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New Performance-Based Standards for Standby Power

REEXAMINING POLICIES TO ADDRESS CHANGING POWER NEEDS

Prepared for

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by

Frank A. Felder, Ph.D.
Director of the Center for Energy, Economic and Environmental Policy

Edward J. Bloustein School
of Planning and Public Policy
Rutgers, The State University of New Jersey

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ABSTRACT

The confluence of advances in technology, increasing and changing needs for standby generation, and environmental concerns suggests a reexamination of standby generation codes and standards. Existing codes and standards are based on the extensive history of a particular technology, the diesel generator, which may no longer be the best option for many standby generation needs. Policymakers should reconsider replacing existing standby generation policies with performance standards that would better suit the needs for standby generation and, potentially, encourage new, more energy efficient, and environmentally friendlier technologies.

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I. INTRODUCTION

Hospitals, emergency call centers, police stations, detention centers, and other critical facilities are legally required to have standby power generation. In addition, many businesses and institutions (e.g., computer data storage centers and bank-check processing facilities) choose to have standby generation available to maintain their operations during power outages. The technical requirements for standby generation are embodied in electrical codes, which are promulgated by national organizations, adopted at the state level, and implemented at the local level. Typically, standby generation units must be online within 10 seconds in the most critical applications and within 30 seconds in less critical applications.

The diesel generator is the technology of choice for the vast majority of standby generation, and it is no surprise that current standby generation codes and standards reflect the technical capabilities of diesel generators. This is a mature technology that has been developed and improved over the past 100 years. As a result, it has low capital costs, and until recently, it had low fuel costs. Since by definition standby generation rarely runs, the increase in the price of diesel fuel has not been much of an issue.

The last several decades have seen three important trends that warrant a rethinking of standby generation codes and standards. First, the tremendous upsurge in electronic and computerized equipment requires continuous power. Even interruptions of power on the order of seconds or less can shut down critical equipment. Second, the increasing numbers of critical facilities for security and disaster relief require sustainable and self-sufficient backup power supplies. Finally, environmental concerns have become prevalent – specifically air emissions of particulate matter, sulfur dioxide, nitrogen oxide, and carbon dioxide, which contribute to smog and global climate change. It is within this new context that existing codes and standards need to be reexamined and perhaps replaced with a broader performance-based approach that would better suit the specific needs for backup power, encourage new technology development, and address environmental issues.

This paper initiates this reexamination. It is organized in the following sections. Section II provides some context for the commonplace use of standby diesel generators. Section III expands upon the trends that are motivating this reexamination. Section IV presents a policy analysis of existing codes and standards and reports that they may not result in the most efficient selection and development of standby generation technologies. Section V outlines some specific recommendations for a performance based code. Section VI concludes.

II. CONTEXT OF STANDBY GENERATION

Standby generation is used in a variety of applications and is required in situations involving human health and safety. In the United States, approximately 80,000 mega-Watts (MW) of backup diesel-generating capacity exists, which is equivalent to approximately 10 percent of the nation's generation capacity.[1] In New Jersey, for example, there are approximately 6,700 diesel generators with a combined capacity of approximately 2,000 mega-Watts (MW), or an average of 0.3 MW (300 kilowatts, or kW) per diesel generator.[2]

An emergency generator produces backup electric power exclusively for use at the facility where it is located during an emergency when the primary power source is not available. Emergency generators are operated only during normal testing and maintenance or during emergencies. All public buildings by code must provide emergency power for lights and alarms, as well as for elevators if required for handicapped egress. Batteries can serve as the backup power source in smaller installations, but engineers typically provide an emergency generator for larger installations and when major electricity loads such as elevators are added. Emergency generators are required to start and take critical loads in 10 seconds upon loss of power.

In addition to code-defined emergency power, many facilities add capacity to the emergency generator with additional "mission critical" or standby generators. Hospitals are required to have two independent utility feeders as well as emergency generators. Since much of the entire facility is often considered a life safety or critical load, hospitals often have 50 to 100 percent of their peak electric power available from onsite generators. The typical building electric generator supplies 10 percent or less of the building peak electric load.[3]

Backup power supplies also help ensure against large financial costs due to the loss of power for many industries. For example, one study estimated that the cost of downtime to the cellular communications industry is $41,000/hr, telephone ticket sales $72,000/hr, credit card operations $2,580,000/hr, and brokerage operations $6,480,000/hr.[4]

Table 1 lists a variety of facilities with standby generation needs.

Table 1: Critical Facilities[5]

Type	Examples
Emergency Services	Police stations, fire stations, paramedic stations, emergency communication transmitters
Water Systems	Water supply pumping stations, wastewater pumping stations and treatment plants
Transportation Systems	Traffic intersections, aviation terminals and air traffic control, railroad crossings, electric rail systems
Medical Centers	Hospitals, nursing homes, mental health treatment facilities, specialized treatment center (e.g., out-patient surgery, dialysis, cancer therapy), rehabilitation centers, blood donation centers
Schools	Nursery schools, kindergartens, elementary schools, high schools, colleges and universities, business and trade schools
Day Care Operations	Registered facilities, sitter services, after-school centers
Senior Centers	Senior citizens centers, retirement communities
Social Service Centers	Homeless/transient shelters, missions and soup kitchens, shelters (for youths, families, and battered persons), heating/cooling shelters
Detention Centers	Jails, youth detention centers
Community Centers	Libraries, civic centers, recreational facilities
Public Assembly Structures	Stadiums, auditoriums, theaters, cinemas, religious facilities, malls, conference centers, museums
Hotels	Hotels, motels, boarding houses
High-rise Buildings	Apartments, condos, commercial
Food Services	Restaurants, supermarkets, food processing facilities
Industries	Hazardous material handling, computer centers, computer chip manufacturing facilities, banks

III. TRENDS MOTIVATING A REEXAMINATION OF STANDBY GENERATION CODES AND STANDARDS

Three important trends suggest revisiting standby generation policies: the need for standby generation is increasing (since September 11, 2001, security issues in particular have provided further impetus for increasing standby generation), advancing technology has produced alternatives to diesel generators, and environmental concerns are on the rise.

Mark Mills and Peter Huber point out the unique role the grid has in a modern society and discuss the need for increased standby generation.[6] A modern society's transportation, communication, energy, sanitation, and safety infrastructures depend on electricity. The blackout of August 2003, by no means the first major blackout in the nation's history, demonstrated yet again the consequences of large-scale loss of power. It affected an area populated by an estimated 50 million people. Other major blackouts occurred in 1965, 1977, 1996, 1997, and 2001, and each year thousands of small-scale power interruptions occur throughout the United States.

Table 2 lists major blackouts in North America.[7] It does not include interruptions of power due to distribution system failures, which are much more common but affect fewer people than large-scale blackouts on the transmission system. For instance, National Grid was fined $8.8 million by the New York Public Service Commission for failure to satisfy its customer interruption standards and had more than 1.5 million customer interruptions of five minutes or longer.[8]

Table 2: Major Blackouts in North America

Date of Blackout	Region of North America
1965	Northeast, U.S. and Canada
1977	New York City
1996	Western U.S.
1997	Western U.S.
2001	California
2003	Midwest, Northeast U.S. and Canada

Mills and Huber also note the digitization of modern society. For example, the number of server systems – powerful computers used in data centers and onsite facilities – has doubled to about 28 million worldwide since 2000.[9] Thirty years ago, the consequences of short interruptions of power (that is, five minutes or less) were substantially less significant than they are today. Even shorter interruptions of power supplies of a minute or less can shut down electronic equipment such as computers, instrumentation, and other devices, requiring them to be manually rebooted and recalibrated. In many critical applications, the loss of equipment for even a minute poses human safety risks or has potentially catastrophic financial implications. One particular facility that processes checks would lose $1 million a minute in revenue if it were to shut down.[10]

This digitization trend is accelerating just as the nation's electric transmission and distribution systems are rapidly approaching their limits. Investments in these systems have not kept pace with their depreciation. According to a recent press report, "Engineering experts now believe the nation is entering a period that could be marked by a dramatic increase in localized power outages unless considerably more is spent on replacing old and deteriorated lines."[11] This same report notes that utilities have been using equipment far beyond its intended life in order to keep costs down, and often equipment is run until it fails rather than replaced at the end of its intended life.

Although diesel generators are a mature technology, their performance and environmental emissions continue to improve. Nevertheless, diesel generators fail regularly.[12] Experience from both the Federal Aviation Agency (FAA), which uses backup diesel generators for control towers, and the nuclear power industry, which uses them for power for critical safety systems when there is loss of offsite power, is not reassuring.[13]

Mills and Huber summarize the experience with reliability of diesel generators:

> Some of the most pampered, carefully maintained backup diesel generators in the world reside at nuclear power plants. Yet about 1 percent of all nuclear-plant diesels fail to start when required, and fully 15 percent of the units will fail if run for 24 hours. The operators and regulators of nuclear power plants are well aware of these limitations, and most nuclear plants have three separate, independent emergency power systems for just that reason. Because they are much less well maintained, diesel generators at hospitals and many other sites have failure rates 10 times higher. The May 2000 FAA report (noted earlier) identified failure rates in some of their diesel-generator-based systems at air traffic control centers that approached the grid's failure rates. More importantly, the same study showed a doubling in the past decade of the mean-time-to-repair for standby power systems.[14]

Alternatives to diesel generators exist and, given their immaturity compared to diesel generators, are expected to improve substantially in cost and performance as technology advances. For example, fuel cells are becoming increasingly attractive. Fuel cells are very clean and quiet, although they depend on either large onsite fuel storage tanks or reliable supplies and transportation of offsite fuel. They can be powered by natural gas or hydrogen. When powered by hydrogen that is produced in a carbon-neutral manner, fuel cells emit only nitrogen oxide (NOx) at levels that are barely detectable. Natural gas and hydrogen fuel cells do not emit sulfur dioxide (SO_2). Microturbines are lighter and quieter than diesel generators, almost as clean as fuel cells when fueled by natural gas, but are slightly less cost competitive than diesel generators. Like diesel generators, but not like fuel cells, microturbines use combustion to produce electricity. In some cases, solar power could be an alternative option.[15]

Table 3 provides costs comparison among different generation technologies. For very short-term power needs, on the order of minutes to hours, uninterruptible power supplies (UPS) and batteries are deployed. Since UPS and batteries only store power and do not produce it, they are not comparable to the technologies listed in Table 3.

Table 3: Distributed Generation Cost Comparison[16]

Technology	Size Range (kW)	Installed Costs (kW)	Heat Rate (Btu/kWH)	Approximate Efficiency (%)	Variable O&M ($/kWh)
Diesel Engine	1-10,000	350-800	7,800	45	0.025
Natural Gas Engine	1-5,000	450-1,100	9,700	35	0.025
Natural Gas Engine w/CHP	1-5,000	575-1,225	9,700	35	0.027
Dual Fuel Engine	1-10,000	625-1,000	9,200	37	0.023
Microturbine	15-60	950-1,700	12,200	28	0.014
Microturbine w/ CHP	15-60	550-1,700	11,000	28	0.014
Combustion Turbine	300-10,000	700-2,100	11,000	31	0.024
Combustion Turbine w/CHP	300-10,000	700-2,100	11,000	31	0.024
Fuel Cell	100-250	5,500+	6,850	50	0.01-0.05
Photovoltaics	0.01-8	8,000-13,000	--	n/a	0.002
Wind Turbine	0.2-5,000	1,000-3,000	--	n/a	0.010

Table 4 shows a range of emissions from diesel generators, and Table 5 shows nitrogen oxide (NOx) and particulate matter of 10 microns (PM10) for some alternatives to diesel generators.[17] Note that pollutant emissions from diesel generators are much higher than the alternatives. As a result, the Southern California Air Quality Management District exempts fuel cells from requiring a written air permit.[18]

Table 4: Ranges of Pollutant Emissions from Diesel Generators

Pollutant	Low Range (lb/MWh)	High Range (lb/MWh)
NOx	5.9	17.1
PM	0.74	3
CO_2	1482	1700
CO	7.6	30
VOC	0.73	2
SO_2	0.3	0.5

Table 5: Emissions of NOx and PM10 for Some Alternatives to Standby Diesel Generators

Alternative	NOx (lb/MWh)	PM10 (lb/MWh)
Lean Burn IC Engine	3	0.4
Small Gas Turbine	1.1	0.2
Microturbine	1	0.09
Rich Burn IC Engine w/catalyst	0.6	0.4
Combined Cycle Gas Generator	0.06	0.04
Phosphoric Acid Fuel Cell	0.03	0
Solid Oxide Fuel Cell	0.01	0

During the 2001 California electricity shortage, diesel-fueled backup generators supplied 1,537 MW or 18.8 percent of that state's power reduction needs. An extensive study of these events found that ozone levels were likely to be reduced near the operation of the generators but increased downwind of the diesel generators.[19] It did find that the use of these generators at the present rate and extent of electricity should not pose a threat to public health, except in rare cases where a generator is located in an enclosed area near sensitive populations.[19] That being said, the study also noted that exposure to diesel particulate from backup generators can produce cancer risks greater than 10 in 1 million, which many regulatory agencies consider unacceptable.[21]

Another important soft technological development is the development of probabilistic risk analysis (PRA). This analytical tool, which has several names and variations, systematically identifies, describes, and assigns probabilities or frequencies to sequences of events that lead to loss of power to critical facilities. PRA has dramatically improved the ability to analyze low-risk, high-consequence events (it is flexible enough to apply to any such event), reduce their frequency, and improve responses.[22] It can also be used to quantify the relative uncertainties of various sequences that lead to loss of power, which further helps in preventing and responding to these situations.

With a wider variety of options to employ and improved hard and soft technologies, standby diesel generators may no longer be the preferable option in many critical power applications. Case-by-case analysis of particular applications and their context may be appropriate, rather than the typical one-size-fits-all approach. A tailored approach is further necessary to address environmental concerns: although standby generation runs only when needed (which is relatively infrequent), the emissions from diesel generators may not be acceptable in many cases. For example, a fuel cell has provided electricity to a police station in New York's Central Park since 1999. There is no grid power available, and the exhaust and noise generated from operating diesel generators around the clock would be unacceptable.

IV. POLICY ANALYSIS OF STANDBY GENERATION CODES AND STANDARDS

From a policy perspective, standby generation codes and standards present two important questions. The first is whether some type of regulatory intervention is necessary. If intervention is necessary, the second question asks what type is appropriate.

The first question can be answered quite readily. Society relies upon extensive public health and safety regulation of drugs, food, buildings, consumer products, and in many other areas. In an economic policy context, building owners do not bear all the costs of the consequences when a building loses power. Consequently, without government intervention, they would under invest in backup power supplies. Furthermore, society insists that its buildings are safe, and its members are not expected to conduct extensive safety investigations prior to entering public places. Thus, government intervention is necessary to ensure sufficient levels of standby power.

The question now turns to what type of policy intervention is appropriate. Again, using an economic framework, there are two major categories of intervention. The first is command-and-control intervention, which has two subcategories: technology-based and performance-based regulations. The second category of intervention is market-based. A technology-based standard specifies the equipment or method to be used to achieve the desired emission reduction. In contrast, a performance-based standard stipulates the performance to be satisfied but not the technology. In the context of regulation, current standby generation regulations are a performance standard (although perhaps in name only) because they stipulate that the standby source of power must be able to come online within 10 seconds for critical applications or 30 seconds for non-critical ones. These requirements are not based on the electrical loads of the building but on the time it takes to start a diesel generator. In other words, the performance standard is written around the technical capabilities of diesel generators, which in effect converts it to a technical standard. Engineers can always comply with the standard by selecting a diesel generator, so in many cases they see no reason to investigate or select an alternative technology that can be online in less than 10 seconds, particularly if that alternative is more expensive or less familiar.

In general, performance standards yield greater social value than technical requirements because the increased flexibility of performance standards allows for the same level of public benefits (e.g., improved power reliability, lower costs, and emissions reductions) than would occur with a technical standard. Performance standards also encourage more innovation than technology standards. If a firm were to develop a new technology that achieves the performance standard at a lower cost, it could use that new technology and save money, which it could not do under a technology standard. According to three analysts, "Flexible policy instruments, based on economic incentives rather than mandatory compliance methods, are more likely to encourage the development and implementation of cost-effective technology."[23]

Under the current codes and standards for standby generation, the performance standard is too narrow. Even excluding the argument that the current code is, in effect, a technology requirement, existing performance standards are not based on the needs of a particular building and the functions within that building. For instance, perhaps the performance standard for a hospital should be that power loss to critical equipment that results in its shutdown or loss of function must occur less than one time in a thousand years.[24]

This type of performance standard (used only as an illustration) is technology-neutral. Moreover, with the development of PRA (described in the previous section), compliance with such performance standards can be evaluated. The performance standard would be written based on the needs of the facility, not around the capability of a particular technology. Today's codes and standards for backup power supplies do not address what policymakers really want to achieve, which is to reduce the probability of power outages in critical facilities to below some threshold, based on risk analysis. Addressing this issue may speed the opening of the backup power supply industry to new and superior technologies.

A market-based mechanism, like cap and trade, would not be appropriate for standby generation. With legislative origins in the Clean Air Act Amendments of 1977, "cap and trade" refers to regulatory programs under which the government sets a cap on the volume of harmful emissions (e.g., carbon dioxide) that will be permitted and then distributes the rights to emit (called allowances, permits, or credits), which firms are then free to buy or sell. For positive externalities, such as standby power, a "floor and trade" mechanism would allow excess backup power at one location to be "traded" to meet a shortfall at another location, which clearly makes no sense. Thus, a standard economic analysis suggests that performance standards are most appropriate for standby generation.

The analysis above implies a strong assumption regarding the ability of markets to create new, socially desirable technologies to replace less desirable existing ones. There are two components to this assumption. First, society may under invest in socially optimal technology generally and in environmentally beneficial technologies in particular.[25] In the case of standby power technologies, this under investment problem is likely exacerbated by standby generation codes and standards that favor diesel generators. Second, there may be technological lock-in, a phenomenon described by Cowan and Hultén:

> The path that leads to the lock-in of a technology often starts with a small historical event or sequence of such events. The historical event is often an accident, a haphazard marketing gadget or a political problem demanding immediate action. In standard models of path-dependence an initial advantage gained by one technology can create a snowballing effect, based on learning-by-doing, learning-by-using and learning-about-pay-offs, which quickly makes the technology preferred to others.[26]

Cowan and Hultén argue that technology lock-in may also prevent the development of competing technologies, and that the path of a particular technology depends on technical, economic, and political decisions that develop gradually.[27]

Some theorists believe that technology lock-in can and does occur, resulting in the continued use of some technologies despite the availability of superior technologies, and that this may be a particular problem with respect to environmental protection.[28] There is good reason to believe that this possibility exists with respect to backup power supplies because in many applications, the demand is required by governmental regulation written with a particular technology (diesel generators) in mind.

Complementing the analysis above, the societal benefits of improving the reliability of power supplies and of addressing global climate change and other environmental issues suggest that public policymakers should consider policies that accommodate and even promote technological advances in backup generation. Recent reports by the Intergovernmental Panel on Climate Change (IPCC)[29] and others, along with a political shift in Washington, have elevated the issue of global climate change. A host of emerging, less-polluting distributed generation technologies are expanding the options and performance potential of backup power supplies. Two analysts caution against focusing on short-term cost efficiencies to the detriment of developing more advanced technologies and conclude that without these new technologies, stricter emission reduction targets may not be feasible.[30]

Several independent reasons support the reconsideration of existing standby generator codes and standards. First, such standards are, at best, a narrow performance standard, if not a de facto technology standard. Thus, existing policies provide insufficient incentives for industry to develop and for users to adopt new and advanced standby generation technologies. Second, besides the likely societal under investment in beneficial new technology in general, technological lock-in is a distinct possibility with respect to diesel generators. Finally, pollution control and global climate change may require fundamental changes in generation technology, which could be enhanced by developing and deploying alternatives to the diesel generator.

V. NEW STANDARDS FOR CONSIDERATION

There are several approaches to revising the existing backup supply standards to be more performance based. Three approaches are outlined here that would require further refinement if adopted.

A. Combined Utility and Backup Power. The broadest approach would be an overall performance standard encompassing utility and backup power supplies. These two systems combined would have to satisfy a performance standard regarding the availability of power to the load.[31] A more reliable utility power supply would reduce the backup supply requirement and vice-versa. This broad approach allows for the most flexibility in meeting a required minimum level of power availability, enabling building owners and their backup power supplies to pursue more innovative and cost-effective solutions than otherwise. The power availability requirements may be different for different types of loads, such as hospitals versus commercial buildings. One limitation of this approach is that it requires data from utilities regarding power availability to each load.

Using this broad approach, the performance metric of interest is the availability of the combined utility and standby power system. Availability is the percentage of time that power, whether utility or standby, is available to the facility in sufficient quantities and quality to run critical loads, such as emergency lights.[32] *A minimum level of availability would be mandated and could be verified based upon actual system performance and using PRA techniques described in Section III.*

B. Backup Power Approach. Another approach is to apply the performance standard just to the backup power supply. In this case, the performance of utility power is not considered. The selection, design and operation of the standby power system would be based upon its ability to satisfy the standby performance requirement. This would allow for flexibility within choices for standby power systems, but would not permit optimizing the standby power system based upon the performance of the utility power system. This reduced flexibility compared to the broad approach outlined previously does have the advantage of avoiding the analysis of the availability of utility power.

If a performance standard were to apply only to the standby power system, the performance metric that could be used is the probability that standby power is available when utility power is not available in sufficient quantities and quality to operate critical loads. The standby system only provides a service if it works when utility power is not available. Associated with this performance metric would be a minimum threshold that the standby power system would have to satisfy. Verification that the standby system met this threshold could be based upon actual system performance and PRA.

C. Technology Based Performance Standards. Finally, a technology standard for each type of standby power technology could be developed. This approach would be the least flexible but would avoid some of the administrative complexities of verifying a performance standard.

Regardless of which approach is taken, consideration should be made for the possibility of a fundamental change in the electric power system from a centralized generation station model as the primary source of power backed up with standby generation, to one in which distributed generation is the primary source of power backed up with utility power. In this latter model, distributed generation is running all the time and if it is unavailable, utility power immediately takes over.[33] There is no ten-second-transition time between the failure of the primary source of power and the provision of backup power. As discussed in Section III, the increased digitization of electric loads may result in a ten-second transition time being too long. In addition, the grid of the future may be self-healing and able to draw upon distributed generation not located at the load to provide backup power supply.

VI. CONCLUSION

Standby generation policies have centered on narrow performance standards crafted with diesel generators in mind. The context that led to the use of diesel generators as the standard technology for backup power supplies has changed. Environmental concerns, development of new competing technologies, and the digitization of the economy individually and collectively suggest that policymakers need to revisit standby generation codes and standards. In this changing and broader context, establishing meaningful performance-based standards for standby generation should be given serious consideration. Either a broad or narrow performance standard or technology-specific standards could be developed for alternatives to diesel generators. As the context and technology of standby power change, so too must public policy including the very codes and standards that are designed to ensure society's safety.

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ENDNOTES

1 Mills and Huber, 2003, p. 2. Singh, 2001, p. 3, reports that in 1996 there were 102,000 MW of diesel generators of all types, not just standby, and that their growth rates are between 1.7 and 2.6 percent each year.

2 Based upon an email from Joseph Sullivan of the New Jersey Board of Public Utilities.

3 See the National Electric Code, Article 700 Emergency Systems and the National Fire Protection Association (NFPA) 110A, Stored Electrical Energy Emergency and Standby Power Systems. In addition, discussions with multiple experts confirmed the statements in this paragraph.

4 Bluestein *et al*, 2002, p. 11.

5 Based upon modified versions of *Critical Power,* 2003, p. 14 and Department of Energy, 2001.

6 *Critical Power*, 2003.

7 For a more complete listing of U.S. power outages since 1992, see the North American Reliability Corporation Disturbance Analysis Working Group annual reports at http://www.nerc.com/~filez/dawg-disturbancereports.html.

8 Buffnews.com Nov. 8, 2007.

9 Carlton, 2006.

10 Based upon the author's confidential consulting experience.

11 Smith, 2006. See also Hirst, 2004.

12 *Critical Power*, 2003, p. 39.

13 See *Critical Power,* 2003, p. 39, Golay, et. al., 1998, and FAA, 2000.

14 *Critical Power*, 2003, p. 39.

15 Rickerson and Colson, 2007, pp. 50-52 and Clean Energy Group, "Energy Security & Emergency Preparedness: How Clean Energy Can Deliver Reliable Power for Critical Infrastructure and Emergency Response Mission," October 2005 at *http://www.cleanegroup.org/Reports/CEG_Clean_Energy_Security_Oct05.pdf.*

16 Bluestein, et al, 2002, p. 9.

17 See University of California, 2005, pp. A-2 and 31, respectively.

18 Rule 219 (b)(3), available at *http://www.aqmd.gov/rules/reg/reg02/r219.pdf.*

19 University of California, 2005, p. viii.

20 University of California, 2005, p. 7.

21 University of California, 2005, p. viii.

22 See, for example, Haimes, 2004.

23 Jaffe *et al*., 2003.

24 For hospitals, there is no such performance-based standard, only the requirement to have backup generation described above.

25 Jaffe et al., 2003, p. 28.

26 Cowan and Hultén, 1996, p. 3.

27 Cowan and Hultén, 1996, pp. 3-4.

28 See Carrillo-Hermosilla, 2006, Cowan, 1990, Cowan and Hultén, 1996 and Unruh, 2000. Liebowitz and Margolis, 1995, present a skeptical view.

29 See http://www.ipcc.ch/

30 Sandén and Azar, 2005.

31 With the restructuring of the U.S. electric power industry, the electricity supply chain no longer consists of a vertically integrated utility, and involves multiple entities such as independent system operators, independent power producers, and transmission and distribution utilities. For convenience, utility power is used as a shorthand to designate power produced and delivered to a load from the grid.

32 Mathematically, availability is the mean time to failure of the system divided by the sum of the mean time to failure plus the mean time to repair.

33 Another possibility is that distributed generation power is not providing all of the load's power requirement and is supplemented by utility power.

ABOUT THE AUTHOR

Frank A. Felder, Ph.D.

Frank Felder is the Director of the Center for Energy, Economic and Environmental Policy at the Rutgers' Edward J. Bloustein School of Planning and Public Policy. Professor Felders primary research area is the reliability and efficiency of restructured electric power systems. He has published widely in professional and academic journals on market power and mitigation, wholesale market design, reliability, transmission planning, and rate design issues. For industry clients, he has conducted several market power analyses and has testified before the Federal Energy Regulatory Commission and several state utility commissions on market power and mitigation. Frank is a reviewer for several academic journals including *The Energy Journal* and the *IEEE Transactions on Power Systems*.

In addition to his academic work, Frank has consulted for a wide variety of electric industry clients including utilities, an independent system operator, energy management companies, and generators, particularly in the Northeast. He has worked on wholesale market designs in New England, New York, and PJM including policies to accommodate price-responsive load and distributed resources in wholesale markets. He has also conducted studies to evaluate the benefits of two wholesale natural gas pipelines switching from a cost-of-service rate structure to an incentive-based system.

Contact Information

Professor Frank Felder
Director, Center for Energy, Economic & Environmental Policy
Edward J. Bloustein School of Planning and Public Policy
Rutgers, The State University of New Jersey
Civic Square Building, Room 158
33 Livingston Avenue
New Brunswick, NJ 08901
Phone (732) 932-5680 x670
Fax (732) 932-0934
Email: ffelder@rci.rutgers.edu
www.policy.rutgers.edu/ceeep

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CleanEnergyGroup
Innovation in Finance, Technology & Policy

50 State Street, Suite 1
Montpelier, VT 05602
Phone 802.223.2554
Fax 802.223.4967
Email ceg@cleanegroup.org
Web www.cleanegroup.org