# H.R. 4393

# Clean Distributed Energy Grid Integration Act

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# H.R. 4393 | The Clean Distributed Energy Grid Integration Act
## Environmental Perspectives

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## Disclaimer

Cover photograph adapted from New York Magazine, 2012.

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# Executive Summary

The Clean Distributed Energy Grid Integration Act is a bipartisan piece of legislation designed to address the carbon intensity and inefficiency of the United States energy grid, which dates back to the early 20th century. It proposes funding to stimulate the research and development of clean energy generation technologies deployed on the consumer side of grid infrastructure, as well as the formation of stakeholder working groups to identify regulatory and technical barriers to deployment. If fully utilized, these technologies have the potential to help the United States meet rising demand for electricity while increasing the reliability and resiliency of the grid, ensuring that high-quality electricity is available for tens of millions of consumers.

Energy generation in the United States is currently dominated by centralized, large-scale facilities. Substantial amounts of energy are lost during transmission over long distances between producer and consumer. If the generation or transmission infrastructure fails, as it did during Superstorm Sandy in 2012, millions of consumers may be left without power and deprived of essential services for weeks until infrastructure can be rebuilt. Distributed, consumer-side generation technologies supplement the existing system by increasing the number of sites where energy is produced and loaded onto the grid. This approach reduces average transmission distance while adding redundancy that makes the system less susceptible to large-scale failure in the face of severe weather events and other threats.

In addition to the national benefits of a diversified, integrated and modernized energy grid, increasing clean energy sources as a proportion of the overall energy mix could help the United States mitigate its greenhouse gas emissions. Greenhouse gases are a driver of anthropogenic climate change, the myriad effects of which are expected to include more frequent and more severe weather events. Approximately one third of United States greenhouse gas emissions originate from the fossil-fuel dependent energy sector, and the United States recently committed to significantly reducing its emissions as part of the Paris Climate Agreement.

Here, we examine the current state of electricity generation and consumption in the United States from an empirical standpoint. We then outline the specific actions that the Clean Distributed Energy Grid Integration Act proposes as solutions to the challenges posed by the existing system. We begin by providing operational definitions for key terms that are foundational to our report. Our subsequent analysis is divided into six sections: (1) Background and context for the Act and its legislative details, (2) The legislative provisions laid out in the Act, (3) Environmental considerations related to current energy generation and infrastructure, (4) Proposed solutions to technical and environmental challenges, (5) Metrics of success for evaluating the outcomes of the legislation, and (6) our Conclusions regarding the efficacy of the Act in addressing these challenges, and our recommendations for moving forward.

# Key terms

| | |
|---|---|
| **Carbon intensive** | A descriptor used for any energy source that produces more than 0.82 metric tons of carbon dioxide per megawatt-hour of electricity when burned to generate electricity. |
| **Clean energy** | Defined by the Clean Energy Standards Act of 2012 to include any source of energy that produces less than 0.82 metric tons of carbon dioxide per megawatt-hour of electricity when burned. |
| **Climate change** | Long term changes in global temperatures, weather patterns, and geochemical cycles as a consequence of increasing concentrations of greenhouse gases in the atmosphere. |
| **Carbon dioxide equivalent** | Standardized units that account for the variance in the contribution of different atmospheric gases to the greenhouse effect and climate change by relating them to carbon dioxide. For example, methane traps heat in the atmosphere 84 times more efficiently than carbon dioxide, so 1 ton of methane gas equals 84 tons of carbon dioxide equivalent. |
| **Distributed energy** | Electricity generation technologies that are installed on the consumer side of the electricity meter. |
| **Generation efficiency** | A measure of how much energy is lost during the process of fuel combustion for electricity generation. |
| **Greenhouse gas** | Any of several gaseous compounds that trap infrared radiation escaping from the earth's surface and re-emit it as heat. Major greenhouse gases include carbon dioxide, methane, and water vapor. |
| **Grid integration** | The two-way exchange of electricity between electricity generation technologies and grid infrastructure. |
| **Megawatt-hour** | A standard unit of electricity consumption equivalent to 1000 watts of continuous electricity flowing for 1 hour. |

# Background and Context

When Thomas Edison launched the first commercial electric grid—a network of infrastructure able to deliver electricity—in Lower Manhattan in 1882, he likely did not imagine that much of the United States (U.S.) would use the principles behind it on a national scale to power millions of homes, businesses, and public facilities.

Just as the expansion of Edison's grid led to the replacement of his direct current system by Nikola Tesla and George Westinghouse's more efficient and reliable alternating current, rising demand and advances in new forms of clean energy generation technology may call for the evolution of aging and rigid contemporary infrastructure. The Clean Distributed Energy Grid Integration Act (H.R. 4393) aims to create a framework for transitioning the U.S. energy grid away from carbon-intensive energy sources and toward a distributed system. Distributed electricity generators are located on the consumer side of the meter and can both accept energy from the grid and contribute excess energy back to the larger system. In this section, we explore the background and context behind the need to transition to a distributed system.

Edison's original grid was meant to serve 59 consumers. In its current form, it serves more than 140 million. Energy demand in the U.S. has risen by 10 percent over the last decade, and the grid has not experienced any major restructuring since it was interconnected immediately following World War II (EIA, n.d.a). The legacy of the patchwork expansion of the U.S. energy grid is evident in the fragmentation of its current infrastructure and regulatory framework. The national grid is broken into three large systems that provide electricity to the eastern states, western states, and Texas (EIA 2015), overseen by a complex body of federal and public agencies as well as public and private utility companies. These stakeholders have a range of values, perspectives, and goals that can be in opposition to one another.

More than two thirds of energy are lost during the generation, transmission and distribution of electricity, an indication of the inefficiency of what was once a cutting-edge engineering feat (Pellegrino et al., 2004). In addition, the U.S. experiences more blackouts than any other developed nation. These effects cost U.S. taxpayers billions of dollars every year (Amin, 2011). H.R. 4393 provides much-needed funding for research into solutions to these problems. H.R. 4393 would bring these stakeholders together in a unified working group in order to address conflicts of interest and to facilitate a smooth transition to a more efficient system.

Current systems of centralized electricity generation and distribution are inherently vulnerable to damage from severe weather events. When Hurricane Sandy hit the East Coast in 2012, all of Lower Manhattan lost power, leaving eight million people without essential services and causing $65 billion in damages. This problem is not unique to New York City. Outages from weather events across the nation have risen from five per year before 1980 to 100 per year. Climatologists project more frequent and more powerful severe weather events within the next 20 to 30 years as a consequence of climate change (IPCC, 2012). The Act promotes a de-centralized and distributed generation system that will have the dual effect of increasing the grid's resiliency to weather events while mitigating greenhouse gas emissions that contribute to climate change.

While coal-powered plants still generate 33 percent of U.S. electricity (See Figure 1), cleaner forms of energy production from renewable sources and natural gas are emerging and becoming economically viable thanks to advances in technology, storage, and extraction techniques.

Distributed energy sources can be located much closer to the consumer than the large, centralized plants that power the current grid, reducing electricity losses during transmission and distribution. At the same time, advanced generation methods emit less greenhouse gas into the atmosphere.

Finally, adopting and integrating clean energy sources on a national scale would contribute toward the U.S. commitment of reducing greenhouse gas emissions by 26-28 percent by 2025 relative to 2005 levels, signed in April 2016 as part of the Paris Climate Agreement. Some technical and research gaps remain, however, before distributed grid technologies can be adopted.

# The legislative approach

The following section details the provisions laid out in the Clean Distributed Energy Grid Integration Act that dictate the actions to be taken once it passes into law. H.R. 4393 explicitly sets out a process to advance the integration of clean distributed energy into the national electric grid. The Secretary of Energy will direct the actions described below.

### H.R. 4393 addresses the technological and regulatory state of the current grid

The actions prescribed by H.R. 4393 begin with research study, the purpose of which is to assess the current status of grid integration of the integration of distributed energy and existing technical barriers to its deployment, providing focus and direction for targeted research and development. A stakeholder working group will be established to review the findings of the study, identify potential regulatory barriers to deployment, and make recommendations on how these barriers may be removed. The stakeholder group will complement research and development by addressing the fragmentation of current regulatory structures.

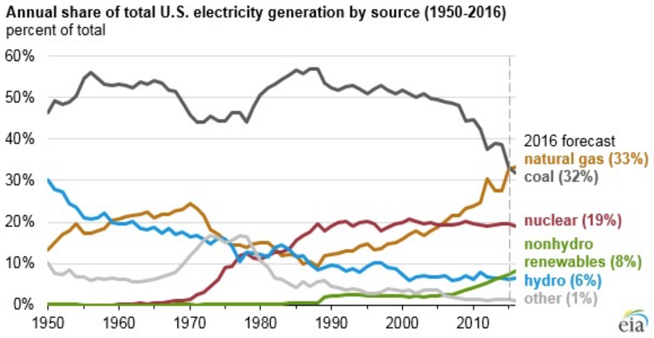


**Figure 1 | Changing composition of the United States energy mix**. Historically, the United States has relied heavily on coal for electricity production. In recent years, the increased availability and decreased price of natural gas have led to its rapid increase as a fuel source and it currently accounts for a third of national electricity production. Renewable energy sources make up approximately 15% of the national energy mix. Data are from the United States Energy Information Administration (2016).

The Secretary of Energy will make grant funding available to eligible entities that propose appropriate demonstration projects of grid-integrated clean distributed energy systems in order to lessen the financial burden of developing new technologies. Grants will have a maximum value of $5 million each and no more than $15 million may be distributed in total in a given fiscal year.

On an annual basis, the Secretary of Energy will report to Congress on the progress of the process described above, as well as on any related technical and regulatory issues that require legislative action.

### Clean, distributed energy provides benefits for grid operators and consumers

H.R. 4393 states that research by the Secretary of Energy and the Administrator of the Environmental Protection Agency has identified that clean distributed energy can benefit both the host facility (the consumer) and the electric grid operator (typically the utility company). For the host, these benefits include:

- Lower electricity bills
- Revenue from providing ancillary services to the

grid operator

- Reliability of electricity supply in the event
- of grid outages
- Improved electric power quality.

For the grid operator, these benefits include:

- Avoiding investment in transmission and distribution infrastructure upgrades
- Enhanced grid stability provided by reactive power
- Voltage and frequency stabilization
- More reliable and stable operation of the grid provided by dispatchable energy to the grid when supply or capacity is insufficient
- Dynamic, adaptive, and anticipatory response to changing grid conditions offered by intelligent technology (this also benefits the host).

## Diverse technologies and fuel sources are included within the definition of clean energy

H.R. 4393 explicitly defines terms that are applicable to its provisions. For example, energy technologies are classified as distributed if they are located on a customer site, operating on the customer side of the electric meter, and are connected to the grid.

Notably, the category of clean energy is not confined to renewable sources such as hydroelectric, solar and wind power, which are the largest renewable components of the present U.S. energy mix (Figure 1). It includes waste heat to power, natural gas, qualified waste heat resource (e.g. electricity generated through the combustion of waste gas that would otherwise have been flared), combined heat and power, and fuel cell technology.

## The Secretary of Energy directs the evaluation of the current energy grid and reports progress to Congress

Section 4 of H.R. defines the legislation process that will guide its implementation. This section states that the Secretary of Energy shall lead a process summarized as follows:

(1) Conduct a formal study into the status of grid integration and report findings to Congress. This will focus on the benefits of clean, distributed energy grid integration, technical issues to be resolved, and regulatory barriers in place.
(2) Research into the technical barriers to the integration of clean distributed energy with the grid. Research will be grant-commissioned and may last up to two years.
(3) Creation of a stakeholder working group. The purpose of the group is to provide guidance on how to address the technical, regulatory and economic factors that limit the grid-integration of clean distributed energy. The Secretary of Energy will select group members from applicants who are qualified and represent a balance of interests. The group will be responsible for reviewing the report mentioned in (1) above. The group will also identify additional regulatory barriers and recommend to the Secretary of Energy how these may be removed. The Secretary will report to Congress based on the recommendations of the group.
(4) Demonstrations of intelligent grid integration of clean distributed energy systems. The Secretary of Energy will issue a solicitation for technology demonstration projects. Eligible entities, which include private companies, state and local agencies, public institutions, electric utilities and equipment manufacturers, will be granted up to $5 million per project to demonstrate that distributed energy resources can be integrated with the grid. The total amount available for funding will not exceed $15 million per fiscal year.
(5) Progress report. The Secretary of Energy will report annually to Congress on the progress made against steps 1 to 4 above, as well as any technical and regulatory issues that require

legislative action.

In summary, the legislative approach of H.R. 4393 aims to facilitate the increased deployment of clean, distributed and integrated energy. It is an evolutionary, rather than revolutionary, approach. The provisions of H.R. 4393 lay the groundwork for a transformation of the existing grid into one that is more resilient, efficient and less carbon-intensive. In this way, H.R. 4393 recognizes the existing grid's shortcomings. The inefficiency and carbon-intensity of existing infrastructure are the root causes of the environmental problems surveyed below.

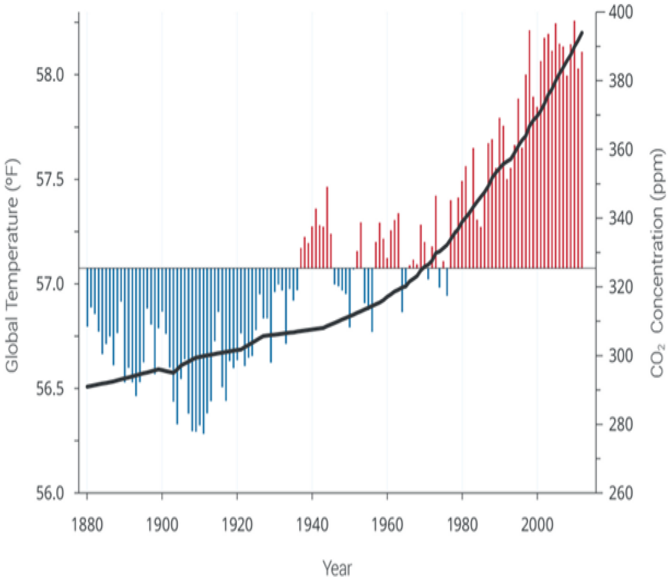


**Figure 2 | Mean global temperatures scale with atmospheric carbon dioxide concentrations**. The global temperature continues to rise as CO2 increases in the atmosphere. Data are from the National Climate Assessment (2014).

# Environmental considerations

Earth’s climate is changing over an unnaturally short time scale due to anthropogenic greenhouse gas emissions. The consequences of these rapid changes, including the increased severity and frequency of severe storms, threaten critical and vulnerable energy infrastructure. In the following section, we summarize the underlying mechanisms of climate change and the major manifestations of its impacts as they pertain to the United States. We then examine the contribution of electricity generation and grid inefficiency to U.S. greenhouse gas emissions.

## Climate change is driven by the rapid accumulation of greenhouse gases in the atmosphere

Earth absorbs energy from the sun in the form of high-energy shortwave radiation. This energy leaves the earth's surface as longwave radiation and travels back toward the atmosphere. As a consequence of their molecular structure, greenhouse gases absorb the outgoing longwave radiation and scatter it into the atmosphere. However, shortwave radiation from the sun passes through. These properties cause greenhouse gases to insulate the planet, trapping heat energy near earth’s surface. This heat-trapping process is referred to as the greenhouse effect, and it allows life on the planet to flourish.

Although the greenhouse effect is a natural process, humans have rapidly increased the release of carbon dioxide and other greenhouse gases into the atmosphere. Human activities, particularly the combustion of carbon-intensive fossil fuels for energy generation and transportation, released 49 million tons of greenhouse gases into the atmosphere in 2010 alone, and annual emissions continue to grow (IPCC, 2014).

Natural processes that remove carbon dioxide from the atmosphere, such as dissolution into the oceans and the uptake of carbon dioxide by plants during photosynthesis, operate on slow time scales that cannot keep up with anthropogenic production of carbon dioxide (Falkowski et al., 2000). Rapid addition of carbon dioxide, coupled with slow removal processes, results in steadily rising concentrations of atmospheric carbon dioxide. This leads to more thermal energy trapped in the lower layers of the atmosphere and higher average global temperatures (Figure 2).

## Climate change has ecological and economic consequences for the United States

Immediate and long term impacts of climate change include rising global temperatures (Karl, 2003), warmer oceans (Levitus, 2000), and melting glaciers and ice sheets (Dyurgerov, 2000). Increasing global average temperatures perturb global systems such as ocean circulation and the water cycle, which in turn drive changes in weather, precipitation and evapotranspiration patterns (e.g. Zhang, 2007; Williams et al., 2015). These changes often occur more quickly than species can adapt, and the ecological and economic impacts of rising global temperatures are already felt worldwide. For example, warming ocean temperatures have resulted in the widespread bleaching and mortality of corals (Hoegh-Guldberg, 1999) in tropical waters such as the Gulf of Mexico, placing economically important fisheries at risk (Pratchett et al. 2008).

The impacts of climate change that are felt most acutely vary by region, both globally and within the United States. For example, the Northeastern U.S. is experiencing sea level rise, heat waves, and increasing storm intensity and frequency. The Southwestern U.S. already faces widespread drought and is expected to see even higher temperatures and less precipitation in the next 50 years (GCRP, 2014). In the Midwestern U.S., primary concerns include flooding, drought, and heat waves, threatening the agricultural productivity of the area (GCRP, 2014).

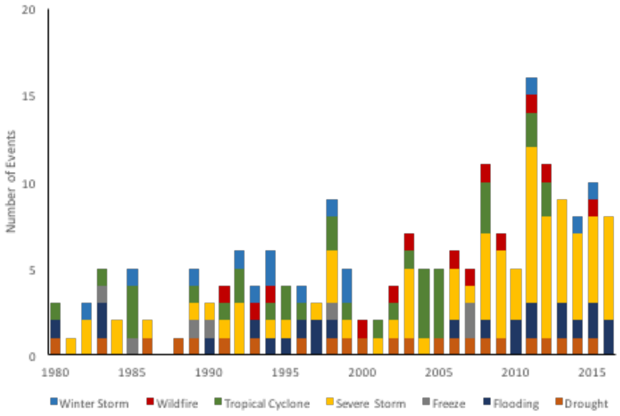


**Figure 3 | Frequency of natural disasters in the United States with damages exceeding $1 billion**. Over the last 34 years extreme and expensive weather events, such as severe storms, have been increasing. Data are from the U.S. Department of Energy (2015).

Many of these events pose direct or indirect threats to critical and vulnerable energy infrastructure in the U.S. In the last 40 years, there has been an upward trend in the frequency of

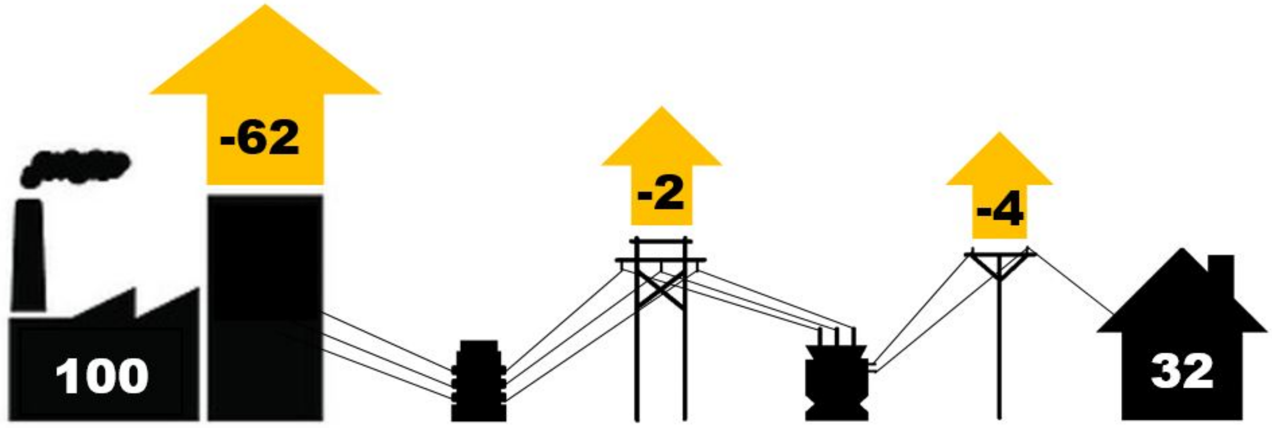


**Figure 4 | Current technologies for energy generation, transmission and distribution are inefficient**. Most of the energy lost between the generation site and the consumer is lost during the process of combustion (far left; standardized units); however, the 6 percent lost in the two subsequent steps over the course of a single day would be sufficient to meet the energy needs of 50,000 average United States homes for one year. Loss data are from the United States Energy Information Administration (2016d).

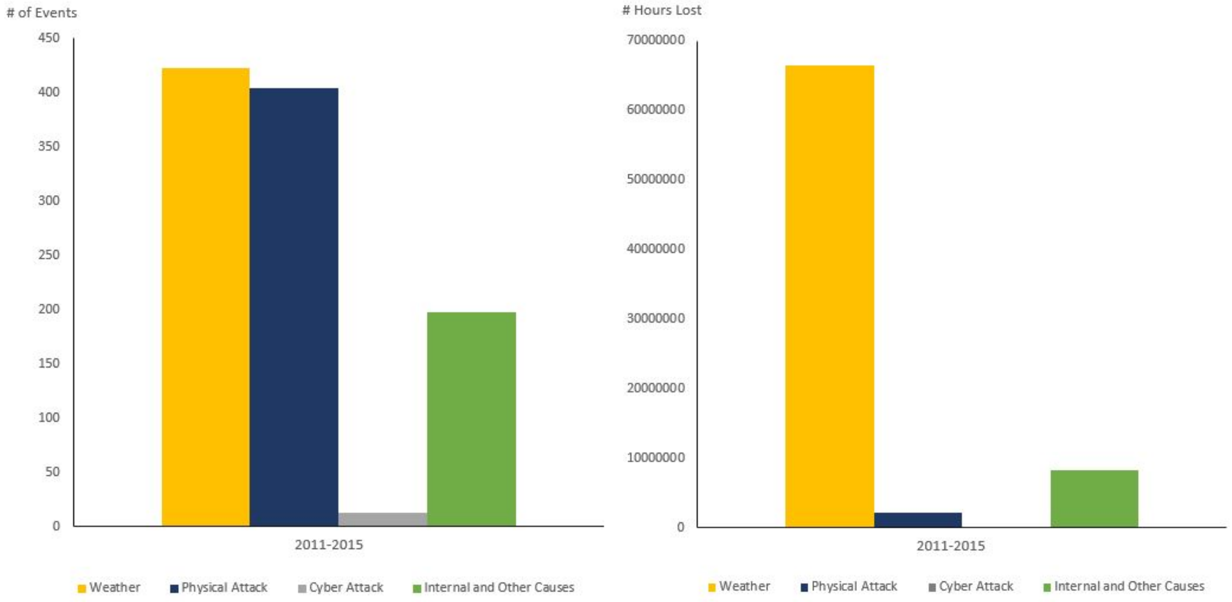


**Figure 5 | Weather events are the leading cause of electricity outages in the United States**. Weather events are the most frequent cause of outages (left panel) and are responsible for the vast majority of hours that customers spend without power (right panel). The latter pattern is evidence of the lack of resilience in current electricity gird infrastructure and of the extent of damage caused by weather events. Data are from the U.S. Department of Energy (2015).

weather-related natural disasters in the U.S. resulting in damages of over $1 billion (Figure 3). This trend is expected to continue as greenhouse gases accumulate further in the atmosphere (IPCC 2012). In the following section, we examine the contribution of electricity generation, transmission and distribution to U.S. greenhouse gas emissions.

## Carbon intensive fuels and inefficient infrastructure are the major causes of greenhouse gases in the United States

Electricity generation is the largest source of carbon dioxide in the U.S., due to a dependence on fossil fuels, which provide 67 percent of electricity (EIA, 2016a). 37 percent of national emissions come from the electricity sector (EIA, 2016b). While coal only produces one-third of U.S. energy it is the sector's primary source of carbon dioxide, responsible for 71 percent of emissions (EIA, 2016b).

The U.S. energy grid contributes to carbon dioxide emissions due to inefficiency in electricity production, transmission and distribution. Additional energy must be produced in order to compensate for this wasted energy, generating additional greenhouse gases. The average efficiency of U.S. energy production is only 31 percent, meaning that less than one third of possible energy from a fuel source is ultimately loaded onto the grid (see Figure 4). Coal power plants contribute one third of U.S. electricity but have an average generation efficiency of only 33 percent, while natural gas plants, which contributes another third, average 43 percent (EIA, 2016a).

During transmission and distribution, another 6 percent of the energy that enters the grid is lost before reaching the customer (EIA, 2016c; Figure 4). This inefficiency in transmission and distribution is due to the centralized nature of the grid, which requires energy to be moved over long distances to reach consumers. Altogether, the U.S. has about 642,000 miles of high-voltage transmission lines, and 6.3 million miles of distribution lines (DOE, 2015). As electricity moves along electrical lines, resistance and friction build up and some energy is lost as heat (FERC, 2007).

## Current energy grid infrastructure is vulnerable to severe weather events

In addition to contributing to emissions, aging and unstable grid infrastructure is vulnerable to the effects of climate change. Although weather incidents are responsible for less than half of intermittent interruptions, they are responsible for the vast majority of long-term electrical outages (Figure 5), such as New York City experienced after Superstorm Sandy. The following section outlines the vulnerabilities of grid infrastructure to a selection of weather-related events associated with a changing climate.

### *Sea level rise threatens coastal infrastructure*

Climate change is expected to result in higher sea levels, and increases in storm frequency and intensity along the northeastern and southeastern United States. Storms in these regions can cause substantial damage to the energy grid, and their impact is only expected to grow. When Superstorm Sandy (see Case Study) hit the east coast, 8.66 million customers lost electricity and communities as far west as Wisconsin were affected (DOE, 2015). With a dense population of 144 million people, and an aging energy infrastructure, these regions are already strained and especially susceptible to weather-induced power interruptions (DOE, 2015). In the last century, global sea levels have risen roughly eight inches (GCRP, 2014). An additional six inches of sea level rise and a 3 percent increase in storm wind speed is expected by 2030. Taken together, these effects threaten electrical infrastructure via coastal erosion, storm surge, flooding, and wind damage.

**Table 1 Comparative generation and conversion efficiencies of energy technologies**. Notional efficiency figures provided for solar and wind which may vary significantly for each technology based on site-specific technology and environmental factors (EIA, 2011). Data are from the United States Energy Information Administration (2011, 2016d, n.d.b).

| Fuel / energy type | Technology type | Efficiency (%) |
|---|---|---|
| Coal | Steam generator | 33.8 |
| Petroleum | Steam generator | 33.6 |
| | Gas turbine | 25.4 |
| | Internal combustion | 32.8 |
| | Combined cycle | 34.4 |
| Natural gas | Steam generator | 32.8 |
| | Gas turbine | 30.0 |
| | Internal combustion | 36.4 |
| | Combined cycle | 44.6 |
| Nuclear | Steam generator | 32.6 |
| Solar* | Photovoltaic / thermal power | 12 to 21 |
| Wind* | (not mentioned) | 26 |

*Wildfires in the American west can engulf inland infrastructure*

The frequency of wildfires is expected to increase in the American northwest and southwest due to rising temperatures and declining precipitation in these regions (DOE, 2015). In the northwest, the frequency of wildfires is expected to increase by up to 175 percent, and the annual area burned in the west is expected to increase by 54 percent by 2050 (DOE, 2013). Wildfires pose a significant threat to energy infrastructure. In 2007, a single wildfire in California left 80,000 residents without electricity, some for several weeks (GCRP, 2014). Energy demand is also expected to rise in these regions, due to population growth and warmer summers, which will further strain the fragile energy grid (DOE, 2013).

*Heavy precipitation and flooding threaten energy infrastructure in the U.S. Interior*

The Department of Energy (2013) projects that flooding and erosion are projected to increase in the midwest and Great Plains due to changes in precipitation. Heavy rainfall events are expected to double in frequency by the end of the century and become more intense with 10-25 percent more precipitation per event (DOE, 2013). The inundation of energy infrastructure can be costly. The flooding of a single midwestern substation in 2013 resulted in over $1 million in damages (Mullen, 2014). Flooding in the Great Plains has the potential to threaten electricity supplies across nationwide, as 50 percent of electricity produced in the region is exported to other states.

The current U.S. energy grid is dependent on energy produced in centralized locations and distributed through inefficient systems. Regions within the U.S. face increasingly severe threats to energy grid infrastructure as a result of climate change, including floods, heat waves and forest fires (GCRP, 2014).

# Proposed Solutions

H.R. 4393 sets out a process to facilitate the transition from the existing centralized energy grid to one that supports clean, distributed and integrated energy solutions. While the previous section outlined the environmental problems associated with the status quo, this section delves into the essential components of the proposed solutions.

**The Clean Distributed Energy Grid Integration Act encourages the development of new technologies for a clean, efficient, and resilient grid**

H.R. 4393 addresses challenges posed by the current grid system through the following legislative mechanisms:

1) Research studies will be undertaken in order to identify regulatory and technical barriers which may prevent increased deployment of integrated distributed energy.
2) The Department of Energy will distribute grants to projects designed to demonstrate that clean, distributed energy facilities can be successfully integrated into the main grid.

**Clean, distributed energy can increase the efficiency of electricity generation, transmission, and distribution while improving power quality**

There are scientific considerations behind the technical processes of energy generation, transmission, and distribution. It is crucial to understand these scientific considerations in order to develop quantitative success measures for the demonstration projects supported by H.R. 4393.

As explained in the Environmental Considerations section of this report, the generation of electricity in the U.S. currently depends largely on the use of fossil fuels, which contribute to global warming. The solution proposed by H.R. 4393 aims to transition from fossil fuels to cleaner energy sources that produce less carbon dioxide per megawatt-hour of electricity, as summarized in Table 1.

In addition to the lower carbon intensity of clean energy sources, H.R. 4393 will encourage the development of more efficient means of generating electricity. Current utility-scale generation typically achieves generation efficiencies of less than 40 percent. This means that 60 percent or more energy is wasted in the process of generation and is not converted to electricity. Several of the technologies proposed by H.R. 4393 achieve greater generation efficiency (Table 1).

Technologies that successfully reduce greenhouse gas emission must either be more efficient in the generation of electricity, such as combined heat and power, or avoid the use of fossil fuels altogether, such as wind and solar (Table 1).

The third attribute of the solution is integration. When distributed energy facilities are integrated with the main grid they can provide:

- Reactive power
- Voltage stabilization
- Dispatchable energy during periods of insufficient capacity or supply.

The three benefits of integration noted above all help to improve the stability of the main grid, which is important because aging infrastructure is being called upon to meet rising demand for electricity. The scientific explanation behind these grid-stability solutions is explained further below.

Reactive power is important because it ensures that the active power used by consumers can travel through the transmission lines in the grid. Reactive power keeps the voltage in the lines at a steady level, thereby allowing active power to flow. When reactive power is provided by distributed generation facilities, it effectively makes space within distribution lines so that centralized, utility-scale power plants can transmit more electricity to consumers (DOE, 2007).

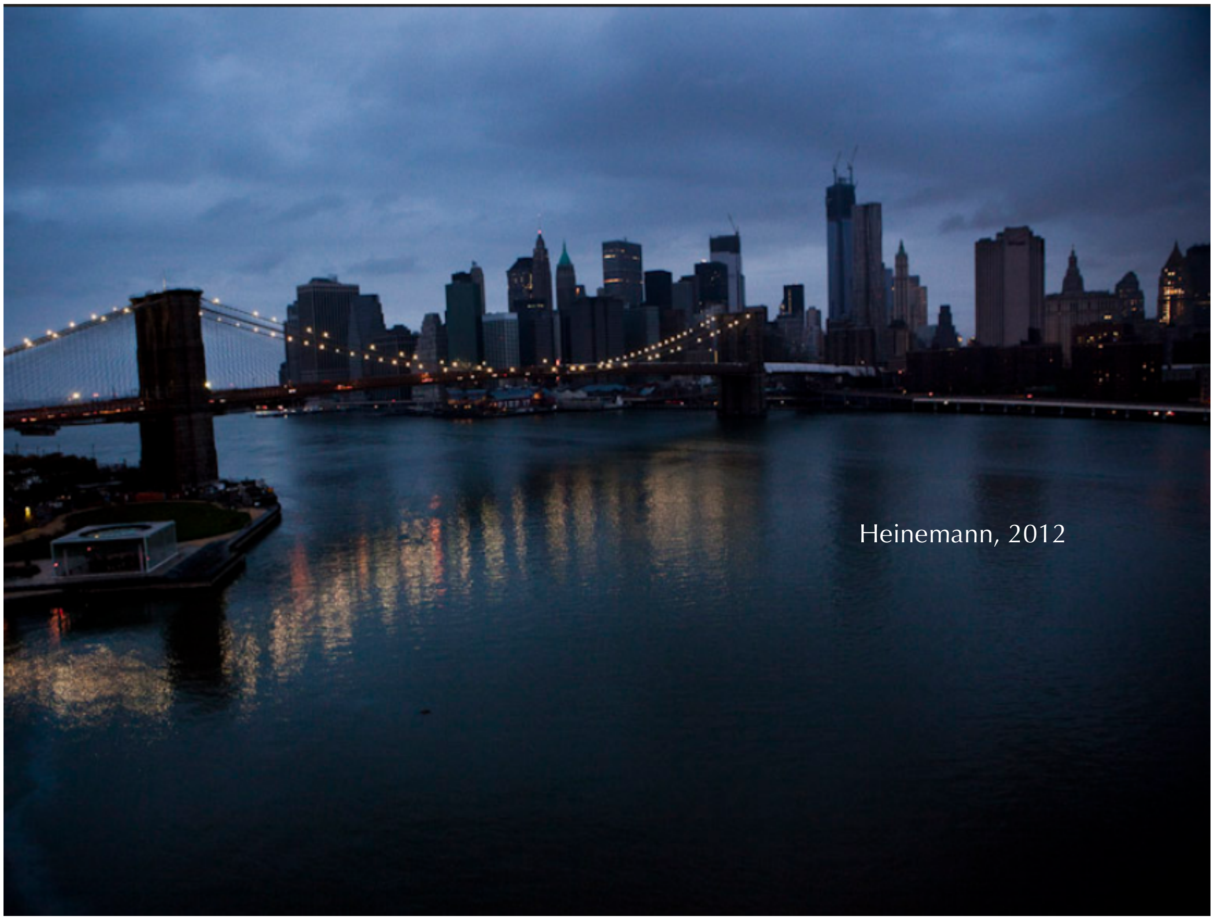
Distributed generation facilities provide voltage stabilization in the distribution lines in the grid. This is because distributed generation facilities operate at a constant voltage. Integration of the facility with the main grid allows voltage in the major transmission lines to remain high even when the power load on the grid exceeds consumption demand and causes lines to trip (Viawan, 2008), making the grid more resilient to outages and while ensuring that electricity is available for consumers.

At a dispatchable facility, the generation process can be controlled in order to meet the needs of either the consumer or a third party, such as the grid operator. An example of a non-dispatchable generation facility is a rooftop solar array, whereas a combined heat and power plant can be configured to be dispatchable. The operator of a rooftop solar array cannot switch the energy source (the sun) on or off, or adjust its intensity. The operator of a combined heat and power plant, however, can control the fuel supply and electricity generation intensity, and therefore the output of the process. When distributed energy facilities are dispatchable and integrated with the main grid, they can provide electricity when other generation facilities may be unable to meet heightened demand. This increases overall grid reliability and stability.

## Scientific uncertainties and differing stakeholder goals are potential sources of conflict and controversy

Controversies surrounding the aims and intentions of H.R. 4393 cannot be characterized as solely scientific issues—stakeholder positions, preexisting

# Case study | The Impact of Superstorm Sandy on the electricity infrastructure of New York City, NY.



Heinemann, 2012

The damage wrought on New York City's electrical infrastructure by the 2012 Superstorm Sandy was immense. From this single storm, over one-third of the City's electric generating capacity was lost and almost two million people in New York City alone were left without power weeks. The loss of a single transformer put 250,000 people in the dark (Sugarman, 2012). As a result of the blackout, Hospitals were evacuated, residents lost access to running water, and transit-systems were immobilized. Of the 50 of the 87 deaths indirectly caused by Sandy, were attributed to the power outage (PCEA, 2013). This event highlighted the vulnerability of not only New York City's, but the national electrical grid, and foreshadows the potential impacts of climate change on the nation's energy supply (City of New York, 2013).

biases and priorities will inevitably affect the legislative outcomes of the Act. Stakeholders will include electrical utility providers, diverse private and federal regulatory bodies, consumers, and commercial owners, as well as scientists and engineers who provide advisory information. Controversies arise from judgement calls and biases in stakeholder perceptions, which stem from uncertainties in available data and/or the lack of an established body of research. Scientific uncertainties relevant to the transition towards clean, distributed energy grid integration include (1) the possibility of unintended consequences of new fuel sources, such as the exchange of carbon dioxide for methane gas (2) uncertain impacts of large-scale distributed energy generation technologies on grid stability, and (3) uncertainties inherent in the scalability, environmental impacts and downstream effects of new and untried technologies.

### Methane gas leakage could offset the reduced carbon dioxide emissions of natural gas

The definition of clean energy, as provided by the Clean Energy Standards Act of 2012, evaluates energy sources based solely on the production of carbon dioxide per megawatt-hour of electricity. However, this definition is not useful when considering other greenhouse gases. For example, natural gas plants emit 0.62 metric tons of carbon dioxide per megawatt hour of electricity, a significant improvement over coal-fired power plants. However, leakages during the extraction, production and distribution of natural gas result in methane gas emissions that are not accounted for in the carbon intensity of natural gas.

Although carbon dioxide is 500 times more abundant than methane gas in the atmosphere, methane is a potent greenhouse gas with a strong positive climate forcing on the atmosphere. It is a highly effective absorber of longwave radiation, with has a warming effect 84 times stronger than carbon dioxide in the first two decades after its emission from natural gas generation facilities (EDF, 2012). As methane rises to the upper levels of the atmosphere, it loses some of its intensity, resulting in an average potency of 25 times that of carbon dioxide over a 100-year period following emission (EPA, 2010).

Methane gas leakage during the extraction and production of natural gas has only recently been subjected to scrutiny. Uncertainties over measurement methodologies and the location and extent of supply networks lead to a considerable variation in estimated leakage rates from different regions of the United States (EDF, 2012). Current technical solutions to reduce methane leakage include replacing leak-prone distribution pipeline materials, recapturing leaked gas with compressors and pumps, and using flares to burn escaping methane (EDF, 2014). However, the latter solution simply converts escaped methane into carbon dioxide gas and therefore does not eliminate greenhouse gas emissions.

### In the absence of full-scale implementation, the precise benefits of distributed generation are impossible to quantify

At present, the U.S. grid is designed for a traditional one-way flow of electricity from producers to consumers. Utility companies argue that the integration of distributed energy sources can cause voltage fluctuations and imbalances, reversed power flows, and temporary overloads or short-circuits. Studies conducted by the National Renewable Energy Laboratory and funded by the California Energy Commission have reported that high reliance on intermittent energy generation from renewable resources has the potential to destabilize the grid (Alexandra, 2016). These technical problems have not yet been studied in detail but could prove solvable through research, development and the staggered integration of new technologies.

**Table 2 | Proposed metrics for individual demonstration project evaluation**.

| Metric | Area of interest | Objective/rationale | Units of measurement | Other considerations |
|---|---|---|---|---|
| Carbon dioxide equivalent emission rate, compared to a state-specific average | Greenhouse gas reduction | Use an all-inclusive measure of greenhouse gases to more accurately assess emissions | Metric tons of carbon dioxide equivalents per unit electricity | Progress must be measured against a state average, given that each state has different available energy sources and energy goals |
| Loss of electricity in transmission and distribution | Energy efficiency | Measure the amount of energy available to the end user relative to the amount of energy produced | Percent | Varies significantly by region. The eastern grid averages 9 percent while the western can be as low as 5 percent |
| Generation efficiency | Energy efficiency | Measure the ability of generation equipment to generate useful energy from the energy source | Percent | National average generation efficiency for fossil fuel power stations in 2014 was 33.6 percent |
| Outage interruption frequency | Grid reliability | Measure the number of times electricity flow is interrupted within the grid and for how long | Frequency and average duration of interruptions | Should continue to improve as increased numbers distributed energy sources are brought online |
| Voltage stability | Grid reliability | Measure the average voltage carried in transmission lines | Volts | Voltage variations can reduce the grid's reliability as well as negatively affecting equipment that uses energy |

**Widespread implementation of new technologies can have unforeseen social and environmental impacts**

Community resistance to the construction of new generation facilities or to particular technologies could limit the expansion and implementation of clean and distributed energy. Community concerns may include:

- Ambient noise and exhaust produced during the installation and operation of engines and gas turbines
- Toxic pollutants including nitrous oxides, volatile organic compounds, sulfur dioxide, carbon monoxide and particulate matter from combined heat and power plants (NYSERDA, 2008), leading to respiratory illnesses. Toxic pollutants like ash and slag are produced from thermal combustion, which can contain heavy metals, dioxins and furans that also have negative human health impacts.

These concerns are important because "not in my backyard" arguments from communities with disproportionate resources and social clout can lead to the siting of projects in areas with young, poor and minority residents and the unequal distribution of human health costs (Mock, 2016). Environmental justice issues may arise that cannot be reliably predicted but should nevertheless be taken into account during the analysis and revision of the energy regulatory structure.

# Measurements of Success

The Clean Distributed Energy Grid Integration Act addresses several shortcomings in the U.S. electricity generation sector. H.R. 4393 proposes a framework to increase the deployment of clean, distributed energy generation facilities. In this section, we define metrics in two dimensions to assess the Act's legislative progress. We will refer to the first dimension as the set of Outputs. This dimension encompasses the Act's first legislative aspect, detailed in the Legislative Approach section above. We will refer to the second dimension as Outcomes, which will involve evaluating the individual demonstration projects that receive grants from the Department of Energy as outlined by the Act.

**Research must translate into recommendations for policy changes; grants must be allocated to successful projects**

Measurements of the success of this dimension should focus on the completion of specific milestones and activities outlined by the Act. Indicators of success include:

- A research report that assesses barriers to integration of distributed energy facilities into the main grid is completed and delivered to the Department of Energy
- Representative stakeholders convene in a working group that produces a set of specific policy recommendations
- The Secretary of Energy submits a progress report to Congress with specific recommendations for legislative actions on an annual basis
- The Department of Energy allocates grants to demonstration projects showing that clean and distributed energy can be successfully integrated with the main grid.

**Implemented technologies must demonstrate increased generation efficiency and reduced greenhouse gas emissions**

The overall goal of the grant allocations for potential research projects is to provide an economic stimulus that will accelerate the development and integration of new energy technologies. As outlined in previous sections, H.R. 4393 provides a framework that will help the U.S.

set the way to transform its aging grid while reducing greenhouse emissions. Specifically, the evaluation of each project that receives a grant must take into account the following considerations:

1. Technologies must produce less than 0.82 metric tons of carbon dioxide per megawatt-hour of energy generated.
2. Technologies must reduce overall energy loss during electricity generation, transmission and distribution.
3. Technologies must contribute to a diverse energy mix, ensuring that electricity is continuously available to consumers and providing resilient, reliable, high-quality power.

In order to provide an objective and quantifiable measure, we suggest that each demonstration project is evaluated using specific metrics of performance (Table 2).

**Figure 6 | Distributed energy sources powering The Solar Settlement in Freiburg, Germany**. This community produces 300 percent more energy than it requires to operate. The sale of excess energy back to the grid generates annual profits of $5000 per household. Image from Wikipedia.org (2016).

**Evaluations of improvement must take into account site-specific characteristics, including the relative availability of energy sources**

The overall objective of the proposed metrics is to evaluate the Act's ability to expand research into clean, distributed energy. The efficiency of the United States varies significantly between regions, and each state has a different mix of available and potential energy resources (e.g. solar availability, average wind intensity, and natural gas reserves). The metrics must provide a quantifiable measure to assess the potential of the research to help transition the grid into a more stable and reliable one. Finally, evaluation metrics must be standardized for all demonstration projects and measured against the performance of the current system.

# Conclusions

The Clean Distributed Energy Grid Integration Act provides an opportunity to transition United States energy production and transmission to a cleaner, more efficient, and more stable system. The Act does this by funding research and development into technologies that produce energy while reducing overall greenhouse gas emissions and producing energy on the consumer side of the grid, decreasing the amount of electricity wasted during transmission and distribution. These technologies include renewable resources such as solar and wind (Figure 6), as well as combined heat and power and waste heat to energy.

In addition, the Act proposes the formation of a stakeholder working group to determine regulatory barriers to the deployment of these technologies. The projects developed using funding from the Act will allow researchers to identify the feasibility of incorporating clean, distributed energy into the grid on a larger scale. This is the first step toward what could be an evolution of the United States electricity system.

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