April 2020

Energy Policy Guiding Principles

The American Society of Mechanical Engineers®
ASME®

OVERVIEW

Energy technology is currently undergoing the most rapid technological change since the replacement of gas streetlights with electric lighting and the horse with the internal combustion engine. The widespread adoption of renewable electrical generation, the deployment of electric vehicles, increased production of natural gas, and the development of grid-level energy storage are some of the most visible aspects of this transformation. Because of the impact of these technology changes on national priorities, it is in the national interest that third-party organizations provide accurate and unbiased technical advice to policy makers.

Energy policy decisions should incorporate science and engineering analysis that show the impacts of policy decisions over the entire energy system using approaches that incorporate life cycle analysis from procurement and construction through operation and decommissioning, as well as longer-term impacts. These analyses should be coupled with sound economic analysis that translates these impacts into economic and societal costs and benefits.

The ASME recommends that the five following principles be applied to the development of U.S. energy policy:

1. *The goal of United States energy policy should be to provide energy that is affordable, reliable, and sustainable.*

2. *All decisions regarding energy generation and usage in the United States should be based on viewing energy as an integrated system.*

3. *Energy efficiency, and not just the generation and movement of energy, is part of a sound national energy policy.*

4. *Aggressive federal, state, and private investments in energy technology should be complemented by policies that allow these technologies to reach the market and support the development of a broad energy economy.*

5. *Changing technology will require substantial and sustained investment in an educated work force.*

GUIDING PRINCIPLES IN FOCUS

> ***1. The goal of United States energy policy should be to provide energy that is affordable, reliable, and sustainable.***

Affordable energy impacts U.S. economic competitiveness and standards of living. In many manufactured products, energy is a major cost. These costs are highest in the seven industries classified as “energy-intensive”: food, pulp and paper, basic chemicals, refining, iron and steel, and nonferrous metals (such as aluminum, and nonmetallic minerals such as cement). In steelmaking, energy accounts for 27 percent of total costs. In cement-making, among the most energy-intensive industries, energy accounts for as much as 40 percent of the total costs . Because these industries often provide the raw materials for other economic sectors ranging from auto-making to household goods, these costs cascade throughout the economy. Energy costs are seen even in economic sectors not traditionally associated with energy usage, such as agriculture. Numbers from the USDA show that the combined costs of fuel, electricity, and energy-intensive fertilizers accounted for more than half the cost of a bushel of wheat .

The average American household spent $1,340 on electricity, $644 on natural gas, propane, and other heating fuels and $1,977 on gasoline in 2017, accounting for 6.5 percent of household income. In many households, persons living in older less efficient housing and living on fixed incomes have energy expenses that are a much larger share of household budgets.

Reliable energy traditionally has been defined in terms of the ability of electric generation to match demand and to remain resilient to meet challenges such as mechanical failure. Americans expect on-demand electricity for their homes and businesses. This definition of reliability also includes timely distribution of non-electric energy sources, such as gasoline and natural gas, to their point of use. Reliability has changed significantly in the past decade. Mechanical reliability must be complimented by resiliency: the ability of an energy system to both avoid, and rapidly recover from, events that may compromise power delivery.

The aftermath of Hurricane Maria and recent earthquakes on Puerto Rico illustrates the challenges of resiliency. Hurricane Maria was the first Category Five hurricane to strike Puerto Rico in recorded history, and the island’s aging energy infrastructure was heavily damaged by the storm. The physical factors of rugged terrain and lack of connection to the electrical grid of the continental U.S. complicated restoration of power, with more than 10 months passing until full power was restored. Future energy systems should be designed and maintained to better withstand natural disasters, to minimize the consequences of local failures, and to recover more quickly.

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[1] As noted later in this document, the ASME believes that energy costs should be assessed as part of a life-cycle analysis. This means that, for both industrial and agricultural energy use, the ASME uses estimates that take into account capital costs, and not just operating costs. Therefore, the values quoted for energy use as a percentage of total costs in these contexts is lower than values quoted that look only at operating costs.
[2] USDA 2013 Agricultural Resource Management Survey (ARMS)

Natural disasters are not the only point of vulnerability in energy systems. As an example, the 2015 cyber-attack on Ukraine's electrical system demonstrated the vulnerability of electrical generation to attack by both state and non-state actors. These vulnerabilities are not confined to the electrical generation and distribution systems: they are present in all energy systems. Given the complexity of these systems, it is clear that they will never be invulnerable: instead they must be able to recover rapidly.

Sustainable energy is the most challenging of these three energy goals to define. The impact of the energy system on human health and the environment should not be minimized. Energy production is most strongly associated with air pollution from combusting gases, which include: particulates, organic compounds, carbon monoxide, carbon dioxide, nitrogen oxides, and sulfur oxides. Other forms of air pollution, including methane, may be released during fossil fuel production. Energy production also contributes to water pollution, and creates solid waste such as coal ash.

Air pollution is not the only sustainability issue tied to the energy system: concerns about the environmental impact of rare earth metals used in energy storage and the effects of all forms of electric generation on the environment. Energy is also a major user of water, an increasingly scarce resource. Energy production and transmission have an impact on wildlife, including loss of birds to wind turbines, pipelines interfering with migration routes, and the environmental damage associated with petroleum spills during production or transmission. In this context, minimizing the impact of any energy technology over its life cycle, and not just the time and point of use, becomes a major engineering challenge.

2. ***All decisions regarding energy generation and usage in the United States should be based on viewing energy as an integrated system.***

Changes made in one component of the energy generation network to meet the goals of affordable, reliable and sustainable energy will also have other impacts. For instance, widespread adoption of electric vehicles will change the requirements of electric generation and distribution. The scale of increased electric generation has the potential to be massive: current road vehicles use the equivalent of about 20 percent of current U.S. electric generation. This shift will only be economical, reliable, and sustainable if the expanded electrical production and transmission system is also economical, reliable, and sustainable.

Vehicle owners may wish to utilize electricity generated using intermittent renewables such as solar or wind. Changes will be needed to the electric grid to manage new patterns of electricity usage. Production of electric vehicles will also require the production of energy storage materials, which will impact the manufacturing economy as well as increasing demand for heavy earth metals. Policy makers must take a holistic view of the energy system to ensure that decisions made to encourage new technologies do not have undesirable impacts elsewhere in the energy system.

The technological challenges of integrating electric vehicles into the U.S. grid are only one example of the technological challenges in energy integration. In addition, as state and local governments set more ambitious renewable energy portfolio requirements, and as companies commit to using more renewable energy, the U.S. electrical grid must be upgraded and modernized to support such transitions. Because of both technological development and financial incentives such as tax credits, wind and solar dominate renewable electricity generation. Managing the intermittency of these resources as they become a larger percentage of U.S. electrical production will require both grid-scale storage, and smarter grid management. Grid-scale energy storage solutions will be different than storage solutions currently used in electrical vehicles, but will still create a need for new materials, whose mining and manufacturing will have environmental impacts. Active management of the electrical grid creates new vulnerabilities, including cyber-security challenges.

Policy makers can work to ensure that technological change results in increased affordability and sustainability while maintaining reliability in several ways. These include ensuring the availability of a broader range of renewable energy technologies by leveling tax incentives across renewable energy technologies to allow the use of the best technological solutions. They can provide appropriate incentives for storage and effective grid management, while encouraging effective cybersecurity. Finally, policies should use life-cycle analysis to ensure the goal of increased sustainability is truly met.

3. *Energy efficiency, and not just the generation and movement of energy, is part of a sound national energy policy.*

Because there is no "zero impact" energy, energy efficiency is not only more sustainable, but more economically competitive. As shown earlier in this discussion, energy costs are a significant portion of both U.S. industrial and agricultural costs, and a significant drain on household finances. In many cases, opportunities for improved energy efficiency are lost either due to a lack of information, or a failure to properly consider life-cycle energy costs. Metrics for measuring energy efficiency are crucial to enabling efficient use of energy.

The potential savings can be shown by looking at a single example of energy consumption: U.S. data center energy usage, which accounts for 73 billion kilowatt-hours (kW-hrs.) of annual energy use. A major challenge in data centers is the amount of power that goes into ventilation and cooling of the electronics. For conventional data centers, for every 1000 Watts of power that go to the electronics and generates economic value, 600 Watts are spent on cooling. For highly efficient "hyper-scale" centers which are already being deployed, this amount can be reduced to around 100 Watts. Research systems designed to maximize cooling efficiency through technologies such as liquid cooling and waste heat recovery have demonstrated that this amount can be reduced to 20 Watts. This shows that systems engineering, and consideration of life-cycle costs can reduce the amount of wasted energy in data centers by a factor of six in existing commercial systems, and as much as a factor of 30 in next-generation systems. This is captured by a metric for data center energy efficiency; the Power Usage Efficiency, or PUE, which allows direct comparison of data center efficiency.

While not every technology offers the opportunities for improved energy efficiency seen in data centers, the basic principles of clear metrics for energy efficiency as well as consideration of life cycle energy impacts can be applied across the entire range of economic sectors that use energy.
This includes home energy efficiency, the efficiency of both private and commercial vehicles, and the development of industrial processes.

4. ***Aggressive federal, state, and private investments on energy technology should be complemented by policies that allow these technologies to reach the market, and support the development of a broad energy economy.***

Transformative new energy systems are needed to reach the goal of reliable, affordable, and sustainable energy to support the needs of our growing global population. This goal requires energy research and development programs that progress from the fundamental research led by agencies such as the National Science Foundation (NSF) and the Department of Energy's Office of Science through applied research led by the Department of Energy's technology-focused programs. This should include not only investments in new generation technologies, but enabling technologies such as smart grids and energy storage. There is a role for rapid, high-risk energy technology investments that may not fit neatly into any of conventional categories, such as the work supported by the Advanced Research Projects Agency-Energy (ARPA-E.)

While research investments in renewable energy technologies have been the most publicized successes of energy programs, technology investments in fossil and nuclear power generation have also led to improvements in efficiency, reliability, and sustainability. For instance, new high-temperature materials, advanced combustion processes, and new pollutant removal technologies have improved the efficiency of coal and natural gas plants while reducing their environmental impact. Continued research investments in renewables, fossil energy, and nuclear energy will lead to additional gains in these areas.

Energy planning for the future requires a portfolio approach to investments that enhances all energy technologies and is sometimes referred to as an "all of the above" strategy. This approach mitigates the risk of any one technology not achieving desired goals. It also recognizes that energy choices are influenced by geography, including the solar resource in the Southwest, the hydropower resources throughout the U.S., wind resources of the Great Plains, and concentrations of coal, oil, and natural gas. Movement of fuel and electricity to areas of greater demand requires added infrastructure, leading to increased cost and environmental impact.

Innovative ideas for new or improved energy technologies can be readily studied at laboratory and bench scales to evaluate their promise for further development into a deployable energy system. Equipment and financial support needs are small at these scales. Validation experiments need not address how the proposed technology would integrate with the overall system. However, practice has shown that a prototype at a scale representative of a commercial system must be built and operated successfully to attract financial support to further advance the technology toward deployment in the marketplace.

Development costs and technical risks are large for demonstrating advanced energy technologies. Private investors will not usually fully fund such endeavors. Aggressive federal, state, and private investments, complemented by policies that reduce investment and deployment risks, are needed to enable new technologies to successfully pass through the demonstration phases to reach the market. In consideration of the above challenges, technology demonstration and commercialization policies should reflect the following attributes:

a) The U.S. Department of Energy should dedicate programmatic funding support to sustain a continually updated portfolio of candidate scale-up and demonstration projects that will lead to the commercialization of new energy technologies.

b) The federal government should co-invest with private partners, using flexible cost share guidelines where appropriate, to support the large-scale demonstration of promising technologies for commercialization in domestic and international markets.

c) A range of financial incentives, including Federal loan programs, investment tax credits, production tax credits, commercial lending practices / repayment guarantees, and similar programs should be enacted to promote new investments in viable technologies.

However, the long-term consequences of tax credits as technologies mature should also be considered. As noted earlier, current tax credits are not evenly distributed among mature renewable energy technologies, which may affect arriving at the most effective grid-scale solutions.

Due to the costs associated with operating large-scale demonstration projects, the Department of Energy should maintain effective management procedures to cancel unsuccessful projects on a timely basis, develop funding cycles that promote continual updating of the demonstration program portfolio, and work collaboratively with other federal agencies to share the costs of energy demonstration projects.

5. Changing technology will require substantial and sustained investment in an educated work force.

The rapid changes in energy technology require a workforce that is capable of designing, deploying, and maintaining increasingly complex technology and mastering new skills such as cybersecurity, robotics, and artificial intelligence (AI) while retaining the institutional knowledge needed to maintain and update systems that may be decades old. The potential loss of institutional knowledge goes beyond dealing with existing systems. As engineers with experience in designing power plants retire and leave the workforce without passing on their expertise, the ability to design safe and affordable plants may be lost. The loss of skills goes beyond the engineering work force: skilled trades needed in the energy industry such as machining and specialized welding are also at risk.

The U.S. has an aging workforce in the engineering and non-engineering energy areas with the median age of 55 years old. Strategies for combatting the potential loss of knowledge are being developed throughout the country in order to try to capture and disseminate this information before it is lost. Successful college students can earn Associate, Bachelors and Master's degrees in the energy field. There are also apprentice and operator certification programs to train the incoming classes of power plant operators. New energy technologies require a more educated work force at all levels, from the trades to advanced engineering degrees.

The rapid rate of technology change makes energy an appealing area to many students. As Brian Malone, a student recently quoted in an NSF report, stated:

> "Distributed energy resources; smart grid, electric vehicle charging, data analytics, cybersecurity, molten salt reactors, power electronics and all of the challenges in power make it impossible to be bored or complacent in this field. The best part is I am only scratching the surface and there is a lifetime of work ahead."

The U.S. needs to channel this enthusiasm and move forward with the education and technology needed incorporating workforce development policies and action across the board. In addition to changes in educational policy, changes in trade, taxation, regulation, and fiscal and monetary policy should be considered.

The federal, state, and local governments, businesses, and educational institutions should work together to develop power universities, vocational schools, community colleges, apprenticeship and operator training programs to ensure that the incoming workforce is trained and ready to take on future challenges in power, AI, robotics, and all forms of renewable energy sources. This will lead to the internationally competitive work force needed to achieve the goals of affordable, reliable, and sustainable energy, as well as an internationally competitive U.S. economy.

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