APRIL 2012

BEYOND BOOM & BUST

PUTTING CLEAN TECH ON A PATH TO SUBSIDY INDEPENDENCE

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In the absence of significant and timely energy policy reform, the recent boom in US clean tech sectors could falter.

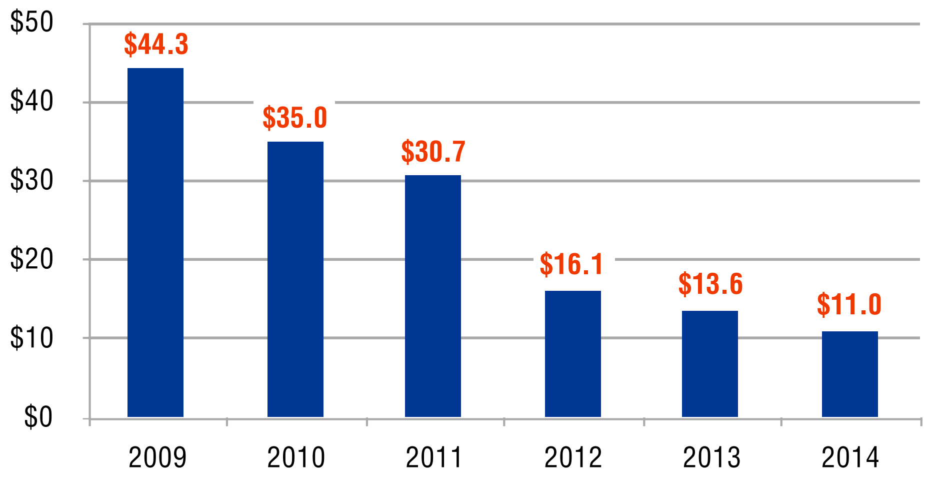
Driven by private innovation and entrepreneurship as well as critical public sector support in the form of tax credits, grants, and loan guarantees, several clean energy technology (or "clean tech") segments have grown robustly in recent years while making progress on cost and performance.

Renewable electricity generation doubled from 2006 to 2011, construction is under way on the nation's first new nuclear power plants in decades, and American manufacturers have regained market share in advanced batteries and vehicles. Prices for solar, wind, and other clean energy technologies fell, while employment in clean tech sectors expanded by almost 12 percent from 2007 to 2010, adding more than 70,000 jobs even during the height of the recession.[1]

Despite this recent success, however, nearly all clean tech segments in the United States remain reliant on production and deployment subsidies or other supportive policies to gain an expanding foothold in today's energy markets. Now, many of these subsidies and policies are poised to expire—with substantial implications for the clean tech industry.

Figure ES1

Total Federal Clean Tech Spending by Year (billions)



This report aims to take stock of the coming changes to federal clean tech subsidies and programs (Part 1); examine their likely impact on key clean tech market segments (Part 2); and chart a course of policy reform that can advance the US clean tech industry beyond today's policy-induced cycle of boom and bust (Part 3).

Along the way, this report provides a comprehensive analysis of the spending trajectory of 92 distinct federal policies and programs supporting clean tech sectors over the 2009 to 2014 period. As this analysis illustrates, an era of heightened clean energy spending supported by the American Recovery and Reinvestment Act of 2009 (ARRA) is now coming to an end, coinciding with the expiration of several additional time-delimited tax credits and programs. As a result, key portions of the clean tech industry can now anticipate substantially reduced federal support (see Figure ES1).

At the same time, market subsidies are being cut in several European markets,[2] reducing export opportunities for US clean tech manufacturers and leading to oversupply and declining margins,[3] even as pressure mounts from both low-cost natural gas at home[4] and foreign clean tech manufacturers abroad.[5]

US clean tech sectors therefore face a combination of new challenges, despite the growth and progress achieved in recent years. The specific market impacts will vary by sector (see Part 2). But without timely and targeted policy reform, several sectors are likely to experience more bankruptcies, consolidations, and market contraction ahead.

And yet the demise of the current clean tech subsidy system need not be disastrous. In fact, it may provide an opportunity for needed reform and further industry growth, albeit one that must be carefully approached by both policy makers and business leaders.

Many of today's existing subsidies and clean energy programs, after all, are poorly optimized, characterized by a boom and bust cycle of aid and withdrawal, or in need of thorough revision thanks to either recent progress in the price and performance of subsidized technologies or the mounting fiscal burden imposed by some programs.

The end of the present policy regime therefore offers the opportunity to implement smart reforms that not only avoid a potential "clean tech crash" but also accelerate technological progress and more effectively utilize taxpayer resources. Well-designed policies that successfully drive innovation and industry maturation could provide US clean energy sectors a more stable framework within which to advance towards both subsidy independence and long-term international competitiveness.

Along these lines, this report finds that:

- The US federal government will spend just over $150 billion on clean tech over the 2009-2014 period, a more than three-fold increase from the 2002-2008 period.[6] We estimate that these investments will leverage an overall cumulative public and private sector investment of $327 billion to $622 billion in US clean tech segments during the 2009 to 2014 period.

- Federal clean tech funding is now at a key inflection point however: absent Congressional action, annual clean tech support will be cut nearly in half from 2011 to 2012.

- A portion of this scheduled drawdown in federal clean tech spending can be explained by the planned expiration of ARRA-funded programs: roughly a third of total spending over the 2009 to 2014 time period originates from one-time federal stimulus programs.

- Including ARRA-funded programs, annual federal clean tech spending is poised to decline to $11 billion by 2014, a 75 percent decline relative to the high of $44.3 billion reached in 2009. Furthermore, by the end of 2014, 70 percent of all federal clean energy policies in place in 2009 will have expired.

- Even excluding ARRA funds, a sharp decline in federal support for clean tech sectors is evident, with normal, non-ARRA annual clean tech funding scheduled to decline by more than half, from a peak of $24.3 billion in 2010 to $10.9 billion by 2014.

- Nearly three-quarters of all clean energy spending over the 2009-2014 period is directed to subsidize clean technology deployment and adoption, yet this funding is poised to fall sharply. Absent policy action, annual funding for these deployment policies will drop nearly 80 percent from 2009 to 2014, wiping away the large bulk of today's current clean energy deployment regime.

- Clean tech manufacturing receives just 8 percent of federal clean tech spending during the 2009-2014 period. Nearly all of this funding is due to temporary stimulus-supported programs that have already expired, leaving little remaining direct support for US clean tech manufacturing.

- US investment in clean energy research, development, and demonstration (RD&D) constitutes roughly 18 percent of federal clean tech spending over 2009-2014. While energy RD&D funding is relatively stable over this period, it averages just $4.7 billion per year, roughly one-half to one-third the optimal funding levels recommended by numerous business leaders, researchers, and national science advisors[7] and far lower than annual investments in other key national innovation priorities, such as space research and exploration ($19 billion), health research ($34 billion), and defense-related research ($81 billion).[8]

In light of these budgetary findings, this report concludes that policy makers and business leaders need to unite behind timely energy policy reform that supports US innovation, rewards continual improvements in clean tech price and performance, and secures subsidy independence for clean tech markets as rapidly as possible. The key implications of this report's analysis are:

- The maintenance of perpetual subsidies is not a sustainable solution to the new challenges facing the US clean tech industry. Clean tech markets in America have lurched from boom to bust for decades, and the root cause remains the same: the higher costs and risks of emerging US clean tech products relative to either incumbent fossil energy technologies or lower-cost international competitors, which make US clean tech sectors dependent on subsidy and policy support.

- Cost competitiveness is achievable, but until technological innovation and cost declines can secure independence from ongoing subsidy, clean tech segments will remain continually imperiled by the threat of policy expiration and political uncertainty. Continual improvement in price and performance is thus the only real pathway beyond the cycle of clean tech boom and bust.

- Maintaining a viable US clean tech industry will require policy makers to reform the nation's myriad energy subsidies, which should be optimized to drive improvements in technology price and performance and ensure clean tech segments achieve subsidy independence as rapidly as possible.

- Federal clean energy policies should reward firms for continually improving the performance and reducing the cost of their technologies, or for inventing and commercializing next-generation, advanced energy technologies, not simply for deploying current-generation technologies without advancing them towards subsidy independence.

- Energy subsidies should be temporary and targeted to drive the maturation and improvement of emerging technologies. Just as subsidies for clean tech sectors should phase out as these sectors mature, it is long-past time to end subsidies for well-established fossil energy production methods and technologies as well.

- The United States can leverage its strengths as an innovation leader and accelerate the pathway to clean tech subsidy independence by increasing funding for energy RD&D, accelerating advanced energy technology commercialization, and harnessing the advanced manufacturing capabilities, regional industry clusters, and high-skilled energy workforce that are crucial to a robust innovation system.

- Establishing subsidy independent, highly innovative US clean tech markets will also position US firms to compete effectively in growing international markets for clean energy products. With the right reforms, the United States has the opportunity to be a leader in the invention and production of next-generation technologies for sale to an energy-hungry global market.

KEY RECOMMENDATIONS FOR A NEW ERA OF CLEAN ENERGY POLICY

As to how, specifically, the nation might move toward a new era of clean energy policy, this report concludes that the United States should now build on its historic strengths as a leader in innovation, entrepreneurship, and advanced manufacturing by accelerating the development, adoption, and improvement of cost-effective clean energy technologies. Therefore, policy makers and business leaders alike should pursue reform on two fronts that will put clean tech on a path to subsidy independence and secure US leadership in clean energy markets:

1.

Reform Energy Deployment Subsidies and Policies to Reward Technology Improvement and Cost Declines

Expiring policies and programs are poised to wipe away the large bulk of today's clean energy deployment regime. This creates a clear need for urgent policy reform to sustain market opportunities for advanced energy technologies, more effectively deploy limited public resources, and support innovative entrepreneurs and firms. Whatever form they take, a new suite of clean tech deployment policies must simultaneously drive market demand *and* continual innovation. In particular, clean tech deployment policies should:

→ **ESTABLISH A COMPETITIVE MARKET.** Deployment policies should create market opportunities for advanced clean energy technologies while fostering competition between technology firms.

→ **DRIVE COST REDUCTIONS AND PERFORMANCE IMPROVEMENTS.** Deployment policies should create market incentives and structures that demand and reward continual improvement in technology performance and cost.

→ **PROVIDE TARGETED AND TEMPORARY SUPPORT FOR MATURING TECHNOLOGIES.** Deployment policies must not operate in perpetuity, but rather should be terminated if technology segments either fail to improve in price and performance or become competitive without subsidy.

→ **REDUCE SUBSIDY LEVELS IN RESPONSE TO CHANGING TECHNOLOGY COSTS.** Deployment incentives should decline as technologies improve in price and performance to both conserve limited taxpayer and consumer resources and provide clear incentives for continued technology improvement.

→ **AVOID TECHNOLOGY LOCK-OUT AND PROMOTE A DIVERSE ENERGY PORTFOLIO.** Deployment incentives should be structured to create market opportunities for energy technologies at different levels of maturity, including new market entrants, to ensure that each has a chance to mature while allowing technologies of similar maturity levels to compete amongst themselves.

→ **PROVIDE SUFFICIENT BUSINESS CERTAINTY.** While deployment incentives should be temporary, they must still provide sufficient certainty to support key business decisions by private firms and investors.

→ **MAXIMIZE THE IMPACT OF TAXPAYER RESOURCES AND PROVIDE READY ACCESS TO AFFORDABLE PRIVATE CAPITAL.** Deployment incentives should be designed to avoid creating unnecessarily high transaction costs while opening up clean tech investment to broader private capital markets.

Many of today's clean tech deployment subsidies and policies should be reformed with these criteria in mind. Examples of possible policies that could meet these criteria include competitive deployment incentives,[9] steadily-improving performance-based standards, "top-runner" standards or incentives,[10] demanding government procurement opportunities, and reverse auction programs. If structured to adhere to these criteria, a new era of clean tech deployment policies will neither select "winners and losers" *a priori*, nor create permanently subsidized industries. Rather, these policies will provide opportunity for all emerging clean energy technologies to demonstrate progress in price and performance, foster competitive markets within a diverse energy portfolio, and put clean tech segments on track to full subsidy independence.

2.

Strengthen the US Energy Innovation System to Make Clean Energy Cheap

A new energy policy consensus to secure an internationally competitive, subsidy-independent clean tech sector must also harness America's strengths as an innovator.[11] The United States is home to world-class universities, generations of trained scientists and engineers, potent centers of entrepreneurship, finance, and advanced manufacturing, and a creative culture capable of attracting talent from around the world. Yet when it comes to energy, America's innovation system falls short.[12] Policy makers must strengthen the US energy innovation system to catalyze clean energy breakthroughs and support continual technology improvement. Along these lines, the nation should:

→ **STEADILY INCREASE INVESTMENT IN RD&D WHILE REFORMING AND STRENGTHENING THE US ENERGY INNOVATION SYSTEM.**

Policy makers should steadily scale-up investment in energy RD&D to triple today's levels to match the scale of other national innovation priorities.

America's energy innovation system must also be modernized to leverage regional innovation opportunities and strengthen new institutional models at the federal level, including the Energy Frontier Research Centers (EFRCs), the Advanced Research Projects Agency-Energy (ARPA-E), and the

Energy Innovation Hubs. Efforts to build public-private partnerships responsive to both industry needs and regional strengths should continue to be encouraged across the Department of Energy (DOE) and particularly in the National Labs in order to ensure a maximum return on the federal investment in RD&D.[13]

→ UNLOCK CLEAN ENERGY ENTREPRENEURSHIP BY IMPLEMENTING EFFECTIVE POLICIES TO ACCELERATE COMMERCIALIZATION OF ADVANCED ENERGY TECHNOLOGIES.

The DOE's Loan Programs Office, which funded Solyndra, should be replaced by a more flexible, independent, and sophisticated suite of financial tools and other mechanisms designed to draw private capital into cleantech projects through a variety of investment, credit, securitization, insurance, and standardization activities. Whether delivered through a Clean Energy Deployment Administration (CEDA) or other entities or programs, the clear mission of these activities would be to accelerate the commercialization and deployment of critical advanced energy technologies.[14]

A National Clean Energy Testbeds program (N-CET) should be established to take advantage of public lands to accelerate technology demonstration and commercialization. This new program would provide access to pre-approved, monitored, and grid-connected public lands and waters ideal for demonstration of innovative energy technologies, thereby reducing the cost, time, and permitting challenges associated with technology commercialization.[15]

The power of military procurement should also be leveraged to drive demanding early markets for advanced energy technologies that meet tactical and strategic military needs and may have later commercial applications.[16] Energy technologies with dual-use military and commercial potential include advanced vehicle technologies, aviation biofuels, advanced solar power, improved batteries, and small modular nuclear reactors.

Similarly, federal agencies should work both independently and with the states to address infrastructure and regulatory challenges that may prevent the commercialization of new energy technologies.[17]

→ HARNESS ADVANCED MANUFACTURING, REGIONAL INDUSTRY CLUSTERS, AND A WORLD-CLASS ENERGY WORKFORCE TO ENHANCE AMERICA'S INNOVATIVE EDGE.

Advanced manufacturing[18] is an integral part of the innovation system and a key area for cost reductions and performance improvements in emerging technologies. Innovation thus suffers when divorced from manufacturing activities.[19] US advanced manufacturing must play a key role in accelerating advanced energy innovation. Technical support programs, public-private research consortia, and other strategic policies can help domestic manufacturers of advanced energy technologies remain at the cutting edge.[20]

Likewise, the nation needs to develop more potent, catalytic ways to leverage and enhance regional clean tech industry clusters. Such industry clustering has been shown to accelerate growth by promoting innovation, entrepreneurship, and job creation.[21] Policy makers should increase investment in competitive grants to support smart regional cluster initiatives, designed not in Washington but on the ground close to the "bottom up" innovation that has broken out in numerous states and metropolitan areas.[22]

Finally, American clean tech leadership will require a highly educated, globally competitive advanced energy workforce. The nation must make new investments in energy science, technology, engineering, and mathematics education[23] and make smart reforms to immigration policies to ensure America remains the destination of choice for the world's best entrepreneurs and innovators.

Clean energy policy in America is at a crossroads. Federal support for clean tech is now poised to decline precipitously—unless policy makers and industry work together to enact smart reforms that can ultimately free clean energy from subsidy dependence and put clean tech sectors on a path to sustainable, long-term growth.

A business-as-usual strategy of perpetual policy expiration and renewal is no longer sustainable. Yet neither is the immediate cessation of clean tech subsidies in the national interest. Supporting the development of a new portfolio of cost-competitive, scalable clean energy technologies offers substantial opportunities for enhanced American energy security, new technology exports, and improved public health.

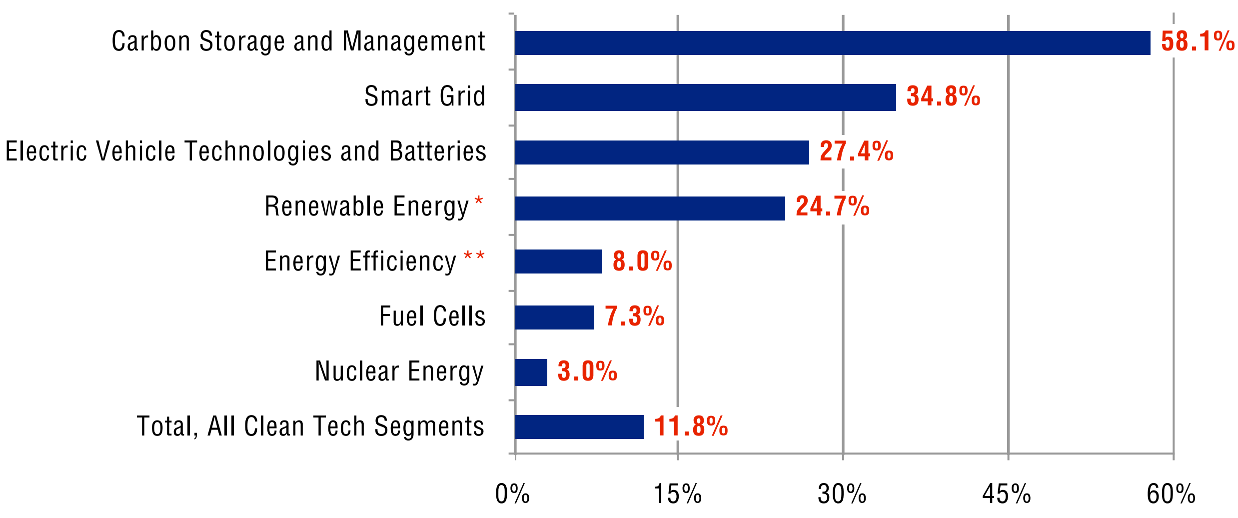
The time has come to craft a new energy policy framework specifically designed to accelerate technology improvements and cost reductions in clean tech sectors, ensure scarce public resources are used wisely to drive technologies towards subsidy independence as soon as possible, and continue the growth and maturation of America's clean tech industries. This report lays out the challenges facing policy makers and business leaders with the aim of sparking a national conversation on the route forward.

→ PART 1 ←
FROM CLEAN TECH BOOM TO FEDERAL SPENDING BUST

In recent years, US clean energy technology ("clean tech") sectors have grown rapidly, despite the economic turmoil gripping the nation. By the end of 2010, installed wind power capacity in the United States stood 60 percent above 2008 levels,[24] while solar power capacity had increased 120 percent over the same period.[25] The United States regained global market share in advanced battery and vehicle segments,[26] and construction commenced on the first new US nuclear reactors in decades.[27] Robust expansion can be observed across virtually all segments of the clean tech sector, with total employment across clean technology segments growing 11.8 percent from 2007 to 2010,[28] a period when overall US employment was stagnant (Figure 1). US renewable energy and energy efficiency segments alone attracted $48 billion in investment in 2011, up 42 percent from 2010 and over twice as high as 2009 levels.[29]

Figure 1

Percent Growth in Employment in Selected US Clean Tech Segments, 2007–2010



Source: "Sizing the Clean Economy," Brookings Institution Metropolitan Policy Program, July 2011. Available at http://www.brookings.edu/metro/Clean_Economy/

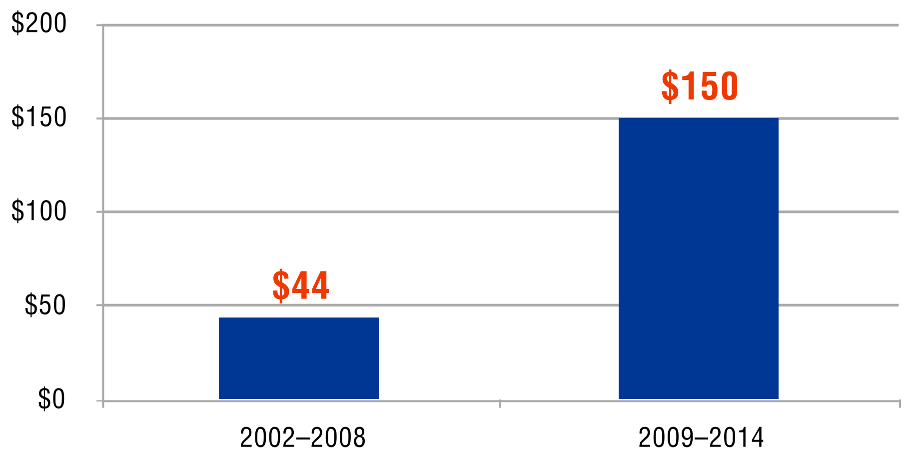
**Renewable energy segments include: geothermal, hydro, wind, solar photovoltaic, solar thermal, waste-to-energy, wave/ocean energy, and biofuels/biomass.*

*** Energy efficiency segments include: energy-saving building materials, energy-saving consumer products, green architecture and construction services, HVAC and building control systems, lighting, professional energy services, and efficient appliances.*

This recent expansion of clean tech segments is due in large part to a substantial increase in federal investment and policy support. Cumulative federal support for clean tech totaled an estimated $44 billion over the 2002-2008 period.[30] That level compares to a cumulative $150 billion between 2009-2014, the period examined in this report (see Figure 2), with $80 billion in expenditures in 2009 and 2010 alone. This increased federal support for clean tech segments includes $51 billion in spending under programs created or expanded by the American Recovery and Reinvestment Act of 2009 (ARRA), as well as several pre-existing federal policies augmented and extended during this period, including the Department of Energy (DOE) loan guarantee programs, the production tax credit (PTC) and investment tax credit (ITC) benefitting renewable electricity sources, and a variety of federal tax credits for alcohol fuels and biodiesel.

Figure 2

Cumulative Federal Spending on Clean Tech by Period (billions)



Source: For 2002-2008, see "Estimating U.S. Government Subsidies to Energy Sources: 2002-2008," Environmental Law Institute; for 2009-2014, see Energy Innovation Tracker, www.energyinnovation.us, Breakthrough Institute Research.

Clean tech segments, from renewable and nuclear power plants to alternative transportation technologies and energy efficient products,[31] receive a variety of federal incentives, including direct grants, tax credits, financing guarantees, and other subsidy programs. Similarly, nearly all clean energy research and development benefits from some form of federal support. These federal incentives help clean energy segments gain a foothold in energy markets by overcoming the higher costs or risks these nascent technologies currently face relative to highly mature fossil fuels or vehicle technologies.

Though current subsidies could be better optimized to drive innovation (see discussion in Part 3), many clean tech companies have nonetheless achieved significant technology improvements in recent years, often with the assistance of these federal programs. Federal support for clean energy technologies has fostered market competition and improvements in technology and/or manufacturing efficiencies in areas like advanced batteries and vehicles, solar panels, and wind turbines, and other technologies.

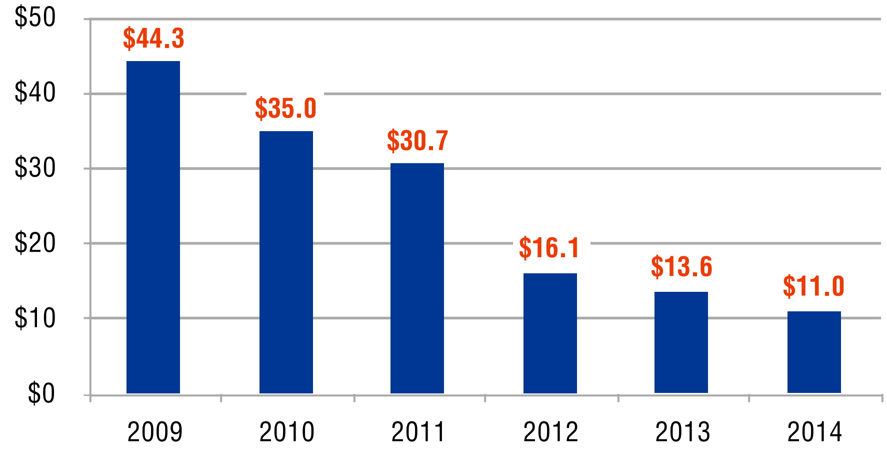
Unfortunately, despite these recent price improvements, nearly all clean tech segments remain reliant on public policy support and subsidy. That support is now poised to decline precipitously, presenting new challenges and raising the possibility of market turmoil ahead for several US clean tech markets.

This section presents the results of a comprehensive analysis of federal policies and incentives supporting clean tech segments. In summary, this report finds that annual federal clean tech spending peaked in 2009 at $44.3 billion and has already declined steadily through 2011 to $30.7 billion. Yet the sharpest reductions in federal clean tech support are still ahead: unless Congress intervenes, clean tech spending will be cut nearly in half from 2011 to 2012 and will fall to just one-quarter of 2009 levels by 2014 (see Figure 3). Absent Congressional action, only 30 percent of the clean tech policies and programs in place in 2009 will remain at the end of 2014.

This impending mass-expiration of federal policy support comes at a time of corresponding subsidy declines in many European markets as well as heightened competition from both foreign clean tech manufacturers and record-low prices for natural gas – the chief domestic competitor to many clean electricity generation technologies, from wind and solar to nuclear power. Without action, the combination of these forces could see recent years of clean tech boom go bust, and they will certainly present new challenges and headwinds for clean tech sectors in the years ahead (see Part 2).

Figure 3

Federal Clean Tech Spending by Year (billions)



METHODOLOGY

This report examines 92 distinct federal policies and programs supporting clean tech segments in the United States over the years 2009 to 2014 (inclusive).[32] Clean tech segments examined include renewable electricity sources (wind, solar, geothermal, biomass, etc.), nuclear power, carbon capture and storage for fossil energy, biofuels, advanced vehicle technologies (electric and plug-in hybrid vehicles, fuel efficient vehicles, alternative fuel vehicles, and advanced batteries), high-speed rail, smart grid technologies, and energy efficiency technologies (efficient lighting, building, industrial, and consumer products). Federal programs examined include those supporting research, development and demonstration (RD&D), manufacturing, and market adoption and deployment.

This analysis utilized a broad set of data sources to compile a comprehensive estimate of federal clean tech spending. Primary among these sources was federal tax expenditure accounting provided by the Office of Management and Budget (OMB), the Congressional Research Service (CRS), and the Joint Committee on Taxation (JCT). For direct spending, this analysis primarily used fiscal year budget data released by relevant federal agency and department budget offices. All ARRA spending excluding RD&D investments was derived from DOE accounting of ARRA programs, as well as resources from recovery.gov, a government-run website responsible for monitoring and tracking stimulus spending programs. For federal RD&D spending, this analysis relied primarily on the *Energy Innovation Tracker*, an online tool created and administered by the Breakthrough Institute and the Information Technology and Innovation Foundation (ITIF).[33] Future spending amounts are projected either using data from OMB, CRS, or JCT or by extrapolating the historic ratios of an agency's energy program spending relative to total agency budgets.

The full data set is listed in the Data Appendix at the end of this report (organized by expenditure type and listed in descending order by spending total over the 2009-2014 period) along with program descriptions, annual funding figures, and the specific methodology and sources for each program. This data set is also available for download as a spreadsheet at http://bit.ly/BBB_Dataset.

ANALYSIS OF FEDERAL CLEAN TECH SPENDING, 2009 TO 2014

This report identifies $150.7 billion in total federal expenditures on clean tech over the 2009-2014 period.[34] This is a significant increase from the period 2002-2008, when estimated clean tech support totaled $44 billion (see Figure 2).

This federal support can be categorized as one of three general forms of policy support:

- Direct spending
- Tax expenditures[35]
- Loans or loan guarantees

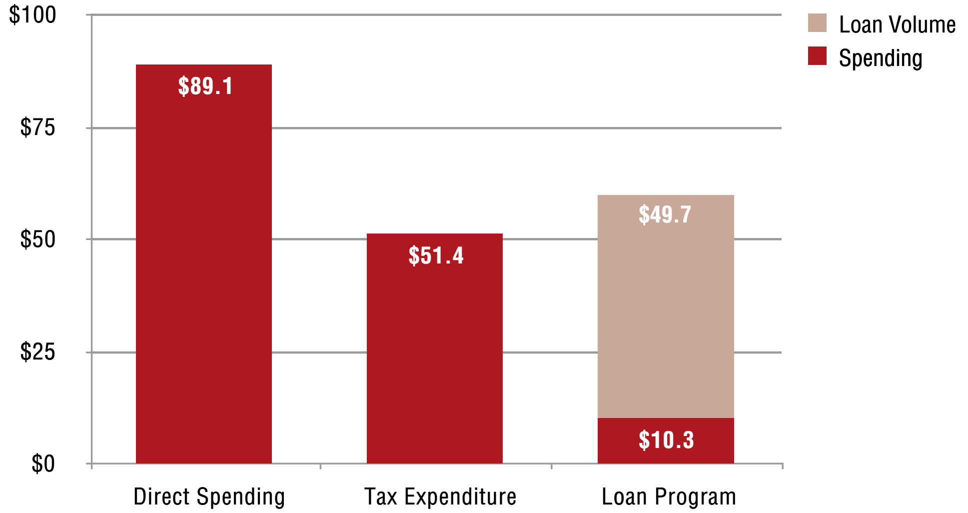
Figure 4 breaks down total spending into these categories. Over the 2009-2014 period, the majority (59 percent) of federal support is provided through direct spending. This reverses trends in the 2002-2008 period, when tax expenditures were a larger portion of federal support by roughly 2-to-1, and when loans and loan guarantees played a minimal role in federal clean tech support. The increase in direct spending is largely attributable to ARRA, which was responsible for $51 billion in new or expanded direct spending during this period, including the temporary conversion of some tax expenditures for renewable electricity sources to direct grants from 2009-2011 (e.g., the Section 1603 grant program).

As depicted below, federal loans and loan guarantees for clean tech segments are funded through appropriations that are designed to cover expected losses due to any defaults in the portfolio of loans. Thus, limited federal appropriations are used to support a much greater volume of debt financing. Approximately $10 billion in federal funds appropriated to clean tech loan programs during the 2009-2014 period therefore supports an estimated $50 billion in total loan volume (note that the federal spending totals in this report include only the appropriated funds).

Furthermore, each form of federal spending leverages additional investment from the private sector (as well as state and municipal governments). Every dollar of direct federal clean tech spending supports roughly $1.5 to $3 in total public and private investment; each dollar in federal tax expenditures supports roughly $3 to $5 in total investment; and funds appropriated to loans and loan guarantees support total investment 4 to 10 times larger.[36] This analysis therefore estimates that the $150.7 billion in cumulative federal expenditures distributed amongst the three spending types as depicted below likely supports an overall cumulative public and private sector investment of $327 billion to $622 billion in US clean tech segments during the 2009 to 2014 period.[37]

Figure 4

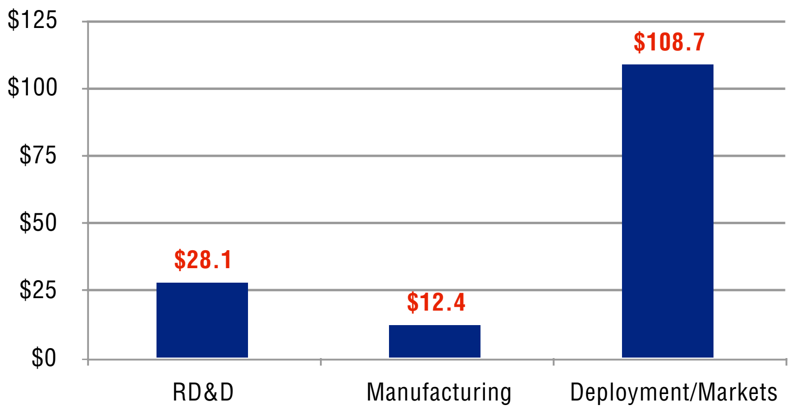
Total Federal Clean Tech Spending by Expenditure Type (billions), 2009-2014



Federal support for clean tech during this period is heavily weighted towards subsidies for market adoption and deployment of clean technologies. Nearly three-quarters of total federal spending during this period is dedicated to clean tech deployment, while investments in RD&D constitute 19 percent of federal clean tech spending and support for US clean tech manufacturing receives just 8 percent of the total (see Figure 5). Figure 5 below illustrates the distribution of clean tech spending across these three market stages.

Figure 5

Total Federal Clean Tech Spending by Market Stage (billions), 2009-2014



Clean tech RD&D spending originates overwhelming from the DOE, which is responsible for nearly three-quarters of all federal energy RD&D. Additional energy research is supported by other federal agencies, notably the National Science Foundation and the Department of Defense.

Federal support for manufacturing originates from only a few distinct programs, including temporary battery manufacturing grants program and the short-lived Section 48C advanced manufacturing tax credit, both initiated by the Recovery Act. The Advanced Technology Vehicle Manufacturing (ATVM) Loan program and a relatively small portion of the Section 1705 loan guarantees, two programs operated by the DOE's Loan Programs Office, also benefit US clean tech manufacturing. Manufacturers of efficient appliances also received a tax credit until its expiration at the end of 2011.

The recent growth of clean tech deployment has been powered largely by major ARRA-funded grants for solar panels, fuel cells, advanced batteries, electric grid infrastructure, and other advanced energy technologies. Additional deployment support was provided through tax expenditures (including key tax credits for renewable electricity and renewable fuels) and the temporary 1603 Treasury grants for renewable electricity projects. The federal PTC and ITC for renewable electricity are widely credited with enabling significant growth across a broad suite of renewable energy technologies, particularly conventional wind turbines and solar photovoltaic (PV) panels. These three programs alone — PTC, ITC, and 1603 grants — will provide nearly $28 billion over the 2009-2014 period. Energy generation projects also made up 92 percent of the total loan volume guaranteed by the Section 1705 DOE loan guarantee program. The single largest contributor to federal clean energy deployment expenditures over this period, however, was a set of tax credits and incentives for the production and use of ethanol and other biofuels, which totaled $19.7 billion.

Figure 6

Share of Federal Clean Tech Spending by Technology, 2009-2014

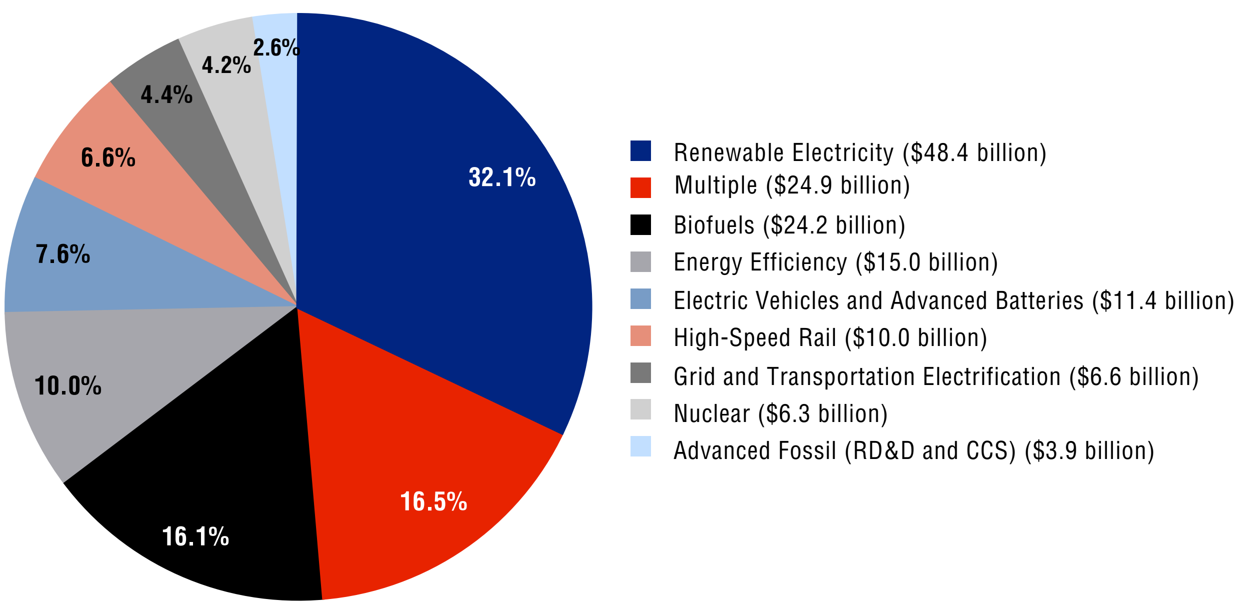


Figure 6 breaks down federal support for various technology segments. As illustrated above, renewable electricity segments, including wind, solar, geothermal, and biomass-fueled power, are the primary beneficiaries of clean tech support over the 2009-2014 period. Funding for renewable electricity derives primarily from the PTC and ITC, the temporary Section 1603 grant program, and the DOE Section 1705 loan guarantee program. Funds labeled "Multiple" include programs that benefit a combination of renewable electricity, alternative fuels or vehicles, energy efficiency measures, and other clean energy categories. This category includes most general energy RD&D directed toward various technology segments, primarily from DOE offices like ARPA-E, and programs like the Section 48C advanced manufacturing tax credit. Biofuels funding derives almost entirely from the excise tax credit for ethanol fuels. Advanced fossil technology spending funds federal research into capturing and storing emissions from fossil-fuel power plants.

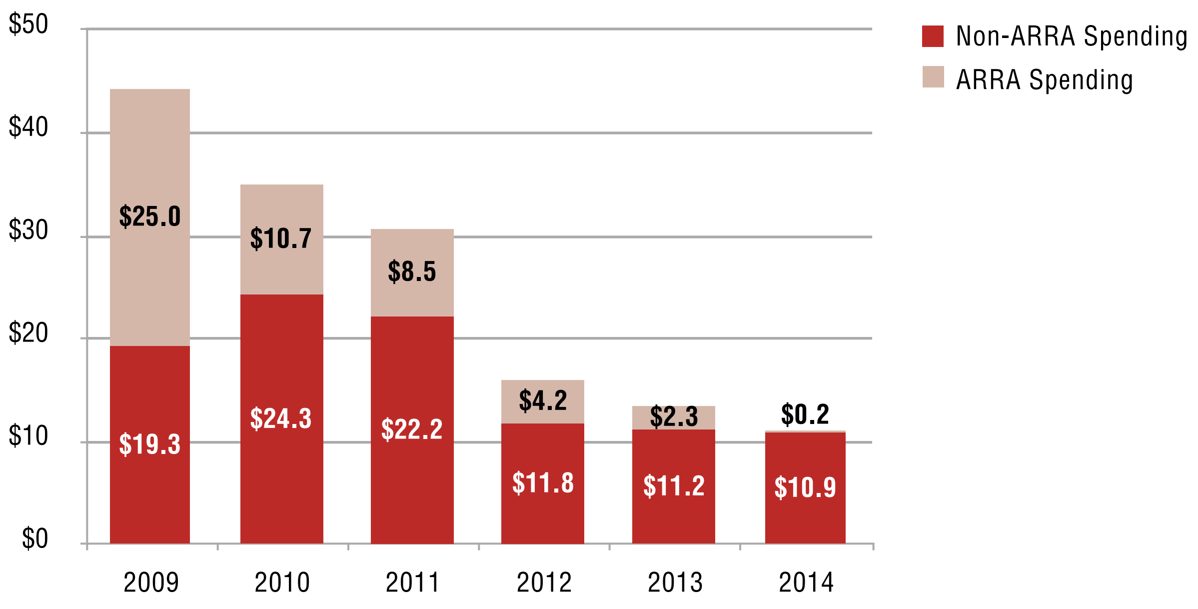
THE FEDERAL CLEAN TECH FUNDING CLIFF

While total clean tech spending during the 2009 to 2014 period is at historic highs, federal clean energy investment is now at a key inflection point, with annual spending already on a downward trajectory and set to drop sharply from 2012 onward.

As Figure 7 below illustrates, annual federal clean tech spending peaked at $44.3 billion in 2009 before falling steadily by 31 percent to $30.7 billion in 2011. Absent Congressional action, projected federal spending on clean tech will decline another 48 percent from 2011 to 2012, falling to $16.1 billion or 64 percent below the 2009 peak. Clean tech expenditures in 2014 are set to decline further to just $11 billion by 2014, one-quarter of 2009 peak funding levels.

Figure 7

Federal ARRA and Non-ARRA Spending on Clean Tech by Year (billions)



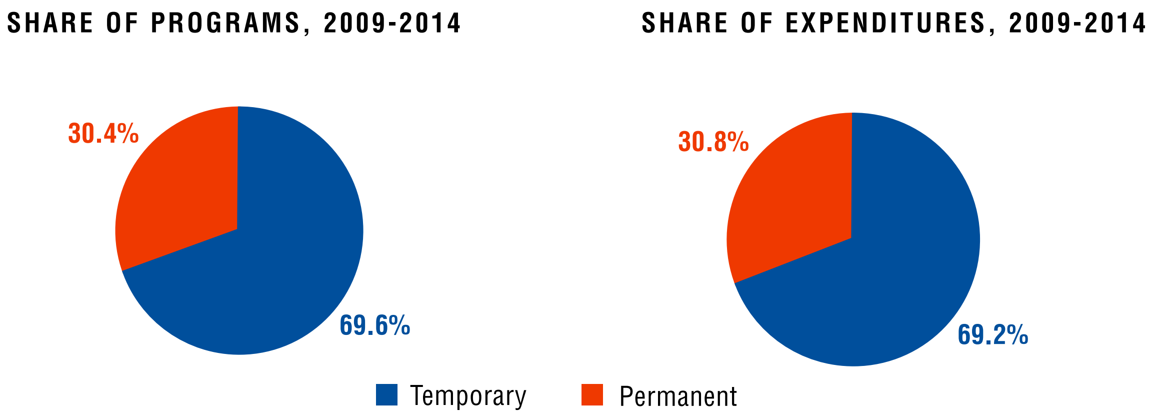
As Figure 7 illustrates, a sizable portion of federal clean energy investments in this period originated with the 2009 ARRA stimulus bill. According to our analysis, one-time ARRA investments account for $51 billion or 34 percent of total federal spending over the 2009-2014 period.[38]

The expenditure of temporary stimulus funds, however, is not the sole factor responsible for declining federal clean tech support. Excluding ARRA funds, a sharp 47 percent decline in annual spending is still observable from 2011 to 2012, while funding levels in 2014 will be roughly half of non-ARRA funding levels in 2009.

Furthermore, the vast majority of US clean tech policy support has always been erratic and temporary by nature, with sunset dates or volumetric limits built into the programs from the beginning. The federal PTC, for example, has been extended seven times since it was first created in 1992. Today, roughly 70 percent of all federal clean tech programs and an equal portion of total expenditures are temporary programs with preset expiration dates or volumetric limits, and nearly all of these will expire by the end of 2014 (see Figure 8).

Figure 8

Permanent and Temporary Federal Clean Tech Programs and Expenditures



The pending decline in federal funding hits each market stage from clean tech RD&D to manufacturing to deployment, although manufacturing support and deployment programs seem the deepest declines (see Figure 9 below). Despite receiving the lion's share of clean tech investment over this period, deployment subsidies and expenditures also see the most dramatic decline, falling by nearly 80 percent from 2009 to 2014. Additionally, by the end of 2014, the only direct support for US clean tech manufacturing will consist of any remaining appropriations not yet allocated to cover loans under the DOE's ATVM loan program. Finally, while RD&D spending is the most consistent funding category, as most research programs receive regular appropriations as part of the annual budget process, federal clean tech RD&D expenditures are also expected to decline steadily. After a temporary boost under ARRA, federal clean tech RD&D spending has already fallen to less than $4 billion annually, leaving clean tech RD&D both underfunded and vulnerable to further cutbacks in future budget cycles.

Figure 9

Annual Federal Clean Tech Spending by Market Stage (billions)

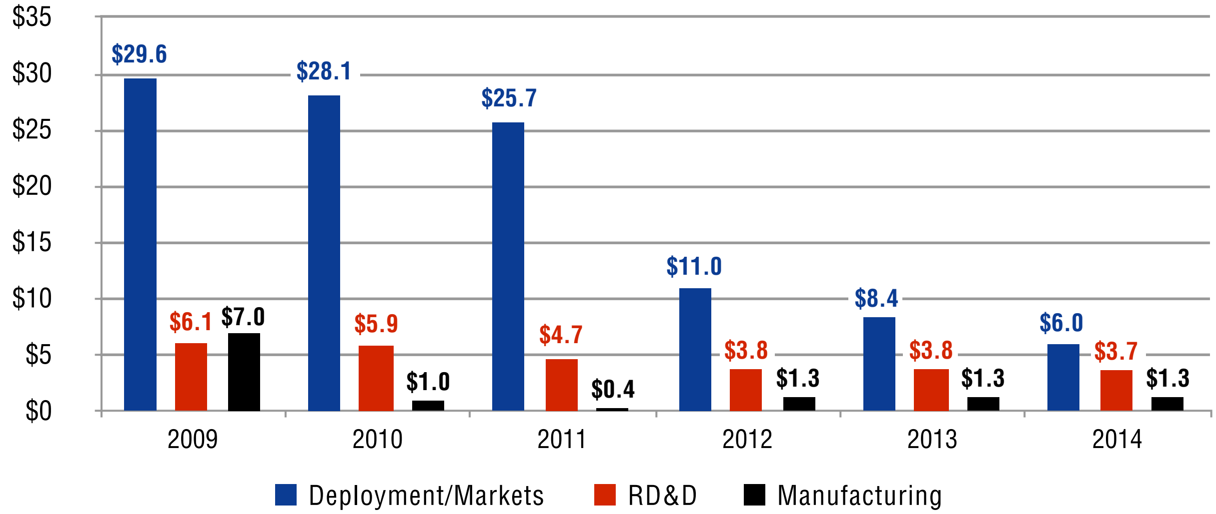
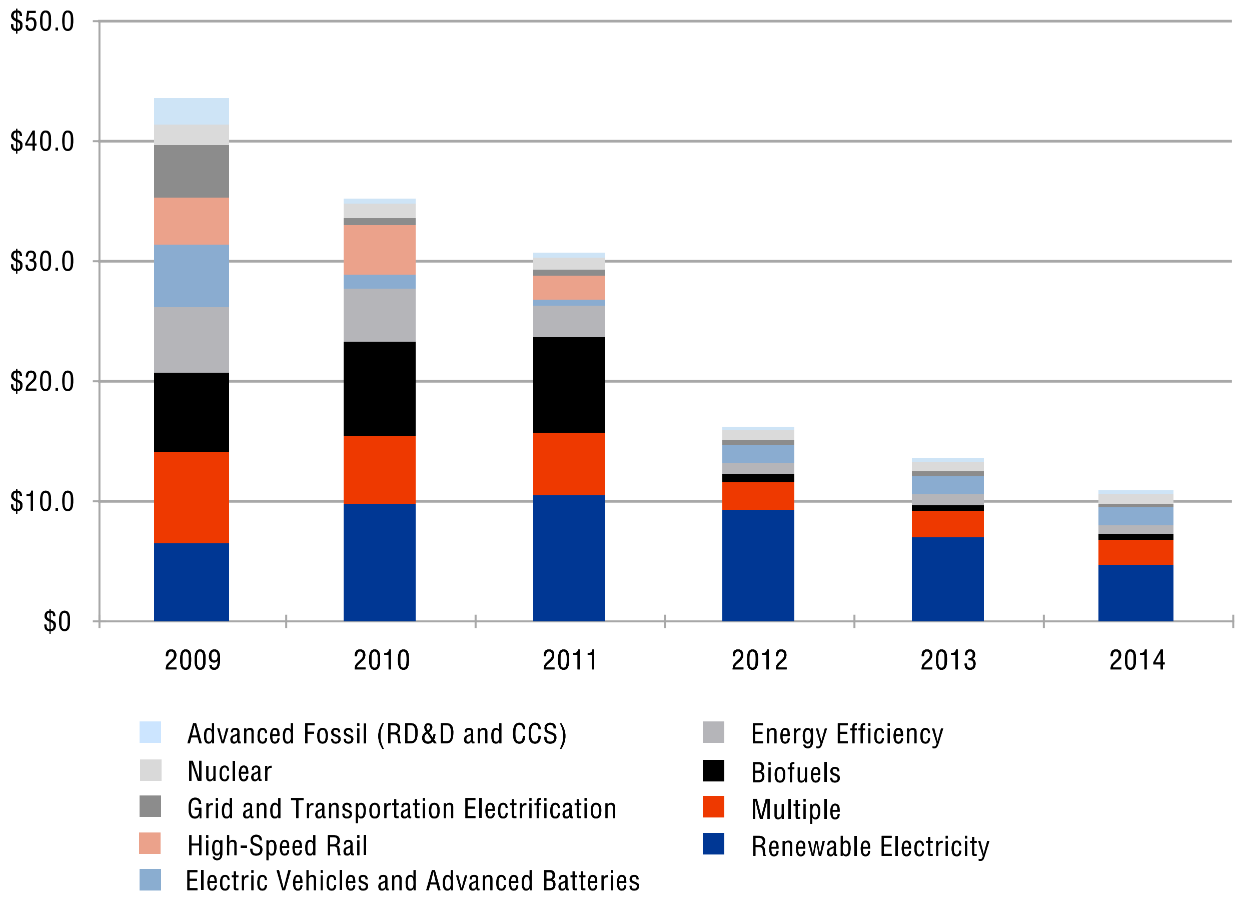


Figure 10

Annual Federal Clean Tech Spending 2009-2014 (billions)



Federal spending over the 2009-2014 period declines more precipitously for some clean tech segments than others. For instance, as Figure 10 demonstrates, federal support for electric grid and vehicle electrification technologies as well as energy efficiency exhibit sharp declines after surges of ARRA-funded investment in 2009 and 2010, while support for renewable electricity actually grows through 2012, before dropping again with the scheduled expiration of the PTC for wind. Programs that benefit multiple technology categories, primarily federal agency spending on RD&D, see a fairly modest decline in federal spending over the six-year period. Federal support for biofuels endures the most severe crash of all the categories, with nearly all federal spending eliminated by the 2011 expiration of the excise tax credits for corn-based ethanol.

WHAT'S LEFT AFTER 2014?

In the absence of legislative action to extend or replace current subsidies, America's clean tech policy system will have been largely dismantled by the end of 2014, a casualty of the scheduled expiration of 70 percent of all federal clean tech policies. Examples include:

→ The Section 48C advanced manufacturing tax credit (volumetric cap reached as of January 2010).

→ The Section 1705 DOE Loan Guarantee Program for advanced energy technologies (expired September 2011).

→ The Section 1603 Treasury Grants for renewable electricity projects (expired end of 2011).

→ The Volumetric Ethanol Excise Tax Credit (expired end of 2011).

→ The PTC enjoyed by wind power and other renewables (expires at the end of 2012 for wind and at the end of 2013 for other technologies).

→ Tens of billions of dollars in direct clean energy expenditures under the Recovery Act.

Furthermore, many of the remaining programs will end shortly after 2014. The solar industry, for example, will be left with just two more years before the 30 percent ITC buoying solar markets expires at the end of 2016, reverting to a permanent 10 percent credit. The only other ongoing programs left after 2014 include the nation's underfunded and politically vulnerable energy RD&D programs and a handful of tax credits and grant programs for energy efficiency and conservation.

→ PART 2 ←
CLEAN TECH MARKET IMPACTS

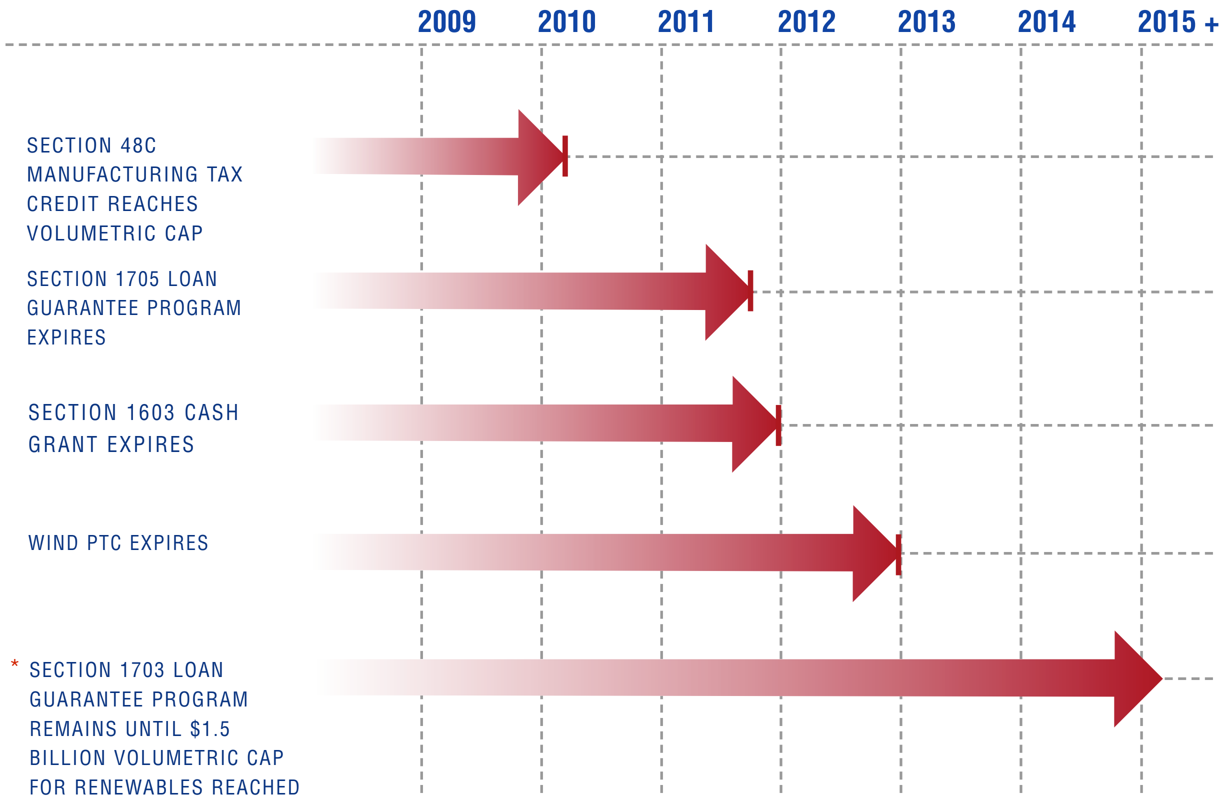
The expiration of key federal programs, including the Section 1603 renewable energy grant program and other ARRA-created programs, has already begun to impact clean tech markets and investments. Furthermore, the scheduled expiration of other programs, including the wind PTC at the end of 2012 and the broader collapse in funding scheduled to unfold by 2014, are all well within the time horizon relevant to investment decisions being made today by clean tech firms and financiers.

With virtually all clean tech segments dependent in one way or another on policy support, how this emerging industry will weather this policy collapse remains to be seen. Market impacts will certainly vary by industry segment. Clean electricity sources competing directly with gas-fired power plants may face the most severe economic challenges, as low natural gas prices (see Box 1) coincide with declining clean tech incentives. Furthermore, with many European nations reducing clean energy subsidies as well,[39] markets for solar and wind power products are currently oversupplied, reducing producer profit margins, tightening international competition, and prompting both bankruptcies and consolidations.[40] Absent policy reform, several US clean tech segments will face new headwinds, making their market outlooks increasingly uncertain. This section examines the impact of expiring federal policies on wind, solar, and nuclear power, corn and cellulosic biofuels, and plug-in hybrid/electric vehicles and advanced batteries.

WIND POWER

At present, the federal PTC for wind power production brings the levelized cost of electricity from new wind power projects down to an estimated range of $33-65 per megawatt-hour (MWh), depending on the quality of wind resource.[41] At these prices wind power is broadly competitive with new gas-fired generation (with levelized costs as low as $52 at likely gas prices, see Box 1), supporting robust market expansion.

However, the PTC is scheduled to expire at the end of 2012, creating significant market uncertainty[42] and prompting manufacturers of wind turbine components to prepare for layoffs and substantial market contraction.[43] Without the PTC, the unsubsidized cost of a typical new wind power project ranges from about $60-90 per MWh (for "Class 3" and above wind sites), making wind energy competitive with gas-fired generation only in the best of wind regimes with ready access to existing transmission capacity.[44] Very few of these ideal sites remain available for development. If the PTC expires without any replacement, market analysts expect annual wind energy installations to collapse from a projected peak of 8-10.5 gigawatts (GW) in 2012 to just 1.5-2 GW in 2013.[45]



* *Program expires in 2015 or later. Where applicable, volumetric cap may be reached at earlier date.*

Already, the expiration of the ARRA-funded Section 1603 grant program for renewable electricity projects has forced wind developers to return to the complex and more expensive tax equity market to monetize the value of the PTC and secure project finance, raising financing costs and constraining available investment for wind energy projects.[46] The expiration of the 1603 grant program has raised the cost of debt capital for wind projects an estimated 3-8 percentage points, a roughly 50-130 percent increase in the cost of financing a wind project.[47]

Furthermore, as the available pool of tax equity finance is restricted to a small number of large financial institutions, reliance on tax equity markets could constrain total available investment in renewable energy projects. The US Partnership for Renewable Energy Finance estimates that renewable energy project developers will demand $7-10 billion in project finance during 2012, while tax equity markets are likely to only be able to supply only $3.6 billion.[48] Financing constraints imposed by the expiration of the Section 1603 cash grant project could thus significantly constrain wind and other renewable energy deployment in 2012 and beyond, even with the PTC in place.

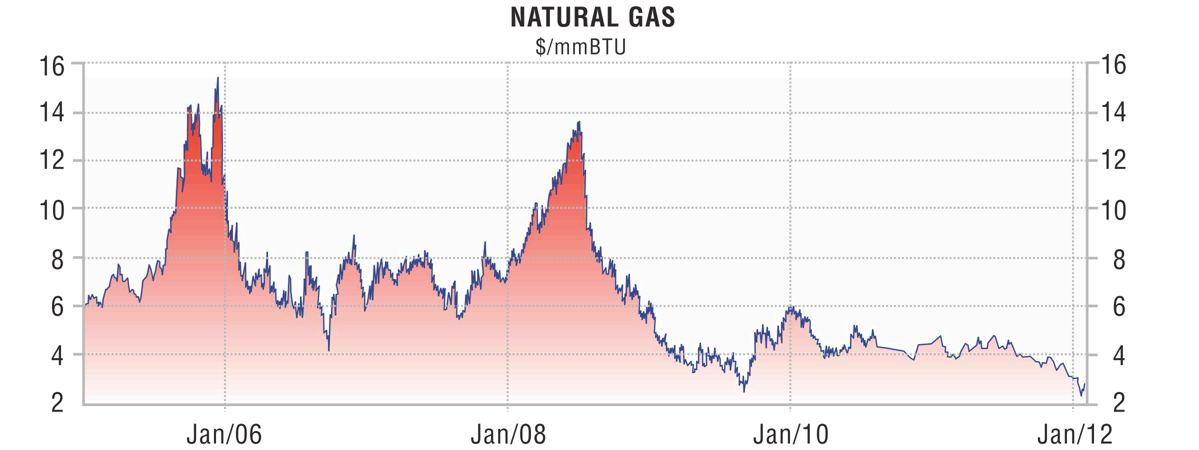
The simultaneous expiration of the Section 1705 DOE loan guarantee program also deprives wind developers of a source of affordable project finance.[49] Before expiring, the Section 1705 program closed loan guarantees totaling $1.7 billion for wind power projects. Going forward, some wind projects may still qualify for loan guarantees from the Section 1703 loan program. The program currently has $1.5 billion in remaining authorized loan volume available to renewable energy projects able to pay their own credit subsidies, as well as an additional $170 million in appropriated funds to pay credit subsidies for projects that had previously applied to the Section 1705 program but were not selected before the expiration of that program. The DOE is confident it will use all of its authorized loan authority for wind and other renewable energy technologies,[50] although the fate of the now controversial DOE Loan Programs Office, which has come under fire since the bankruptcy of DOE loan guarantee recipient Solyndra, remains unclear.

While wind power will continue to benefit from mandates requiring utilities to adopt renewable energy enacted in 29 US states and the District of Columbia, without the PTC and other federal incentives and with increased costs of project finance, the costs of compliance with such standards may trigger the various cost containment provisions enacted in each of these policies, reducing the market opportunities for renewables.[51]

Market uncertainty and declining deployment incentives impact not just project developers but also take their toll on US manufacturers of wind power components. For example, Danish-based wind turbine maker Vestas estimates that if the PTC expires, the company will have to layoff 1,600 workers at US factories as demand falls for turbines in US markets.[52] Furthermore, declining market incentives in the US follow the expiration of the temporary Section 48C Advanced Energy Manufacturing Tax Credit created by ARRA, which provided a 30 percent credit for companies investing in new, expanded, or reequipped domestic manufacturing facilities for clean energy products. Before reaching its volumetric cap in 2010, the 48C credit awarded $364 million to 52 US wind manufacturing projects.[53] Since 2010, there has been no direct policy support for US wind manufacturing.

Box 1: Low Natural Gas Prices Pressure Clean Electricity Technologies

From a high of $13 per million British Thermal Units (mmBTU) in 2008, natural gas prices have plummeted to below $2.50 per mmBTU, nearing record-setting lows. Natural gas prices are likely to stay in the $3-4 per mmBTU range over the next several years, as low-cost production from shale gas resources expands North American production. Ultimately, given the marginal production costs of domestic gas supplies, gas prices over the medium term are likely to settle within a $4-6 per mmBTU band, still well below levels prior to the North American shale gas boom.



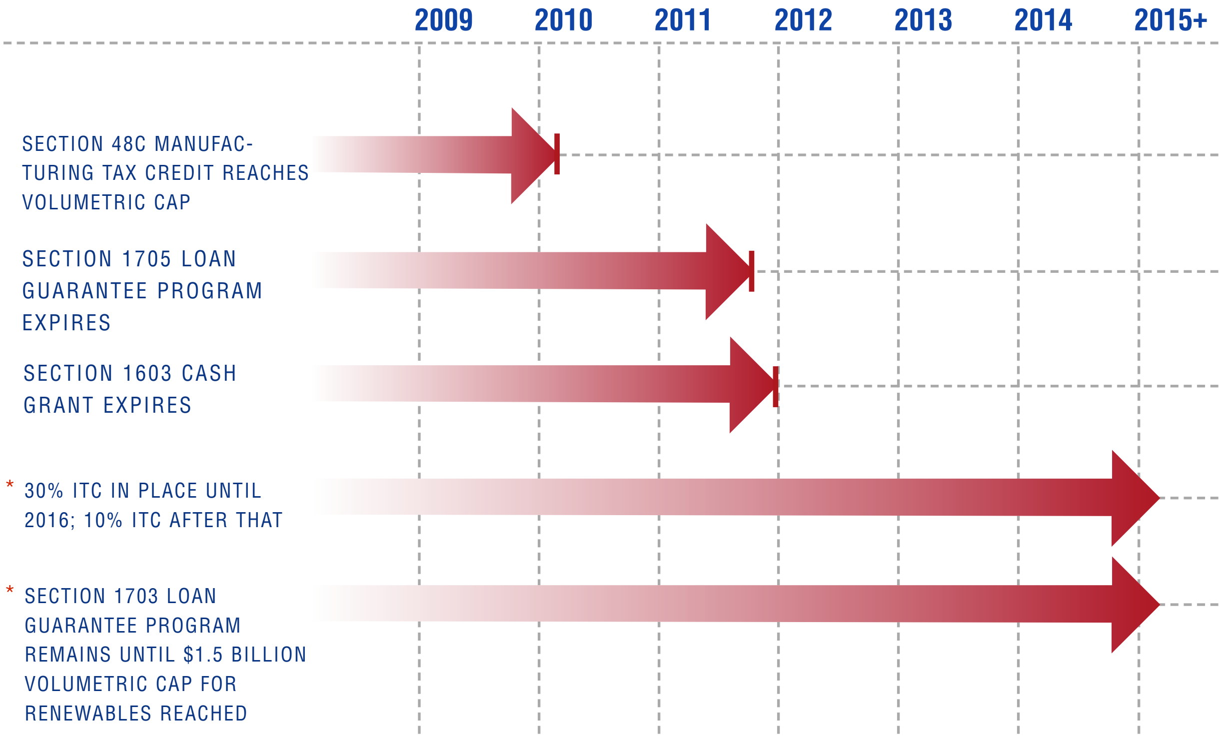
At these prices, electricity from gas-fired power plants has become the benchmark for new low-cost power generation, edging out even coal-fired power and providing added economic pressure for wind, solar, and nuclear power plants. The figure below illustrates the range of likely levelized costs of electricity from both advanced combined cycle gas plants (typically used for baseload and intermediate generation and competing with wind, nuclear, and baseload coal-fired power plants) and plants using conventional combustion turbines (typically used for peak or load-following power and competing with central-station solar and peaking coal-fired power plants).

Figure 1. Estimated Levelized Cost of Electricity (LCOE) From New Gas-fired Power Plants

Natural Gas Price ($/mmBTU)	Advanced Combined Cycle Gas Plant ($/MWh)	Conventional Combustion Turbine Plant ($/MWh)
3	52.1	71.5
4	59.1	81.5
5	66.1	92.5
6	72.1	103.5

Source: Alex Trembath and Jesse Jenkins, "Gas Boom Poses Challenges for Renewables, Nuclear," Breakthrough Institute, April 2012.

SOLAR POWER



* *Program expires in 2015 or later. Where applicable, volumetric cap may be reached at earlier date.*

Like wind power, utility-scale solar power projects are pressured by competition from low-cost natural gas. Large, central-station solar PV and solar thermal power projects typically compete most closely with peaking power plants, often gas combustion turbines, with estimated costs in the $71.5-103.5 per MWh range at likely gas prices (see Box 1). In contrast, the unsubsidized levelized cost of electricity from typical utility scale solar PV installations fell between $111 and $181 per MWh in late 2011, a broad range that captures wide discrepancies in regional solar resources.[54] With the support of federal and state subsidies, solar projects in California, the largest solar market in the United States, have achieved contract bids below $90 per MWh, a historic low-point in the trend towards cost parity in solar markets.[55] Despite significant declines in solar costs in recent years, however, solar PV projects still have difficulty competing in wholesale power markets with new gas-fired generation without subsidy or policy support, except perhaps in regions with the highest solar resource.

Going forward, analysts expect continued declines in solar PV module and system prices. With the right innovation and market supply/demand conditions, unsubsidized utility scale solar PV costs may decline into the $90-150 per MWh range by 2014 and the $40-66 per MWh range by 2020.[56] These forecasts show solar achieving wide cost parity with natural gas generation within the decade, but will require sustained innovation by industry and optimized public policy support.

In the meantime, solar currently benefits from a 30 percent investment tax credit (ITC) not scheduled to expire until 2016, which will help solar PV remain competitive in a much wider range of markets. After 2016, the ITC reverts to a permanent 10 percent business tax credit, while a personal income tax credit for residential installations expires. Several states also offer additional tax credits and incentives for solar power producers.[57] For the time being, US solar markets thus face somewhat greater policy certainty than wind power markets.

Furthermore, solar power projects on residential, commercial, and industrial rooftops compete less directly with wholesale prices for gas-fired generation. Instead, these "behind-the-meter" installations must reach a price that is competitive with the higher retail electricity rates offered by utilities, a point often referred to as "grid parity."

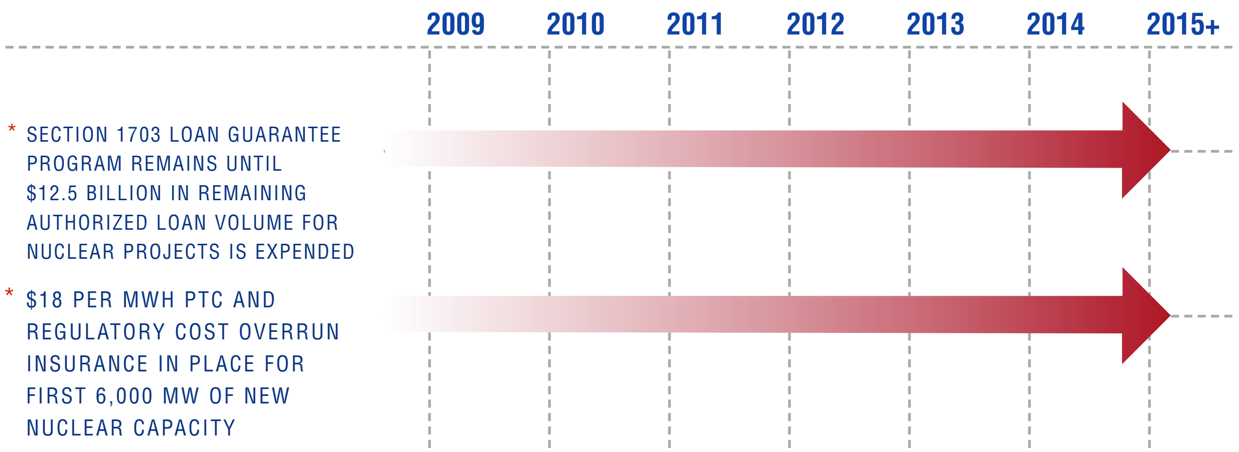
After significant recent cost reductions, the unsubsidized cost of electricity from solar installations on residential rooftops dropped to a range of $178 to $345 per MWh in late 2011, although higher prices are possible for projects with poor capacity factors.[58] These prices are now at or near cost parity with retail electricity rates in certain US markets with the right combination of high electricity prices and/or high solar irradiance. Rooftop solar projects are typically cost competitive now without subsidy in Hawaii, where retail electricity rates average $281/MWh. Depending on the pace of innovation and cost reductions, rooftop solar is also within striking distance of unsubsidized retail grid parity in several sunny states with relatively high electricity rates, including California, Texas, Florida, and Nevada, as well as a set of northeastern states (Connecticut, New York, New Jersey, and New Hampshire), where residential electricity rates exceed $160 per MWh and solar irradiance is modestly high.[59] With the benefit of the ITC and additional state incentives, markets for rooftop solar are currently robust in each of these states.[60]

Despite this relatively positive outlook, expiring federal subsidies are having a negative effect on solar markets. As in the case of the wind industry, the expiration of the ARRA-funded Section 1603 cash grant program has left solar project developers dependent on tax equity markets, significantly increasing the cost of project finance and constraining the pool of available investors (see wind discussion above for more). According to an analysis commissioned by the US Solar Energy Industries Association, the expiration of the 1603 grants will reduce the pace of solar energy installations by a cumulative 5,343 MW between 2012 and 2016—a market contraction of nearly 12 percent—as the industry reverts to reliance on the less effective ITC.[61]

The Section 1705 DOE loan guarantee program also expired at the end of September 2011, depriving solar developers of another lower-cost financing option. Before expiring, the 1705 program closed 12 loan guarantees for solar generating projects, supporting more than $4.4 billion in total investment.[62] As with other renewable electricity projects, some solar projects may tap the $1.5 billion in remaining authorized loan volume for renewable energy technologies under the Section 1703 loan guarantee program, as well as $170 million in appropriated funds set aside to cover credit subsidies for projects that had previously applied to the Section 1705 program but were not selected before the expiration of that program.

The expiration of both the Section 1705 program and the 48C Advanced Energy Manufacturing Tax Credit leaves US solar manufacturing with little direct federal policy support, while facing intense international competition from manufacturers in China, Germany and elsewhere. Before expiring, four US solar manufacturers received support from the Section 1705 loan guarantee program, including now-bankrupt Solyndra.

NUCLEAR POWER

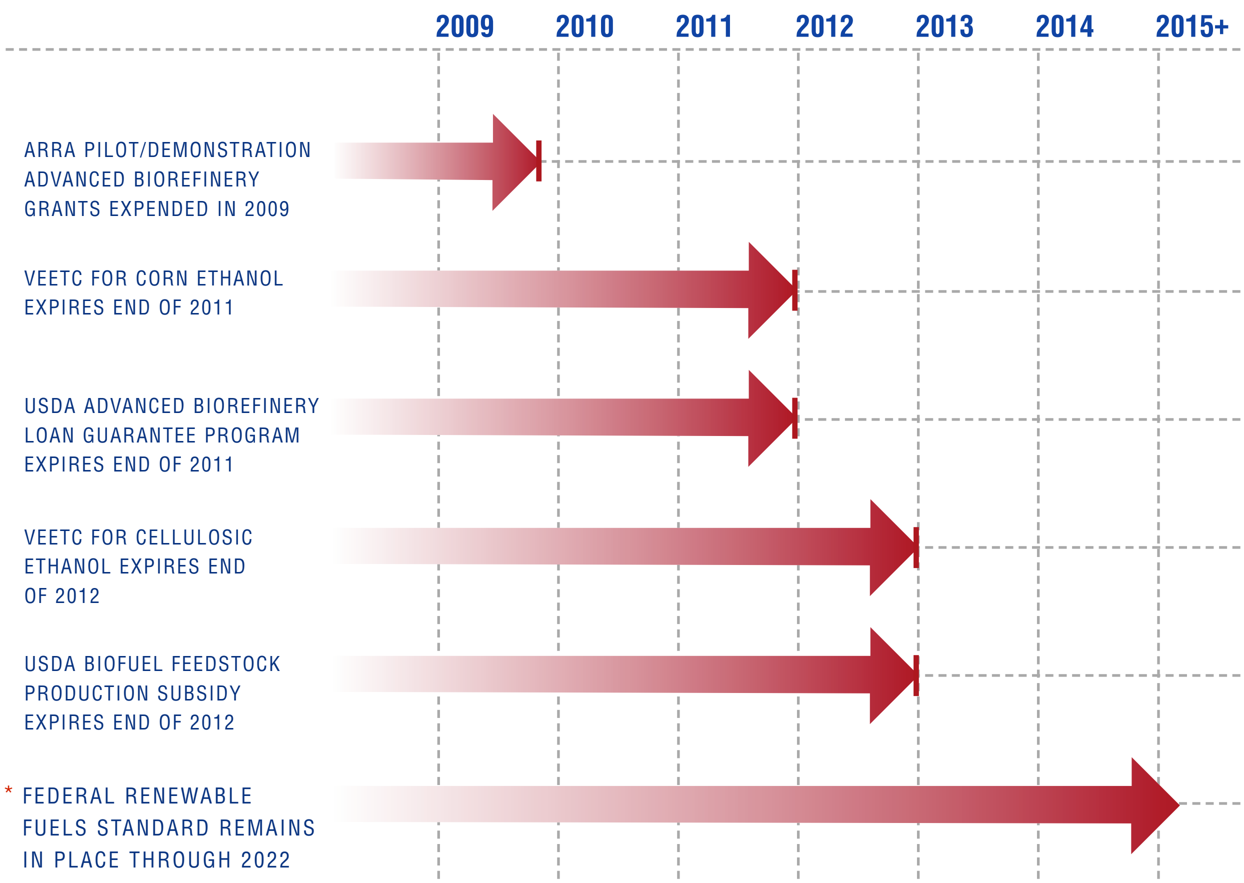


* *Program expires in 2015 or later. Where applicable, volumetric cap may be reached at earlier date.*

Persistent challenges in the financing of nuclear generation facilities, caused by high upfront capital requirements and a stringent regulatory environment, are mitigated somewhat by federal loan guarantees and incentives for new production. The Section 1703 DOE Loan Guarantee Program is authorized to guarantee up to $22.8 billion in total loans to the nuclear sector, including both new power plants and "front-end" fuel cycle projects, of which the DOE has committed $10.3 billion to date. New nuclear power projects also benefit from a production tax credit of $18/MWh available to the first 6,000 MW of new installed generation as well as federal cost overrun insurance in the event of regulatory delays to construction.[63] With over 30 proposed reactors being reviewed by the Nuclear Regulatory Commission as of March 2011,[64] there is no shortage of potential new nuclear generation.

At the same time, however, new nuclear projects must also compete with the surging availability of low-cost natural gas. The US Energy Information Administration (EIA) estimates the levelized cost of electricity from new nuclear plants at around $114 per MWh for reactors entering construction now and becoming operational in the 2016-2020 time period. Given the overall uncertainty about construction costs for new reactors, this estimate should be considered tentative, but EIA does rely on total overnight capital cost estimates consistent with the expected cost of two Westinghouse AP1000 reactors currently under construction by Georgia Power. Thus, the first few nuclear power plants built in the United States are likely to have levelized costs in excess of $100 per MWh. The PTC available to the first 6,000 MW of new nuclear generation helps reduce this cost somewhat, but at these projected costs, new nuclear power plants will remain uncompetitive with new gas-fired combined cycle power plants at likely gas prices. As Exelon CEO John Rowe, whose company owns one-seventh of the nuclear generating capacity in the United States, recently noted, "Neither new nuclear, coal with carbon capture and sequestration, wind, nor solar are economic [with current gas prices]."[65]

ETHANOL AND ADVANCED BIOFUELS

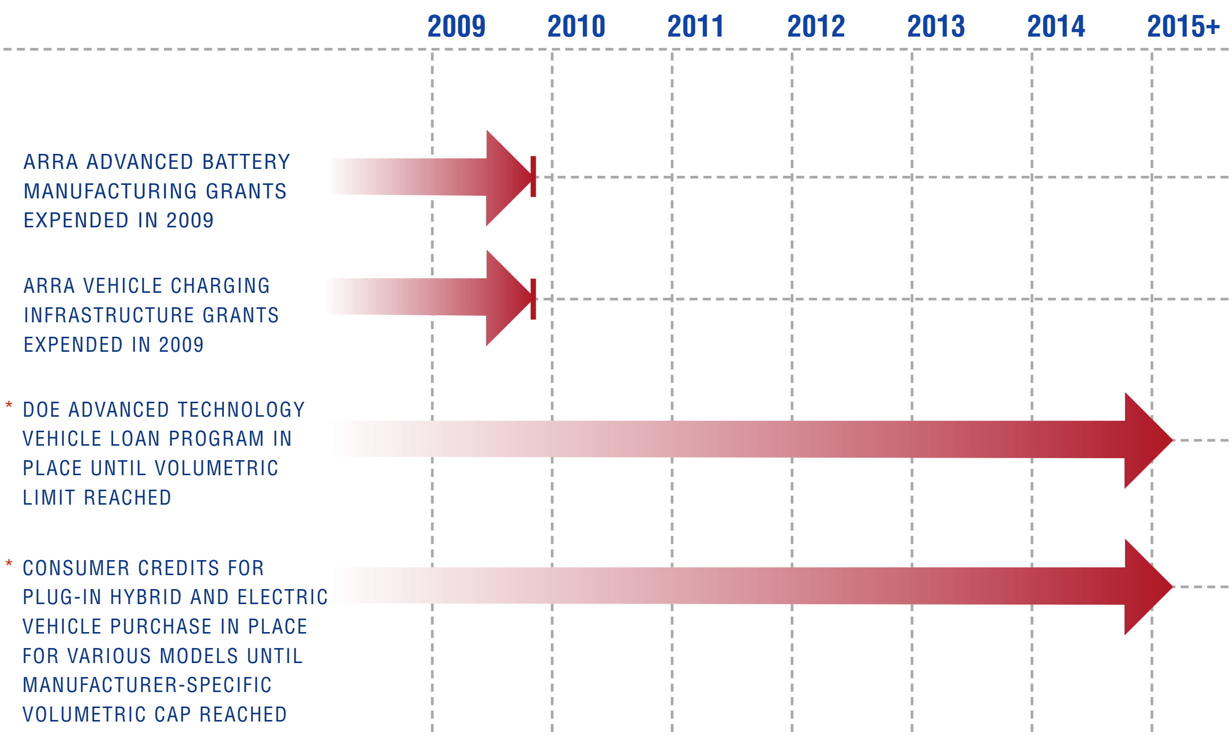


* *Program expires in 2015 or later. Where applicable, volumetric cap may be reached at earlier date.*

The Volumetric Ethanol Excise Tax Credit (VEETC) long benefiting corn-based ethanol producers expired at the end of 2011 and has not been renewed. Conventional ethanol producers are expected to weather the loss of their primary subsidy far better than other sectors, however, thanks to the relatively competitive price of ethanol relative to current oil prices[66] and the ongoing presence of a national Renewable Fuels Standard. This market mandate requires the annual use of ethanol and other biofuels to steadily expand from 12.6 billion gallons in 2011 to 14.4 billion gallons in 2014. According to agricultural commodity analysts Advanced Economic Solutions, the removal of the VEETC will therefore result in "only a modest reduction in US ethanol production" as the current application of the VEETC only marginally increases total production above what the Renewable Fuels Standard mandates regardless.[67]

Advanced biofuels produced from inedible cellulosic material and other non-corn feedstocks face more substantial impacts from expiring federal supports. A subsidy generally worth $1.01 per gallon for cellulosic ethanol producers is scheduled to expire at the end of 2012, alongside a USDA Bioenergy Program supporting production of feedstocks for advanced biofuels. A temporary ARRA-supported program appropriated $800 million to support pilot- and demonstration-stage biorefineries for advanced biofuels, but all funds were expended by the end of 2009. Finally, a USDA Biorefinery Assistance Program created by the 2008 Farm Bill offers loan guarantees to cover a portion of the development, construction, or retrofitting costs of new, commercial-scale advanced biofuel refineries, yet new lending authority for this program expired in the spring of 2011. While the federal RFS creates demand for non-corn biofuels, fuel producers are only obligated to purchase advanced biofuels if they are available in sufficient quantities and at low enough prices. With public subsidy for next-generation biofuels approaching a nadir, the market outlook for this nascent sector appears highly uncertain.

PLUG-IN AND ELECTRIC VEHICLES AND ADVANCED BATTERIES



* *Program expires in 2015 or later. Where applicable, volumetric cap may be reached at earlier date.*

US-based advanced battery and plug-in hybrid and electric vehicle manufacturers benefitted from $2.4 billion in ARRA-funded grants for advanced battery manufacturing, which reached its volumetric cap on funding by the end of 2009. The ATVM program operated by the DOE Loan Programs Office also provided three loans totaling more than $2.4 billion to support plug-in hybrid and electric vehicle manufacturing by three firms (Nissan North America, Inc., Tesla Motors, and Fisker Automotive).[68] The ATVM program retains an estimated $4 billion in appropriated credit subsidy to leverage additional loan guarantees (see Data Appendix for exact figures and methodology). However, with the fate of ATVM uncertain and the short-lived battery manufacturing grants a thing of the past, direct federal support for advanced vehicle and battery manufacturing in America has largely lapsed.[69]

Domestic markets for plug-in hybrid and electric vehicles are likely to be buoyed by a consumer tax credit worth up to $7,500 per vehicle (depending on the size of the vehicle battery). This credit begins to phase out for vehicles produced by a given manufacturer once that manufacturer has sold 200,000 qualifying vehicles in the United States. Demand for plug-in and electric vehicles is also supported by increasing federal fuel economy standards and several additional state purchase incentives and could be enhanced if oil prices continue to rise in the coming years.[70]

However, current costs for plug-in hybrid and electric vehicles are often double that of a comparably sized and equipped conventional vehicle, limiting widespread consumer interest until further cost declines are achieved.[71] Sales of plug-in hybrid and electric vehicles have so far lagged market forecasts, with fewer than 20,000 vehicles sold in 2011, a year that marked the release of several mass-market models, including the Nissan Leaf and Chevy Volt.[72] By the end of 2014, plug-in hybrid and electric vehicle sales are likely to total well below 100,000 per year. The most optimistic industry analysts project US plug-in hybrid and electric vehicle sales will continue to grow robustly from this small base, albeit to just about 2 percent of projected light vehicle sales by 2017 (or about 360,000 vehicles).[73]

Consumer uptake of plug-in and electric vehicles will also be limited by the availability of charging infrastructure, both at private residences and public parking locations. The only direct federal support for deployment of charging infrastructure, however, was a short-lived ARRA-funded Transportation Electrification Initiative, which provided $400 million to several communities to expand charging infrastructure in 2009.

→ PART 3 ←
PUTTING CLEAN TECH ON A PATH TO SUBSIDY INDEPENDENCE

Part 1 of this report defined the full scale of pending cuts to federal support for clean tech sectors, which are now poised to see annual clean tech spending decline 75 percent from 2009 to 2014. Part 2 described how the combination of these sharp cuts in federal clean tech spending alongside intensified competition from both cheap natural gas and low-cost overseas manufacturers threatens to turn boom years to bust for several key clean tech segments. This section considers how policy makers and business leaders can maintain the vitality of clean tech industries while freeing them from policy dependence—and the attendant market booms and busts—as rapidly as possible.

This is not the first time booming clean tech markets in America have been on the brink of a bust. US markets for clean tech segments from wind, nuclear, and solar power to electric vehicles and alternative fuels have each surged and declined in the past. While a drawdown of federal subsidies is most often the immediate trigger of clean tech market turmoil, the root cause remains the same each time: the higher cost and risk of US clean tech products relative to either mature fossil energy technologies or lower-cost international competitors, which make US clean tech sectors dependent on subsidy and policy support.

New industry sectors are often volatile, as innovative technology firms must challenge both established incumbents and competing upstarts. Clean tech sectors are no exception.

Yet in energy, unlike biotechnology or information technology, price is king. Like steel or copper, energy is a commodity, principally valued not for its own qualities but for the services and products derived from it. As such, while new drugs, software, or consumer electronics command a price premium from customers by offering new value-added features and hence command a premium price from customers, new energy technologies must routinely compete on price alone, even if they offer other long-term benefits.[74]

It would be a difficult feat for any nascent technology to enter a commodity market and compete immediately on cost, but clean tech sectors face a particularly challenging rival: well-entrenched fossil fuel incumbents that have had more than a century to develop their supply chains and make incremental innovations to achieve high levels of efficiency. These mature fossil energy industries have long enjoyed sizable, stable flows of subsidy support as well as a regulatory environment and established infrastructure both geared towards fossil fuel models of energy procurement, delivery, and use.[75]

Most clean tech segments, by contrast, are relatively young, are still developing supply chains, and are steadily improving manufacturing techniques, product designs, and efficiencies. Higher perceived technology risks make financing the commercialization and scale-up of new clean technologies particularly challenging.[76] Imbalances between supply and demand can quickly develop in immature clean tech supply chains, causing wild swings in prices and profit margins.[77] New business models and novel technologies often require market or regulatory reforms, new enabling infrastructure, or other changes to fully scale-up.[78] Meanwhile, several different technology pathways are still in active competition for specific emerging clean tech market niches, with a clear winner yet to emerge.[79] In short, clean tech sectors still have a lot of learning and maturing to do.

Indeed, innovative companies have made strides in several clean tech segments in recent years, often buoyed by supportive federal clean tech policies. Though current subsidies were never optimized to drive innovation, higher levels of federal clean tech spending have indirectly supported market competition and improvements in technology and/or manufacturing efficiencies in areas such as advanced batteries and vehicles, solar panels, and wind turbines, just as did past federal support for hydroelectric dams, nuclear plants, and shale gas.[80]

The cost of new wind turbines has fallen 27 percent from 2008 to 2011 and levelized costs for new wind power projects have similarly declined between 24 and 39 percent from 2002-2003 to today.[81] Wind power is now nearly as cheap as low-cost natural gas in prime locations with high wind resources and good proximity to existing transmission. The cost of solar power has fallen even more sharply in recent years, the result of both real, incremental technology improvements and more temporary, fortuitous supply and demand dynamics (including a 70 percent decline in the price of refined polysilicon). Between 2007 and 2011, the global average cost of installed solar PV systems dropped by more than 50 percent, from $7.20 per watt in 2007 to $3.47 per watt in 2011.[82] In the United States, the average module cost for solar dropped 40 percent from Q4 2010 to Q4 2011 alone,[83] putting solar power within close reach of "grid parity" – cost competitiveness with retail electricity rates – in locations with either expensive electricity costs, plenty of sun, or both (see Part 2). And a new generation of nuclear designs that promises to be safer, cheaper, and easier to scale may ultimately provide zero-carbon baseload power is now moving through permitting processes and into the marketplace.[84]

These and other clean energy technologies, however, must continue to improve substantially. Costs overall remain higher than fossil competitors, and as the emergence of low-cost shale gas demonstrates, the energy sources that clean technologies are competing against are not standing still. After three decades of private and public-sector collaboration to develop cost-effective technologies to extract natural gas from shale deposits, the "shale revolution" has unlocked large new supplies of domestic natural gas and slashed spot market prices to one-fifth of the peak levels reached in 2008.[85] Solar, wind, nuclear and other zero-carbon energy must now redouble efforts to reduce costs to stay competitive in North American electricity markets (see Part 2 above).

Fortunately, energy technology experts at the International Energy Agency[86] point to numerous remaining technical opportunities to achieve significant cost reductions and performance improvements across a range of clean tech segments, from wind and solar power to enhanced geothermal energy systems, advanced nuclear designs, and improved vehicle technologies and fuels. Successful competition with fossil fuels is possible in the near- to medium-term—the steady process of innovation is the key.

Still, the reality is that until technological innovation and cost declines can secure independence from ongoing subsidy, clean tech segments will remain continually imperiled by the threat of subsidy expiration and political uncertainty. Meanwhile, public tolerance for significant energy subsidies or the internalization of higher prices for energy is limited.[87] If clean energy technologies scale up without corresponding declines in price, this limited tolerance will eventually be expended, leading to another market bust. This means that the simple, perpetual extension of today's clean energy subsidies and policies, with its somewhat passive approach to innovation, offers no sustainable path beyond a cycle of clean tech boom and bust.

It is true that the federal government has historically devoted greater total subsidies to fossil energy sources than to clean energy sources[88]—a fact that changed only recently with the large temporary increase in federal clean tech spending documented in this report[89]—and that fossil sectors continue to enjoy subsidies to this day. It is long-past time to end subsidies for mature fossil energy technologies as well. If subsidies for clean tech sectors must phase out as these sectors mature, there is little rationale for perpetual subsidization of well-established fossil energy production methods and technologies.

At the same time, subsidies for clean tech markets in the United States are many times greater than US fossil fuel subsidies when considered per unit of energy generated, meaning that the wholesale termination of all energy subsidies would not automatically make clean energy technologies cost competitive.

Policy makers who may disagree about the appropriate role of government in the energy sector should therefore seek neither across the board cuts to energy subsidies nor their simple maintenance. Rather, they must engage in serious-minded, innovation-centered reform.

For their part, clean tech companies and investors would do well to lead this energy policy reform effort. While many clean tech entrepreneurs deserve credit for achieving innovation and technology improvements under existing subsidy regimes that should better reward their efforts, others have obtained subsidies without facing pressure to reduce costs or improve performance. Embracing innovation-focused policy reform will ensure US firms are well positioned to outcompete international challengers, as well. Simple deployment subsidies or policies to create demand, for example, still allow foreign competitors to undercut domestic manufacturers and seize larger and larger market shares, as Chinese solar PV companies have proven in the last three years.[90] Only steady innovation can keep US firms at the leading edge of clean tech sectors, and a supportive policy regime will be essential.

Businesses and policy makers alike must therefore understand that the true economic rewards in clean energy industries will come not from producing technology for subsidy-created markets that vacillate wildly with the public mood and the political cycle but rather by producing cheap and reliable clean energy technologies that can compete on cost with both international competitors and conventional fossil fuels.

The coming collapse of US clean tech policies thus presents a critical opportunity for intelligent energy policy reform. With the US clean energy policy system set to be effectively wiped clean in the coming years, American business and policy makers must now unite to craft a coordinated new set of limited but direct federal strategies optimized to drive innovation and make clean energy subsidy independent over time. With such a strategy in place, the United States also has the potential to successfully make clean energy technologies cheap enough for widespread export to energy-hungry markets throughout the world.

To these ends, policy makers and business leaders should together pursue reform on two fronts.

1.

Reform Energy Deployment Subsidies and Policies to Reward Technology Improvement and Cost Declines

Annual federal incentives and subsidies for deployment and market adoption of clean technologies are poised to fall 80 percent from 2009 to 2014, wiping away the large bulk of today's clean energy deployment regime (see Part 1). This creates a clear need for urgent policy reform to both sustain market opportunities for advanced energy technologies and implement smart new policies that more effectively shepherd public resources and support innovative entrepreneurs and firms.

Reducing the cost of clean energy technologies will require continuous innovation and improvement even after technologies are commercialized and launched into the marketplace. Yet, by and large, today's energy subsidies do not do enough to support America's innovators, and they have not yet succeeded in driving down the costs of clean energy far enough to compete with fossil fuels.

The government, however, has a long history of successfully driving innovation and price declines in emerging technologies by acting as a demanding customer to spur the early commercialization, large-scale deployment, and steady improvement of cutting-edge technology.[91] Unfortunately, clean tech deployment policies today often closely resemble crop supports, offering a flat production subsidy for any clean energy produced, rather than the demanding military procurement policies that delivered steady improvements and the eventual mass-adoption of everything from radios, microchips, and jet engines, to gas turbines, lasers, and computers.[92]

Many of today's clean energy subsidies are focused primarily on supporting the deployment of existing energy technologies at current prices, and most provide no clear pathway to subsidy independence. The federal renewable electricity PTC, for example, has provided the same level of subsidy to wind power and closed-loop biomass-fueled power plants since initial enactment in 1992 and to geothermal and other qualifying renewable electricity sources since 2004, when it was first extended to them. Subsidy levels increase each year at the rate of inflation, keeping per MWh subsidy levels constant in real dollar terms and providing no clear incentive for continual cost declines or pathway to eventual subsidy independence.

If not designed with care, deployment policies can also lock out more promising but higher risk technologies from markets, slowing their development. Renewable portfolio standards, for example, which require utilities to purchase a certain percentage of electricity generation from renewable sources, encourage deployment of the lowest-cost renewable energy technology available—generally wind power or biomass. But they do little to drive down the price of other, clean energy technologies, such as solar or advanced nuclear power designs, that may have higher costs now but hold the potential to become much cheaper in the long-run.[93]

The intermittent and haphazard nature of US energy policy also wreaks havoc with the business confidence necessary for the long-term investments required to develop new and improved products.[94] The PTC for wind power, for example, was first enacted in 1992, but has since expired three times, and has been renewed a total of seven times, often with less than a month to spare before pending expiration. Other clean tech subsidies, including key tax credits for solar, biofuels, energy efficient products, and other segments have experienced similarly erratic expirations. The market effects are chilling, and many private firms are forced to focus principally on ramping-up production for subsidized markets while they last, rather than pioneering next-generation designs and manufacturing processes for the long-term.

In the worst cases, maintaining lucrative, blunt subsidies over prolonged periods can even create a disincentive for firms to innovate[95] or can support "dead end" technologies that have no viable path to long-term competitiveness.[96]

The United States can do better than this. Deployment subsidies and policies must be reformed and designed from the beginning to better support innovative US firms and reward companies for developing, producing, and improving advanced technologies that can ultimately compete on price with both fossil fuels and international competitors alike. Each dollar of federal support today should be optimized to advance clean tech sectors towards eventual subsidy independence as soon as possible. Whether through production or investment subsidies, consumer rebates, market-creating regulations or standards, or other market incentives, a new suite of clean tech deployment policies must simultaneously drive both market demand *and* continual innovation.

In particular, many of today's clean tech deployment subsidies and policies should be reformed to ensure they:

- **ESTABLISH A COMPETITIVE MARKET.** Deployment policies should create market opportunities for advanced clean energy technologies while fostering competition between technology firms.

- **DRIVE COST REDUCTIONS AND PERFORMANCE IMPROVEMENTS.** Deployment policies should create market incentives and structures that demand and reward continual improvement in technology performance and cost.

- **PROVIDE TARGETED AND TEMPORARY SUPPORT FOR MATURING TECHNOLOGIES.** Deployment policies must not operate in perpetuity, but rather provide targeted and temporary support for clean tech segments that are still maturing and improving. Incentives should be terminated if technology segments either fail to improve in price and performance or become competitive without subsidy.

- **REDUCE SUBSIDY LEVELS IN RESPONSE TO CHANGING TECHNOLOGY COSTS.** Deployment incentives should decline as technologies improve in price and performance to both conserve limited taxpayer and consumer resources and provide clear incentives for continued technology improvement.

- **AVOID TECHNOLOGY LOCK-OUT AND PROMOTE A DIVERSE ENERGY PORTFOLIO**. Deployment incentives should be structured to create market opportunities for energy technologies at various levels of maturity, including new market entrants, to ensure that each has a chance to mature while allowing technologies of similar maturity levels to compete amongst themselves.[97] More expensive technologies that are still nascent and have the technical potential to develop into low-cost, high-performance energy sources should not be locked out of markets by more mature clean technologies that have had the benefit of more time to reduce costs. A diverse energy portfolio will strengthen America's energy security and encourage greater market competition.

- **PROVIDE SUFFICIENT BUSINESS CERTAINTY.** While deployment incentives should be temporary, they must provide sufficient certainty to support key business decisions by private firms and investors. The process for reducing subsidies and the schedule for support should be clear, transparent, and planned over a multi-year horizon.

- **MAXIMIZE THE IMPACT OF TAXPAYER RESOURCES AND PROVIDE READY ACCESS TO AFFORDABLE PRIVATE CAPITAL.** Deployment incentives should be designed to avoid creating unnecessarily high transaction costs while opening up clean tech investment to broader private capital markets. As deployment subsidies are reformed, care should be taken to maximize the impact of limited taxpayer resources and avoid wasteful program design. For example, reforming tax credits to provide direct cash incentives could as much as double the impact of each taxpayer dollar.[98]

Several policies could be structured to meet these criteria. Competitive deployment incentives could be created for various clean tech segments of similar maturity, with incentives for each segment falling steadily over time to demand and reward continual innovation and price improvements.[99] Steadily improving performance-based standards could create both market demand and spur consistent technology improvement.[100] Such incentives or performance standards could also be set competitively by "top-runners," the leading industry performers in each market segment, forcing other firms to steadily innovate to stay competitive in the market.[101] Demanding federal procurement opportunities could be created to drive both market opportunities and ensure steady improvement of each successive generation of product, particularly when clean tech products align with strategic military needs.[102] And where direct government procurement does not make sense, reverse auction incentives could be established for varying technologies to drive industry competition and innovation.[103]

If structured to adhere to these criteria, a new era of clean tech deployment policies will neither select "winners and losers" *a priori* nor create permanently subsidized industries. Rather, these policies will provide opportunities for all emerging clean energy technologies to demonstrate progress in price and performance, foster competitive markets within a diverse energy portfolio, and put clean tech segments on track to full subsidy independence.

2.

Strengthen the US Energy Innovation System to Make Clean Energy Cheap

Subsidy reform by itself will not be sufficient to drive the needed technology innovation and subsequent adoption of affordable clean energy technologies. For that reason, a new energy policy consensus to secure an internationally competitive, subsidy-independent clean tech sector must harness America's strengths as an innovator. The United States is home to world-class universities, generations of trained scientists and engineers, potent centers of entrepreneurship, finance, and advanced manufacturing, and a creative culture capable of attracting talent from around the world. Yet when it comes to energy, America's innovation system falls short.[104] Policy makers must strengthen the US energy innovation system to catalyze clean energy breakthroughs and support continual technology improvement.

Along with the key reforms to deployment policies discussed above, the nation should pursue policy reform along three additional fronts:

Steadily increase investment in RD&D while reforming and strengthening the US energy innovation system.

Stepped up investment in energy RD&D is sorely needed to both invent new technologies and improve the cost and performance of existing ones to make them more competitive with conventional energy sources. Currently, neither the private nor the public sector invests the resources required to accelerate clean energy innovation and drive down the cost of clean energy. For that reason, policy makers should **steadily scale up investment in clean energy RD&D to at least triple today's levels.**

Multiple barriers prevent firms from adequately investing in the development of new, high-risk energy technologies. These include: knowledge spillover risks from private investment in research; the commodity nature of most energy markets, which prevent nascent, higher cost energy technologies from charging a premium; inherent technology and policy risks in energy markets; the financial scale and long time horizon of many clean energy projects; and a lack of wide-spread enabling clean energy infrastructure.[105] As a result of these and other barriers, US energy firms reinvest well below one percent of revenues in RD&D. This stands in stark contrast to firms in the information technology, semiconductor, and pharmaceuticals sectors, which typically reinvest 15 to 20 percent of their revenue in RD&D and new product development.[106]

This private sector gap is due in part to an analogous one in the public sector. Federal energy RD&D spending stands at less than $4 billion in 2012.[107] By contrast, the US invests almost $19 billion per year in the National Aeronautic and Space Administration (NASA) and $33.5 billion each year into health research (primarily through the National Institutes of Health), even as private sector firms invest nearly $60 billion of their own funds in health and biomedical research.[108] Defense related R&D now approaches $80 billion annually.[109] At 10 percent of total economic activity,[110] the vast size and critical importance of the energy sector to the US economy and national security calls for investments in advanced energy innovation of a similar order of magnitude. As such, a number of energy experts — including business leaders, energy researchers, leading think tanks, and the president's science advisors — all recommend increasing energy RD&D investment to roughly $15 billion annually.[111]

Even as the nation increases federal energy RD&D investment, it must also **modernize the American energy innovation system to leverage regional innovation opportunities and strengthen new institutional models at the federal level.**

Congress should expand new energy research programs that closely align research efforts with the needs of the private sector. These include:

- → The **Energy Frontier Research Centers** (EFRCs) program, which funds small, collaborative groups of researchers around the country working to create scientific breakthroughs that may unlock new pathways to overcome key engineering obstacles blocking clean energy development.

- → The **Advanced Research Projects Agency-Energy** (or ARPA-E), which funds small groups of researchers, engineers, and entrepreneurs focused on translating technological breakthroughs into commercial products.

- → **Energy Innovation Hubs**, large, collaborative teams of scientists and engineers that work together over a longer time frame to achieve goals for specific topics, such as dramatically cheaper solar energy, next generation nuclear reactor designs, or more energy-dense batteries.

Congress should also **create a network of regional energy innovation consortia or institutes** that would mobilize local private sector, university, and government researchers alongside investors and private sector customers to tackle big energy challenges, translate basic science insights into commercial innovation, and strengthen diverse regional clean tech clusters.[112] Existing efforts to build public-private partnerships responsive to both industry needs and regional strengths should also be encouraged across the DOE and particularly in the National Labs in order to ensure a maximum return on the federal investment in RD&D.[113]

Investment in RD&D should not end when clean technologies reach subsidy independence, as fossil fuel technologies and international competitors will not stop innovating and improving. As the recent emergence of low-cost shale gas illustrates, national investments in energy innovation will continue to bear fruit for consumers and the economy even after industries reach a significant scale..

Unlock clean energy entrepreneurship by implementing effective policies to accelerate commercialization of advanced energy technologies.

To ensure a fully competitive energy market, the federal government must also do more to speed the demonstration and commercialization of new advanced energy technologies. Due to multiple market barriers, private sector financing is typically insufficient to move new energy innovations from early-stage laboratory research on to proof-of-concept prototype and then to full commercial scale. There are two financing gaps, in particular, that kill off too many promising new technologies before they have a chance to develop. These are known as the early-stage "Technological Valley of Death" and the later-stage "Commercialization Valley of Death."[114]

The Technology Valley of Death occurs early in the development of a technology, as breakthrough research and technological concepts aim to develop commercially viable products. Investors are typically reluctant to fund early-stage research and product development, and many entrepreneurial start-ups fail to attract sufficient capital to see their research concepts translated into commercial products. New institutional arrangements for federal research support discussed above can help address this Technology Valley of Death, including ARPA-E and new regional innovation consortia.[115]

The Commercialization Valley of Death exists between the pilot/demonstration and commercialization phases of the technological development cycle. This financial gap plagues technologies that have already demonstrated proof of concept but still require large amounts of capital—often on the order of hundreds of millions of dollars—to demonstrate that their design and manufacturing processes can be brought to full commercial scale. This scale of funding exhausts the comparatively limited resources of typical venture capital-led financing rounds, and many VCs are beginning to eschew these nascent and capital-intensive energy technologies in favor of companies with more timely returns to investment.[116]

To avoid locking America's entrepreneurs and innovators out of energy markets, Congress should **implement new policies to navigate the clean energy valleys of death**. Without such policies, conventional fossil energy technologies are effectively insulated from new challengers, preventing a fully competitive US energy market. Meanwhile, America's innovators will likely be forced to commercialize their technologies in other countries, where foreign governments offer greater policy support, putting the United States at a competitive disadvantage.

Clean energy policy reform should thus extend to policies designed to address the Commercialization Valley of Death, including the DOE's Loan Programs Office, which funded Solyndra. The DOE loan programs were established in part to help address the Commercialization Valley of Death by investing in a portfolio of innovative energy technologies. Yet the office was soon caught in a mix of competing objectives — job creation, near-term stimulus, and long-term innovation. The DOE Loan Programs Office should therefore be replaced by a more **flexible, independent, and sophisticated suite of financial tools** and other mechanisms designed to draw private capital into clean tech projects through a variety of investment, credit, securitization, insurance, and standardization activities. Whether delivered through a Clean Energy Deployment Administration (CEDA) or other entities or programs, the clear mission of these activities would be to accelerate the commercialization and deployment of critical advanced energy technologies.[117]

A **National Clean Energy Testbeds** program (N-CET) should also be established to take advantage of public lands to accelerate technology demonstration and commercialization. This new program would provide access to pre-approved, monitored, and grid-connected public lands and waters ideal for demonstration of innovative energy technologies, thereby reducing the cost, time, and permitting challenges associated with technology commercialization.[118]

The federal government can also **leverage the power of military procurement** to create demanding early markets for advanced energy technologies that meet tactical and strategic military needs and may have later commercial applications. Energy technologies with dual-use commercial and military potential include advanced vehicle technologies, aviation biofuels, advanced solar power, improved batteries, and new, modular nuclear reactors. Procurement opportunities could help many of these technologies cross the Commercialization Valley of Death and improve steadily in price and performance, much as DOD procurement was instrumental in the early development of computing, microchips, jet engines, and other widely adopted technologies.

Similarly, the federal agencies should work independently and with the states to address infrastructure and regulatory challenges that may prevent the commercialization of new energy technologies. The full extent of the current shale gas revolution would not be possible without the rapid expansion of natural gas pipelines in the prior 15 years. Over 11,000 miles of interstate gas pipeline were built between 2000 and 2007, while only 668 miles of high voltage transmission was been built in the same time frame.[119] Whether access to the grid or plans for alternative fuel infrastructures, many new clean energy technologies are similarly reliant on the larger energy infrastructure. Reform should also be considered where the existing regulatory process prevents advanced energy commercialization. For example the Nuclear Regulatory Commission's process of approving new reactors makes it extremely difficult to commercialize designs that may be smaller or offer waste and proliferation solutions.[120] Careful reform in land use regulation, environmental regulation, health and human safety regulation and other areas may be necessary to make the commercialization of new energy technologies possible. This does not mean regulations should be weakened, but rather established in such a way that innovative solutions to the regulation's original goals are recognized.

Harness advanced manufacturing, regional industry clusters, and a world-class energy workforce to enhance America's innovative edge.

To build an innovative, competitive clean tech industry, policy makers must also **harness America's advanced manufacturing sector.**[121] Manufacturing is an integral part of the innovation system, and innovation suffers when divorced from manufacturing.[122] Indeed, nearly two-thirds of industry investment in R&D comes in the manufacturing sector and an equal percentage of the nation's scientists and engineers work there as well. US advanced manufacturing must play a key role in accelerating advanced energy innovation, and technical support programs, public-private research consortia, and other strategic policies can help domestic manufacturers of advanced energy technologies remain at the cutting edge.[123]

Likewise, the nation needs to develop more potent, catalytic ways to leverage and enhance regional clean tech industry clusters. Such industry clustering has been shown to accelerate growth by promoting innovation, entrepreneurship, and job creation a well as economic efficiency. However, notwithstanding some initial pilot policy efforts, the leveraging of local industrial and innovation systems for clean tech innovation and deployment remains an under-exploited opportunity. Policy makers should therefore **increase investment in competitive grants to support smart regional cluster initiatives**, designed not in Washington but on the ground close to the "bottom up" innovation that has broken out in numerous states and metropolitan areas.[124] Most notably, moves to scale up competitive awards like the Economic Development Administration's i6 Green Challenge for the establishment or expansion of regional proof of concept centers in various clean tech fields has the power to further accelerate both innovation and regional economic growth.

Finally, American clean tech leadership will require a highly educated, globally competitive advanced energy workforce. Just as programs like the G.I. Bill and the National Defense Education Act created a generation of highly-educated Americans that drove technological revolutions in information and communications technology, a new generation of energy scientists and engineers is needed to drive a technological revolution in energy.

Policy makers should **increase investments in energy science, technology, engineering, and mathematics (STEM) education** from K-12 all the way through post-graduate education.[125] K-12 investment should include teacher training and curriculum development related to energy literacy and STEM subjects. The United States is also in great need of interdisciplinary clean energy innovation programs at undergraduate and graduate institutions across the country. Federal investments should also be made available for competitive financial aid to support undergraduates entering energy-related fields and could also support fellowships for ambitious students entering graduate schools in energy science and engineering. Lastly, policy makers should provide postdoctorate research awards to support early-career researchers in cutting-edge, clean energy-related science and innovation fields.

Policy makers must also **ensure America remains the destination of choice for the world's top talent.** Foreign-born scientists and engineers fuel US innovation. Immigrants comprise nearly half of all scientists and engineers in the United States who have a doctoral degree and accounted for 67 percent of the increase in the US science and technology workforce from 1995 to 2006. Today, the United States is in a competition for the world's top talent as never before, and more countries are working hard to retain or attract the most highly educated scientists and engineers. The United States should not only grow its domestic STEM workforce but also remove barriers to legal immigration for foreign scientists and engineers who wish to work in United States, particularly those focusing on energy technology issues.

→ CONCLUSION ←

Clean energy policy in America is at a crossroads. Federal support for clean tech is now poised to decline precipitously—unless policy makers and industry work together to enact smart reforms that can ultimately free clean energy from subsidy dependence and put clean tech sectors on a path to sustainable, long-term growth.

A business-as-usual strategy of perpetual policy expiration and renewal is no longer sustainable. Recent efforts to once again extend the current subsidy environment for one more year have proven increasingly challenging,[126] leaving key clean tech sectors in tumult and threatening another shift from boom years to bust. As long as clean energy sectors remain dependent on public support, they will be continually imperiled by the threat of policy collapse. Continued innovation and cost reduction is thus the only real route beyond today's policy-induced cycle of boom and bust.

Yet the immediate cessation of clean tech subsidies is also not in the national interest. Clean energy sectors are still emerging and maturing and must compete against well-entrenched fossil energy sources with over a century of incremental improvements, federal subsidization, and established infrastructure and regulatory environments behind them. Supporting the development of a new portfolio of cost-competitive, scalable clean energy technologies offers substantial opportunities for enhanced American energy security, economic growth, new technology exports, and improved public health, but will take time.

The time has come then to craft a new energy policy framework specifically designed to accelerate technology improvements and cost reductions in clean tech sectors, ensure scarce public resources are used wisely to drive technologies towards subsidy independence as soon as possible, and continue the growth and maturation of America's clean tech industries. This report presented the challenges facing policy makers and clean tech business leaders. It is now time for a new national conversation on the route forward.

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→ DATA APPENDIX ←

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
TAX EXPENDITURES												
Credits for Alcohol Fuels and Biodiesel (6 credits)	2012	5,639	6,893	7,207	9	-	-	**19,748**	1	Alternative Fuels (Alcohol Fuels, Biofuels, Biodiesel)		$
Description: Coordinated income and excise tax credits for renewable fuels. Ethanol tax credit generally 45¢ per gallon (extra 10¢ for small producers); credit generally 60¢ per gallon for alcohol other than ethanol; $1 per gallon for biodiesel, agri-biodiesel, and renewable diesel (extra 10¢ for small producers of agri-biodiesel); alternative fuels generally 50¢ per gallon; cellulosic biofuels (excluding black liquor) generally $1.01 per gallon. Depending on the specific incentive, tax credits go to fuel producers and/or blenders. **Methodology:** 6 tax credits besides ethanol tax credit accumulated together; ethanol credit calculated by multiplying the subsidy amount of the credit by IEA figures for total annual US ethanol production. Cellulosic figures for 2012 were based on EPA projections of 8.65 million gallons blended in the year (see here: http://1.usa.gov/AgqcJZ)												
Production Tax Credit (PTC) for Renewable Energy (Wind)	2012	700	900	1,200	1,500	1,600	1,500	**7,400**	2	Renewable Energy (Wind)		$
Description: A 2.2 cents per-kilowatt-hour tax credit to encourage the operation of wind-powered electricity generation projects (adjusted annually for inflation).												
Credit for Non-business energy property	2011	1,133	1,133	1,133				**3,400**	1	Energy Efficiency (Building Technologies)		$
Description: Tax credit for 10% of qualified investments in residential energy improvements made to HVAC systems, furnaces, or boilers. Credit limited to $500.												
Residential Renewable Energy Tax Credit	2016	566	566	566	566	566	566	**3,396**	1	Renewable Energy (Solar, Wind, Geothermal), Fuel Cells		$
Description: Personal tax credit for 30% of qualified expenditures associated with installation of residential fuel cells or renewable energy generating technologies, including solar, wind and geothermal.												
Exceptions for energy-related publicly traded partnerships	None	560	560	560	560	560	560	**3,360**	1	Multiple		$
Description: Publicly traded energy-related businesses may be treated as other than corporations if 90% of their gross incomes are derived from some combination of interests, dividends, real property rents, or other types of qualifying income.												
Investment Tax Credit (ITC) for Renewable Energy	2016	270	530	600	680	420	370	**2,870**	2	Renewable Energy (Multiple), Fuel Cells, Micro-turbines, Combined Heat and Power (CHP)		$
Description: A tax credit worth 30% of qualifying investments in solar, wind, geothermal or other renewable energy sources, fuel cells, micro-turbines and combined heat and power (CHP).												
Advanced Energy Manufacturing Tax Credit (Section 48C)	2009	2,300	-	-	-	-	-	**2,300**	1	Renewable Energy (Solar, Wind), Fuel Cells, Micro-turbines, Hybrid-Electric Motor Vehicles, Fuel Blending Equipment, Energy Efficiency (Multiple)		⚙
Description: A tax credit equivalent to 30% of the qualified investment for manufacturing projects producing clean electricity, alternative fuel, and energy efficiency products.												
Production Tax Credit (PTC) for Renewable Energy (Other)	2013	383	383	383	383	383	383	**2,300**	2	Renewable Energy (Multiple)		$
Description: A per-kilowatt-hour tax credit to encourage the operation of electricity generation projects powered by solar, geothermal, biomass, or other renewable energy sources. 2.2 cents for geothermal and closed-loop biomass; 1.1 cents for others (each adjusted annually for inflation).												

$ DEPLOYMENT/MARKETS ⚙ MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
Modified Accelerated Cost-Recovery System	2012	220	220	220	220	220	220	**1,320**	2	Renewable Energy (Multiple), Fuel Cells, Micro-turbines, Combined Heat and Power (CHP)		$
Description: Qualified renewable energy technologies benefit from the federal MACRS program, which allows for depreciation capital investments over five years enabling investors to recover the costs of their investment.												
Credit for Other Alternative Fuel Vehicles	2014	200	200	200	200	200	200	**1,200**	1	Alternative Vehicles (Hybrid, Electric Vehicle, Biofuels, Lean-Burning Fuels)		$
Description: Fuel cell vehicles: $4,000 for vehicles weighing less than 8,500 pounds (heavier vehicles up to $40,000); credit of up to $4,000 is available for cars and light trucks that exceed the 2002 base fuel economy; A 10% credit, up to $2,500, is available for the cost of electric-drive low-speed neighborhood vehicles. A 10% credit, up to $4,000, is available for conversion to a plug-in electric drive vehicle. Lean burn vehicles are eligible for the same credit as hybrid vehicles. Alternative fuel vehicles can qualify for a credit of up to $4,000 for cars and light trucks and $32,000 for heavy vehicles. Credit amount varies according to the vehicle's incremental cost and ratio of alternative fuel use (expired); Credits available for plug-in electric vehicles are available up to $7,500 depending on kilowatt hour capacity of vehicle (prior to 2010 the credit limit was higher, up to $15,000 for qualifying heavy vehicles).												
Residential Energy Efficiency Tax Credit	2016	180	180	180	180	180	180	**1,080**	1	Energy Efficiency (Building Technologies), Biomass (Stoves)		$
Description: Personal tax credit for purchase of efficient building technologies (furnaces, water heaters, boilers, AC, insulation, windows etc.) as well as biomass stoves.												
Energy-Efficient Commercial Buildings Tax Deduction	2013	100	200	200	200	200	-	**900**	2	Energy Efficiency (Buildings)		$
Description: A tax deduction for qualifying upgrades to existing buildings and new energy efficient commercial buildings.												
Credit for Holding Clean Renewable Energy Bonds (CREBs)	None	70	80	100	120	140	140	**650**	2	Renewable Energy (Multiple)		$
Description: Credit paid in lieu of interest by investor-owned utilities that hold Clean Energy Renewable Bonds. **Methodology:** $2.2 billion in bonds allocated.												
Energy Efficient Appliance Manufacturing Tax Credit	2011	100	200	100	-	-	-	**400**	2	Energy Efficiency (Appliances)		$
Description: A tax credit for manufacturers of high-efficiency residential dish washers, refrigerators, and clothes washers.												
Credit for Holding Qualified Energy Conservation Bonds (QECBs)	None	0	10	40	80	110	120	**360**	2	Energy Efficiency (Multiple)		$
Description: Income tax credit available to holders of Qualified Energy Conservation Bonds. **Methodology:** $3.2 billion in bonds allocated.												
Exclusion of interest on state and local government private activity bonds for energy production facilities	None	50	50	50	50	50	50	**300**	1	Renewable Energy (Multiple), Energy Efficiency (Multiple)		$
Description: Exclusion of interest on state and local bonds for qualifying investments in renewable energy, conservation, and green buildings.												
Credits for Clean Fuel Vehicle Refueling Property	2014	63	63	63	*	*	*	**189**	1	Alternative Fuels (Refueling Infrastructure)		$
Description: A tax credit for 30% of qualifying clean vehicle refueling property investments, capped at $30,000 for business property and $1,000 for nonbusiness property. **Methodology:** *Credit remains for hydrogen refueling property, which is assumed to be negligible.												
Tax Credits for Hybrid Vehicles	2010	50	50	-	-	-	-	**100**	1	Alternative Vehicles (Hybrid)		$
Description: The first 60,000 hybrid cars or light trucks sold per manufacturer are eligible for a credit of $400 to $2,400 (depending on fuel economy). An additional credit of $250 to $1,000 is available depending on a vehicles expected lifetime fuel savings. Heavy vehicles (those exceeding 8,500 pounds) qualify for up to $30,000 in credits which are not subject to a volume cap.												

DEPLOYMENT/MARKETS MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
Residential Energy Conservation Subsidy Exclusion	None	16.6	16.6	16.6	16.6	16.6	16.6	**100**	1	Energy Efficiency (Multiple Residential)		Deployment/Markets
Description: A subsidy exclusion provided by the US Code allowing that conservation subsidies provided by utilities shall not be taxable.												
Energy Efficient New Homes Tax Credit for Builders	2011	30	20	20	20	-	-	**90**	2	Energy Efficiency (Buildings)		Deployment/Markets
Description: A tax credit for contractors who complete construction of a qualified energy efficient home, for a maximum of $2000.												
Nuclear Power Production Tax Credit	None (but volumetric cap)	-	-	-	-	-	-	**0**	3	Nuclear Energy		Deployment/Markets
Description: A 1.8-cents/kilowatt-hour tax credit for the first eight years of operation, up to $125 million annually per 1,000 megawatts. Available to the first 6,000 MW of new nuclear capacity. **Methodology:** Note that with no nuclear power plants assumed to come online in this period (2009–2014), this program is not expected to distribute any funds.												
DIRECT SPENDING												
Section 1603 Treasury Grant for Renewable Energy	2011	1,050	3,090	4,460	4,240	2,360	230	**15,430**	2	Renewable Energy (Solar, Wind, Geothermal, Biomass), Fuel Cells, Combined Heat and Power (CHP), Others		Deployment/Markets
Description: Grants provided by the Department of Treasury for clean energy electricity generation facilities in lieu of the energy investment tax credit (ITC) and the production tax credit (PTC).												
Funding for High Speed Rail[A]	2011	3,948	4,149	2,020	-	-	-	**10,117**	8	High-Speed Rail		Deployment/Markets
Description: ARRA and Department of Transportation funding for intercity high-speed electric rail ($8 billion from ARRA). **Methodology:** Recovery Act funds are calculated in the entirety of their originally appropriated amount, spread across 2009–2011 in the following method: 0.4*(2009)+0.4(2010)+0.2*(2011).												
DOE Office of Science R&D	None	904	1,009	1,187	1,113	1,113	1,113	**6,439**	9	Multiple		RD&D
Description: DOE funding for clean energy R&D in its Office of Science. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget..												
DOE Weatherization Assistance Program[A]	None	2,000	2,220	1,250	250	250	250	**6,220**	7	Energy Efficiency (Weatherization)		Deployment/Markets
Description: Home weatherization assistance provided by the Department of Energy ($5 billion provided by ARRA). **Methodology:** Recovery Act funds are calculated in the entirety of their originally appropriated amount, spread across 2009–2011 in the following method: 0.4*(2009)+0.4(2010)+0.2*(2011).												
DOE Energy Efficiency and Renewable Energy (EERE), R&D	None	905	1,143	1,309	723	723	723	**5,526**	9	Renewable Energy (Multiple), Energy Efficiency (Multiple)		RD&D
Description: DOE funding for clean energy R&D in its Office of Energy Efficiency and Renewable Energy. **Methodology:** Projected budgets are calculated as equivalent ratios of R&D or other spending over total departmental budget.												
DOE Energy Efficiency and Renewable Energy (EERE), Other	None	541	1,057	1,046	581	581	581	**4,387**	1	Renewable Energy (Multiple), Energy Efficiency (Multiple)		Deployment/Markets
Description: Non-R&D funding for DOE's Office of Energy Efficiency and Renewable Energy.												
DOE State Energy Program[A]	None	1,240	1,315	1,315	75	75	75	**4,095**	7	Renewable Energy (Multiple), Energy Efficiency (Multiple)		Deployment/Markets
Description: Federal grants to state energy offices and programs that support clean energy and energy efficiency ($3.1 billion from ARRA). **Methodology:** Recovery Act funds are calculated in the entirety of their originally appropriated amount, spread across 2009–2011 in the following method: 0.4*(2009)+0.4(2010)+0.2*(2011).												

DEPLOYMENT/MARKETS MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech	Phase
ARRA Non-ARPAe R&D	2009	1,841	1,841	-	-	-	-	**3,681**	9	Multiple	RD&D
Description: ARRA funding for clean energy R&D outside of ARPA-E. **Methodology:** ARRA spending on R&D through various agencies, labs, and universities; split evenly across 2009 and 2010.											
Funding for the Electric Grid[A]	2009	3,375	-	-	-	-	-	3,375	7	Electric Grid (Smart Grid)	DEPLOYMENT/MARKETS
Description: ARRA funding for DOE's Smart Grid Investments Grant Program to deploy smart grid technologies and monitoring devices.											
Energy Efficiency and Conservation Block Grants Program[A]	2009	1,280	1,280	640	-	-	-	**3,200**	7	Energy Efficiency (Multiple)	DEPLOYMENT/MARKETS
Description: State block grants for energy efficiency and conservation improvements ($3.2 billion from ARRA). **Methodology:** Recovery Act funds are calculated in the entirety of their originally appropriated amount, spread across 2009–2011 in the following method: 0.4*(2009)+0.4(2010)+0.2*(2011).											
DOE Office of Nuclear Energy, Other	None	1,016	511	431	347	347	347	**2,999**	9, 10	Nuclear Energy	DEPLOYMENT/MARKETS
Description: Non-R&D funding for DOE's Office Of Nuclear Energy.											
DOE Office of Fossil Energy (Clean Energy R&D)	None	681	404	403	327	327	327	**2,469**	9	Fossil Energy (Energy R&D)	RD&D
Description: Clean energy R&D funded by DOE's Office of Fossil Energy. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.											
Advanced Battery Manufacturing Grants[A]	2009	2,400	-	-	-	-	-	**2,400**	7	Advanced Batteries	MANUFACTURING
Description: ARRA funding to accelerate the manufacturing and deployment of the next generation of US batteries and electric vehicles.											
DOE Office of Nuclear Energy, R&D	None	334	346	481	387	387	387	**2,322**	9	Nuclear Energy	RD&D
Description: DOE funding for clean energy R&D in its Office of Nuclear Energy. **Methodology:** Projected budgets are calculated as equivalent ratios of R&D or other spending over total departmental budget.											
Small Business Innovative Research Program (SBIR)	None	360	360	360	360	360	360	**2,160**	14	Multiple	RD&D, DEPLOYMENT/MARKETS
Description: Research in clean energy R&D performed by the federal Small Business Innovative Research program. **Methodology:** Characteristic outlay levels were assumed based on 2010 spending levels; funding for energy R&D documented by the authors of this report.											
Funding for Industrial Carbon Capture and Storage[A]	2009	1,520	-	-	-	-	-	**1,520**	7	Carbon Capture & Storage	DEPLOYMENT/MARKETS
Description: ARRA funding for a competitive solicitation process for the large-scale demonstration of industrial carbon capture and storage (CCS).											
DOE Advanced Research Projects Agency-Energy (ARPA-E)	None	400	180	180	180	180	180	**1,300**	9, 10	Multiple	RD&D
Description: A lab within the Department of Energy doing applied research in clean energy technologies, including next-generation fuels, clean electricity generation, and smart grid technologies.											
USDA Biomass Crop Assistance Program	2012	5	602	112	248	-	-	**967**	7	Renewable Energy (Biomass), Alternative Fuels (Biofuels)	DEPLOYMENT/MARKETS
Description: Financial assistance provided by the USDA to biomass producers who sell their crops to qualified biomass conversion facilities. **Methodology:** Annual funding allocations are used for every year except 2012, in which we assume equivalent funding levels as the previous year's cap ($112 million). However, no cap is set for funding the program in 2012, and according to the CRS, "USDA could use a virtually unlimited amount of funding" before the program expires in September 2012.											

DEPLOYMENT/MARKETS MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
DOE Office of Electricity Delivery, Other	None	134	171	185	139	139	139	**907**	10	Electric Grid (Multiple)		Deployment/Markets
Description: Non-R&D funding for DOE's Office of Electricity Delivery. **Methodology:** Projected budgets are calculated as equivalent ratios of R&D or other spending over total departmental budget.												
ARRA Biomass Program[A]	2009	800	-	-	-	-	-	**800**	7	Alternative Fuels (Biofuels)		Deployment/Markets
Description: ARRA funding for pilot- and demonstration-stage biorefineries for advanced biofuels.												
ARRA Clean Coal Power Initiative[A]	2009	800	-	-	-	-	-	**800**	7	Carbon Capture & Storage		Deployment/Markets
Description: ARRA funding to expand DOE's Clean Coal Power Initiative.												
Energy Frontier Research Centers (EFRCs)	2014	129.5	129.5	129.5	129.5	129.5	129.5	**777**	12	Multiple		RD&D
Description: The EFRCs are partnerships between the DOE and research universities and private businesses conducting scientific research for next-generation clean energy technology applications.												
DOE Office of Electricity Delivery, R&D	None	83	121	140	105	105	105	**659**	9	Electric Grid (Multiple)		RD&D
Description: DOE funding for R&D in its Office of Electricity Delivery. **Methodology:** Projected budgets are calculated as equivalent ratios of R&D or other spending over total departmental budget.												
DOD Energy R&D	None	49	54	94	92	92	92	**473**	9	Multiple		RD&D
Description: Department of Defense funding for clean energy R&D. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.												
Retrofit Ramp-ups in Energy Efficiency[A]	2009	454	-	-	-	-	-	**454**	7	Energy Efficiency (Residential Buildings)		Deployment/Markets
Description: ARRA funding for home energy efficiency retrofits.												
NSF Energy R&D (non-SBIR non-ARRA)	None	108	60	63	63	63	63	**420**	9	Multiple		RD&D
Description: Funding for clean energy R&D that does not come from ARRA or SBIR.												
Funding for Transportation Electrification[A]	2009	400	-	-	-	-	-	**400**	7	Electric Grid, Alternative Vehicles (Hybrids, Electric Vehicles)		Deployment/Markets
Description: ARRA funding for the Transportation Electrification Initiative (TEI), for the deployment, development, and analysis of EVs and EV infrastructure.												
USDA Bioenergy Program for Advanced Biofuels	2012	80	80	110	130	-	-	**400**	7	Alternative Fuels (Biofuels)		Deployment/Markets
Description: This program provides payments to ethanol and biodiesel producers to increase production of bioenergy.												
DOT Energy R&D	None	32	42	53	91	91	91	**400**	9	Multiple		RD&D
Description: Department of Transportation funding for clean energy R&D. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.												
Funding for Innovative Approaches to Energy Efficient Building Upgrades[A]	2009	390	-	-	-	-	-	**390**	7	Energy Efficiency (Buildings)		Deployment/Markets
Description: ARRA funding for the deployment of innovative energy efficiency upgrades.												

DEPLOYMENT/MARKETS MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
NASA Energy R&D	None	0	63	80	82	82	82	**389**	9	Multiple		RD&D
Description: National Aeronautics and Space Administration funding for clean energy R&D. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.												
DOE Energy Innovation Hubs	2014	74.6	74.6	74.6	74.6	74.6		**373**	11	Renewable Energy (Solar), Alternative Fuels, Advanced Batteries, Nuclear Energy		RD&D
Description: Centers of applied research in specific energy technology areas.												
Funding for Energy Efficient Building Technologies[A]	2009	346	-	-	-	-	-	**346**	7	Energy Efficiency (Building Technologies)		Deployment/Markets
Description: ARRA funding for deployment of building efficiency technologies and techniques.												
Energy Efficient Appliance Rebates / ENERGY STAR[A]	2010	300	-	-	-	-	-	**300**	7	Energy Efficiency (Appliances)		Deployment/Markets
Description: ARRA funding to promote purchase of ENERGY STAR appliances.												
Alternative-Fueled Vehicles Pilot Grant Program[A]	2009	300	-	-	-	-	-	**300**	7	Alternative Vehicles (Hybrid, Electric Vehicle,Biofuels)		Deployment/Markets
Description: ARRA funding for the purchase of alternative-fueled vehicles by public transportation agencies and airports.												
USDA Rural Energy for America Program	2012	64	64	64	64	-	-	**256**	6	Renewable Energy (Multiple), Energy Efficiency (Multiple)		Deployment/Markets
Description: REAP provides grants to agricultural producers and rural small businesses to purchase renewable energy systems or make efficiency improvements.												
Funding for the Industrial Technologies Program[A]	2009	256	-	-	-	-	-	**256**	7	Energy Efficiency (Industrial Technologies)		Deployment/Markets
Description: ARRA funding for improvements in major industrial sectors.												
USDA Energy R&D	None	0	50	49	48	48	48	**243**	9	Multiple		RD&D
Description: Department of Agriculture funding for clean energy R&D.												
NREL Grants[A]	2009	122	-	-	-	-	-	**122**	7	Renewable Energy (Multiple), Alternative Fuels (Biofuels)		RD&D
Description: Grants made to NREL for renewable energy and site infrastructure, a Biorefinery Research Facility, and to support utility-scale renewable energy projects.												
Solar Technologies Program[A]	2009	115	-	-	-	-	-	**115**	7	Renewable Energy (Solar)		Deployment/Markets
Description: ARRA funding targeted towards accelerating the commercialization of solar energy technologies.												
DOE Nuclear Energy University Program	2013	30	27	27	27	-	-	**111**	13	Nuclear Energy		RD&D
Description: Program within the DOE's Office of Nuclear Energy to fund nuclear energy research and equipment upgrades at US colleges and universities and student educational support.												
Funding for Geothermal Innovative Exploring Techniques[A]	2009	100	-	-	-	-	-	**100**	7	Renewable Energy (Geothermal)		Deployment/Markets
Description: ARRA funding to support projects that include exploration, siting, drilling, and characterization of a series of exploration wells utilizing innovative exploration techniques.												

DEPLOYMENT/MARKETS MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
EPA Energy R&D	None	15	19	17	15	15	15	**96**	9	Multiple		RD&D
Description: Environmental Protection Agency funding for clean energy R&D. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.												
Repowering Assistance Program[A]	2009	50	15	15	15	-	-	**95**	7	Renewable Energy (Biomass)		Deployment/Markets
Description: ARRA funding for eligible biorefineries to produce power from clean biomass in place of fossil fuels.												
DOC Energy R&D	None	11	19	19	15	15	15	**94**	9	Multiple		RD&D
Description: Department of Commerce funding for clean energy R&D. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.												
Energy Efficiency Funding for Cities, Counties, and Tribes[A]	2009	64	-	-	-	-	-	**64**	7	Energy Efficiency (Multiple)		Deployment/Markets
Description: ARRA funding for grants to support energy efficiency upgrades in counties, cities, and tribes.												
Funding for Geologic Sequestration Site Characterization[A]	2009	50	-	-	-	-	-	**50**	7	Carbon Capture & Storage		Deployment/Markets
Description: ARRA funding for geologic site characterization for industrial carbon sequestration.												
Funding for Fuel Cell Markets[A]	2009	41.9	-	-	-	-	-	**41.9**	7	Fuel Cells		Deployment/Markets
Description: ARRA funding for 13 projects to accelerate the deployment and demonstration of fuel cell power technologies.												
Funding for a Geothermal Data System[A]	2009	30	-	-	-	-	-	**30**	7	Renewable Energy (Geothermal)		Deployment/Markets
Description: ARRA funding for a DOE data system in domestic geothermal resources characterization.												
DOI Energy R&D	None	0	3	6	6	6	6	**27**	9	Multiple		RD&D
Description: Department of Interior funding for clean energy R&D. **Methodology:** Projected R&D spending calculated based on historic ratio of R&D to total departmental budget.												
Funding for Geologic Sequestration Training and Research[A]	2009	20	-	-	-	-	-	**20**	7	Carbon Capture & Storage		Deployment/Markets
Description: ARRA funding to train future scientists, geologists, and engineers in disciplines needed to staff a national CCS program.												
USDA High Energy Cost Grant Program	2010	9	6	-	-	-	-	**15**	5	Multiple		Deployment/Markets
Description: USDA program providing grants to rural communities making upgrades or installations for the generation, transmission, and distribution of energy.												
NREL National Wind Technology Center[A]	2009	10	-	-	-	-	-	**10**	7	Renewable Energy (Wind)		RD&D
Description: ARRA funding for a wind technology research center at the National Renewable Energy Laboratory (NREL).												
Funding for Interoperability Standards and Framework[A]	2009	10	-	-	-	-	-	**10**	7	Electric Grid (Transmission, Smart Grid)		Deployment/Markets
Description: ARRA funding for national electricity grid interoperability standards and framework.												

DEPLOYMENT/MARKETS MANUFACTURING RD&D

Program	Expiration	2009	2010	2011	2012	2013	2014	Total	Source	Tech		Phase
Renewable Energy Production Incentive (REPI)	2009	5	-	-	-	-	-	**5**	1	Renewable Energy (Multiple)		$
Description: Provides a 2.2 cents per-kilowatt-hour financial incentive payment for electricity generated and sold by qualifying renewable energy facilities operated by entities that do not pay corporate income tax. Funding appropriations, administered by DOE, were eliminated after FY2009 payments made for electricity generated in FY2008.												
Nuclear Power Standby Support	None (but volumetric cap)	-	-	-	-	-	-	**0**	3	Nuclear Energy		$
Description: Standby support, or regulatory risk insurance, to help pay the cost of regulatory delays for up to six new commercial nuclear reactors. **Methodology:** Note that with no nuclear power plants assumed to come online in this period (2009–2014), this program is not expected to distribute any funds.												
LOAN PROGRAMS												
Advanced Technology Vehicles Manufacturing Loan Program	None (but volumetric cap)	2,265	936	299	1,333	1,333	1,333	**7,500**	15	Hybrid/Electric Vehicles, Efficient Vehicles, Alternative Fuel Vehicles		⚙
Description: The ATVM Loan Program provides loans to automobile and automobile parts manufacturers for the cost of reequipping, expanding, or establishing manufacturing facilities in the United States to produce advanced technology vehicles or qualified components, and for associated engineering integration costs. In 2010, Section 136 was amended to include ultra-efficient vehicles within the definition of advanced technology vehicles. **Total disbursed loan volume to date: $8.4 billion.** **Methodology:** Annual outlays for years beyond 2011 treated as equivalent yearly expenditures from the credit subsidy; projected total loan volume calculates equivalent ratio of total credit subsidy to current loan volume (9122). Assumes all of the credit subsidy will be depleted by end of FY2014.												
DOE Loan Guarantee Program (Section 1705)[A]	2011	72	1,291	1,137	-	-	-	**2,500**	15	Renewable Energy (Multiple), Electric Grid (Multiple)		$
Description: A temporary loan guarantee portfolio added to the DOE's Loan Program Office by the American Recovery and Reinvestment Act. In contrast to Section 1703, Section 1705 focused on less risky technology projects and did not require borrowers to pay a credit subsidy. **Total disbursed loan guarantee volume: $16.1 billion.** **Methodology:** Annual outlays calculated as equivalent proportion of annual loan volume to total loan volume and annual subsidy credit to total subsidy credit. Total loan volume calculated as separate amount, not included in our aggregate figure of $150 billion.												
DOE Loan Guarantee Program (Section 1703)	Loan volume cap	*	*	42.5	42.5	42.5	42.5	**170**	15	Nuclear Energy, Renewable Energy (Multiple), Energy Efficiency (Multiple), Carbon Capture and Storage (CCS), Electric Grid (Multiple), Alternative Fuel Vehicles		$
Description: Section 1703 of Title XVII of the Energy Policy Act of 2005 authorizes DOE to support innovative clean energy technologies that are typically unable to obtain conventional private financing due to high technology risks. In addition, the technologies must avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases. **Total authorized loan guarantee volume to date: $12.3 billion.** **Methodology:** *The 2011 Continuing Resolution appropriated an additional $170 million in credit subsidy for renewables projects whose loan commitments were not completed within Section 1705 before its September 2011 expiration. Credit subsidy to cover loans made outside the $170 million loan loss reserve is covered by credit subsidy payments from borrowers. Guaranteed loan volumes are capped for various technology categories as follows: $18.5 billion for nuclear; $4.3 billion for front-end nuclear; $2 billion for advanced fossil; $2 billion for mixed authority; and $1.5 billion for renewables.												
USDA Biofuels Loan Guarantee Program	2011	50	50	50	-	-	-	**150**	16	Renewable Energy (Biofuels), Alternative Fuels (Biomass)		$
Description: The Biorefinery Assistance Program (Section 9003 of the 2008 Farm Bill) provides loan guarantees to advanced biofuels projects. **Total authorized loan volume: $1.7 billion.** **Methodology:** Annual outlays calculated as equivalent proportion of annual loan volume to total loan volume and annual subsidy credit to total subsidy credit.												

$ DEPLOYMENT/MARKETS ⚙ MANUFACTURING RD&D

Data Appendix Sources:

1. *Molly F. Sherlock and Margot L. Crandall-Hollick, "Energy Tax Policy: Issues in the 112th Congress," Congressional Research Service, April 14, 2011.*

2. *"Analytical Perspectives: Budget of the US Government, Fiscal Year 2011," Office of Management and Budget, 2010.*

3. *Mark Holt, "Nuclear Energy Policy," Congressional Research Service, May 27, 2010.*

4. *Tribal Energy Program, United States Department of Energy Office of Energy Efficiency and Renewable Energy, http://apps1.eere.energy.gov/tribalenergy/.*

5. *Rural Development Office Grant Assistance, United States Department of Agriculture Office of Rural Development, http://www.rurdev.usda.gov/RD_Grants.html.*

6. *Rural Development Energy Programs, United States Department of Agriculture Office of Rural Development, http://www.rurdev.usda.gov/Energy.html.*

7. *"Recovery Act Recipient Data," United States Department of Energy (updated weekly), http://energy.gov/downloads/recovery-act-recipient-data.*

8. *"Recovery Act: Funding Used for Transportation Infrastructure Projects, but Some Requirements Proved Challenging," Government Accountability Office Report to Congress, June 2011.*

9. *See Energy Innovation Tracker, http://energyinnovation.us/.*

10. *United States Department of Energy Budget & Performance, http://energy.gov/about-us/budget-performance.*

11. *Energy Innovation Hubs, United States Department of Energy, http://energy.gov/hubs.*

12. *Energy Frontier Research Centers, United States Department of Energy Office of Science, http://science.energy.gov/bes/efrc/.*

13. *Nuclear Energy University Program, United States Department of Energy, https://inlportal.inl.gov/portal/server.pt/community/neup_home/600.*

14. *Small Business Innovation Research/Small Business Technology Transfer, Awards, http://www.sbir.gov/past-awards.*

15. *"Our Projects: The Financing Force Behind America's Clean Energy Economy," United States Department of Energy Loan Program Office, https://lpo.energy.gov/?page_id=45.*

16. *Biorefinery Assistance Program, United States Department of Agriculture Office of Rural Development, http://www.rurdev.usda.gov/BCP_Biorefinery.html.*

Superscript "A" indicates program is one-time direct spending from the 2009 American Recovery and Reinvestment Act (ARRA).

→ NOTES AND CITATIONS ←

1 Non-hydro US renewable electricity generation increased from 96 million megawatt-hours in 2006 to 195 million megawatt-hours in 2011. See: US Energy Information Administration, "Electric Power Monthly," March 27, 2012, http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1 Accessed April 4, 2012.

Up from 2 percent in 2008, the United States is expected to make up 40 percent of the market for advanced batteries by 2014. See "Transforming America's Transportation Sector: Batteries and Electric Vehicles," Department of Energy, July 2010. http://www.whitehouse.gov/files/documents/Battery-and-Electric-Vehicle-Report-FINAL.pdf.

The global average cost of solar installations fell more than 50 percent between 2007 and 2011, while wind turbine costs fell 27 percent from 2008 to 2011. See Ron Pernick, Clint Wilder, and Trevor Winnie, "Clean Energy Trends 2012," Clean Edge, March 2012, http://www.cleanedge.com/sites/default/files/CETrends2012_Final_Web.pdf; and Mark Bolinger and Ryan Wiser, "Understanding Trends in Wind Turbine Prices Over the Past Decade," Lawrence Berkeley National Laboratory, October 2011, http://eetd.lbl.gov/ea/emp/reports/lbnl-5119e.pdf.

Employment in the following sectors grew by 71,633 jobs from 2007 to 2010: renewable energy, nuclear energy, carbon storage and management, fuel cells, energy efficient buildings, lighting, and consumer products and appliances, smart grid, and electric vehicle technologies and advanced vehicle batteries. See: Mark Muro, Jonathan Rothwell, and Devashree Saha, "Sizing the Clean Economy: A National and Regional Green Jobs Assessment," Brookings Institution and Batelle Technology Partnership Practice, 2011. http://www.brookings.edu/~/media/Files/Programs/Metro/clean_economy/0713_clean_economy.pdf"

2 Declining clean tech funding and program expirations in the United States are mirrored by cuts to clean tech subsidies in several key European countries. In spring of 2011, Italian ministers cut subsidies to wind power[1] and cut solar feed-in tariffs by between 22 and 30 percent in 2011, 23 and 45 percent in 2012, and 10 and 45 percent in 2013, depending on the size of the PV system[2]. In January 2012, the Spanish government announced a temporary closing of the national feed-in tariff program, after enduring years of subsidy cuts to solar deployment. In reaction to austerity-driven policies in Italy and Spain, markets have contracted considerably, with tens of thousands of solar industry jobs lost in Spain following subsidy cuts[3].

In contrast, Germany and the United Kingdom continue to experience growing renewables capacity amidst strategically declining subsidy regimes. Germany, while sustaining a relatively generous feed-in tariff program for solar panels, recently accelerated the marginal cut in domestic deployment subsidies of between 20 and 30 percent in April 2012 and scheduled to decrease by 0.15 cents per kWh per month thereafter[4]. The German government hopes to reduce new annual solar capacity additions from 7,500 megawatts (MW) brought online in 2011 to between 2,500 and 3,500 MW in future years, or an annual market contraction of 53 percent or more. The United Kingdom meanwhile remains committed to expanding clean electricity generation, with plans to increase installed solar capacity twenty-fold by 2020. However, two rounds of cuts to feed-in-tariffs last year were followed by another cut in February 2012. The British government plans to further cut wind and solar feed-in tariffs by 40 and 50 percent, respectively, with implementation of the new rates pending a final decision by lawmakers[5].

The dramatic fall in solar panel costs in particular that began in 2008 have made it difficult for governments to avoid creating investment bubbles. As prices dropped, existing subsidies became extremely attractive, creating bursts of installations that far exceed projections. Some subsidies were perhaps set too high in the first place. This phenomenon highlights how difficult it can be to ensure subsidies provide both investor certainty and respond to evolving market conditions. The unexpected pressure on public budgets and the follow on efforts by government to both limit their growing liability and to better match market costs cause domestic market contractions that are difficult for the domestic value chain to cope with. This points to the need to plan for falling prices and a close monitoring of market conditions from the start of any subsidy program. Prices may fall faster or slower than projected and sound subsidies account for this variation.

Sources: [1] Heather O'Brian, "Italy leaves out detail of FIT legislation," *Windpower Monthly*, March 4, 2011, accessed February 25, 2012, http://www.windpowermonthly.com/news/1058414/Italy-leaves-detail-FIT-legislation/. [2] "Italy changes solar FITs," *Renewables International,* accessed February 25, 2012, http://www.renewablesinternational.net/italy-changes-solar-fits/150/510/30890/. [3] "Spain's conservative government decreed a moratorium on renewable energy," Regulación Eólica con Vehículos Eléctricos, February 1, 2012, accessed February 25, 2012, http://www.evwind.es/noticias.php?id_not=16325. [4] Erik Kirschbaum and Christopher Steitz, "Germany to cut solar subsidies faster than expected," *Reuters*. February 23, 2012, accessed February 25, 2012, http://www.reuters.com/article/2012/02/23/us-germany-solar-incentives-idUSTRE81M1EG20120223. [5] Alex Morales and Marc Roca, "U.K. Sets Rolling Solar-Subsidy Cuts, Sees 22-Gigawatt Capacity," *Bloomberg*.February 9, 2012, accessed February 25, 2012, http://www.bloomberg.com/news/2012-02-09/u-k-sets-rolling-solar-subsidy-cuts-sees-22-gigawatt-capacity.html.

3 Brett Prior and Carolyn Campbell, "Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry," GTM Research, January 18, 2012, http://www.greentechmedia.com/research/report/polysilicon-2012-2016/; Bolinger and Wiser, LBNL, op cit. note 1.

4 Interestingly, the competitive pressures facing clean tech segments due to recent declines in natural gas prices are also the result of successful, targeted federal support for advanced energy innovation. Federal R&D, demonstration, and subsidies for shale drilling drove the development of horizontal drilling, microseismic imaging, and hydraulic fracturing in shale which enabled the recent shale gas revolution. Public research at agencies like the Energy Research and Development Agency (ERDA) and the nascent Department of Energy (DOE) drove initial work in massive hydraulic fracturing, while the federal tax credits subsidized unconventional gas drilling technology. The government eventually partnered directly with Mitchell Energy, the Texas gas company widely credited with commercializing shale drilling technology, in the company's first successful horizontal drill. Said Dan Steward, former Mitchell Energy Vice President, "DOE started it, and other people took the ball and ran with it. You cannot diminish DOE's involvement." See Michael Shellenberger et al, "New Investigation Finds Decades of Government Funding Behind Shale Revolution," Breakthrough Institute, December 2011, http://thebreakthrough.org/blog/2011/12/new_investigation_finds_decade.shtml.

5 See Pew Charitable Trusts, *Who's Winning the Clean Energy Race? G-20 Investment Powering Forward*, March 2011, http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/G-20Report-LOWRes-FINAL.pdf

6 Clean tech segments analyzed in this report include: solar, wind, geothermal, biomass, and nuclear power technologies, fuel cells, combined heat and power (CHP), efficiency (industrial, building, weatherization), smart grid, carbon capture and sequestration (CCS), alternative fuels (alcohol fuels, biofuels, biodiesel), advanced batteries, hybrid and electric vehicles, and high speed rail. Figures include programs supporting research, development and demonstration (RD&D), manufacturing, and market adoption and deployment.

7 See e.g., "Report to the President on Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy" from the President's Council of Advisors on Science and Technology (PCAST), which calls for $12 billion in annual federal funding for energy research, development and demonstration (RD&D); "A Business Plan for America's Energy Future" from the American Energy Innovation Council (AEIC), which calls for $16 billion in annual federal funding for energy RD&D; a letter from 34 Nobel Laureates calling for $15 billion in annual federal funding for clean energy R&D; a letter signed by the Association of Public and Land-grant Universities (APLU) and the Association of American Universities (AAU) calling for $15 billion in annual federal funding for clean energy R&D; Atkinson et al, *Rising Tigers, Sleeping Giant,* Breakthrough Institute and Information Technology and Innovation Foundation, which called for $15-30 billion in annual federal funding for clean energy R&D.

8 For R&D spending on health and defense, see American Association for the Advancement of Science, "Trends in Federal R&D by Function, FY 1949-2013," data published February 2012, http://www.aaas.org/spp/rd/histda13tbl.pdf.

For space research and exploration, see National Aeronautics and Space Administration, "Fiscal Year 2012 Budget Estimates," http://www.nasa.gov/pdf/516674main_FY12Budget_Estimates_Overview.pdf.

9 Steven Hayward, Mark Muro, Ted Nordhaus, and Michael Shellenberger, *Post-Partisan Power*, American Enterprise Institute, Brookings Institution, and Breakthrough Institute, November 2010, http://thebreakthrough.org/blog/Post-Partisan%20Power.pdf (22-23).

10 Japan's "top-runner" or "front-runner" energy efficiency program, for example, sets minimum standards for the energy efficiency of a variety of appliances, personal and freight vehicles, and lighting technologies. These standards are automatically revised on a periodic basis with new performance standards set based on the real performance of the most efficient products on the market in each technology segment. Market leaders thus set the bar for the next performance standard, and competing firms must improve their technology performance to keep pace, driving market competition, innovation, and steady improvement in performance across each technology segment. See "Top Runner Program: Developing the World's Best Energy-Efficient Appliances," Ministry of Economy Trade and Industry of Japan, March 2010, http://www.enecho.meti.go.jp/policy/saveenergy/toprunner2010.03en.pdf.

Environmental and air quality regulations requiring the implementation of "best available control technology" (e.g., certain New Source Review regulations implementing the Clean Air Act) operate on similar principles as well, requiring steady improvement in performance as available technologies improve.

11 Letha Tawney and others, *Two Degrees of Innovation—How to seize the opportunities in low-carbon power*, World Resources Institute, September 2011.

12 See PCAST, AEIC, APLU/AAU, Nobelists letter, op cit. note 7. See also: Duderstadt et al, *Energy Discovery-Innovation Institutes: A Step Towards America's Energy Sustainability*, Brookings Institution, February 2009, http://www.brookings.edu/~/media/Files/rc/reports/2009/0209_energy_innovation_muro/0209_energy_innovation_muro_full.pdf; Hayward et

al. 2010, op cit. note 10; Jesse Jenkins, Joshua Freed, and Ari Zevin, "Jumpstarting a Clean Energy Revolution with a National Institutes of Energy," Breakthrough Institute and Third Way, September 2009, http://thebreakthrough.org/blog/Jumpstarting_Clean_Energy_Sept_09.pdf.

13 Duderstadt et al. 2009 and Jenkins, Freed, and Zevin, 2009, op cit. note 12.

14 Jesse Jenkins and Sara Mansur, "A Clean Energy Deployment Administration: Unlocking Advanced Energy Innovation and Commercialization," Breakthrough Institute, November 2011, http://thebreakthrough.org/blog/CEDA.pdf. See also Josh Freed and Mae Stevens, "A Small Tax Change, Big Clean Energy Results," Third Way, December 2011 for background on the potential of using master limited partnerships (MLPs) to open up significant new sources of private sector finance to clean tech markets.

15 Jesse Jenkins, Sara Mansur, Alexandra Tweedie, and Paul Sharfenberger, "A National Clean Energy Testbeds Program: Using Public Lands to Accelerate Advanced Energy Innovation and Commercialization," Breakthrough Institute, November 2011, http://thebreakthrough.org/blog/Testbeds.pdf.

16 Hayward et al. 2010, op cit. note 9 (23-24).

17 For example, transmission and the structure and interactions of electricity markets can help or hinder the ability of renewable electricity technologies to access markets. See Letha Tawney and others, *High Wire Act: Electricity Transmission Infrastructure and its Impact on the Renewable Energy Market*, World Resources Institute, March 2011.

18 According to the President's Council of Advisors on Science and Technology (PCAST), "Advanced manufacturing is a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting edge materials and emerging capabilities enabled by the physical and biological sciences, for example nanotechnology, chemistry, and biology. It involves both new ways to manufacture existing products, and the manufacture of new products emerging from new advanced technologies." See *Report to the President on Ensuring American Leadership in Advanced Manufacturing*, President's Council of Advisors on Science and Technology, June 2011, p. ii.

19 Ryan McConaghy and Devon Swezey, *Manufacturing Growth: Advanced Manufacturing and the Future of the American Economy*, Breakthrough Institute and Third Way, October 2011, http://thebreakthrough.org/blog/BTI_Third_Way_Idea_Brief_-_Manufacturing_Growth_.pdf; Stephen J. Ezell and Robert D. Atkinson, *The Case for a National Manufacturing Strategy*, Information Technology and Innovation Foundation, April 2011, http://www.itif.org/files/2011-national-manufacturing-strategy.pdf.

20 Ibid.

21 See Muro et al. 2011, op cit. note 1. Clusters promote innovation and growth by facilitating and accelerating dense knowledge flows, the sharing of vital resources, and the matching of specialized workers to firms. In one influential discussion the urban economist Gilles Duranton has identified three critical mechanisms by which clusters work: learning, sharing, and matching. See Gilles Durnton and others, *The Economics of Clusters: Evidence from France*. (Oxford: Oxford University Press, 2010).

22 Mark Muro and Bruce Katz, "The New `Cluster Moment:' How Regional Innovation Clusters Can Foster the Next economy," Brookings Institution, 2010.

23 Hayward et al. 2010, op cit. note 9 (18-20).

24 See American Wind Energy Association, "U.S. Wind Industry Fourth Quarter 2011 Market Report," January 2012, http://www.awea.org/learn-about/publications/reports/upload/4Q-2011-AWEA-Public-Market-Report_1-31.pdf.

25 See Solar Energy Industry Association and Greentech Media Research, "U.S. Solar Market Insight Report: Q3 2011," http://www.seia.org/galleries/pdf/SMI-Q3-2011-ES.pdf.

26 Department of Energy 2010, op cit. note 1.

27 Steven Mufson, "NRC approves construction of new nuclear power reactors in Georgia," *Washington Post*, February 9 2012, http://www.washingtonpost.com/business/economy/nrc-approves-construction-of-new-nuclear-power-reactors-in-georgia/2012/02/09/gIQA36wv1Q_story.html?tid=pm_business_pop.

28 Muro et al. 2011, op cit. note 1.

29 Joshua Reichert, Phyllis Cuttino, Joseph Dooley, Jessica Frohman Lubetsky, Laura Lightbody, and Julia Rotondo, "Who's Winning the Clean Energy Race? 2011 Edition," Pew Charitable Trusts, April 2012, http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/FINAL_forweb_WhoIsWinningTheCleanEnergyRace-REPORT-2012.pdf. See also Pew Charitable Trusts 2011, op cit. note 5.

30 See “Estimating U.S. Government Subsidies to Energy Sources: 2002-2008,” Environmental Law Institute, 2009; Energy Innovation Tracker, www.energyinnovation.us; Breakthrough Institute research.

31 Clean tech segments analyzed in this report include: solar, wind, geothermal, biomass, and nuclear power technologies, fuel cells, combined heat and power (CHP), efficiency (industrial, building, weatherization), smart grid, carbon capture and sequestration (CCS), alternative fuels (alcohol fuels, biofuels, biodiesel), advanced batteries, hybrid/electric vehicles, and high-speed rail.

32 Note that this report only includes actual annual expenditures during the 2009-2014 period. Future spending obligated during the 2009-2014 time period but not expended until after 2014 is not included in this analysis. For example, wind power projects are eligible to claim a production tax credit for their first ten years of power generation. Any tax expenditures associated with wind projects completed during the 2009 to 2014 period but claimed after 2014 are not included in this analysis. Likewise, credits claimed between 2009 and 2014 by wind projects that may have been completed before 2009 are included in this analysis, as they represent tax expenditures during our period of analysis.

Due to the unavailability of Defense Department operations and outlays, the full extent of DOD spending on RD&D, procurement, and deployment of clean energy technologies is not captured by this report. Included in our report are DOD ARRA expenditures on energy for RD&D and deployment, as well as all publicly available data for annual DOD RD&D spending via the Energy Innovation Tracker. For more on DOD spending on clean tech, see "Energy Innovation at the Defense Department: Assessing the Opportunities," Clean Air Task Force and the Consortium for Science, Policy and Outcomes, March 2012.

33 See Energy Innovation Tracker, op cit. note 30.

34 Note that our figures for FY2011 differ from a recent Congressional Budget Office report titled “Federal Financial Support for the Development and Production of Fuels and Energy Technologies.” CBO arrives at $20.6 billion for clean tech, not counting their estimates for fossil spending and nuclear decommissioning costs, which do not parallel with our spending estimates. Our figure for 2011 is $30.7 billion. The discrepancy comes from: a more inclusive account on our part of the tax expenditures for clean electricity production, which is inclusive of the entire Production Tax Credit and the Investment Tax Credit; $2.4 billion in uncounted DOE funding (see Energy Innovation Tracker at energyinnovation.us); $2.0 billion for high speed rail; $1.0 billion each for Weatherization, the State Energy Program, and credits for non-business energy property; the loan guarantee programs — including appropriations for Sections 1705 and 1703, the Advanced Technology Vehicle Manufacturing Program, and the USDA Biofuels Loan Guarantee Program — which total roughly $1.5 bilion for 2011 by our estimates; and a series of smaller tax credits and departmental R&D expenditures outside of the Department of Energy. The total difference comes to $9.5 billion, within the range of the nominal discrepancy between CBO’s figure and ours.

35 Tax expenditures include all foregone revenues associated with provisions in the US tax code, including tax credits and deductions claimed on personal and business taxes.

36 Multiplier assumptions are derived from typical private investment support initiated by federal programs. For instance, federal R&D grants have been shown to generate research expenditures from private labs and small businesses that match or exceed federal outlays (see Kevin Bullis, “Can ARPA-E Solve Energy Problems?” *MIT Technology* Review, March 5 2012, http://www.technologyreview.com/energy/39843/). The Investment Tax Credit for Solar provides a 30% income tax credit, generating additional private investment on the order of three to five times that amount (additional project finance plus supply chain activity). The USDA Biofuels Loan Guarantee Program allocates $150 million in appropriated credit subsidy to support $1.7 billion in total loan volume, a multiplier of more than 10 times; in comparison, the Department of Energy Section 1705 Loan Guarantee Program closed a cumulative $16.1 billion in loans with $2.5 billion in appropriated credit subsidy, a multiplier of more than six times.

37 On the low end of this multiplier estimate, we have total federal direct spending multiplied by 1.5 ($81.9 billion x 1.5), federal tax expenditures multiplied by 3 ($51.3 billion x 3), and appropriated loan guarantee authority multiplied by 4 ($10.3 billion x 4), equaling $327.8 billion. On the high end of the multiplier estimate, we have total federal direct spending multiplied by 3 ($81.9 billion x 3), federal tax expenditures multiplied by 5 ($51.3 billion x 5), and appropriated loan guarantee authority multiplied by 10 ($10.3 billion x 10), equaling $626.8 billion.

38 This estimate includes spending associated with all new programs created by ARRA as well as incremental spending associated with policies or agency budgets expanded or augmented by ARRA funding. This figure does not include spending associated with tax credits that were extended by ARRA without modification or expansion (e.g., the PTC), as these temporary tax credits are frequently extended as part of other legislation.

39 Op cit. note 2.

40 Prior and Campbell 2012, Wiser and Bolinger 2011, op cit. note 1. See also Ed Crooks and Ajay Makan, "First Solar warns of sustained margin pressure," *Financial Times*, December 14 2011, http://www.ft.com/intl/cms/s/0/d548a324-2675-11e1-9ed3-00144feabdc0.html#axzz1p7XRj1HV; "Overcapacity could drag on solar for some time," Associated Press, February 14, 2012, http://finance.yahoo.com/news/overcapacity-could-drag-solar-time-161831797.html.

41 See Alex Trembath and Jesse Jenkins, "Gas Boom Poses Challenges for Renewables, Nuclear," Breakthrough Institute, April 2012; and Ryan Wiser, Eric Lantz, Mark Bolinger, Maureen Hand, "Recent Developments in the Levelized Cost of Energy From U.S. Wind Power Projects," Lawrence Berkeley National Laboratory and National Renewable Energy Laboratory, February 2012, http://eetd.lbl.gov/ea/ems/reports/wind-energy-costs-2-2012.pdf.

42 Felicity Carus, "Wind Rush: US Industry Hurdles Towards a Cliff Without Production Tax Credit," AOL Energy, November 14 2011, http://energy.aol.com/2011/11/14/wind-rush-us-industry-hurdles-towards-a-cliff-without-productio/.

43 Flemming Emil Hansen and James Herron, "Wind Giant Vestas Cuts Back," *Wall Street Journal*, January 13 2012, http://online.wsj.com/article/SB10001424052970204542404577156200233431724.html.

44 Trembath and Jenkins 2012, op cit. note 41; and Wiser and Bolinger, LBNL, op cit. note 1.

45 Felicity Carus, "Wind Rush," op cit. note 42; "Impact of the Production Tax Credit on the U.S. Wind Market," Navigant Consulting, December 2011, http://www.novoco.com/energy/resource_files/reports/awea_impact_of_ptc_on_us_wind_market_121112.pdf.

46 Renewable energy project developers typically do not have taxable incomes sufficient to monetize the full value of the federal PTC or ITC available to wind, solar, and other renewable energy projects. As such, project developers must turn to tax equity partners, typically large banks, and other financial institutions, who purchase an equity stake in the renewable energy project and in turn take the value of the PTC or ITC to offset a portion of their own tax bills. The temporary Section 1603 program, in place from 2009 to 2011, provided cash grants to renewable projects in lieu of the PTC or ITC, allowing project developers to bypass the tax equity markets and lowering the cost of debt capital.

47 See "Reassessing Renewable Energy Subsidies," Bipartisan Policy Center, March 2011, http://bipartisanpolicy.org/sites/default/files/BPC_RE%20Issue%20Brief_3-22.pdf; "ITC Cash Grant Market Observations," U.S. Partnership for Renewable Energy Finance (USPREF), December 2011, http://uspref.org/wp-content/uploads/2011/07/US-PREF-ITC-Grant-Market-Observations-12.1.2011-v2.pdf.

48 "ITC Cash Grant Market Observations," op cit. note 47.

49 Before expiring in September 2011, the Section 1705 program closed four loan guarantees to wind generation projects, with a total loan guarantee volume of nearly $1.7 billion.

50 Morgan Wright, Loan Programs Office, US Department of Energy. Interview by Alex Trembath. Telephone interview. Washington DC, March 1, 2012.

51 Navigant Consulting, op cit. note 45.

52 "Wind Giant Vestas Cuts Back," op cit. note 43.

53 Michaela D. Platzer, "U.S. Wind Turbine Manufacturing: Federal Support for an Emerging Industry," Congressional Research Service, September 23 2011, http://www.fas.org/sgp/crs/misc/R42023.pdf.

54 Trembath and Jenkins 2012, op cit. note 41; and Pernick et al. 2012, op cit. note 1.

55 "Renewables Portfolio Standard Quarterly Report: Q4 2011," California Public Utility Commission, January 2012.

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57 See Database of State Incentives for Renewables & Efficiency (DSIRE), http://www.dsireusa.org/.

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59 Ibid. See also: Ch. Breyer, A. Gerlach, J. Mueller, H. Behacker, A. Milner, "Grid-Parity Analysis for EU and US Regions and Market Segments: Dynamics of Grid-Parity and Dependence on Solar Irradiance, Local Electricity Prices and PV Progress Ratio," 2011.

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"New Study Shows Significant Job Growth in 2012 from One-Year Extension of Successful Treasury Program," Solar Energy Industry Association, October 2011, http://www.seia.org/cs/news_detail?pressrelease.id=1648.

62 US Department of Energy Loan Program Office (LPO), "Our Projects," https://lpo.energy.gov/?page_id=45.

63 Given that no new nuclear projects are expected to be completed before 2014, both of these programs will remain in place but unutilized throughout the 2009-2014 time period examined by this report.

64 Nuclear Regulatory Commission, http://www.nrc.gov/reactors/new-reactors.html.

Seth Borin, Todd Levin,,Valerie M. Thomas, "Estimates of the Cost of New Electricity Generation in the South." Georgia Institute of Technology, 2010. https://docs.google.com/viewer?url=http%3A%2F%2Fwww.spp.gatech.edu%2Ffaculty%2Fworkingpapers%2Fwp54.pdf

65 John W. Rowe, "Energy Policy: Above All, Do No Harm." Speech to the American Enterprise Institute. March 8, 2011. http://www.exeloncorp.com/assets/newsroom/speeches/docs/spch_Rowe_AEI2011.pdf.

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68 DOE Loan Guarantee Program Projects, op cit. note 62.

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77 Commodities prices dramatically affect the final cost of clean energy technologies. Greentech Media documents the precipitous decrease in prices for polysilicon: a drop of over 70 percent from 2008 to 2012, and over 30 percent from 2010 to 2012 alone (from from $65/kg to $45/kg, expected to settle at $35/kg in 2014-2015). See Brett Prior and Carolyn Campbell, "Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry," GTM Research, January 18, 2012, http://www.greentechmedia.com/research/report/polysilicon-2012-2016/. As Lawrence Berkeley National Laboratory's Ryan Wiser and Mark Bolinger document, the price of steel, which makes up 70 percent of the mass of a wind turbine, has had a large impact on the price of turbines over the past decade. Over 2001-2008, the price of steel and other

component materials rose faster than the rate of inflations, contributing to turbine price increases from $750/kW in 2000-2002 to $1500/kW in 2008. See Wiser and Bolinger 2011, op cit. note 1.

78 See Lester and Hart 2011, op cit. note 74; Charles Weiss and William Bonvillian, *Structuring an Energy Technology Revolution*, (Cambridge, MA: Massachusetts University Press, April 2009).

79 For instance, the solar module market is and has been traditionally dominated by polysilicon panels. In an era of high costs for refined silicon, competitors of various thin-film varieties, including cadmium-telluride (CdTe) and copper indium gallium diselnide (CIGS), gained prominence, although their comparative advantage has been somewhat erased by the precipitous decline in silicon prices. Alternately, concentrating solar power, or CSP, is an increasingly common application, whereby large system arrays focus thousands of parabolic mirrors, lenses, or reflective dish structures on high-efficiency generating cells.

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89 Ibid.

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91 Jenkins et al. 2010, op cit. note 80.

92 Ibid.

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ate feed-in tariffs. For new technologies some kind of feed-in tariffs are necessary as they encourage diffusion, learning-by-doing activities and ultimately cost reductions. However, apart from this they also restrict competition and thus induce higher-cost windmills to come into operation. This latter effect is likely to be more destructive for relatively mature technologies (i.e., technologies with high diffusion levels) such as wind power. Thus, clearly announced gradual decreases in feed-in tariff levels over the lifetime of the windmill may be an important element of an efficient renewable energy technology policy." See Patrick Soderholm and Ger Klaase, "Wind Power in Europe: A Simultaneous Innovation–Diffusion Model," *Environmental and Resource Economics,* 36:164-190 (2007).

96 Corn ethanol subsidies, for example, long-supported a technology with no clear path to long-term scalability that is only cost competitive when grain prices are low or deeply subsidized and oil prices are high.

97 See Jenna Goodward and others "Is the FIT Right? Considering Technological Maturity in Renewable Energy Policy," World Resources Institute, June 2011.

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Furthermore, analysis from Bloomberg New Energy Finance commissioned by the Bipartisan Policy Center shows that deployment of 19 gigawatts of wind energy in the United States from 2005-2008 was supported by $10.3 billion in tax expenditures under the wind production tax credit (PTC). In contrast, the results could have been achieved using approximately $5 billion if federal incentives were delivered as a cash payment (rather than a tax credit) at the time of each project's commissioning. Although ensuring projects deliver valuable electricity, rather than simply complete construction, could argue for a production-based incentive rather than lump-sum cash payment upon project completion, a cash production incentive rather than a tax credit would allow project developers to monetize the value of the subsidy without incurring additional transaction costs associated with the tax equity finance arrangements necessitated by tax credit-based incentives. See "Reassessing Renewable Energy Subsidies," Bipartisan Policy Center, March 2011.
http://bipartisanpolicy.org/sites/default/files/BPC_RE%20Issue%20Brief_3-22.pdf

99 Hayward et at. 2010, op cit. note 9 (22-23).

100 Corporate Average Fuel Economy standards (CAFE) for passenger and freight vehicles or Emissions Performance Standards for new power plants each demand progressively improved technology performance. Similar standards could be designed to drive improvements in key factors determining technology costs or performance, such as the electric conversion efficiency of power plants.

101 Japan's "top-runner" or "front-runner" energy efficiency program, for example, sets minimum standards for the energy efficiency of a variety of appliances, personal and freight vehicles, and lighting technologies. These standards are automatically revised on a periodic basis with new performance standards set based on the real performance of the most efficient products the market in each technology segment. Market leaders thus set the bar for the next performance standard, and competing firms must improve their technology performance to keep pace, driving market competition, innovation, and steady improvement in performance across each technology segment. See "Top Runner Program: Developing the World's Best Energy-Efficient Appliances," Ministry of Economy Trade and Industry of Japan, March 2010, http://www.enecho.meti.go.jp/policy/saveenergy/toprunner2010.03en.pdf.

Environmental and air quality regulations requiring the implementation of "best available control technology" (i.e. certain New Source Review regulations implementing the Clean Air Act) operate on similar principles as well, requiring steady improvement in performance as available technologies improve.

102 Hayward et al. 2010, op cit. note 9 (23-24).

103 Saqib Rahim, "Republicans Weigh a Federal 'Reverse Auction' to Push Clean Energy," *New York Times*, April 4 2011, http://www.nytimes.com/cwire/2011/04/04/04climatewire-republicans-weigh-a-federal-reverse-auction-18453.html?pagewanted=all; U.S. Senator Dick Lugar's Practical Energy and Climate Plan, http://lugar.senate.gov/energy/legislation/pdf/2pager.pdf.

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107 See Part 1. See Data Appendix for details.

[108] For R&D spending on health and defense, see American Association for the Advancement of Science, "Trends in Federal R&D by Function, FY 1949-2013," data published February 2012, http://www.aaas.org/spp/rd/histda13tbl.pdf.

For space research and exploration, see National Aeronautics and Space Administration, "Fiscal Year 2012 Budget Estimates," http://www.nasa.gov/pdf/516674main_FY12Budget_Estimates_Overview.pdf.

[109] AAAS, Ibid.

[110] From Lester and Hart 2011, op cit. note 74, chapter 1

[111] PCAST, AEIC, AAU/APLU, Nobelists, Breakthrough, Third Way, Brookings, op cit. note 7.

[112] See Duderstadt et al. 2009, op cit. note 12, Hayward et al. 2010, op cit. note 9; "Clean Energy Clusters: What You Need To Know," New England Clean Energy Council (NECEC), September 6 2011, http://www.cleanenergycouncil.org/blog/2011/09/06/clean-energy-clusters-what-you-need-to-know/.

[113] See Duderstadt et al. 2009 and Jenkins, Freed, and Zevin, 2009, op cit. note 12.

[114] See Jenkins and Mansur 2011, op cit. note 76; and "Crossing the Valley of Death: Solutions to the next generation clean energy project financing gap," Bloomberg New Energy Finance, June 2010.

[115] Ibid.

[116] See e.g., Jenkins and Mansur 2011, op cit. note 76; AEIC, op cit. note 7; "Nothing Ventured: The Crisis in Clean Tech Investment," Third Way, November 2011, http://content.thirdway.org/publications/456/Third_Way_Report_-_Nothing_Ventured_The_Crisis_in_Clean_Tech_Investment.pdf.

[117] See Jenkins and Mansur 2011, and Freed and Stevens 2011, op cit. note 14.

[118] Jenkins et al. 2011, op cit. note 15.

[119] See *Approved Pipeline Projects (1997-2002)*, Federal Energy Regulatory Commission (FERC), (n.d.), http://www.ferc.gov/industries/gas/indus-act/pipelines/approved-projects/1997-2002.asp.; *Approved Pipeline Projects (2003-2008)*, Federal Energy Regulatory Commission (FERC), (n.d.), http://www.ferc.gov/industries/gas/indus-act/pipelines/approved-projects/2003-2008.asp.; *Renewable Power Opportunities for Rural Communities*, United States Department of Agriculture - Office of the Chief Economist, Office of Energy Policy and New Uses, (n.d.).

[120] U.S. Department of Commerce and International Trade Administration, *The Commercial Outlook for U.S. Small Modular Nuclear Reactors*, US Department of Commerce, February 2011 (6), http://trade.gov/mas/ian/build/groups/public/@tg_ian/@nuclear/documents/webcontent/tg_ian_003185.pdf.

[121] PCAST 2011, op cit. note 18.

[122] McConaghy and Swezey 2011, op cit. note 19.

[123] Ibid.

[124] Muro and Katz 2010, op cit. note 22.

[125] Hayward et al. 2010, op cit. note 9 (18-20)

[126] For example, the US Senate rejected an amendment to the Surface Transportation Authorization Bill (S. 1812) to extend key clean energy subsidies on a 49-49 vote recorded March 13th, 2012. Four Senate Democrats joined all voting Republican members to oppose the measure. The amendment, sponsored by Senator Debbie Stabenow (D-MI) would have extended the renewable electricity production tax credit (PTC) through the end of 2013 and restored the expired Section 1603 cash grant program for renewable electricity projects and the Section 48c tax credit for clean energy manufacturers. See "US Senate Roll Call Votes 112th Congress, S.Amdnt. 1812 to S. 1813," United States Senate, http://www.senate.gov/legislative/LIS/roll_call_lists/roll_call_vote_cfm.cfm?congress=112&session=2&vote=00039.

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