Motors Corporation—$100,000.

The research and development funding has allowed Xunlight to develop its manufacturing technology, backed by two recently completed venture capital financings: a $7 million Series A financing in 2007 and a $22 million Series B financing in April 2008. These financings will be used to build a pilot production line at the company's Toledo, Ohio, headquarters.

Intellectual resources

Intellectual resources in some ways overlap with industrial resources. This report draws the two distinctions between them:

1. Intellectual resources are considered to lie within universities, federal laboratories, and public-private cooperative ventures, as opposed to within industrial resources that generally are found in private firms. In some cases, these are cross-cutting because industry laboratories will cooperate with national laboratories and universities, including sharing facilities and scientists.
2. Intellectual resources generally contribute to the earlier stages of the innovation process (basic and applied research), whereas industrial resources are more heavily involved in later stages (development, demonstration, and deployment).

Intellectual resources include a broad range of activities, capabilities, and skills. Within universities, for example, intellectual resources include human capital embodied in students and professors, the research lab infrastructure, and the expertise and training in specific scientific and technological disciplines. States with concentrations of technology firms or firms that employ advanced manufacturing have similar assets in private industry.

The development of intellectual resources generally requires a longer time frame and provides benefits that are more difficult to quantify than those from the development of natural resources or industrial resources. The strength of intellectual resources largely derives from the development of networks of people and institutions that work on shared issues. These networks can be critical to the development of new industries, but require years or even decades to develop, making returns on state investments difficult to quantify.

Intellectual resources, however, are often more important to a state's long-term economic outlook than either industrial or natural resources. Strengths in specific industries now are not guaranteed to remain the same in the future. Natural resources are critical, but to effectively leverage them, states need a skilled workforce and technologically capable firms, both of which are generated and supported by strong intellectual resources.

Universities

Universities play an essential role in the process of clean energy RD&D. Many universities have developed expertise in clean energy-related fields through years of research, in large part funded by the federal government through the National Science Foundation, U.S. DOE, and U.S. Department of Defense, among others. Many universities now have portfolios of clean energy patents and work with established and emerging firms to develop new technologies.

Because of the large capital costs and long timelines of clean energy RD&D, universities can most effectively contribute their expertise if they have additional support from outside sources. There are many examples of successful university-state partnerships in clean energy RD&D, including **Oregon**'s proposed National Wave Energy Research and Demonstration Center (**Box 10, page 18**), **Connecticut**'s Global Fuel Cell Center (**Box 14, page 23**), and **North Carolina**'s Advanced Transportation Energy Center (**Box 23, page 31**). In each of these cases, the university's existing strengths (for example, electrochemical and battery research at the North Carolina center) were recognized and promoted by state government.

Private funding is also instrumental in many university RD&D efforts. The largest recent example is the $500 million investment by BP, the global energy group, to create the Energy Biosciences Institute at the University of **California**, Berkeley; the University of **Illinois**, Urbana-Champaign; and Lawrence Berkeley National Laboratory.[29] BP's goal is to tap the existing expertise at these institutions to develop the next generation of vehicle fuels, recognizing that investing in existing intellectual resources will likely provide faster and better results than attempting to invest internally to duplicate that expertise.

Another prominent example of academic expertise attracting private funding is the Gulf Coast Carbon Center (GCCC),[30] managed by the Bureau of Economic Geology at the University of **Texas** (UT), Austin. The Bureau of Economic Geology has conducted cutting-edge research in geoscience since its founding in 1909; it doubles as the state's Geological Survey. UT Austin, as a natural hub for RD&D in geologic carbon sequestration, was able to attract funding from Shell, Chevron, Schlumberger, and other private firms to create the GCCC, which is now a world player in carbon sequestration technologies.

National laboratories

The national laboratories[31] are an important intellectual resource for the nation, and for clean energy. All of the national labs have essentially evolved and expanded their expertise beyond their original missions and into clean energy. The National Renewable Energy Laboratory (NREL) in Golden, **Colorado**, is the primary national lab for clean energy RD&D. The following national labs are also working heavily in the area of clean energy:

- Oak Ridge National Lab, in Oak Ridge, **Tennessee**, originally established for nuclear research and production, now has expertise in research, development, demonstration, and evaluation in a variety of solar, wind power, hydropower, and biomass technologies.
- Sandia National Lab, in Albuquerque, **New Mexico**, also first established primarily for nuclear and defense research, now specializes in a number of solar technologies, as well as wind and geothermal power, at both the R&D and demonstration stages. Sandia also has a number of projects underway to develop more efficient distributed generation networks to enable power production from intermittent renewable sources.
- Los Alamos National Laboratory, in Los Alamos, **New Mexico**, has significant and long-standing programs in energy sciences, energy assessment and modeling, and—both domestically and internationally—clean energy and energy efficiency.
- Lawrence Berkeley National Laboratory, in Berkeley, **California**, in addition to sharing the focuses of Los Alamos National Laboratory, has programs in advanced photocell, fuel cell, clean combustion, advanced biofuels, energy modeling and market assessment, energy efficiency, building technologies, and end-use behavior.
- Argonne National Laboratory, in Argonne, **Illinois**, conducts research on semiconductor materials and on the life-cycle impacts and benefits of biofuel feedstocks and fuels.
- Brookhaven National Laboratory, in Upton, **New York**, conducts work on solar cell materials, fuel cells, and the future of the United States and global energy system.
- Pacific Northwest National Laboratory (PNNL), in Richland, **Washington**, has divisions researching the management of the nuclear energy fuel cycle, as well as linked energy-climate modeling and low-carbon energy systems. PNNL is also extensively involved in technology transfer from the national laboratories to both public and private ventures.
- **Idaho** National Laboratory (INL) is a science-based applied engineering national laboratory dedicated to supporting U.S. DOE's missions in nuclear and energy research, science, and national defense. By 2015, INL aims to be the preeminent nuclear energy laboratory with synergistic, multiprogram capabilities and partnerships.

The national laboratories are tremendous assets not only to the states in which they are located, but—because their mission is to serve the interest of the nation as a whole—to any state that secures funding or other support from them. A new partnership between NREL and the state of **Hawaii** aptly illustrates this **(Box 8).**

Box 8: NREL's Assistance in the Hawaii Clean Energy Initiative

In January 2008, the state of **Hawaii** and the U.S. Department of Energy established the Hawaii Clean Energy Initiative. With the active support and involvement of Hawaii Governor Linda Lingle and the state government, NREL and First Wind—aka UPC Wind—agreed to establish a wind energy R&D center at the UPC First Wind site on Maui.

Hawaii recently passed legislation with the goal of obtaining 20 percent of its electricity from renewable sources by 2020. The partnership between NREL and UPC First Wind is one of the first important steps toward meeting that goal. The Hawaii-based R&D site is the first partner site for NREL's wind technology R&D program that is not located at the lab itself. The R&D program combines the expertise of NREL with the resources and energy demands of Hawaii. Early plans for the research agenda are focusing on advanced wind technologies, including grid integration, storage, and operations. The benefits of NREL's partnership also extend beyond Hawaii; the lab will develop technologies and skills that can be used by other states.

Synergies between resources

States will most efficiently invest in clean energy if they can identify synergies between the three types of resources: natural, industrial, and intellectual. Implementing programs or policies that leverage the most state resources are more likely to be successful and provide the greatest returns. For example, a state with substantial solar resources and expertise in the form of research universities, national labs, or manufacturing firms may want to consider providing funding or other incentives to bring those groups together (discussed in more detail later in this report). A recently launched effort by the Electric Power Research Institute (EPRI), which seeks to collaborate with utilities, states, and others to demonstrate clean energy technologies, takes advantage of the three types of resources **(Box 9)**.

Preserve, enhance, or add?

States should build on existing strengths as their first priority, enhance and grow emerging strengths where possible, and break ground in new areas only with great care and careful consideration.[9] The advantage, and imperative, of working from strengths is that states can support existing firms and strengthen core industries, maintaining current workforces. All else being equal, a clean energy RD&D project is more likely to succeed if it can leverage established expertise, rather than starting from scratch.

However, it is worth noting that many of the clean energy industries are still in the early stages of their development, and there are opportunities for many states and firms that do not exist as mature industries.

Box 9: EPRI Climate Technology Demonstrations

In May 2008, EPRI launched seven climate technology demonstration projects to accelerate the availability of technology options to meet growing electricity demand and to reduce greenhouse gas emissions. Utility companies, suppliers, and state and federal governmental organizations are being invited to collaborate in the following demonstrations:

- **Energy Efficient Technology Demonstrations.** This project will demonstrate "hyperefficient" electricity-use technologies currently deployed in Japan, Korea, and Europe. The project is designed to increase understanding of technical and other obstacles for adopting these technologies in the United States, which could lead to substantial reductions in electricity consumption for several major end-uses of electricity.
- **Smart Grid Demonstrations.** This project will conduct several regional demonstrations to integrate distributed power generation, storage, and demand-response technology into a demand-side "virtual power plant." Demonstrations will include both utility-side and customer-side technologies.
- **Compressed Air Energy Storage.** Integrating large-scale renewable energy, such as wind and solar PV generators, whose output fluctuates over time and may produce power at unwanted periods, will require accommodation from the power grid through devices like bulk energy storage. This project aims to design, build, and operate two demonstration compressed air energy storage plants.
- **Advanced Coal with Carbon Capture and Sequestration using Chilled Ammonia.** This project will build on lessons learned from a smaller-scale project with We Energies, Alstom, and 30 other collaborators to test chilled ammonia to capture CO_2 emissions at utility scale.
- **Advanced Coal with Carbon Capture and Sequestration using a Different Capture Technology.** This project will look to scale up a different capture technology to reduce the costs and increase the number of CO_2-capturing options.
- **Low-Cost Oxygen Production.** Many advanced coal technologies require significant levels of oxygen for operation. This project seeks to address the need to reduce the costs of oxygen production for advanced coal generation, and ultimately, the cost of electricity from clean, advanced coal.
- **Integrated Gasification Combined Cycle (IGCC) with Carbon Capture and Storage.** This project will demonstrate CO_2 capture in a modern IGCC plant and address real-world integration and operational issues, which are critical steps in advancing this technology.

States may want to take more aggressive actions to support the development of technologies or industries where they may have a comparative advantage or head start, even if they do not have an established strength. **Oregon's** effort to develop ocean wave energy illustrates this example: The technologies are still commercially unproven, but the state is uniquely positioned to bring them to fruition **(Box 10).**

Box 10: Oregon National Ocean Wave RD&D Energy Center

In **Oregon**, a group of public and private organizations is working to establish in the state a national hub for ocean wave energy research. Oregon is ideally situated for wave research: Its coastal characteristics endow it with reliable and high-energy waves, and its population is concentrated along the coast, obviating the need for expensive new transmission lines.[32]

Oregon also benefits from world-class engineering facilities. Oregon State University (OSU) in Corvallis houses the Motor Systems Resource Facility (MSRF), the highest powered university energy systems laboratory in the country, as well as the Hinsdale Wave Research Lab, which provides an artificial testing ground for wave-powered devices.[33] Adding to these benefits are the expertise and infrastructure of Oregon's paper milling, fisheries, and manufacturing industries.

OSU has applied to DOE's Office of Energy Efficiency and Renewable Energy for a grant to establish a National Wave Energy Research and Demonstration Center based at OSU.[34] While this project is pending, other progress is being made. The Oregon Wave Energy Trust (OWET)[35]—a newly established advisory body with representation from state government, universities, utilities, and industry—is coordinating demonstration projects with OSU's existing wave energy technologies, ensuring the involvement of all relevant stakeholders.

Wave energy in Oregon shows how a state can build on, and seek synergies between, its existing strengths. In Oregon's case, a wave energy industry may also help replace jobs that have been lost in the fishing and forestry industries.[32] The state can play, and has already played, an important role in getting diverse groups together to realize the opportunities of clean energy.

Consider needs as well as strengths

In formulating investment strategies for clean energy, states should consider not only their strengths but also their needs. A state may face challenges relating to air or water pollution, traffic congestion, high electricity costs, solid waste disposal, loss of manufacturing jobs, or economic marginalization of rural areas. The following examples show how these environmental and economic problems in certain areas can be turned into clean energy RD&D opportunities:

- **Waste from dairy cattle.** With one of the largest dairy industries in the country, **Minnesota** has both a waste disposal problem and an untapped source of renewable energy. Methane produced by manure, rather than escaping as a greenhouse gas, can be converted to electricity by anaerobic digesters. This technology is becoming commercially viable, as exemplified by a demonstration project at Haubenschild Dairy Farm with assistance from the Minnesota Department of Agriculture, the University of Minnesota, and the nonprofit Minnesota Project.[36]

- **Air pollution in urban basins.** Even after decades of efforts to improve urban air quality, **California** is home to six of the top 10 most ozone-polluted cities in the United States.[37] The California Air Resources Board (ARB) has launched many initiatives to combat this problem, including the Innovative Clean Air Technologies Program,[38] which provides grants for pollution-reducing demonstrations.

- **High prices for electricity and gasoline.** Because of its remote location, the state with the highest energy costs in the country is **Hawaii**, with an average residential electricity price of 20.7¢ per kWh in 2006 (compared with the nationwide average of 8.9¢).[39] These energy prices pose a burden to Hawaii and its residents, and have motivated the state government to pursue an ambitious policy of clean energy RD&D.[40] Fortunately, Hawaii's needs align with its strengths: Its potential energy production from solar, wind, wave, biomass, and geothermal resources could meet its energy requirements many times over.

It may be appropriate for states to lower the investment threshold in situations when developing new clean energy technologies can simultaneously solve an existing problem and provide a benefit.

Securing Funding for RD&D

State budgets must accommodate many competing priorities, and a clean energy RD&D program can only succeed with sufficient funding. This section outlines state options for seeking external RD&D funding—namely, through federal programs and through private equity or venture capital—and then discusses how a state can most strategically spend its own funds.

Current trends in RD&D funding for clean energy

The development of the clean energy industry has greatly accelerated in the last few years. Currently, RD&D funding for clean energy comes primarily from the U.S. DOE and other federal programs, private firms, and venture capitalists, with a modest amount from state programs. State and federal legislation have increased RD&D funding, created requirements for the increasing use of renewable resources, and promoted the adoption of efficient technologies **(Box 11)**. The private sector has also responded.

More than $100 billion was invested in renewable energy in 2007, with one estimate of $148 billion, marking a significant global milestone. Of this, investments in research and development (public and private) account for about $16 billion. The majority of these occur in the public sector, but venture capital investments in clean energy have risen approximately 15-fold since 2003, from $235 million to an estimated $3.4 billion in 2007.[41]

Clean energy RD&D is big business, and getting bigger. However, the number of worthwhile clean energy RD&D projects far exceeds the funding available. The following sections outline how a state can effectively compete for outside funds, and how it can best leverage its own expenditures.

Box 11: Michigan's 21st Century Jobs Fund

Announced in 2005, the 21st Century Jobs Fund is a 10-year $2 billion initiative proposed by **Michigan** Governor Jennifer Granholm—approved by the Michigan Legislature and administered by the Michigan Economic Development Corporation (MEDC)—to accelerate the diversification of Michigan's economy.

Funded mainly by securitized tobacco settlement funds, the first round of monies resulted in the Strategic Economic Investment and Commercialization (SEIC) board awarding $126.3 million to 78 organizations. These organizations are doing high-tech research, commercializing new products, and creating new jobs in four main sectors, including alternative energy. In the first round, six proposals that focused on alternative energy were awarded $11.6 million.

Federal funding opportunities

Federal funding is still one of the largest sources of money for clean energy RD&D, although it has been outstripped in recent years by the sum of funding in the 50 states.[42] Funding allocated to renewables and other clean technologies has seen some gains since 2006, and is predicted to increase in coming years.[43] Certain technologies have benefited more than others: funding increases are targeted for solar, biomass, and hydrogen RD&D, at the expense of conservation and efficiency, hydropower, and geothermal power. However, federal support is available for virtually all technologies, and provides a range of options a state can pursue to fund its own clean energy RD&D programs **(Box 12)**.

Federal RD&D programs

A number of U.S. DOE programs provide funding for clean energy technologies. These support states whose academic and private-sector resources match the programmatic mandates. The following federal offices and laboratories distribute and utilize this funding:

- The Office of Energy Efficiency and Renewable Energy (EERE);
- The Office of Fossil Energy; and
- The National Laboratories (13 in total), including
  - NREL and
  - The National Energy Technology Laboratory (NETL).

EERE administers most of U.S. DOE's grants for clean energy research, including renewable and efficiency technologies, which are available to both universities and private companies through a variety of mechanisms. The Office of Fossil Energy provides funds for U.S. DOE's research on clean coal, carbon capture and sequestration, and hydrogen.

The national laboratories provide opportunities for universities and businesses through a variety of mechanisms, including traditional solicitations and awards, technology licensing and transfer, cooperative R&D agreements, and subcontracting, and the provision of technical support and research facilities. Much of their work is specifically focused on clean energy. For example, in late 2007, U.S. DOE announced the distribution of $7.2 million for a Technology Commercialization Development Fund that was split between the NREL, Oak Ridge National Laboratory, and Sandia National Laboratories for the express purpose of supporting full-scale clean energy commercialization.[44]

Box 12: Experimental Program to Stimulate Competitive Research (EPSCoR)

EPSCoR is a federal-state partnership that awards grants to promote scientific and technological innovation in a variety of disciplines.[45] What makes EPSCoR unusual is that it is focused solely on states that "have historically received lesser amounts of federal research and development funding." Currently, 24 states are eligible for the program. EPSCoR began as a National Science Foundation initiative in 1979, but with recognition of the valuable role it could play in promoting RD&D in states whose potential tended to be overlooked, it was adopted by many other federal agencies, including U.S. DOE in 1991.

U.S. DOE's EPSCoR program has two different funding mechanisms. Implementation grants of up to $750,000 annually aim to "improve the capability of the designated state ... to conduct sustainable and nationally competitive energy-related research." A state can only apply for one Implementation grant, but individuals within the state can apply for multiple National Laboratory Partnership grants, which total up to $150,000 annually. Funding for this program in 2008 is expected to be approximately $8 million; states must provide matching funds (50 percent for Implementation grants and 10 percent for National Laboratory Partnership grants).

EPSCoR's effectiveness lies not only in its targeting of states with the greatest unmet need for research funding, but also in its flexible funding mechanisms and its emphasis on partnerships. EPSCoR facilitates collaboration between its grantees and scientists from nearby national laboratories. Sometimes, states direct their EPSCoR funds toward small businesses. A number of states have parceled out EPSCoR funds in grants of a few thousand dollars to help small businesses prepare applications for federal RD&D awards, such as the Small Business Innovation Research[46] awards—an example of leveraging funding to its fullest.

Venture capital and private industry funding

One of the recent bright spots in clean energy RD&D is the veritable explosion of venture capital investments in emerging technologies. Clean technology, in particular, energy technology, is now the third largest component of all venture capital investment in the United States, with a number of individual start-ups attracting more than $100 million in venture capital funds, and some business efforts approaching $1 billion **(Box 13)**. Now more than ever, the private sector plays a critical role in clean energy RD&D.

Types of private funding available

There are many different categories of private funding available to support clean energy RD&D. Brief descriptions of the main types of private funding follow:

- **Business incubators.** Incubators, also called "accelerators," support start-ups at their earliest stages, usually when they have five or fewer employees. Incubators provide many services, including office space, business development expertise, legal and accounting assistance, and sometimes small amounts of capital.
- **Seed financing.** This is the earliest stage of financing, with equity in amounts of $100,000 to $5 million. A few venture capital firms do invest seed capital, but most seed money comes from private individuals, often referred to as "angel investors."
- **Venture capital.** Venture capital (VC) funds typically invest $7 million to $25 million in equity capital in early stage companies.
- **Hedge funds.** These are large pools of private equity capital with a flexible investment strategy. Although some hedge funds do invest in early stage ventures, hedge fund money is particularly well-positioned to underwrite the costs of the first commercial manufacturing plants, for which the capital required is too large for most VC funds, and the financing is too risky for commercial banks.
- **Bank debt.** When a company's product is commercially proven and the firm is profitable, commercial banks and investment banks can provide low-cost, long-term debt capital to finance new manufacturing facilities and other capital projects.

Note that in the following sections, the term "venture capital" is used somewhat more loosely than it is defined above; for instance, it may include somewhat smaller or larger investments, or investments at different points on the innovation timeline.

Current trends in venture capital funding

Venture capital funding for clean energy is skyrocketing. The numbers vary depending on which technologies are included, but the overall trends remain the same. According to data from Thomson Financial, venture capitalists invested over $2.2 billion into more than 200 clean technology deals in 2007, representing a 340 percent increase from 2005. In the last year alone, venture capital investment grew 47 percent and shows no signs of slowing. The number of venture capital firms investing in the clean technology sector more than doubled. This increased interest is driven by a number of factors, the most important being the promise of return on innovation in the space.

The venture capital community overwhelmingly predicts that investments in clean technologies will continue to increase in 2008 and beyond. In fact, investment in clean tech is trending along similar paths to that of the semiconductor industry 35 years ago and the biotechnology industry 20 years ago, with the potential of energy even more promising than in the previously mentioned sectors.

Venture funding for clean energy has so far been concentrated in a few locations, closely mirroring the concentration of venture funding in general, with **California, Massachusetts,** and **Texas** receiving the most funds. Attracting venture funding is more challenging for states that lack a state-of-the-art technology infrastructure. For innovators, it is frequently easier to move to areas with strong existing venture capital and technology communities.

However, venture capital funding is increasing in nontraditional regions. Based on 2007 figures, the National Venture Capital Association highlighted five regions that have seen dramatic increases in the number of deals and the total amount of VC investments over the previous decade. For three of the regions (**New Mexico,** Pittsburgh, and Los Angeles), clean energy is one of the top three industries attracting venture funding.[47]

Box 13: Google's "Renewable Energy Cheaper than Coal" Initiative

In November 2007, Google launched a new initiative[48] called "Renewable Energy Cheaper than Coal" (RE<C). The project aims to produce one gigawatt of renewable electricity—enough to serve one million people—within "years, not decades." Although Google has not disclosed the total amount of this investment, it is in the hundreds of millions of dollars, and may be one of the largest such projects undertaken by a private firm.

Despite the expense, the project's goal is low-cost renewable electricity. The initiative's title is aspirational; the mission statement is to "demonstrate a path toward producing energy at an unsubsidized cost below that of coal-fired power plants." To achieve this, Google's philanthropic foundation, Google.org, will provide grants to a variety of organizations, including private companies, laboratories, and universities.[vi] The initial focus is on three technologies—advanced solar thermal power, wind power, and enhanced geothermal power. In parallel with these grants, Google.com is assembling a team of engineers to work on the technical challenges internally.

RE<C is an example worth noting for several reasons: its sheer size, which suggests that the capacity of private capital to fund clean energy research is greater than ever before; its origin in a company outside of the energy sector; and its aggressive optimism about achieving profitable results on a large scale. It may be an indicator of how the private investment landscape will change for clean energy in the years ahead.

Attracting venture capital funding

In order to facilitate private investment in clean energy, one of the biggest levers that policy makers have is in creating a predictable policy environment that will ensure consistency and financial relevance with the venture capital investment horizon.

"Priming the pump" with investments in energy research and incentives for clean energy deployment (such as via a Renewable Portfolio Standard) can attract significant private-sector funding. Over the past several years, the run-up in energy sector venture capital has been focused closely around innovation "incubators" that are themselves located in regions with aggressive clean energy deployment strategies.

Nontraditional VC regions can attract attention and funds by leveraging and expanding their existing science and technology expertise. One way to do this is to improve college and university training in the skills needed by leading-edge firms. Some regions are also able to leverage world-class research facilities that provide an anchor for high-tech industrial growth. For example, Sandia National Labs, Carnegie Mellon University in Pennsylvania, and the California Institute of Technology (Caltech), which rank among the foremost research institutions in the country, are able to attract federal funding and researchers and nurture a climate that is supportive of entrepreneurs and clean energy start-ups.

State funding: Leveraging and balancing with other priorities

While federal and venture capital RD&D funding for clean energy have been rapidly increasing in the past two or three years, gaps remain in the funding and innovation system that states can effectively target, particularly to take advantage of their own natural, scientific, and industrial resources. Nine states currently have Clean Energy R&D funds: **California, Connecticut, Florida, Illinois, Massachusetts, Minnesota, New Jersey, New York,** and **Wisconsin**. Many states also have programs in place that can provide targeted loans, grants, and project funding. One advantage is that states do business with energy users. Because they have a direct relationship with these stakeholders, states can also develop policies to help support indigenous energy resources.

Collectively, the states also invest substantially in clean energy RD&D and often work collaboratively through organizations such as Association of State Energy Research and Technology Transfer Institutions (ASERTTI) and the Clean Energy States Alliance (CESA) as well as through the National Association of State Energy Officials (NASEO), and with U.S. DOE and other federal agencies.

Federal funding has concentrated on solar power and solid-state lighting, with more limited funding going into a number of other promising and important technologies. Venture funding, while covering a broader array of technologies, tends to focus on technologies that are close to market-ready, and tends to concentrate only in certain regions. This leaves a number of openings for states.

[vi] According to the Google.org Web site, in 2004, when Google founders wrote to prospective shareholders about their vision for the company, they included a commitment to contribute 1 percent of Google's equity and profits, as well as employee time, to address some of the world's most urgent problems. That commitment became Google.org.

Which projects should states fund?

There are specific niches where state action will be the most effective, depending on the needs and advantages of individual states. State investments in a particular technology can be useful along the entire chain of the innovation process; in some cases, targeted basic research in support of a specific industry may be a productive use of state funds.[49] **Connecticut**, for example, invested state RD&D funds in basic research in support of the state's fuel cell industry, to address fundamental materials science questions that would advance the technology for a number of state companies **(Box 14)**.

However, states generally do not have sufficient funds to act as a primary source of funding for general RD&D, especially compared with the level of funding from both the federal government and the venture capital community. If states are going to invest in traditional RD&D programs, as opposed to other uses of state funds described here, the investments need to be strategic and careful. In other cases, the preferred path may be establishing clean energy incubators in connection with research universities or federal labs.

There is no single rule for how states should support clean energy investments. However, specific options include providing seed funds to fill the funding gap between lab research and venture funding, loans to technology firms, matching funds, financial support for demonstration projects or first deployment, assistance in expanding manufacturing, and incentives for widescale deployment of generating facilities or the adoption of efficiency technologies.

What funding mechanisms are possible?

States have become particularly creative in their approaches to funding RD&D. In some cases, states use a combination of grants, equity investments, and loans. In addition, state programs differ in the way funds are raised to invest in RD&D. Some states add surcharges to utility bills, raising funds directly from ratepayers for clean energy investments **(Box 15)**. Other states directly support RD&D programs from public funds, usually as the result of legislation rather than regulatory decisions. **(Box 16)**.

Box 14: Connecticut Fuel Cell Initiatives

The **Connecticut** Global Fuel Cell Center (CGFCC)[50] at the University of Connecticut was established in 2001 with a mix of federal, state, and private funding.[vii] Its mission is to support development and commercialization of fuel cells, and in so doing "propel Connecticut into the forefront of renewable energy innovation and commercialization."

CGFCC tackles a wide spectrum of activities—from basic research to commercial deployment. The center is addressing some of the most fundamental technical problems with fuel cells today, such as developing more efficient processes of catalysis, and creating new materials for electrodes to reduce the amount of platinum needed. The center is also seeking to demonstrate and deploy fuel cell technologies; for example, in 2006, it received a Yankee Ingenuity grant jointly with United Technologies Corporation (UTC) to study the reliability of fuel cells as backup power systems.

CGFCC is a noteworthy example of how a state can get involved at all stages of the innovation process, and how it can leverage its power by partnering with industry and academia. Connecticut has few natural resources relevant to energy production, but that was no impediment to the creation of this unique center. The presence of UTC and a number of other companies with significant research and deployment programs in electrochemistry and materials research—key areas of fuel cell technology research and deployment—made the state a natural hub for the center, and provided those firms with access to world class researchers and research facilities and a skilled workforce.

As part of this process, the Connecticut Center for Advanced Technology established the Connecticut Hydrogen-Fuel Cell Coalition,[51] which has more than 20 industrial partners and linkages to both in-state universities and a number of international partners. These linkages facilitate a range of collaborative and competitive relationships, including the identification of market opportunities, which can be vital in moving companies across the "Valley of Death" (see page 29) by obtaining revenue earlier than might otherwise be possible.

A vital part of the development of the Connecticut Hydrogen-Fuel Cell Coalition was the passage in 2006 of enabling legislation (Public Act 06-187)—signed by Governor M. Jodi Rell—directing the state Department of Economic and Community Development to contract with the Connecticut Center for Advanced Technology, Inc. (CCAT) to develop a fuel cell economic development plan. Connecticut exemplifies the importance of a multifaceted approach to clean energy RD&D.

[vii] A diverse set of funders established CGFCC with an initial investment of $14.5 million. This included $3.5 million from Connecticut Innovations (originally a state-funded institute, but now self-supporting); $3.5 million from state and industrial partner matching funds; $2 million from the U.S. Department of Commerce (matched with $670,000 in state funds); $2.25 million from an in-kind donation of two fuel cells; and $2.5 million from a congressional earmark.

Box 15: The Massachusetts Renewable Energy Trust

The **Massachusetts** Renewable Energy Trust (MRET)[52] is a quasi-public body established by the state and funded by ratepayers, costing each residential customer about 50¢ per month. The trust was established in 1998 through the Electric Restructuring Act, which supported the development and expansion of clean energy firms. Massachusetts was one of the first states to implement such an approach to funding clean energy. A small group of ratepayers challenged the legality of the funding mechanism; however, the Massachusetts Supreme Judicial Court ruled unanimously in favor of MRET, which has continued to grow and fund many successful projects.

The trust supports RD&D projects through a wide variety of programs, including the Business Expansion Initiative (BEI), which provides loans to early stage firms seeking to develop or expand renewable production capacity, and the Sustainable Energy Economic Development (SEED) initiative, which provides funding for the so-called "Valley of Death" (see page 29) technologies—those not sufficiently developed to attract private funds, but advanced beyond laboratory RD&D.

In addition, the trust works closely with the Massachusetts Green Energy Fund (MGEF),[53] which is a $15 million fund managed cooperatively with Commons Capital, a venture capital firm. The fund invests equity capital in Massachusetts renewable energy firms. While not a direct RD&D program, the fund seeks to highlight innovative firms and attract private capital to support RD&D and commercialization for new technologies. Efforts by MRET and MGEF have helped to attract venture capital funds to Massachusetts as a hub of clean-energy development and shifted the emphasis toward longer term investments in projects and technologies.

The U.S. Environmental Protection Agency (EPA), which maintains a list of states with renewable energy trusts[54]—15 at the time of this writing—suggests that states will be more likely to achieve success with a renewable energy trust if they involve diverse stakeholders in the development and administration of the funding mechanism, ensure stability of revenue from year to year, leverage the funding to complement rather than duplicate federal support, and allow flexibility in the types of projects that are funded. Massachusetts, a pioneer in clean energy funding mechanisms, has helped to identify practices from which all states can benefit.

Box 16: Iowa Power Fund

Iowa Governor Chet Culver worked with a group of legislators to create the Iowa Power Fund. An initial appropriation of $25 million was approved along with a standing three-year appropriation of $25 million for grants and loans for increasing the research, development, production, and use of biofuels and other sources of renewable energy, with the goal of improving energy efficiency and reducing greenhouse gas emissions.

The fund is administered by a board of directors, composed of 11 voting members and eight nonvoting ex-officio members. Applications for financial assistance are reviewed by an eight-member due-diligence committee, three of whom sit on the board of directors. The fund is staffed by the newly created Office of Energy Independence. This small entity, which is an adjunct of the governor's office, supports the Power Fund directors, coordinates state energy policy, and advises the governor on energy policy.

In its first year, the Power Fund received approximately 150 applications for financial assistance. Projects proposals included a demonstration of affordable methods of energy-efficient masonry, applied research on corn fractionization technology, a demonstration of the use of pelletized solid waste to power boilers that create soy-diesel fuel, research to determine the feasibility of using wastewater thermal energy in single family dwellings, and applied research on growing algae and transforming it into a rich biological fuel.

As of May 2008, the fund was negotiating its first five financial assistance contracts for a variety of energy clean technology RD&D projects.

Nonmonetary support

Apart from RD&D funds, states may contribute in other ways to support clean energy industries. Nonfinancial examples include streamlining permitting processes or providing state land for demonstration projects. States may also establish business incubators, particularly in conjunction with federal labs or state research universities, or promote technology transfer between federal labs, state universities, and companies. This is discussed in more detail in the next section.

General Strategies for Clean Energy RD&D

The innovation process, central as it is to human endeavor, has been thoroughly studied across a range of sectors. Energy is no exception. This section of the report draws on the innovation literature (both general and energy-specific) to identify some broad strategies for choosing successful investments in clean energy RD&D.

The energy sector departs from a general innovation model in the following ways:

- The industry is highly capital intensive—requiring substantial investments on the order of tens of millions of dollars or more for demonstration projects—which is essential to the successful commercialization of utility-scale clean energy technologies; and

- Energy installations have long lifespans, which may lock in a certain level of technological advancement at construction. This makes the decision to invest in large-scale projects a difficult one, especially for technologies that are being widely deployed for the first time and for which the state of the art continues to improve.

With these constraints in mind, below are some general principles that can help states make profitable investments in clean energy RD&D.

Consider technology push and market pull

For developing trades based on relatively early-stage technologies—which characterize most clean energy industries—there can be an inherent tension between the concepts of "technology push" and "market pull." The former is often emphasized to the neglect of the latter.

- **Technology push** is the idea that new technologies may be developed that offer exciting possibilities, but for which there is no market, or for which a market may need to be created for a firm or a state to fully take advantage of it. Research and development programs, if successful, may result in "technology push" situations.

- **Market pull** is the idea that markets will develop wherever there are vacuums waiting to be filled by technologies and products. Legislative efforts may create "market pull" conditions where the appropriate technologies are lacking. These conditions will not exist in each case, but states should be prepared to balance RD&D programs with efforts to create markets for the targeted technologies.

Clean energy development and deployment is most effective when innovation strategies are combined with equal or greater attention to market creation. Fortunately, there are many ways a state can facilitate "market pull," some of which do not require a significant additional investment in funds. Some of the most effective approaches, including standards, taxes, tax credits, incentives, subsidies, and enabling markets, are outlined below.

Standards

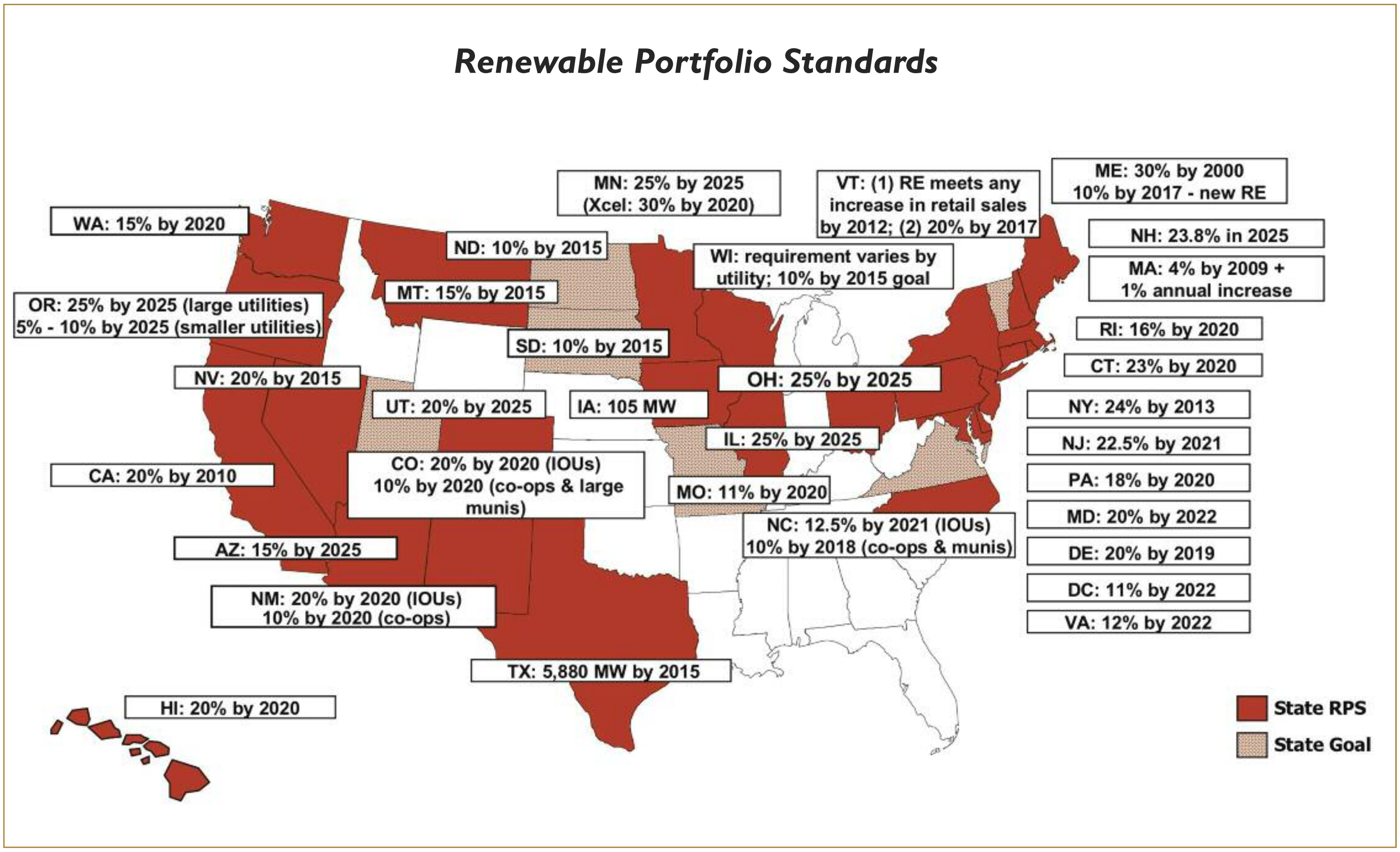
Standards are one way to encourage the adoption of clean technologies. Standards are legal or regulatory requirements to meet a certain defined performance or criteria. They can be enacted at low cost to the state (compared with subsidies) and may be more palatable than a tax. Standards can evolve over time as needed, depending on the development of the technology. However, states are constrained in that they cannot set standards that are incompatible with federal law.

The potential for "leakage" must also be considered; industries that are constrained by energy efficiency or emissions standards may simply move to another state.

Nevertheless, standards are a powerful policy tool if used wisely. Following are examples of standards that are already playing an important role in the development and deployment of clean energy technologies:

- **Renewable Portfolio Standards (RPS).** These mandate that a certain percentage of electricity generation come from renewable sources, usually increasing over time. The EERE[55] reports that more than half of the states have some type of RPS **(Figure 7)**.
- **Low-Carbon Fuel Standards (LCFS).** California was the first state to create a Low Carbon Fuel Standard.[56] The LCFS requires fuel providers in California to ensure that the mix of fuel they sell into the state market meet a declining amount of greenhouse gas emissions per unit of fuel sold. By 2020, the LCFS will produce a 10 percent reduction in the carbon content of all passenger vehicle fuels sold in California, and the LCFS is expected to replace 20 percent of state on-road gasoline consumption with lower-carbon fuels, more than triple the size of the state's renewable fuels market, and place on California's roads more than 7 million alternative fuel or hybrid vehicles.[57]
- **Lighting efficiency standards**. Minimum standards for the efficiency of electric lighting installed in new buildings could catalyze the development of more efficient lighting technologies, such as light-emitting diodes **(Box 17)**.

Figure 7. States with RPS standards as of June 2008 (courtesy DSIRE[58])



Box 17: Federal Funding for Solid State Lighting

The U.S. DOE Solid State Lighting RD&D program demonstrates the role that governments play in using regulatory powers to create demand for new technologies. Solid state lighting, including light emitting diodes (LEDs) and organic light emitting diodes (OLEDs), potentially can replace traditional lights and displays with substantially more efficient and more capable technologies. By some estimates, LEDs are more than twice as efficient as current lighting, with the potential to reduce national electricity demand by approximately 10 percent.[59]

U.S. DOE initiated a solid state lighting research program in 2003 to provide funding and technical assistance to bring LEDs to the efficiency and cost levels needed for widespread commercialization. The department and several private companies are cooperating to support the RD&D and commercialization efforts for LEDs, establishing the "technology push." As LEDs become market-ready, states can create the "market pull" by establishing efficiency standards for lighting in new buildings. This action can facilitate the market penetration of LEDs, and the associated energy and cost savings mean there would be little direct financial cost to the state.

Tax credits and taxes

Tax credits and taxes are two sides of the same coin. The former are easier to enact while the latter have the advantage of generating revenue. States can leverage both to create market pull for clean energy.

Tax credits for clean energy technologies already exist in many states. Tax credits can be awarded based on either the capital investment in the energy system (investment tax credits) or the energy produced by the system (production tax credits). The mechanism can be applied to property taxes (29 states offer property tax credits to clean energy suppliers); income taxes (24 states); and sales taxes (22 states).

For example, **Utah** offers a state income tax credit to help cover the installation costs of both residential and commercial clean energy systems. **Florida** also offers a state income tax credit, but only for commercial systems and only predicated on electricity production ($0.01 per kWh). **Massachusetts** offers credits on all three kinds of taxes, including a partial property tax exemption for homeowners who increase their property's value by installing a renewable energy system.[60]

In deciding when and how to enact tax credits for clean energy, states should consider existing federal tax credits. If state incentives overlap too closely with federal ones, the state may become ineligible for federal assistance.[61] The current federal production tax credit of 1.5¢ per kWh for renewable energy is set to expire on December 31, 2008; it may be renewed, but if not, states may be in a position to bridge the gap.

One tax approach related to clean energy is a carbon tax, which is one of two primary regulatory mechanisms to reduce carbon emissions. The carbon tax penalizes high emitters and rewards low emitters. (The other approach is "cap and trade," discussed on page 28). Both strategies attempt to make fossil fuels more expensive and reward clean energy investments. No state has yet enacted a carbon tax, but several municipalities are in the process of doing so, including Boulder, **Colorado (Box 18)**, and the San Francisco Bay Area.[62]

Box 18: Boulder, Colorado's Electricity Tax

In November 2006, voters in Boulder, Colorado, approved Initiative 202, the Climate Action Plan Tax.[63] This legislation marks the first time in the nation that a municipal government will impose an energy tax on its residents to directly combat global warming. The tax will be collected by the local electric utility and is based on the amount of electricity consumed by businesses and homeowners. This energy tax is also referred to as a carbon tax because most of Boulder's electricity comes from coal, a major source of carbon emissions. The tax, which will generate about $1 million annually, will be used to fund the city's Climate Action Plan, which focuses on energy efficiency programs and educational outreach.

Incentives and subsidies

Incentives and subsidies for clean technologies may incur a greater implementation cost to the state than do standards or taxes, but have the advantage of often being more politically feasible. When choosing to undertake an incentive program, a state needs to weigh the potential benefits of the program with its expense. Often, both the costs and benefits can be considerable, as demonstrated by **California**'s Solar Initiative **(Box 19)**.

However, it is worth noting that incentives need *not* incur an expense to the state. For example, several states, including **Arizona, California, Florida, New Jersey, New York, Tennessee, Utah,** and **Virginia** have passed laws or are piloting efforts that open up carpool lanes to hybrid cars or, in some cases, to any car with fuel efficiency greater than 45 miles per gallon.[64,65] In California, an incentive for the purchase of hybrid cars turned out to be unnecessary. The 85,000 permits issued for the program were quickly used up, and hybrid car owners who were lucky enough to obtain one now can resell their hybrids at a premium price because new owners can gain access to the state's carpool lanes.

Box 19: The California Solar Initiative

An example of the use of incentives to encourage clean energy technologies is the **California** Solar Initiative (CSI).[66] The $3.3 billion allocated for the program established California as one of the largest markets for solar power in the world—a case of "market pull" on a massive scale.

Administered through the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC), the program expects to provide 3,000 MW of solar capacity by 2017, initially funding distributed PVs installations and later expanding to other solar technologies. For installations of less than 100 kW, the program offers a one-time payment of $2.50 per kW of the expected performance of the installed system. For installations of 100 kW and above, payments are made monthly based on the electricity produced by the system for a period of five years.

As more solar PV systems are installed in the coming years, the state-funded incentives for the systems will decline. It is also expected that costs for solar systems will decline and the efficiency of electricity production will improve over the same period, minimizing the impact of the declining incentives on the cost of new installations.

Enabling markets

There are many possible mechanisms for facilitating the emergence of clean energy markets—including overall goal setting, regulation, and consumer education and outreach. Such actions, though not as direct as taxes or subsidies, can have a profound effect. There is not yet a comprehensive body of literature or set of examples on how states can enable clean energy markets, but the following several examples are worth mentioning:

- **Creation of a "cap-and-trade" market system under which emissions rights for carbon (or other pollutants) are limited and tradable and therefore valuable.** These are under development in the Northeast and in the West, under consideration in the Midwest. By August 2008, the Western Climate Initiative and its state partners aim to complete the design of a market-based mechanism to help achieve the initiative's climate reduction goal.[viii] Ten states are cooperating in the Northeast/Mid-Atlantic regional initiative on climate change—the Regional Greenhouse Gas Initiative[ix] (RGGI). RGGI has developed and clarified market-enabling policies for emissions trading from electric utilities scheduled to begin in January 2009.

- **Changing regulations and infrastructure to facilitate the deployment of clean energy.** For example, net metering—allowing a customer to sell electricity back to the grid—encourages installation of residential-scale renewable energy systems.

- **Consumer education.** For instance, ensuring widespread availability of "carbon footprint" analyses, or educating consumers about the benefits of a technology, such as Japan's Sunshine program **(Box 20)**.

These examples do not fall under any of the other categories listed above, mainly because they do not involve the enforcement of standards or the application of state-controlled financial incentives or disincentives. These indirect mechanisms of encouraging market pull are unlikely to result in change as quickly as more direct approaches, but may prove to be a key ingredient of a successful long-term clean energy technology program.

[viii] The Western Climate Initiative, launched in February 2007, includes **Arizona, California, Montana, New Mexico, Oregon, Utah,** and **Washington**. It aims to develop a regional climate change strategy. The Western states, plus British Columbia and Quebec, have agreed to roll back greenhouse gas emissions to 15 percent below 2005 levels by 2020 (*http://www.westernclimateinitiative.org*).

[ix] Ten Northeastern and Mid-Atlantic states have set a 10 percent greenhouse gas reduction from current levels by 2019 in the power sector. **Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island,** and **Vermont** are participating in RGGI. In addition, the District of Columbia and **Pennsylvania** are observers in the process (*http://www.rggi.org/about.htm*).

Box 20: Sunshine in Japan

The Japanese Sunshine solar energy program is an example of coordinated "technology push" and "demand pull" that is rarely seen in industrial policy. Over two decades, starting in the late 1980s, Japan developed and implemented a long-term initiative for solar development and dissemination. The program's success relied on long-term commitments to the entire innovation process. Core investments in basic solar RD&D led to rapid deployment and dissemination of the resulting solar technologies. In addition, the program focused on consumer and utility education, as well as trials in residential, commercial, and industrial locations.

During the **Sunshine** program, the rate of PV installations in Japan grew to more than 300 MW per year, with costs decreasing by 10 percent per year. This level of cost improvement is very impressive, and took place at the same time that Japanese research laboratories made a series of scientific and engineering advances. Several highly successful Japanese PV manufacturing companies grew out of the effort, including Sharp Corporation, which is now the global leader in solar cell and panel production.

Ensure a consistent time frame

The single clearest lesson from the history of local, state, and federal energy research, development, and demonstration efforts is that turning innovation into business and financial opportunity requires a long-term commitment. The time scale for investment in clean energy needs to be long enough for research groups at universities, industries, think tanks, and businesses to begin to produce not just a single patent or process, but a stream of innovations.

The development times for new technology sectors, in energy systems in particular, can range from 5 to 10 years and up to 30 years. Legislators attempting to build an innovative economy based on clean technology need to be cognizant of the time needed to create a sustainable economic base.

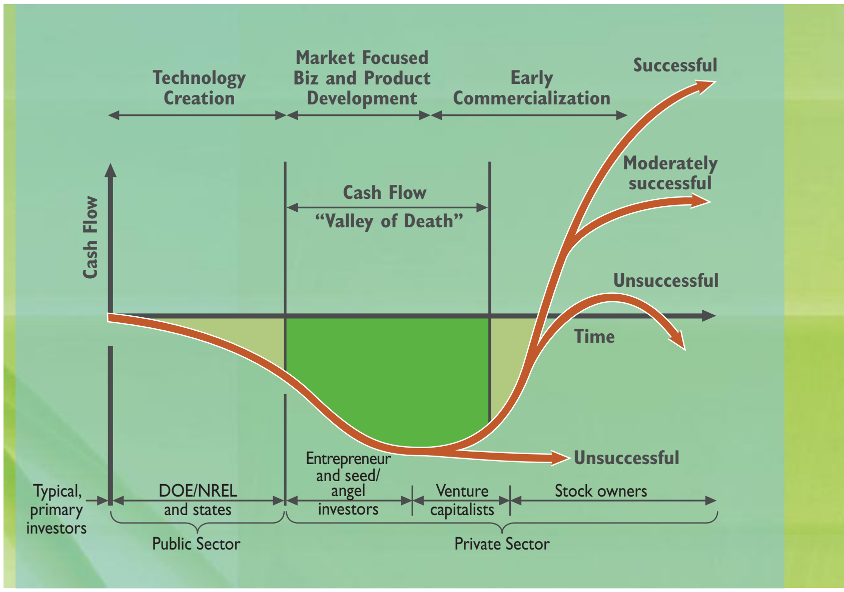
Optimal timing for state interventions

The stage of development at which technologies receive funding can determine their success or failure. States should not limit their interventions to the early stages of development. Depending on a state's available natural resources and technological and industrial capacities, the best approaches may be to target funding at later stages of development, fill in where seed funds are unavailable, or provide funding to allow firms to expand manufacturing for commercial sales, lowering their cost of capital and allowing them to achieve economies of scale.

The "Valley of Death"

Once a technology has been laboratory-proven, its public funding may cease; however, the transition to private funding for further development is uncertain and difficult. Many promising technologies have failed to advance beyond this stage, giving rise to the term "Valley of Death" to describe the funding gap **(Figure 8)**. What makes the "Valley of Death" particularly relevant to clean energy technologies is the substantial capital requirements for later-stage development and demonstration projects.

Figure 8. The "Valley of Death" in research and development funding[67]



There are many projects that have ended in failure, primarily because of a wasted effort in the middle stages of the process. Bridging the "Valley of Death" requires both technology-specific policies and industrial-support practices that sustain promising—but not-yet-viable—technologies during a predictable but problematic phase of technology commercialization and deployment. The "Valley of Death" can be minimized by involving potential users at the outset. This will avoid having technologies developed only to have the final product "sit on the loading dock."

A recent report from NREL[68] highlights the unevenness of state and federal funds that are available for programs designed to help firms cross the Valley of Death. The authors suggest creating a new public-private partnership to improve the likelihood that promising technologies will be able to find the necessary funding to cross the Valley. This would be accomplished through government-funded seed investment nonprofit corporations, which could finance start-ups based on innovative technologies, thereby closing the gap between the lab and traditional private finance.

Several states have already established programs to help bridge the Valley. **Florida** and **Michigan** provide examples of different approaches, with Florida **(Box 21)** providing competitively awarded matching funds, and Michigan creating a nonprofit—NextEnergy—that provides funding as well as technical and business support to emerging companies.[69]

Box 21: Florida's Renewable Energy Technology Grants Program

The 2006 **Florida** Energy Act established Florida's Clean Energy R&D program, which includes the Renewable Energy Technologies Grants program.[70] This program provides matching funds for RD&D and commercialization projects for renewable energy technologies. The goal is to attract capital investment in Florida's energy sector and to support the development and use of renewables. By providing matching funds—to the tune of $12.5 million in 2007—the state attracts valuable proposals and ensures that winning firms are committed to the projects because they have to invest their own funds. The additional funds from the state can help bridge the "Valley of Death."

The critical role of deployment

This report focuses on research, development, and demonstration. However, development is not an end in itself; the ultimate goal is deployment. Although not the main topic of this report, deployment is sufficiently important to merit a discussion here.

For clean energy technologies, policies and programs to support deployment are at least as important as research, development, and demonstration. RD&D strategies that do not include a deployment element will fail to take full advantage of positive RD&D outcomes. This is true in other sectors as well; in agriculture, for instance, the resources devoted to extension and market promotion are often far larger than the RD&D base, a fact that is often not widely recognized.[71]

Technological progress in the development of clean energy industries does depend on research and development, but it also hinges on "learning by doing," which in this case is defined by the widespread adoption of new technologies.[72] It is an insufficient and frequently financially wasteful policy to end state support at the demonstration phase, especially when early deployment of new technologies tends to be a valuable learning experience, with high initial costs that rapidly decrease as companies gain expertise in building and operating new renewable sites.[14,73]

Once technologies have proven their feasibility through demonstration projects, they still face a number of barriers that must be overcome to maximize all possible opportunities. The primary barriers are cost, infrastructure requirements, and the limited need for new generating facilities due to the long lifespan of power plants.[72] Incentives in the early stage of deployment can assist with the learning curve when it is the steepest, resulting in a larger diffusion of the technology.

The following specific actions can help overcome deployment barriers:

- **Subsidize early stage deployment.** For proven technologies, this is the most direct step states can take. The decision to subsidize may be based on the technology's potential performance, potential capacity, and ease of duplication.
- **Serve as the first customer.** State governments can also be the initial purchasers of new clean energy facilities, guaranteeing an early revenue stream by buying electricity contracts.
- **Expedite processes.** States can expedite the siting and permitting processes for clean energy installations, thus removing a formidable roadblock to their deployment.
- **Provide consumer information.** Giving the public information about alternative energy may shift opinions toward technologies that need a certainty of sales before they can be deployed.
- **Coordinate early deployment.** States can instigate the learning-by-doing process earlier in the innovation chain, which can speed deployment and be more cost-effective because potential technical difficulties with scaling or deployment can be addressed earlier.

Catalyze collaboration

Because a state's own financial resources are limited, one of the most effective actions it can take is to facilitate cooperation between other actors involved in clean energy RD&D. A state can play this crucial role in two main ways: encouraging collaboration of key players and cooperation between states or regions.

Collaboration between industry, academia, and government

New industries require a "scientific wealth" coupled with supply chains, industrial relationships, and higher education that, collectively, can move a series of scientific and technological advances into practice.[74,75] Many successful examples exist of states facilitating these kinds of partnerships. Sometimes a state's role is mostly informational and administrative; at other times, it provides a substantial portion of the funding, facilities, personnel, and other resources for a joint project (**Box 22** and **Box 23**).

The industrial innovation and incubation policies that facilitated the "high-technology" corridor around Route 128 west of Boston, **Massachusetts**; in Silicon Valley, **California**; and in the Austin, **Texas**, area are all prominent examples of leveraging university and industry resources to help define new business opportunities. For such activities to be successful, it is important to link participating parties with the projects they will most likely benefit from.

States and regions can foster a "culture of innovation" that can seed new industries, and develop entire regions into technology incubators. The following actions are among the most important to achieve this goal:

- Bring high-technology developers into contact with diverse sets of funding agencies and investors;
- Enact enabling state legislation to open markets for products; and
- Link regional innovation to wider national and global markets and human expertise.[76]

Box 22: The Texas Lone Star Wind Alliance

Texas recently established a major cooperative wind power program to take advantage of its extensive wind resources. Named the Texas Large Wind Turbine Research and Test Center, it was created under the auspices of the Lone Star Wind Alliance.[77] The alliance is composed of NREL, several Texas universities, out-of-state universities, and energy firms with applicable technology and manufacturing expertise that can contribute to and profit from expanded use of wind energy. The center focuses on next generation turbine RD&D, testing and certification, and commercialization, creating a natural pathway for product development that draws on the strengths of alliance members. The state will invest about $18 million through a combination of capital and loans to build the facility and cover start-up costs.

Box 23: North Carolina's Advanced Transportation Energy Center

In February 2008, **North Carolina** Governor Mike Easley announced the creation of the Advanced Transportation Energy Center (ATEC), a public-private research partnership to improve the technology and infrastructure needed for the widespread use of plug-in hybrid electric vehicles (PHEVs).

One of the more remarkable aspects of this center is the number of different players that have come together to support it, with the state in a coordinating role. ATEC will receive funding from the state government—tentatively an initial $5 million, followed by $1 million annually thereafter—as well as resources from the federal government. Duke Energy and Progress Energy also provided initial funding, with General Motors expressing interest in contributing as well.[78]

ATEC will be housed on the Centennial Campus of North Carolina State University (NCSU), and will thus be positioned to draw on the university's expertise in PV and battery technology. (The campus already houses SPEC, the Semiconductor Power Electronics Center.) The public and private investors were attracted not only by NCSU's technological expertise, but, according to the university's Chancellor James Oblinger,[79] by the "ability to build the partnerships needed to make the center a success."

Box 23 (continued)

Governor Easley foresees major benefits from the long-term support of ATEC, including the creation of battery technologies for the next generation of cars and the achievement of environmental goals, but also a flourishing of innovation-related jobs and a strong pull for top talent.[80] North Carolina, in seeking to establish itself as a leader in clean automotive technology, has woven together a dynamic mix of academic and industrial expertise with government support.

There are also several state clean energy research programs and research activities ongoing at North Carolina Agricultural & Technical State University, Appalachian State University and at Advanced Energy.

Box 24: Colorado "Collaboratory"

In 2007, a formal agreement established "the Collaboratory," an agreement between the National Renewable Energy Laboratory, **Colorado** State University, University of Colorado, and Colorado School of Mines. The Collaboratory develops research centers and teams focused on the development of specific renewable energy technologies using public-private partnerships. A significant annual financial investment from the state is used to match federal and private contributions.

In 2007 and 2008, the Collaboratory announced the creation of the Colorado Center for Biofuels and Biorefining (C2B2) and the Center for Revolutionary Solar Photoconversion (CRSP). Centers for wind research and technology development, energy-efficient technologies, and solar technology—which would include solar thermal technologies as well as PV—are also in development.

Cooperation between states or regions

While individual state measures can help develop new industries, in some cases the best approach is for a state to cooperate with its neighbors to capture the full benefits of natural resources that extend across a region. Furthermore, some clean energy industries require the development of multiple technologies that are best supported through multi-state cooperation. For example, states sharing high-potential wind resources may wish to pool resources not only for RD&D but also for transmission lines and other infrastructure.

Regional Transmission Organizations are one type of forum that can serve to help states effectively share information and collaborate on new approaches to overcome barriers to clean energy infrastructure. By collectively addressing transmissions challenges (both physical and regulatory), states may be able to garner private capital to support critical clean energy transmission infrastructure needs.

Several states have established energy RD&D organizations at the university level; for instance, the University of **Illinois** Energy Resources Center at the University of Illinois at Chicago, the **Iowa** Energy Center at Iowa State University, the **Florida** Solar Energy Research Center, and the Washington State University Energy Program. **Colorado**'s "Collaboratory" offers another example **(Box 24)**.

In several states the public utilities commission either mandated or let it be known that it favored a utility-funded energy RD&D organization. The Advanced Energy Corporation in **North Carolina**, the **California** Institute for Energy and Environment, and the Energy Center of **Wisconsin** are examples.

Most of these RD&D organizations are members of the Association of State Energy Research and Technology Transfer Institutions (ASERTTI). The goal of this organization is to share information, participate in planning and program reviews, co-sponsor/co-fund projects, and act as an informal liaison with other organizations. ASERTTI members include state and federal agencies, universities, and private corporations. In 2001, ASERTTI collected annual funding of $1 billion from its members.

There also are several examples of evolving regional climate and energy networks. These include RGGI, as well as similar efforts through the Western Climate Initiative, and the recently established Energy Security and Climate Stewardship Platform for the Midwestern Region.[x] In each of these organizations, networks have already evolved and created opportunities for jointly pushing the clean energy market.

Enlist experts

Given the large investments and long timelines of energy RD&D, it is critical to call on field experts to help with decision-making. Choosing the projects that will emerge as winners, or, more broadly, enable promising technologies to succeed in the market is a major undertaking. However, expert input increases the chances that the selected clean energy RD&D projects will lead to commercial success.

[x] The Energy Security and Climate Stewardship Platform for the Midwest Region establishes shared goals for the Midwest, including specific timelines for the advancement of energy efficiency, the promotion of biobased products and the transmission of renewable electricity. The governors of **Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota,** and **Wisconsin** have adopted all or part of the Platform.

The following suggestions can guide the process of eliciting advice for state RD&D:

- **Enlist technical experts.** Experts from universities and research labs can assess the risks of pursuing each technology under consideration. Some states will have sufficient expertise within their borders; others may seek the input of experts from outside the state or from federal institutions.[9]

- **Ask venture capitalists.** These and other investors help determine the market potential for technologies under consideration, and will typically seek input from industry executives in the fields that would ultimately benefit from commercialization of the prospective project. While clearly indispensable for the implementation of R&D projects, the industrial and financial communities are no less valuable as a source of advice.

- **Use academic peer review.** This approach assists with decision making, both by engaging a diverse set of technical opinions and avoiding political favoritism. For example, grant proposals to **Indiana**'s 21st Century Research and Technology Fund[81] are peer reviewed by a committee made up of scientists, technology researchers, and economic experts from across the country and the world.

- **Create advisory boards.** These should have members drawn from academia and industry across the country and around the globe. Some states have set up a public-private intermediary organization to set strategic direction and make decisions. The advisory board of **Ohio**'s Third Frontier Commission, a public initiative to fund technology research and development, is a diverse group that includes industry executives, health care researchers, officials from three Ohio universities, and the state government.[82]

In the clean energy field, there are numerous organizations with deep knowledge and experience that are able and willing to assist with evaluation of prospective RD&D projects. These include national labs and universities as well as experts in relevant industries.

A wealth of expertise can also be found at private institutions,[83] such as the Electric Power Research Institute, the research organization dedicated to serving municipal and investor-owned utilities across the 50 states. A number of other public and private organizations exist that provide resources and up-to-date information on energy markets, industry, and investment trends on clean energy RD&D.

Create metrics of success

Measuring RD&D inputs in the form of dollars invested is a relatively straightforward task, but measuring the outputs, in terms of new technologies, improved technologies, or businesses created is much more difficult. Often, no attempt is made to quantify the return on an RD&D investment. However, RD&D is an investment and should be thought of as such. Whenever possible, states should attempt to formally measure the success of the RD&D programs they undertake, so that they can adjust their strategies as necessary.

No set of success metrics will be perfect. A common proxy for successful innovation is patenting activity; public investments in energy RD&D have been shown to closely correlate with patenting in the sector. Journal citations are another oft-used proxy.[16] Sometimes, it is also possible to measure the number of jobs or the value of the companies created. However, research shows that RD&D investments generally have positive effects beyond those that can be directly measured, and this is true for clean energy RD&D specifically.[84]

Fortunately, some guiding examples exist on how to set up a useful set of metrics. Probably the best example is the Advanced Technology Program (ATP), funded by NIST until 2007 and now being transformed into the Technology Innovation Program (TIP). As part of its mission, ATP developed an extensive assessment program, which has been commended by the National Academy of Sciences for its thorough and well-documented evidence of successes and failures.[85]

Especially useful is ATP's 2003 report, *A Toolkit for Evaluating Public R&D Investment,*[86] which draws on the lessons learned from reviewing ATP projects and is designed to be adapted to any publicly funded R&D program. In addition to standard metrics, such as firm survival, employment growth, and sales growth, the report lays out methods for determining the impact that R&D programs have on funding gaps, accelerating technology development, improving commercialization, promoting collaboration and networks, and the broader economic and social benefits derived from successful projects.

No analysis can capture all the benefits of an RD&D project, but even an imperfect analysis can provide very useful information to guide future projects. The challenges of developing new clean energy technologies outstrip the amount of funding available to solve them, so every dollar must be used as wisely as possible.

Innovation in clean energy technologies represents a tremendous opportunity for states to attract research and development funding and to expand their industries.

Synthesis and Conclusions

Investing smartly in clean energy RD&D is difficult. While this report attempts to provide guiding principles, every state must undertake its own analysis of risks and challenges in this arena. More so than most other industries, the energy industry—and the clean energy sector in particular—demands long time frames and sizeable capital investments. For any clean energy RD&D project, the payoffs are uncertain and difficult to measure.

Offsetting the challenges and risks of developing clean energy in the medium and long term will be necessary to achieve significant economic and environmental benefits. Innovation in clean energy technologies represents a tremendous opportunity for states to attract research and development funding and to expand and adapt their current industries. Beyond environmental benefits, the deployment of clean energy technologies can offer even greater benefits by boosting state and regional economies, and establishing affordable energy sources, encouraging lower cost over the long term, and diversifying energy sources.

To fully realize the benefits of investing in clean energy RD&D, states must be strategic with their investments and leverage them to the fullest extent possible. States should seek to identify a portfolio of projects with the greatest potential payoffs—for example, by using state funding to attract other types of funding and by awarding modest grants to promising technologies that cross the "Valley of Death."

As seen in the examples in this report, the following principles will help states create successful clean energy RD&D programs:

1. **Create demand push alongside market pull.** The creation of a technology does not ensure its success; ultimately it must find a market. States have many different methods to stimulate markets for clean energy technologies, including standards, taxes, incentives, and subsidies, as well as broad policy initiatives can help spur clean energy markets.

2. **Ensure a consistent time frame.** The benefits of RD&D are realized over a long-term horizon—at least 5 to 10 years, and as long as 20 to 30 years. States can and should contribute to the RD&D process at all stages, providing targeted assistance when it is most needed.

3. **Catalyze collaboration between academia, industry, nonprofits, other states and governments.** State governments are strategically positioned to facilitate these collaborations. Groups of states can also achieve great benefits through regional communication, coordination, and collaboration.

4. **Enlist expert advice to reach the wisest possible investment decisions.** Clean energy RD&D requires not only academic expertise, but also input from industry and business, as well as nonprofits. A balance of opinions should be sought through the creation of diverse advisory boards and peer-reviewed grant programs.

5. **Create metrics of success for the funded RD&D programs.** Although the benefits from RD&D can be defined differently, program evaluation is an important step toward improving future investment decisions. Metrics include journal citations, patents filed, new jobs created, and value of new businesses. Efforts to quantify energy savings and pollutant reductions can also be valuable indicators of success.

States are already incorporating these principles and thus there are already many examples of states achieving success in RD&D programs for clean energy. Some states, such as **Hawaii** are fortunate to have an abundance of renewable natural resources, and can choose to develop their RD&D expertise around them. States with few natural resources, such as **Connecticut**, can nevertheless capitalize on the clean energy economy by focusing on their industrial and intellectual expertise. Many states are positioned to take advantage of clean energy RD&D to solve an existing problem or fulfill a need, such as **Ohio**'s effort to refocus its talents in manufacturing. And examples abound of innovative financing mechanisms **(Massachusetts)** and mandates and incentives **(California)** to achieve clean energy RD&D goals.

The process of creating a clean energy economy is well underway, and the contributions made by states to RD&D in this field to date are encouraging. However, much work and many opportunities remain. States will continue to play a key role in the research, development, and demonstration efforts that are essential to clean energy technological innovation.

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