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PUCO EXHIBIT FILING

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Date of Hearing: 2-20-13

Case No. 11-5201-EL-RDR

PUCO Case Caption: In the Matter of The Review of the Alternative Energy Rider Contained in the Tariffs of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company

List of exhibits being filed:

OCC 10-11-12 & 14

Reporter's Signature:
Date Submitted: 2-25-13

BEFORE THE PUBLIC UTILITIES COMMISSION OF OHIO

- - -

In the Matter of the : Review of the Alternative : Energy Rider Contained in : the Tariffs of Ohio Edison: Company, The Cleveland : Electric Illuminating : Company, and The Toledo : Edison Company. :

Case No. 11-5201-EL-RDR

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PROCEEDINGS

before Mr. Gregory Price and Ms. Mandy Chiles, Attorney Examiners, at the Public Utilities Commission of Ohio, 180 East Broad Street, Room 11-A, Columbus, Ohio, called at 10:00 a.m. on Wednesday, February 20, 2013.

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VOLUME II

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Case No. 11-5201-EL-RDR
In The Matter Of The Review Of The Alternative Energy Rider Contained in the Tariffs Of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company

RESPONSES TO REQUEST

EA Set 1 – INT-12

Please provide the names of the FirstEnergy personnel that were routinely involved in decisions regarding REC purchases and decisions regarding the method of procurement. For each individual, please provide:

a. Name;

b. Position in First Energy;

c. Role/function with respect to RECs procurement issues;

d. Prior experience in procurement (i.e., RECs, power supply, natural gas) on behalf of a utility;

e. Number of years of industry experience; and

f. Highest educational degree obtained.

Response:

a. Dean Stathis
b. Director Regulated Commodity Sourcing
c. Management of the REC RFP and procurements. Interface between Navigant RFP Manager and FirstEnergy Ohio Company to purchase required number of RECS. Management approval for non-RFP purchases.
d. Manager Natural Gas Transactions- responsibilities included procurement of natural gas for both Company-owned generating units and certain gas-fired Non-Utility Generators ("NUGs") Financial Trader, Power Supply group JCP&L and its Pennsylvania affiliates – responsibilities included identification of power supply risks and the deployment of financial hedge instruments to offset these associated risk. Manager, Commodity Sourcing Department – responsibilities included the procurement of energy, capacity and related services to support JCP&L's obligation for the provision of Basic Generation Service ("BGS"). Director, Regulated Commodity Sourcing – Current position.
e. September 1981-Present (30.5 Years)
f. Master of Arts degree in Economics.

a. Richard Schreader
b. Manager Regulated Commodity Sourcing, JCP&L and East
c. Logistical coordination between Navigant RFP Manager and sellers of RECS to complete REC contracts and deliveries in PJM GATS. Recommend and implement other purchases outside the Navigant RFPs to fulfill the REC requirements.
d. Risk Management – emphasis on regulated procurement activities, and the associated supplier master agreements, including developing agreements for the

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companies' rate filings, and executing contracts resulting from the auctions and RFP processes. Manager, PA Commodity Sourcing – Currently responsible for the design and implementation of commodity supply plans for the FirstEnergy Pennsylvania utilities.

e. June 1977-Present (35 Years)
f. Associate Electrical Engineering degree, and have a Pennsylvania Professional Engineering License.

BEFORE THE
PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Annual Alternative Energy Status Report of Ohio Edison Company, The Cleveland Electric Illuminating Company and The Toledo Edison Company	)	Case No. 11-2479-EL-ACP
In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company and The Toledo Edison Company for a Force Majeure Determination for Their In-State Solar Resources Benchmark Pursuant to R.C. § 4928.64(C)(4)(a)	)	

I. INTRODUCTION

Pursuant to Rule 4901:1-40-05 of the Ohio Administrative Code ("O.A.C."), Ohio Edison Company ("Ohio Edison"), The Cleveland Electric Illuminating Company ("CEI") and The Toledo Edison Company ("Toledo Edison") (collectively, the "Companies") submit their Annual Status Report ("Report") for the period January 1, 2010 through December 31, 2010 ("Reporting Period"). This Report addresses the Companies' 2010 baselines and benchmarks utilizing the methodology set forth in R.C. § 4928.64, and O.A.C. 4901:1-40 and the Companies' compliance with the 2010 Renewable Energy Portfolio Standard Benchmarks ("2010 Benchmarks") set forth in R.C. § 4928.64(B)(2) for the Reporting Period.[1] Further, pursuant to R.C. §4928.64(C)(4)(a), the Companies also include in this filing an application for a force majeure determination from the Commission related to the Companies' Ohio Solar Benchmark, the basis for which is explained in detail below.

[1] The statute also contemplates the Companies meeting an advanced energy portfolio benchmark by the year 2025. However, the report for that benchmark is not due to be filed until 2025. O.A.C. 4901-1-40-05(A)(2).

The Companies made aggressive efforts to meet their 2010 Benchmarks. As a result, the Companies are pleased to inform the Commission that they are in compliance with their statutory Non-Solar 2010 Benchmarks. Further, the Companies complied with the benchmarks of R.C. § 4928.64(B)(3) by achieving exactly half of their 2010 Non-Solar Benchmarks from in-state facilities with the other half coming from facilities located in adjacent states. As demonstrated below and in Exhibit A to this Report, the Companies met their 2010 Non-Solar Benchmarks by obtaining Non-Solar Renewable Energy Credits ("RECs").

In addition, the Companies exceeded their performance from 2009 by obtaining all of the Solar Renewable Energy Credits ("SRECs") necessary to meet the 2010 Out-of-State Solar Benchmark, including any shortfall that carried over from 2009. The Companies were able to obtain 1,629 of the 3,206 SRECs ("Ohio SRECs") that they needed to meet the 2010 Ohio Solar Benchmark. However, despite their best efforts, the Companies fell short of meeting their 2010 Ohio Solar Benchmark by 1,577 Ohio SRECs. Accordingly, along with this Annual Status Report, the Companies are requesting a force majeure determination from the Commission for the 2010 Ohio Solar Benchmark pursuant to R.C. § 4928.64(C)(4)(a).[2]

II. ANNUAL STATUS REPORT

O.A.C. 4901:1-40-05(A) requires that each electric utility file "an annual alternative energy portfolio status report analyzing all activities undertaken in the previous calendar year to demonstrate how the applicable alternative energy portfolio benchmarks and planning requirements have or will be met." O.A.C. 4901:1-40-05(A) also requires that the Commission

[2] The Companies previously filed a force majeure application on January 24, 2011, in Case No. 11-0411-EL-ACP. Subsequent to that filing, the Companies were able to secure an additional 1,517 Ohio SRECs. The Companies withdrew the application on April 11, 2011, and hereby file a new request for a force majeure determination regarding their compliance with their Ohio Solar Benchmark.

Staff conduct an annual compliance review of the electric utility's compliance with benchmarks under the alternative energy portfolio standard.

A. BASELINES

O.A.C. 4901:1-40-03(B) provides that an electric utility's baseline for compliance with the alternative energy resource requirements shall be determined using the following methodology:

> . . . the baseline shall be computed as an average of the three preceding calendar years of the total annual number of kilowatt-hours of electricity sold under its standard service offer to any and all retail electric customers whose electric load centers are served by that electric utility and are located within the electric utility's certified territory. The calculation of the baseline shall be based upon the average, annual, kilowatt-hour sales reported in that electric utility's three most recent forecast reports or reporting forms.

In compliance with Rule 4901:1-40-03(B) set forth above, the Companies calculated their total annual number of kilowatt-hours of electricity sold to their respective retail electric customers under their standard service offer ("SSO") for each of calendar years 2007, 2008, and 2009 utilizing their three most recent reporting forms (herein referred to respectively as, the "2007 Sales", "2008 Sales" and "2009 Sales")[3]. The Companies then averaged their respective 2007 Sales, 2008 Sales and 2009 Sales to compute their respective 2010 baselines ("2010 Baseline"). The Companies did not make any adjustments to their 2010 Baselines.

The Companies' respective 2010 Baselines, as defined in Section 4901:1-40-03(B)(2), and 2010 Benchmarks are shown on Exhibit A to this Report. The Companies' 2010 Baselines total 45,500,576 MWh based on the average of the Companies' total annual number of kilowatt-

[3] The actual kilowatt hours sold in each of 2007, 2008, and 2009 were reported on the SE -1 Monthly Historical Electricity Data, Part A.

hours of electricity sold to their respective retail electric customers under their standard service offer for the prior three years (2007-09).[4]

B. BENCHMARKS

The Companies then calculated their respective 2010 Benchmarks in accordance with R.C. § 4928.64(B)(2) and O.A.C. 4901:1-40-03(A) and as amended by the Commission in its March 10, 2010, Finding and Order, Case No. 09-1922-EL-ACP. By 2025, the Companies must provide twenty-five (25) percent of their electricity from alternative energy resources (both renewable and advanced). R.C. § 4928.64(B). Half of the twenty-five (25) percent must be supplied from renewable energy resources. R.C. § 4928.64(B)(2). The law further requires that at least one-half (.5) percent of the twenty-five (25) percent must be supplied from solar energy resources by 2025. *Id.* The law sets annual benchmarks for both renewable energy and solar energy. *Id.* For 2010, the Companies' benchmark was to supply 0.50% of their electricity supply from renewable energy resources and 0.010% of their electricity supply from solar energy resources. *Id.* The Commission's rules state that the Companies are to procure at least one half of the renewable and solar energy resources from facilities located in Ohio, and the remainder can come from out-of state facilities but they must be deliverable into Ohio. O.A.C. 4901:1-40-03(A)(2)(a).

The Companies' 2010 Benchmarks are based on the renewable benchmark equal to 0.50% of their 2010 Baselines. Exhibit A to this Report depicts each company's baseline; the number of RECs and SRECs (both Ohio and Out-of-State) each company needed to obtain to

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[4] Ohio Edison's 2010 Baseline is 20,479,586 MWh; CEI's 2010 Baseline is 16,337,169 MWh; Toledo Edison's 2010 Baseline is 8,683,821 MWh.

meet its 2010 Benchmark; and the number of RECs and SRECs (both Ohio and Out-of State) that each company actually obtained.

1. <u>2010 Non-Solar Benchmarks</u>

The Companies were able to meet one hundred (100) percent of their 2010 Non-Solar Benchmarks. As discussed below, the Companies diligently and proactively procured RECs from existing renewable resources generated within Ohio and other states deliverable into Ohio to comply with the both the Ohio and Out-of-State 2010 Non-Solar Benchmarks. These RECs were obtained through requests for proposals ("RFPs") conducted by the Companies.

2. <u>2010 Ohio and Out-of State Solar Benchmarks</u>

Through the Companies' aggressive efforts, they were also able to comply fully with their 2010 Out-of-State Solar Benchmark. However, while the Companies made good faith efforts to comply fully with their 2010 Ohio Solar Benchmark, as discussed below, they were unable to achieve one hundred (100) percent of the 2010 Ohio Solar Benchmark. The Companies were required to obtain 6,375 total SRECs.[5] At least half of the SRECs were to be generated in Ohio – the Ohio Solar Benchmark – with the other half generated either in Ohio or within a state deliverable to Ohio – the Out-of-State Solar Benchmark. The Companies have satisfied their Out-of-State Solar Benchmark. Despite the lack of sufficient solar renewable resources, the Companies were able to obtain 1,629 of the 3,206 Ohio SRECs, or 51% needed to comply with their Ohio Solar Benchmark. The Companies' efforts to satisfy the Ohio Solar Benchmark, and the reasons they were unable to do so, are fully detailed below in their request for a force majeure determination.

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[5] This number includes the number of SRECs needed to satisfy the Companies' 2010 benchmark (4,550) plus the amount by which the Companies fell short of their 2009 benchmarks (1,825).

III. REQUEST FOR FORCE MAJEURE DETERMINATION

Pursuant to R.C. § 4928.64(C)(4)(a), the Companies hereby request that the Commission make a force majeure determination regarding compliance with their 2010 Ohio Solar Benchmark. The Companies have made aggressive efforts to meet the 2010 Ohio Solar Benchmark, but such efforts have been unsuccessful for reasons beyond their control and through no fault of their own. In granting the Companies' 2009 force majeure request in Case No. 09-1922-EL-ACP, the Commission noted that the Companies would be responsible "for meeting the statutory SER benchmarks through all means available."[6] The Companies took this instruction seriously, but they discovered that they could not meet the 2010 Ohio Solar Benchmark even after using all means available to them.

Although the Companies have pursued a variety of channels to procure SRECs, sufficient SRECs originating in Ohio simply have not been available for purchase by the Companies. For example, the Companies sponsored four RFPs,[7] solicited known suppliers for SRECs, contacted SREC brokers, and participated in a number of SREC auctions. The Companies also considered SREC banking and long-term contracts. Despite these efforts, the Companies could not obtain enough Ohio SRECs to satisfy their 2010 Ohio Solar Benchmark. Thus, the Companies request that the Commission act pursuant to R.C. § 4928.64(C)(4) and O.A.C. 4901:1-40-06 to reduce, because of force majeure, the Companies' 2010 Ohio Solar Benchmark to the level of Ohio SRECs they purchased towards their Ohio Solar Benchmark, namely 1,629 Ohio SRECs.

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[6] *See* Finding and Order, issued Mar. 10, 2010, in Case No. 09-1922-EL-ACP ("March 10th Order").

[7] One of the Companies' RFPs was conducted after the filing of their initial 2010 force majeure application in Case No. 11-0411-EL-ACP.

A. FORCE MAJEURE STANDARD

Pursuant to R.C. § 4928.64(C)(4)(c), if the Commission determines that solar energy resources "are not reasonably available" to meet the Companies' Ohio Solar Benchmark, the Commission shall modify that compliance obligation as appropriate. In order for the Commission to waive or defer the Ohio Solar Benchmark, it must determine that the Companies made "a good faith effort to acquire sufficient ... solar energy resources to so comply [with their Ohio Solar Benchmark], including, but not limited to, by banking or seeking renewable energy resource credits or by seeking the resources through long-term contracts." R.C. § 4928.64(C)(4)(b). The Companies made such a good faith effort to acquire sufficient solar energy resources to comply with their 2010 Ohio Solar Benchmark. However, the supply of Ohio-based solar energy resources was insufficient to allow the Companies to satisfy their 2010 Ohio Solar Benchmark.

B. THE COMPANIES' ATTEMPTS TO SATISFY THEIR OHIO SOLAR BENCHMARK

1. Requests for Proposal

As stipulated by the parties in Case No. 08-935-EL-SSO ("ESP 1") and approved by the Commission, the Companies first attempted to satisfy their solar benchmarks through RFPs. In the ESP 1, the parties specifically stipulated that "[r]enewable energy resource requirements for the period January 1, 2009 through May 31, 2011 will be met using a separate RFP process to obtain Renewable Energy Credits."[8] The Companies' RFPs were independently managed by Navigant Consulting, Inc. ("NCI"). NCI possesses extensive experience with SREC RFPs and

[8] ESP Stipulation at p. 10, Case No. 08-935-EL-SSO (Feb. 19, 2009).

was engaged to conduct two RFPs in 2009, one RFP in 2010, and one RFP in 2011. Each of these RFPs solicited 2010 or earlier vintage SRECs.

In their 2009 Annual Report, which is incorporated herein by reference, the Companies documented NCI's extensive efforts to secure RECs and SRECs in the two RFPs held in 2009. In addition, for the RFP held in 2010, NCI contacted more than two thousand clean energy/solar developers, marketers, owners, aggregators, and brokers. NCI blanketed Ohio and contiguous states with information regarding the Companies' RFP and conducted extensive outreach efforts. NCI, on behalf of the Companies, also personally contacted via telephone nearly five hundred parties known or expected to have solar facilities. On July 15, 2010, NCI hosted an RFP informational session through a webinar in which approximately 100 participants registered. As a result of the RFPs held in 2009 and 2010, the Companies received offers and procured 181 Ohio SRECs that were applied against the Companies' 2010 Ohio Solar Benchmark and 759 SRECs that were used to satisfy in part the Companies' Out-of-State Solar Benchmark. The Companies also procured 4,469 SRECs that will be used to help satisfy the Companies' benchmarks in 2011.

Despite the fact that the Companies had already filed a force majeure request in 2011, the Companies continued to make a good faith effort to procure Ohio SRECs that could be used to comply with their 2010 Ohio Solar Benchmark. Thus, the Companies' held an RFP in 2011, which resulted in the Companies obtaining eleven (11) Ohio SRECs to apply towards their 2010 Ohio Solar Benchmark.[9]

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[9] In this last RFP, only Ohio SRECs were solicited because the other three categories of renewable benchmarks for 2010 had been fulfilled.

Lastly, in the two 2009 RFPs, the Companies contracted to have delivered certain Ohio SRECs in 2011. Thus, in March 2011, the Companies received delivery of Ohio SRECs that were originally intended to be used to help satisfy the Companies' benchmarks in 2011. However, upon receipt of the Ohio SRECs' certificates, the Companies discovered that the Ohio SRECs could be used to satisfy its 2010 Ohio Solar Benchmark. This event allowed the Companies to procure 51% of their 2010 Ohio Solar Benchmark rather than the 3% originally contemplated in their initial force majeure application. The Companies continue to search for any Ohio SRECs, so that it can comply with its Ohio Solar Benchmarks now and into the future. Nevertheless, due to the lack of Ohio Solar Resources, the Companies believe that they have found all Ohio SRECs that can be used to comply with its 2010 Ohio Solar Benchmark and must seek force majeure relief from the Commission.

2. **Auctions and Spot Purchases**

Following the 2010 RFP, while the Companies had contracted for enough RECs to meet their 2010 Non-Solar Benchmarks, the Companies still needed to find more SRECs. Thus, the Companies reached out to known SREC suppliers and brokers to negotiate bilateral agreements. The Companies also established accounts to participate in the following SREC auctions: PJM Envirotrade SREC auction platform ("SAGE"); the SREC Trade Platform ("SREC Trade"); and the Flett Exchange auction platform ("Flett"). The Companies communicated and interacted with these entities on a regular basis seeking to purchase SRECs as they became available to satisfy both their Out-of-State Solar Benchmark and Ohio Solar Benchmark. On December 7, 2010, the Companies procured the remaining SRECs necessary to fulfill their Out-of-State Solar Benchmark, but not the remaining Ohio SRECs to fulfill their Ohio Solar Benchmark.

3. Long-Term Contracts

To satisfy their Ohio Solar Benchmark, the Companies also considered entering into long-term contracts with qualified suppliers. The Companies had discussions with, and received proposals, from two large SREC suppliers regarding long-term contracts for the purchase of SRECs. However, neither of these suppliers could commit to long-term contracts that would supply Ohio SRECs that the Companies could use to comply with their 2010 Solar Benchmarks. Rather, these long-term contract opportunities were to supply SRECs from 2011 and into the future. Nevertheless, the Companies were able to purchase forty-five (45) Ohio SRECs from one of these two companies to apply towards their 2010 Ohio Solar benchmarks under a one year bilateral agreement. Entering into a long-term contract with either of those suppliers would not have cured the Companies' 2010 Ohio Solar Benchmark shortfall.

Moreover, pursuant to the Stipulation in ESP 2 the Companies will conduct an RFP to purchase renewable energy credits using a long-term contract. The Companies' application for approval to conduct an RFP to purchase renewable energy credits using ten-year contracts is pending before the Commission in Case No. 10-2891-EL-ACP. In Staff's comments to the Companies' initial force majeure application, it requested information regarding how the Companies' 2010 Ohio Solar Benchmark shortfall could be incorporated into this RFP process. If the Companies' application is approved by the Commission and the RFP is successful, the Companies will enter into long-term contracts with the successful bidders for the purchase of SRECs.[10] These SRECs will be used towards meeting future compliance requirements, including any shortfall that the Commission incorporates into its 2011 Ohio Solar Benchmark as

[10] Further, entering into long-term contracts outside of this process, could have been interpreted as being inconsistent with the ESP 2 Stipulation, especially if the Companies would have procured enough SRECs so that the long-term contract RFP contemplated in the ESP 2 would have been rendered moot.

a result of this proceeding, assuming the suppliers can generate enough Ohio SRECs in 2011 to meet that benchmark.

While the Companies will conduct an RFP and enter into a long-term contract or contracts, pursuant to the ESP 2, these long-term contracts will impact customers. As recent years have shown, the Companies' Standard Service Offer electricity sales continue to decline due to high levels of shopping and can fluctuate year-to-year. As of December 2010, approximately 70% of the Companies' distribution deliveries were based on generation provided by competitive suppliers last year, making it very difficult for the Companies to predict what their baseline will be over the long term. Indeed, a summary of the Electric Choice Sales Switch Rates for the quarter ending December 31, 2010, illustrates that, on average, the Companies have higher switch rates than any of the other Ohio utilities.[11] The more the Companies' customers shop, the less RECs the Companies need for purposes of complying with state law. Thus, the Companies' strategy in purchasing RECs through RFPs, spot markets and auctions has been both prudent and reasonable for the Companies' standard service customers from whom the Companies' recover their costs to comply with the state's alternative energy laws. In the future, if current shopping rates continue, the Companies' alternative energy benchmarks could either stay the same or decline. Thus, the Companies must carefully consider these factors when entering into any long-term contracts with suppliers so as to minimize customer costs and purchasing more RECs than needed for compliance.

4. Construction of Solar Generation

The Companies also considered the construction of solar generation facilities, but they ultimately did not move forward with that option for several reasons. First and foremost, the

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[11] *See* summary of switch rates attached as Exhibit B.

Companies are *distribution* utilities. They own no generation facilities. The Companies lack the expertise and technical know-how necessary to construct, maintain and operate solar generation facilities. Instead, the Companies have acted consistently with the goals of S.B. 221 and attempted to finance the construction of solar generation in Ohio through their RFP process, attempts to enter into long-term contracts, residential purchase program, participation in SREC auctions, and short-term SREC purchases.

Several commentators to the Companies' initial force majeure application have suggested that S.B. 221 requires the Companies to build solar facilities if they cannot comply with their benchmarks through other alternatives. This suggestion is contrary to the goals of S.B. 221 as well as its express language. S.B. 221's renewable benchmarks were primarily focused on promoting investment in *private* renewable generation by third parties. Thus, R.C. § 4928.64(C)(4)(b) references the acquisition of solar energy resources by an EDU through banking, credits or long-term contracts and makes no mention of construction of solar facilities.

5. **Residential REC Purchase Program**

The Companies also attempted to satisfy their solar benchmark through their Residential REC Purchase Program ("Residential Program"). The Companies worked with The Office of the Ohio Consumers' Council ("OCC") to devise and implement the Residential Program in the ESP 1, a program that the OCC ultimately agreed to when it entered into the stipulation in the ESP 1. Under this program, customers may install renewable energy resources, including solar resources. In their comments to the Companies' initial force majeure application, both the OCC and Solar Alliance criticize the annual re-setting of REC purchase prices under the program. However, the stipulation in the ESP 1, which the OCC signed, provides that residential customers are paid the market price of RECs so that they can take advantage of any increases in those prices. Currently, the Companies only have eight customers under contract and have obtained 51 2010 Ohio SRECs from this program for their 2010 compliance, which was all possible Ohio SRECs that the residential program provided.[12] In 2010, the Companies procured all possible SRECs that the residential program provided.

C. SUFFICIENT SRECS DO NOT EXIST IN OHIO

The Companies have actively and reasonably pursued all options of procuring Ohio SRECs, banked Ohio SRECs and long-term contracts through RFPs, contacts with suppliers, offers by brokers, and successful bids through the auction platforms. Yet, through no fault of their own, they have not been able to meet their Ohio Solar Benchmark. The Companies' aggressive efforts toward compliance demonstrate that an insufficient number of SRECs is available for the Companies to meet the 2010 Ohio Solar Benchmark.

Further, the Companies performed assessments of the Ohio market for the availability of qualified Ohio SRECs. Specifically, the Companies directed NCI, in connection with their RFPs in 2009 and 2010, to assess the availability of qualified Ohio SRECs. NCI concluded that the Ohio SREC market is constrained. In conjunction with their participation in the SREC Trade auction, SREC Trade informed the Companies that there were relatively few solar renewable resources in operation in Ohio. Similarly, the Companies discussion with and market data they obtained from Flett evidenced a constrained market for Ohio SRECs, and that few suppliers were currently participating in SAGE. The Companies will continue to explore opportunities in the nascent Ohio SREC market to spur private investment in renewable resources consistent with the

[12] These SRECs have not been delivered to the Companies and thus were not included in the total amount of SRECs the Companies have procured to comply with their Ohio Benchmark.

goals of S.B. 221. However, as demonstrated above, a 2010 force majeure determination is necessary.

IV. CONCLUSION

As demonstrated above, the Companies achieved full compliance with the 2010 renewable energy benchmark and Out-of-State Solar Benchmark in R.C. § 4928.64(B)(2). While the Companies were unable to fully meet the Ohio Solar Benchmark, their inability to do so was because of circumstances beyond their control despite their good faith efforts. Therefore, the Companies respectfully request that the Commission: (i) make a force majeure determination regarding their 2010 Ohio Solar Benchmark and (ii) reduce their 2010 Ohio Solar Benchmark to the level of SRECs that the Companies acquired in 2010.

Respectfully submitted,

/s/ Carrie M. Dunn

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EXHIBIT A

EXHIBIT A 2010 ALTERNATIVE ENERGY BENCHMARKS AND COMPLIANCE RECONCILIATION

Line No.	Year	Company's SSO Retail Electric Sales	Baseline	Renewable Energy Resource Target %	Solar Energy Target %	Renewable Energy Resource Benchmark	Solar Energy Resource Benchmark - SRECS	Ohio Renewable Less Solar Benchmark - RECS	All Renewable Less Solar Benchmark - RECS	OHIO Solar Energy Resource Benchmark	All Solar Energy Resource Benchmark
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(4)*(5)	(8)=(4)*(6)	(9)=((7)-(8))/2	(10)=(7)-(8) - (9)	(11)=(8)/2	(12)=(8)-(11)
	Ohio Edison Company										
1	2007	21,354,818									
2	2008	21,040,189									
3	2009	19,043,752									
4	2010		20,479,586	0.50%	0.01%	102,398	2,048	50,175	50,175	1,024	1,024
2	2009 Carry Forward									412	397
6	2010 Revised Benchmark (if necessary)									1,436	1,421
	2010 Ohio All Renewable (OH), Zone: OH										
7	***Compliance REC's retired in GATS***							***50,175***	***50,175***	***730***	***1,421***

Column (3) = 2007 through 2009 From PUCO Form(s) SE-1: Monthly Historical Electricity Data, Part A
Column (4) = simple average of preceding three years from Column (3)
Column (5) and (6) from OAC 4901:1-40-03 (A)
Column (7) thru (12) = calculation of benchmarks

EXHIBIT A 2010 ALTERNATIVE ENERGY BENCHMARKS AND COMPLIANCE RECONCILIATION

Line No.	Year	Company's SSO Retail Electric Sales	Baseline	Renewable Energy Resource Target %	Solar Energy Target %	Renewable Energy Resource Benchmark	Solar Energy Resource Benchmark - SRECS	Ohio Renewable Less Solar Benchmark - RECS	All Renewable Less Solar Benchmark - RECS	OHIO Solar Energy Resource Benchmark	All Solar Energy Resource Benchmark
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(4)*(5)	(8)=(4)*(6)	(9)=((7)-(8))/2	(10)=(7)-(8) - (9)	(11)=(8)/2	(12)=(8)-(11)
	The Cleveland Electric Illuminating Company										
1	2007	17,403,753									
2	2008	17,157,556									
3	2009	14,450,199									
4	2010		16,337,169	0.50%	0.01%	81,686	1,634	40,026	40,026	817	817
2	2009 Carry Forward									339	325
6	2010 Revised Benchmark (if necessary)									1,156	1,142
7	***2010*** Ohio All Renewable (OH), Zone: OH ***Compliance REC's retired in GATS***							***40,026***	***40,026***	***587***	***1,142***

Column (3) = 2007 through 2009 From PUCO Form(s) SE-1: Monthly Historical Electricity Data, Part A
Column (4) = simple average of preceding three years from Column (3)
Column (5) and (6) from OAC 4901:1-40-03 (A)
Column (7) thru (12) = calculation of benchmarks

EXHIBIT A 2010 ALTERNATIVE ENERGY BENCHMARKS AND COMPLIANCE RECONCILIATION

Line No.	Year	Company's SSO Retail Electric Sales	Baseline	Renewable Energy Resource Target %	Solar Energy Target %	Renewable Energy Resource Benchmark	Solar Energy Resource Benchmark - SRECS	Ohio Renewable Less Solar Benchmark - RECS	All Renewable Less Solar Benchmark - RECS	OHIO Solar Energy Resource Benchmark	All Solar Energy Resource Benchmark
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(4)*(5)	(8)=(4)*(6)	(9)=((7)-(8))/2	(10)=(7)-(8) - (9)	(11)=(8)/2	(12)=(8)-(11)
	The Toledo Edison Company										
1	2007	9,228,709									
2	2008	9,006,924									
3	2009	7,815,831									
4	2010		8,683,821	0.50%	0.01%	43,419	868	21,276	21,275	434	434
2	2009 Carry Forward									180	172
6	2010 Revised Benchmark (if necessary)									614	606
	2010 Ohio All Renewable (OH), Zone: OH										
7	***Compliance REC's retired in GATS***							***21,276***	***21,275***	***312***	***606***

Column (3) = 2007 through 2009 From PUCO Form(s) SE-1: Monthly Historical Electricity Data, Part A
Column (4) = simple average of preceding three years from Column (3)
Column (5) and (6) from OAC 4901:1-40-03 (A)
Column (7) thru (12) = calculation of benchmarks

EXHIBIT A 2010 ALTERNATIVE ENERGY BENCHMARKS AND COMPLIANCE RECONCILIATION

Line No.	Year	Company's SSO Retail Electric Sales	Baseline	Renewable Energy Resource Target %	Solar Energy Target %	Renewable Energy Resource Benchmark	Solar Energy Resource Benchmark - SRECS	Ohio Renewable Less Solar Benchmark - RECS	All Renewable Less Solar Benchmark - RECS	OHIO Solar Energy Resource Benchmark	All Solar Energy Resource Benchmark
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(4)*(5)	(8)=(4)*(6)	(9)=((7)-(8))/2	(10)=(7)-(8) - (9)	(11)=(8)/2	(12)=(8)-(11)
		Total Ohio									
1	2007	47,987,280									
2	2008	47,204,669									
3	2009	41,309,782									
4	2010		45,500,576	0.50%	0.01%	227,503	4,550	111,477	111,476	2,275	2,275
2	2009 Carry Forward									931	894
6	2010 Revised Benchmark (if necessary)									3,206	3,169
7	***2010*** Ohio All Renewable (OH), Zone: OH ***Compliance REC's retired in GATS***							111,477	111,476	1,629	3,169

Column (3) = 2007 through 2009 From PUCO Form(s) SE-1: Monthly Historical Electricity Data, Part A
Column (4) = simple average of preceding three years from Column (3)
Column (5) and (6) from OAC 4901:1-40-03 (A)
Column (7) thru (12) = calculation of benchmarks

EXHIBIT B

Summary of Switch Rates from EDUs to CRES Providers in Terms of Sales
For the Month Ending December 31, 2010
(MWh)

Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
Cleveland Electric Illuminating Company	CEI	31-Dec	2010	137790	76393	248022	474617
CRES Providers	CEI	31-Dec	2010	355624	453132	217666	1042468
Total Sales	CEI	31-Dec	2010	493414	529525	465688	1517085
EDU Share	CEI	31-Dec	2010	27.93%	14.43%	53.26%	31.28%
Electric Choice Sales Switch Rates	**CEI**	**31-Dec**	**2010**	**72.07%**	**85.57%**	**46.74%**	**68.72%**

Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
Duke Energy Ohio	DUKE	31-Dec	2010	466902	149952	48433	677497
CRES Providers	DUKE	31-Dec	2010	160952	469367	337559	1012790
Total Sales	DUKE	31-Dec	2010	627854	619319	385992	1690287
EDU Share	DUKE	31-Dec	2010	74.36%	24.21%	12.55%	40.08%
Electric Choice Sales Switch Rates	**DUKE**	**31-Dec**	**2010**	**25.64%**	**75.79%**	**87.45%**	**59.92%**

Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
Columbus Southern Power Company	CSP	31-Dec	2010	616431	573843	360948	1555700
CRES Providers	CSP	31-Dec	2010	1	97595	19366	116962
Total Sales	CSP	31-Dec	2010	616432	671438	380314	1672662
EDU Share	CSP	31-Dec	2010	100.000%	85.466%	94.908%	93.007%
Electric Choice Sales Switch Rates	**CSP**	**31-Dec**	**2010**	**0.000%**	**14.535%**	**5.092%**	**6.993%**

Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
The Dayton Power and Light Company	DPL	31-Dec	2010	331451	158847	51428	588724
CRES Providers	DPL	31-Dec	2010	65	136504	235502	448572
Total Sales	DPL	31-Dec	2010	331516	295351	286930	1037296
EDU Share	DPL	31-Dec	2010	99.98%	53.78%	17.92%	56.76%
Electric Choice Sales Switch Rates	**DPL**	**31-Dec**	**2010**	**0.02%**	**46.22%**	**82.08%**	**43.24%**

Source: PUCO, Division of Market Monitoring & Assessment.
Note1: Total sales includes residential, commercial, industrial and other sales.
Note2: The switch rate calculation is intended to present the broadest possible picture of the state of retail electric competition in Ohio. Appropriate calculations made for other purposes may be based on different data, and may yield different results.

***Preliminary Data - will update upon receipt of additional CRES data**

Summary of Switch Rates from EDUs to CRES Providers in Terms of Sales
For the Month Ending December 31, 2010
(MWh)

Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
Ohio Edison Company	OEC	31-Dec	2010	347736	119728	173749	653628
CRES Providers	OEC	31-Dec	2010	477048	495207	357812	1342376
Total Sales	OEC	31-Dec	2010	824784	614935	531561	1996003
EDU Share	OEC	31-Dec	2010	42.16%	19.47%	32.69%	32.75%
Electric Choice Sales Switch Rates	OEC	31-Dec	2010	57.84%	80.53%	67.31%	67.25%

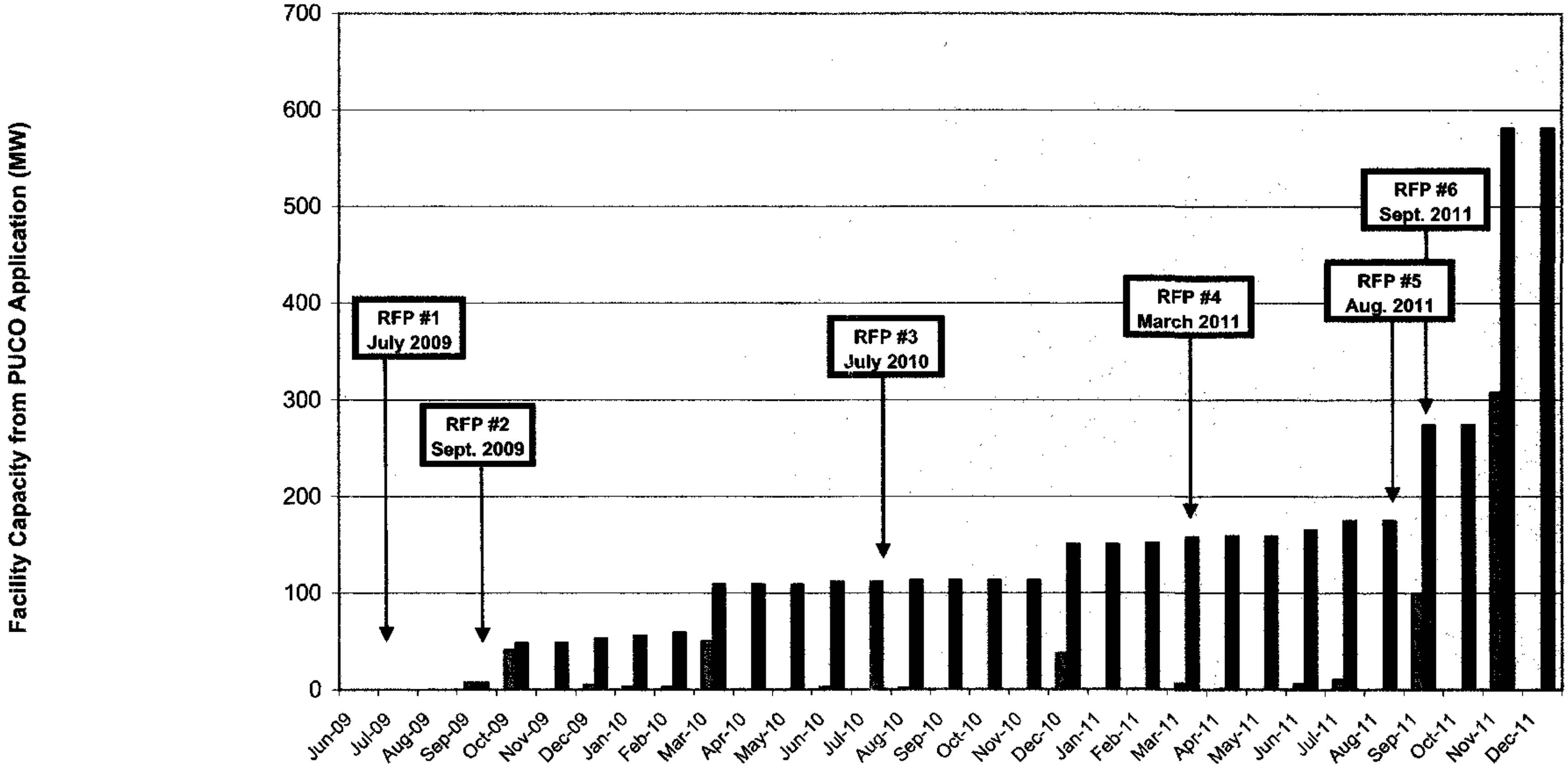
Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
Ohio Power Company	OP	31-Dec	2010	628585	485696	1116821	2238888
CRES Providers	OP	31-Dec	2010	0	954	0	954
Total Sales	OP	31-Dec	2010	628585	486650	1116821	2239842
EDU Share	OP	31-Dec	2010	100.00%	99.80%	100.00%	99.96%
Electric Choice Sales Switch Rates	OP	31-Dec	2010	0.00%	0.20%	0.00%	0.04%

Provider Name	EDU Service Area	Quarter Ending	Year	Residential Sales	Commercial Sales	Industrial Sales	Total Sales
Toledo Edison Company	TE	31-Dec	2010	102530	43700	115020	265504
CRES Providers	TE	31-Dec	2010	119121	203072	244991	569300
Total Sales	TE	31-Dec	2010	221651	246772	360011	834804
EDU Share	TE	31-Dec	2010	46.26%	17.71%	31.95%	31.80%
Electric Choice Sales Switch Rates	TE	31-Dec	2010	53.74%	82.29%	68.05%	68.20%

Source: PUCO, Division of Market Monitoring & Assessment.
Note1: Total sales includes residential, commercial, industrial and other sales.
Note2: The switch rate calculation is intended to present the broadest possible picture of the state of retail electric competition in Ohio. Appropriate calculations made for other purposes may be based on different data, and may yield different results.

*Preliminary Data - will update upon receipt of additional CRES data

In-State All Renewable PUCO Certified MWs by In-Service Month



	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11
Certified MWs by In-Service Date	0	0	0	7	41	0	5	3	3	50	0	0	2	0	2	0	0	0	38	0	1	6	1	0	6	10	0	99	0	307	0
Cummulative MWs	0	0	0	7	48	48	53	56	59	109	109	109	111	111	113	113	113	113	151	151	152	158	159	159	165	175	175	274	274	581	581

Month Credits Could Be Produced Based Upon PUCO Certification or Technology In-Service

Data Source:
http://www.puco.ohio.gov/puco/index.cfm/industry-information/industry-topics/ohioe28099s-renewable-and-advanced-energy-portfolio-standard/ - "List of Approved Cases"

For projects < 1MW the In-Service Date is assumed to be the certification date. For projects > 1MW the certification application was reviewed to determine the In-Service date for REC creation as compared to the PUCO approval date. The later date was then used for reporting purposes herein.

Several biomass facilities in the Commission's report are shown with a capacity value of zero. This report did not attempt to assign a value to any of these facilities.

Cases #s 09-0739 & 10-1382 are for the certification of the same units using different fuel types. The capacity for these units was only counted once.

Exhibit DWS#2

In-State All Renewable PUCO Certified MWs By Month

Certification Month	Ohio Non-Solar Certified MWs	Cummulative Certified MWs	Certified MWs By In-Service Date *	Cummulative MWs By In-Service Date
Jun-09	0	0	0	0
Jul-09	0	0	0	0
Aug-09	0	0	0	0
Sep-09	7	7	7	7
Oct-09	41	48	41	48
Nov-09	0	48	0	48
Dec-09	5	53	5	53
Jan-10	3	56	3	56
Feb-10	3	59	3	59
Mar-10	50	109	50	109
Apr-10	0	109	0	109
May-10	177	286	0	109
Jun-10	2	288	2	111
Jul-10	0	288	0	111
Aug-10	2	290	2	113
Sep-10	0	290	0	113
Oct-10	49	339	0	113
Nov-10	5	344	0	113
Dec-10	38	382	38	151
Jan-11	0	382	0	151
Feb-11	1	383	1	152
Mar-11	6	389	6	158
Apr-11	1	390	1	159
May-11	0	390	0	159
Jun-11	1	391	6	165
Jul-11	10	401	10	175
Aug-11	3	404	0	175
Sep-11	99	503	99	274
Oct-11	0	503	0	274
Nov-11	304	807	307	581
Dec-11	0	**807**	0	**581**
	807		581	

Data Source:
http://www.puco.ohio.gov/puco/index.cfm/industry-information/industry-topics/ohioe28099s-renewable-and-advanced-energy-portfolio-standard/ - "List of Approved Cases"

* For projects < 1MW the In-Service Date is assumed to be the certification date. For projects > 1MW the certification application was reviewed to determine the In-Service date for REC creation as compared to the PUCO approval date. The later date was then used for reporting purposes herein.

TOTAL RENEWABLE ENERGY CASES APPROVED SINCE 6/25/2009: 5,285   TOTAL RENEWABLE ENERGY CAPACTY IN MEGAWATTS (MW): 3,677.37

1. First Case Filed, June 25, 2009. First Case Approved, August 31, 2009.
2. *Co-Fired Projects, listed under Capacity (MW), have not been included in the megawatt capacity summary.*

OCC Set 3-INT-2 Attachment 1

2009 Cases - Sorted by Approval Date (Case Count: 81) (Total MW: 1,477.21)

Name Of Renewable Generating Facility	State	Case No.	Approved	In-Service	Certificate ID	Technology	Capacity (MW)	Nameplate (MW)
American Municipal Power / OMEGA JV 6	OH	09-0724	09/30/2009	09/30/2009	09-WND-OH-GATS-0007	Wind	7.2	
quasar - Buckeye Biogas	OH	09-0526	10/15/2009	10/15/2009	09-BIO-OH-GATS-0012	Biomass	0.6	
Lorain County	OH	09-0562	10/15/2009	10/15/2009	09-BIO-OH-GATS-0013	Biomass	10.91	
Ottawa	OH	09-0563	10/15/2009	10/15/2009	09-BIO-OH-GATS-0014	Biomass	4.09	
Carbon Limestone	OH	09-0561	10/15/2009	10/15/2009	09-BIO-OH-GATS-0016	Biomass	25.024	
Parks Administration Headquarter	OH	09-0705	10/28/2009	10/28/2009	09-WND-OH-GATS-0023	Wind	0.0054	
Bellefontaine Gas Producers LLC	OH	09-0612	12/02/2009	12/02/2009	09-BIO-OH-GATS-0054	Biomass	4.8	
P. H. Glatfelter Company - Chillicothe Facility	OH	09-0730	12/09/2009	12/09/2009	09-BIO-OH-GATS-0064	Biomass	0	92.8
							52.6294	

TOTAL RENEWABLE ENERGY CASES APPROVED SINCE 6/25/2009: 5,285   TOTAL RENEWABLE ENERGY CAPACTY IN MEGAWATTS (MW): 3,677.37

1. First Case Filed, June 25, 2009. First Case Approved, August 31, 2009.
2. Co-Fired Projects, listed under Capacity (MW), have not been included in the megawatt capacity summary.

2010 Cases - Sorted by Approval Date (Case Count: 744) (Total MW: 1,010.48)

Name Of Renewable Generating Facility	State	Case No.	Approved	In-Service	Certificate ID	Technology	Capacity (MW)	Nameplate (MW)
Model	OH	09-1808	01/20/2010	01/20/2010	10-BIO-OH-GATS-0017	Biomass	2.7	
Akron Biosolids to energy Project Phase 1	OH	09-1879	01/20/2010	01/20/2010	10-BIO-OH-GATS-0021	Biomass	0.335	
Pearl Road Wrecking and Salvage, Inc.	OH	09-1923	02/13/2010	02/13/2010	10-WND-OH-GATS-0045	Wind	0.12	
Auglaize Hydroelectric Plant	OH	09-1062	02/24/2010	02/24/2010	10-HYD-OH-GATS-0060	Hydroelectric	1.09	
James and Mary Wenning DBA Wenning Poultry	OH	09-1007	02/27/2010	02/27/2010	10-BIO-OH-GATS-0066	Biomass	1.8	
University of Cincinnati, Utilities (1)	OH	09-0739	03/24/2010	03/24/2010	10-BIO-OH-GATS-0074	Biomass	49	
Conesville Generating Station Unit 3	OH	09-1860	03/31/2010	03/31/2010	10-BIO-OH-GATS-0105	Biomass	0	165
Upper Scioto Valley Wind	OH	10-0097	03/31/2010	03/31/2010	10-WND-OH-GATS-0108	Wind	0.2	
Conneaut Schools Wind	OH	10-0099	03/31/2010	03/31/2010	10-WND-OH-GATS-0110	Wind	0.6	
Conneaut City Wind	OH	10-0100	03/31/2010	03/31/2010	10-WND-OH-GATS-0111	Wind	0.4	
Killen Generating Station	OH	09-0891	04/06/2010	04/06/2010	10-BIO-OH-GATS-0106	Biomass	0	600
Rosenberger Residential Wind Energy	OH	10-0124	04/11/2010	04/11/2010	10-WND-OH-GATS-0128	Wind	0.01	
South Point Biomass Generation Plant (South Point Power)	OH	09-1043	05/19/2010	09/30/2012	10-BIO-OH-GATS- 0156	Biomass	177	
Picway Generating Station	OH	10-0387	05/23/2010	05/23/2010	10-BIO-OH-GATS-0312	Biomass	0	100
ONU Wind, LLC	OH	10-0434	06/13/2010	06/13/2010	10-WND-OH-GATS-0224	Wind	1.2	
Bay Shore Unit 1	OH	09-1042	06/22/2010	06/22/2010	10-BIO-OH-GATS-0129	Biomass	0	136
Bridgewater Dairy Anaerobic Digester	OH	10-0370	06/26/2010	06/26/2010	10-BIO-OH-GATS-0236	Biomass	1.2	
Hoover Road Landfill Gas to Energy Project	OH	10-0848	08/17/2010	08/17/2010	10-BIO-OH-GATS-0345	Biomass	1.6	
Stockwell Wind Turbine 2.5 kW	OH	10-0856	08/23/2010	08/23/2010	10-WND-OH-GATS-0423	Wind	0.0025	
Walter C. Beckjord Generating Station	OH	09-1023	09/08/2010	06/30/2013	10-BIO-OH-GATS- 0315	Biomass	0	1125
University of Cincinnati, Utilities (2)	OH	10-1382	10/15/2010	10/15/2010	10-CMM-OH-GATS-0472	Abandoned Coal Mine Methane	49	
Muskingum River Plant	OH	10-0911	10/15/2010	10/15/2010	10-BIO-OH-GATS-0463	Biomass	0	1425
Indian Lake HS Wind Research Project	OH	10-1235	10/25/2010	10/25/2010	10-WND-OH-GATS-0585	Wind	0.01	
Rock-Tenn Company	OH	10-0177	10/27/2010	10/27/2010	10-BIO-OH-GATS-0297	Biomass	0	19.6
NovoTec Energy Group Plant 1	OH	10-0242	11/10/2010	06/01/2011	10-SWE-OH-GATS-0593	Solid Waste	5	
Smart Papers Holdings LLC	OH	10-0254	12/15/2010	12/15/2010	10-SWE-OH-GATS-0594	Solid Waste	37.8	
							329.0675	

TOTAL RENEWABLE ENERGY CASES APPROVED SINCE 6/25/2009: 5,285 **TOTAL RENEWABLE ENERGY CAPACTY IN MEGAWATTS (MW): 3,677.37**

1. First Case Filed, June 25, 2009. First Case Approved, August 31, 2009.
2. **Co-Fired Projects, listed under Capacity (MW), have not been included in the megawatt capacity summary.**

2011 Cases - Sorted by Approval Date (Case Count: 3,190) (Total MW: 901.35)

Name Of Renewable Generating Facility	State	Case No.	Approved	In-Service	Certificate ID	Technology	Capacity (MW)	Nameplate (MW)
P.H. Glatfelter Company - Chillicothe Facility (2)	OH	10-1060	01/27/2011	01/27/2011	11-BIO-OH-GATS-0187	Biomass	0	92.8
Ada Wind, LLC	OH	10-0433	02/02/2011	02/02/2011	11-WND-OH-GATS-0186	Wind	0.4	
Sheffield Lake Wind, LLC	OH	10-0435	02/09/2011	02/09/2011	11-WND-OH-GATS-0300	Wind	0.1	
Shelby Road Wind, LLC	OH	10-0437	02/09/2011	02/09/2011	11-WND-OH-GATS-0302	Wind	0.1	
Rock Road Wind, LLC	OH	10-0438	02/09/2011	02/09/2011	11-WND-OH-GATS-303	Wind	0.1	
Marblehead Wind, LLC	OH	10-0470	02/09/2011	02/09/2011	11-WND-OH-GATS-0304	Wind	0.4	
VAN ERK DAIRY LLC	OH	11-0028	03/08/2011	03/08/2011	11-BIO-OH-GATS-0450	Biomass	0.45	
Suburban Landfill Generator	OH	11-0256	03/28/2011	03/28/2011	11-BIO-OH-GATS-0584	Biomass	5.6	
Central Ohio BioEnergy	OH	11-0694	04/11/2011	04/11/2011	11-BIO-OH-GATS-0813	Biomass	1	
Stoneacre Farms	OH	11-0990	04/27/2011	04/27/2011	11-WND-OH-GATS-1016	Wind	0.01	
Quasar - Zanesville Energy	OH	10-0692	06/29/2011	06/29/2011	11-BIO-OH-GATS-1553	Biomass	0.91	
Bay View Co-Generation Plant	OH	09-1913	07/06/2011	07/06/2011	11-BIO-OH-GATS-1565	Biomass	10	
V.H. Cooper & Co., Inc.	OH	11-2986	08/07/2011	11/15/2011	11-WND-OH-GATS-1985	Wind	3	
Conesville Generating Station (Units 3, 4, 5, 6)	OH	11-3201	08/28/2011	08/28/2011	11-BIO-OH-GATS-2159	Biomass	0	1695
Paulding Wind Farm II LLC	OH	11-4395	09/20/2011	09/20/2011	11-WND-OH-GATS-2448	Wind	99	
Owens Community College 50 kW Wind Turbine	OH	11-4242	11/14/2011	11/14/2011	11-WND-OH-GATS-2931	Wind	0.05	
Blue Creek Wind Farm	OH	11-5177	11/28/2011	11/28/2011	11-WND-OH-GATS-3072	Wind	304	
							425.12	

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U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis

Anthony Lopez, Billy Roberts, Donna Heimiller, Nate Blair, and Gian Porro

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NATIONAL RENEWABLE ENERGY LABORATORY

U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis

Anthony Lopez, Billy Roberts, Donna Heimiller, Nate Blair, and Gian Porro

Prepared under Task Nos. SA10.1012 and SA10.20A4

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Executive Summary

The National Renewable Energy Laboratory (NREL) routinely estimates the technical potential of specific renewable electricity generation technologies. These are technology-specific estimates of energy generation potential based on renewable resource availability and quality, technical system performance, topographic limitations, environmental, and land-use constraints only. The estimates do not consider (in most cases) economic or market constraints, and therefore do not represent a level of renewable generation that might actually be deployed.

This report is unique in unifying assumptions and application of methods employed to generate comparable estimates across technologies, where possible, to allow cross-technology comparison. Technical potential estimates for six different renewable energy technologies were calculated by NREL, and methods and results for several other renewable technologies from previously published reports are also presented. Table ES-1 summarizes the U.S. technical potential, in generation and capacity terms, of the technologies examined.

The report first describes the methodology and assumptions for estimating the technical potential of each technology, and then briefly describes the resulting estimates. The results discussion includes state-level maps and tables containing available land area (square kilometers), installed capacity (gigawatts), and electric generation (gigawatt-hours) for each technology.

Table ES-1. Total Estimated U.S. Technical Potential Generation and Capacity by Technology

Technology	Generation Potential (TWh)[a]	Capacity Potential (GW)[a]
Urban utility-scale PV	2,200	1,200
Rural utility-scale PV	280,600	153,000
Rooftop PV	800	664
Concentrating solar power	116,100	38,000
Onshore wind power	32,700	11,000
Offshore wind power	17,000	4,200
Biopower[b]	500	62
Hydrothermal power systems	300	38
Enhanced geothermal systems	31,300	4,000
Hydropower	300	60

[a] Non-excluded land was assumed to be available to support development of more than one technology.
[b] All biomass feedstock resources considered were assumed to be available for biopower use; competing uses, such as biofuels production, were not considered.

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Introduction

Renewable energy technical potential, as defined in this study, represents the achievable energy generation of a particular technology given system performance, topographic limitations, environmental, and land-use constraints. The primary benefit of assessing technical potential is that it establishes an upper-boundary estimate of development potential (DOE EERE 2006). It is important to understand that there are multiple types of potential—resource, technical, economic, and market—each seen in Figure 1 with its key assumptions.

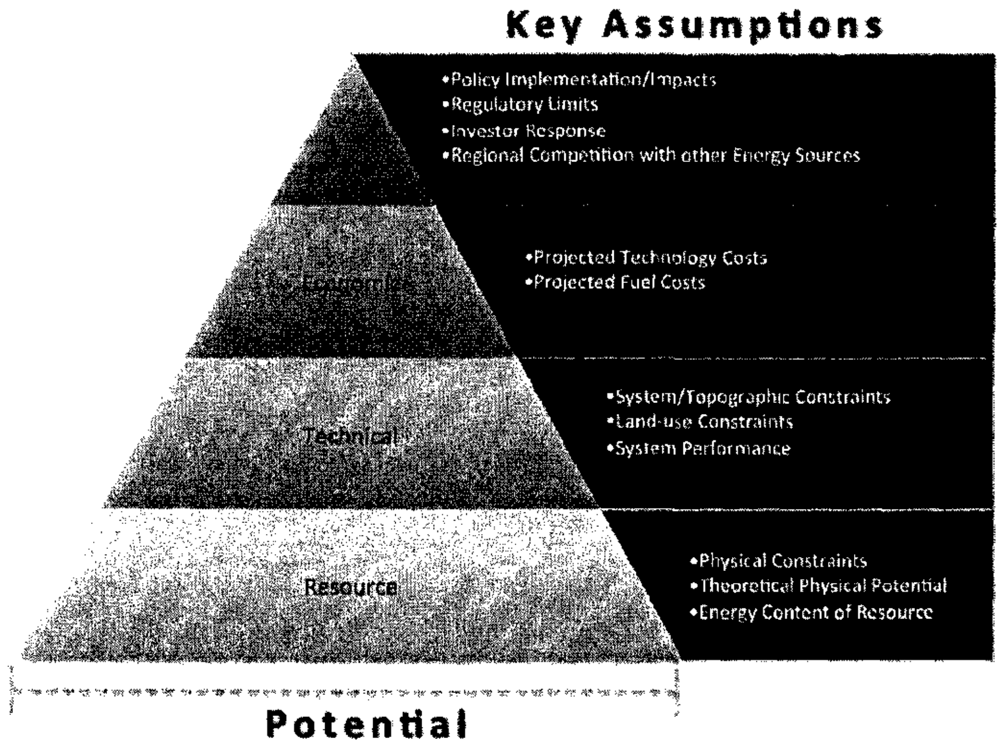

Figure 1. Levels of potential

Figure 1 is based on Table 4-1 in the 2011 update of DOE EERE (2006).

Although numerous studies have quantified renewable resource potential, comparing their results is difficult because of the different assumptions, methodologies, reporting units, and analysis time frames used (DOE EERE 2006). A national study of resource-based renewable energy technical potential across technologies has not been publicly available due to the challenges of unifying assumptions for all geographic areas and technologies (DOE EERE 2006).

This report presents the state-level results of a spatial analysis calculating renewable energy technical potential, reporting available land area (square kilometers), installed capacity (gigawatts), and electric generation (gigawatt-hours) for six different renewable electricity generation technologies: utility-scale photovoltaics (both urban and rural), concentrating solar power, onshore wind power, offshore wind power, biopower, and enhanced geothermal systems. Each technology's system-specific power density (or equivalent), capacity factor, and land-use constraints (Appendix A) were identified using published research, subject matter experts, and analysis by the National Renewable Energy Laboratory (NREL). System performance estimates rely heavily on NREL's Systems Advisor Model (SAM)[1] and Regional Energy Deployment System (ReEDS),[2] a multiregional, multi-time period, geographic information system (GIS) and linear programming model. This report also presents technical potential findings for rooftop photovoltaic, hydrothermal, and hydropower in a similar format based solely on previous published reports.

We provide methodological details of the analysis and references to the data sets used to ensure readers can directly assess the quality of data used, the data's underlying uncertainty, and impact of assumptions. While the majority of the exclusions applied for this analysis focus on evaluating technical potential, we include some economic exclusion criteria based on current commercial configuration standards to provide a more reasonable and conservative estimation of renewable resource potential.

Note that as a technical potential, rather than economic or market potential, these estimates do not consider availability of transmission infrastructure, costs, reliability or time-of-dispatch, current or future electricity loads, or relevant policies. Further, as this analysis does not allocate land for use by a particular technology, the same land area may be the basis for estimates of multiple technologies (i.e., non-excluded land is assumed to be available to support development of more than one technology).

Finally, since technical potential estimates are based in part on technology system performance, as these technologies evolve, their technical potential may also change.

[1] For more information, see http://sam.nrel.gov/.
[2] For more information, see http://www.nrel.gov/analysis/reeds/.

Analysis

Solar Power Technologies

Utility-Scale Photovoltaics (Urban)

We define urban utility-scale photovoltaics (PV) as large-scale PV deployed within urban boundaries on urban open space. The process for generating technical estimates for urban utility-scale PV begins with excluding areas not suitable for this technology. We first limit areas to those within urbanized area boundaries as defined by the U.S. Census Bureau (ESRI 2004) and further limit these areas to those with slopes less than or equal to 3%. Parking lots, roads, and urbanized areas are excluded by identifying areas with imperviousness greater than or equal to 1% (MRLC n.d.). Additional exclusions (Table A-1) are applied to eliminate areas deemed unlikely for development. The remaining land is grouped into contiguous areas and areas less than 18,000 square meters (m^2) are removed to ensure that total system size is large enough to be considered a utility-scale project.[3] This process produces a data set representative of the final available urban open space suitable for PV development. We obtain state-level annual capacity factors using the National Solar Radiation Database Typical Meteorological Year 3 (TMY3) data set (Wilcox, 2007; Wilcox and Marion, 2008) (Table A-2) and the SAM model. The PV system assumed in this analysis was a 1-axis tracking collector with the axis of rotation aligned north-south at 0 degrees tilt from the horizontal, which has a power density of 48 MW per square kilometer (MW/km^2) (Denholm and Margolis 2008a). State technical potential generation is expressed as:

$$State\ MWh = State\sum[urban\ openspace\ (km^2)\ \cdot power\ density\ \left(48\frac{MW}{km^2}\right)$$
$$\cdot\ state\ capacity\ factor\ (\%) \cdot 8760\ (hours\ per\ year)]$$

Utility-Scale Photovoltaics (Rural)

We define rural utility-scale PV as large-scale PV deployed outside urban boundaries (the complement of urban utility-scale PV). Technical potential estimates for rural utility-scale PV begin by first excluding urban areas as defined by the U.S. Census Bureau's urbanized area boundaries data set. We calculate percent slope for areas outside the urban boundaries and eliminate all areas with slopes greater than or equal to 3%. Federally protected lands, inventoried roadless areas, and areas of critical environmental concern are also excluded, as they are considered unlikely areas for development. Table A-3 contains the full list of exclusions. To limit the available lands to only larger PV systems, a 1-km^2 contiguous area filter was applied to produce a final available land layer. Finally, we calculate technical potential energy generation for this available land with the same annual average capacity factors, system design, and power density as for urban utility-scale PV, expressed as:

$$State\ MWh = State\sum[available\ land\ (km^2)\ \cdot power\ density\ \left(48\frac{MW}{km^2}\right)$$
$$\cdot\ state\ capacity\ factor\ (\%) \cdot 8760\ (hours\ per\ year)]$$

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[3] Depending on the PV system, 18,000 m^2 produces roughly a 1-MW system.

Rooftop Photovoltaics

We obtained rooftop PV estimates from Denholm and Margolis (2008b), who obtained floor space estimates for commercial and residential buildings from McGraw-Hill and scaled these to estimate a building footprint based on the number of floors. Average floor estimates were obtained from the Energy Information Administration's 2005 Residential Energy Consumption Survey (RECS) (DOE EIA 2005) and the 2003 Commercial Building Energy Consumption Survey (CBECS) (DOE EIA 2003). Denholm and Margolis (2008b) calculated roof footprint by dividing the building footprint by the number of floors. They estimated 8% of residential rooftops[4] and 63% of commercial rooftops[5] were flat. Orientations of pitched roofs were distributed uniformly. Usable roof area was extracted from total roof area using an availability factor that accounted for shading, rooftop obstructions, and constraints. Base estimates resulted in availability of 22% of roof areas for residential buildings in cool climates and 27% available in warm/arid climates. Denholm and Margolis (2008b) estimated commercial building availability at 60% for warm climates and 65% for cooler climates. Estimated average module efficiency was set at 13.5% with a power density for flat roofs of 110 W/m^2 and 135 W/m^2 for the rest. Denholm and Margolis (2008b) then aggregated state PV capacity to match Census Block Group populations; they then calculated capacity factors for the closest TMY station and applied these to the closest population group.

Concentrating Solar Power

We define concentrating solar power (CSP) as power from a utility-scale solar power facility in which the solar heat energy is collected in a central location. The technical potential estimates for CSP were calculated using satellite-modeled data from the National Solar Radiation Database (Wilcox, 2007), which represent annual average direct normal irradiance (DNI) as kilowatt-hours per square meter per day (kWh/m^2/day) from 1998 to 2005 at a 10-km horizontal spatial resolution. We consider viable only those areas with DNI greater than or equal to 5 kWh/m^2/day (Short et al. 2011).[6] Capacity factor values used in this analysis were generated for a trough system, dry-cooled with six hours of storage and a solar multiple[7] of 2, with a system power density of 32.8 MW/km^2.[8] The capacity factors for each resource class (Table A-4) are generated using the SAM model and TMY3. Land, slope, and contiguous area exclusions are consistent with rural utility-scale PV (Table A-3). Technical state energy generation was expressed as:

$$State\ MWh = State\sum[available\ land(km^2)\ \cdot power\ density\ \left(32.895\frac{MW}{km^2}\right) \cdot state\ capacity\ factor\ (\%) \cdot 8760\ (hours\ per\ year)]$$

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[4] Based on estimates from Navigant Consulting

[5] Based on Commercial Building Energy Consumption Survey (CBECS) database

[6] Technology improvements may lead to improved performance in the future that could affect this threshold.

[7] The field aperture area expressed as a multiple of the aperture area required to operate the power cycle at its design capacity.

[8] Craig Turchi, NREL CSP Analyst, personal communication

Wind Power Technologies

Onshore Wind Power

We define onshore wind power as wind resource at 80 meters (m) height above surface that results in an annual average gross[9] capacity factor of 30% (net capacity factor of 25.5%), using typical utility-scale wind turbine power curves. AWS Truepower modeled the wind resource data using its Mesomap® process to produce estimates at a 200-m horizontal spatial resolution. These resource estimates are processed to eliminate areas unlikely to be developed, such as urban areas, federally protected lands, and onshore water features, Table A-5 includes a full list of exclusions. We estimate annual generation by assuming a power density of 5 MW/km^2 (DOE EERE 2008)[10] and 15% energy losses to calculate net capacity factor.[11]

Offshore Wind Power

We define suitable offshore wind resource as annual average wind speed greater than or equal to 6.4 meters per second (m/s) at 90 m height above surface.[12] The offshore wind resource data consists of a composite of data sets modeled to estimate offshore wind potential generated by AWS Truepower for the Atlantic Coast from Maine to Massachusetts, Texas, Louisiana, Georgia, and the Great Lakes. Other areas are included using near-shore estimates from onshore-modeled wind resources from published research (Schwartz et al. 2010). Because no offshore or near-shore estimates were available for Florida or Alaska (at the time of this publication), these states are omitted from the technical potential calculations. The offshore resource data extend 50 nautical miles from shore, and in some cases have to be extrapolated to fill the extent (Schwartz et al. 2010). We further filter the resource estimates to eliminate shipping lanes, marine sanctuaries, and a variety of other areas deemed unlikely to be developed. Table A-8 contains a full list of exclusions. Our annual generation estimates assume a power density of 5 MW/km^2 and capacity factors based on wind speed interval and depth-based wind farm configurations to account for anchoring and stabilization for the turbines as developed by NREL analysts for use in the ReEDS model (Musial and Ram 2010).

Biopower Technologies

Biopower (Solid and Gaseous)

We obtained county-level estimates of solid biomass resource for crop, forest, primary/secondary mill residues, and urban wood waste from Milbrandt (2005, updated in 2008)[13] who reported the estimates in bone-dry tonnes (BDT) per year. We calculate technical potential energy generation assuming 1.1 MWh/BDT, which represents an average solid biomass system output with an industry-average conversion efficiency of

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[9] Gross capacity factor does not include plant downtime, parasitic power, or other factors that would be included to reduce the output to the "Net" capacity factor.

[10] Represents total footprint; disturbed footprint ranges from 2% to 5% of the total

[11] For more information, see http://www.windpoweringamerica.gov/wind_maps.asp.

[12] This is a typical wind turbine hub-height for offshore wind developments.

[13] For more information, see http://www.nrel.gov/gis/biomass.html.

20%, and a higher heating value (HHV) of 8,500 BTU/lb (Ince 1979). From Milbrandt (2005, partially updated in 2008),[14] we obtained county-level estimates of gaseous biomass (methane emissions), from animal manure, domestic wastewater treatment plants, and landfills; all estimates were reported in tonnes of methane (CH_4) per year. We calculate technical potential energy generation assuming 4.7 MWh/tonne of CH_4, which represents a typical gaseous biomass system output with an industry-average conversion efficiency of 30% (Goldstein et al), and a HHV of 24,250 BTU/lb. Other biomass resources (such as orchard/vineyard pruning's and black liquor) were not included in this study due to data limitations. Also, this analysis assumed that all biomass resources considered were available for biopower and did not evaluate competing uses such as biofuels production. The data from Milbrandt (2005, updated in 2008)[15] illustrates the biomass resource currently available in the United States. Subsequent revisions of this analysis could evaluate projected U.S. resource potential, including dedicated energy crops such as those provided by the recent U.S. DOE update (DOE 2011) of the billion-ton study (Perlack et al. 2005).

Geothermal Energy Technologies

Hydrothermal Power Systems

For identified hydrothermal and undiscovered hydrothermal, we used estimates from Williams et al. (2008), who estimated electric power generation potential of conventional geothermal resources (hydrothermal), both identified and unidentified in the western United States, Alaska, and Hawaii. Williams et al. derived total potential for identified hydrothermal resources by state from summations of volumetric models for the thermal energy and electric generation potential of each individual geothermal system (Muffler, 1979). For undiscovered hydrothermal estimates, we used resource estimates generated by Williams et al. (2009) that used logistic regression models of the western United States to estimate favorability of hydrothermal development and thus, to estimate undiscovered potential. In all cases, exclusions included public lands, such as national parks, that are not available for resource development.

Enhanced Geothermal Systems

We derive technical potential estimates for enhanced geothermal systems (EGS)[16] from temperature at depth data obtained from the Southern Methodist University's (SMU) Geothermal Laboratory.[17] The data ranged from 3 km to 10 km in depth. We consider viable those regions at each depth interval with temperatures ≥150°C. We apply known potential electric capacity (MW_e/km^3) to each temperature-depth interval to estimate total potential at each depth interval based on the total volume of each unique temperature-

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[14] For more information, see http://www.nrel.gov/gis/biomass.html.

[15] For more information, see http://www.nrel.gov/gis/biomass.html.

[16] Deep enhanced geothermal systems (EGS) are an experimental method of extracting energy from deep within the Earth's crust. This is achieved by fracturing hot dry rock between 3 and 10 kilometers (km) below the Earth's surface and pumping fluid into the fracture. The fluid absorbs the Earth's internal heat and is pumped back to the surface and used to generate electricity.

[17] Maria Richards, SMU Geothermal Laboratory, e-mail message to author, May 29, 2009. Data set featured in *The Future of Geothermal Energy* (MIT 2006)

depth interval, shown in Table A-10. Electric generation potential calculations summarize the technical potential (MW) at all depth intervals, electric generation potential (GWh) at all depth intervals with a 90% capacity factor, and annual electric generation potential (GWh) only at optimum depth. We determine optimum depth by a quantitative analysis[18] of levelized cost of electricity (LCOE). An optimum depth is found because drilling costs increase with depth while temperature, and therefore power plant efficiency, generally increase with depth so that power plant costs decrease with depth. Because drilling costs are increasing while power plant costs are decreasing on a per-MW basis, at some point there is a minimum. The optimum depth assumes that the EGS reservoir has a height or thickness of 1 km.

Hydropower Technologies

Hydropower

Source point locations of hydropower estimates were provided by the Idaho National Laboratory and were taken from Hall et al. (2006). The point locations were based on a previous study (Hall et al. 2004) that produced an assessment of gross power potential of every stream in the United States. To generate their own estimates, Hall et al. developed and used a feasibility study and development model. The feasibility study included additional economic potential criteria such as site accessibility, load or transmission proximity, along with technical potential exclusions of land use or environmental sensitivity. Sites meeting Hall et al. (2006) feasibility criteria were processed to produce power potential using a development model that did not require a dam or reservoir be built. The development model assumed only a low power (<1 MWa) or small hydro (>= 1 MWa and <= 30 MWa) plant would be built. To produce state technical potentials, we aggregated the previously mentioned source point locations to the state level.

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[18] We used the quantitative analysis method from Augustine (2011).

Results

For each technology, we provide a brief summary of our findings along with a figure (map) showing the total estimated technical potential for all states and a table listing the total estimated technical potential by state.

Solar Power Technologies

Utility-Scale PV (Urban)

The total estimated annual technical potential in the United States for urban utility-scale PV is 2,232 terawatt-hours (TWh). Texas and California have the highest estimated technical potential, a result of a combination of good solar resource and large population. Figure 2 and Table 2 present the total estimated technical potential for urban utility-scale PV.

Utility-Scale PV (Rural)

Rural utility-scale PV leads all other technologies in technical potential. This is a result of relatively high power density, the absence of minimum resource threshold, and the availability of large swaths for development. Texas accounts for roughly 14% (38,993 TWh) of the entire estimated U.S. technical potential for utility-scale PV (280,613 TWh). Figure 3 and Table 3 present the total estimated technical potential for rural utility-scale PV.

Rooftop PV

Total annual technical potential for rooftop PV is estimated at 818 TWh. States with the largest technical potential typically have the largest populations. California has the highest technical potential of 106 TWh due to its mix of high population and relatively good solar resource. Figure 4 and Table 4 present the total estimated technical potential for rural utility-scale PV.

Concentrating Solar Power

Technical potential for CSP exists predominately in the Southwest. The steep cutoff of potential, as seen in Figure 5, can be attributed to the resource minimum threshold of 5 kWh/m2/day that was used in the analysis. Texas has the highest estimated potential of 22,786 TWh, which accounts for roughly 20% of the entire estimated U.S. annual technical potential for CSP (116,146 TWh). Figure 5 and Table 5 present the total estimated technical potential for concentrating solar power.

Wind Power Technologies

Onshore Wind Power

Technical potential for onshore wind power, which is present in nearly every state, is largest in the western and central Great Plains and lowest in the southeastern United States. While the wind resource intensity in the Great Plains is not as high as it is in some areas of the western United States, very little of the land area is excluded due to insufficient resource or due to other exclusions. In the eastern and western United States, the wind resource is more limited in coverage and is more likely to be impacted by environmental exclusions. Texas has the highest estimated annual potential of 5,552 TWh, which accounts for roughly 17% of the entire estimated U.S. annual technical potential for onshore wind (32,784 TWh). Figure 6 and Table 6 present the total estimated technical potential for onshore wind power.

Offshore Wind Power

Technical potential for offshore wind power is present in significant quantities in all offshore regions of the United States. Wind speeds off the Atlantic Coast and in the Gulf of Mexico are lower than they are off the Pacific Coast, but the presence of shallower waters there makes these regions more attractive for development. Hawaii has the highest estimated annual potential of 2,837 TWh, which accounts for roughly 17% of the entire estimated U.S. annual technical potential for offshore wind (16,975 TWh). Figure 7 and Table 7 present the total estimated technical potential for offshore wind power.

Biopower Technologies

Biopower (Solid and Gaseous)

Solid biomass accounts for 82% of the 400 TWh total estimated annual technical potential of biopower; of that, crop residues are the largest contributor. Gaseous biomass has an estimated annual technical potential of 88 TWh, of which landfills were the largest contributor. Figure 8 and Table 8 present the total estimated technical potential for biopower.

Geothermal Energy Technologies

Hydrothermal Power Systems

In the assessment, 71 TWh of electric power generation potential is the estimated total from existing (identified) hydrothermal sites spread among 13 states. An additional 237 TWh of undiscovered hydrothermal resources are estimated to exist among these same states. Figure 9 and Table 9 present the total estimated technical potential for hydrothermal power systems.

Enhanced Geothermal Systems

The vast majority of the geothermal potential for EGS (31,344 TWh) within the contiguous United States is located in the westernmost portion of the country. The Rocky Mountain States, and the Great Basin particularly, contain the most favorable resource for EGS (17,414 TWh). However, even the central and eastern portions of the country have 13,930 TWh of potential for EGS development. Note that, especially in western states, a considerable portion of the EGS resource occurs on protected land and was filtered out after exclusions were applied. Figure 10 and Table 10 present the total estimated technical potential for enhanced geothermal systems.

Hydropower Technologies

Hydropower

According to Hall et al. (2006), technical potential for hydropower exists predominately in the Northwest and Alaska with a combined total estimated at 69 TWh annually, which accounts for roughly 27% of the entire estimated U.S. annual technical potential for hydropower (259 TWh). Figure 11 and Table 11 present the total estimated technical potential for hydropower.

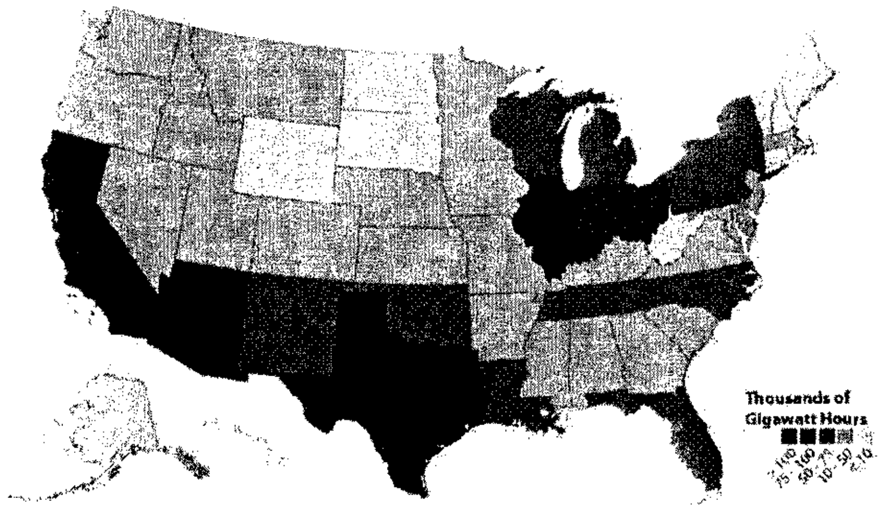

Figure 2. Total estimated technical potential for urban utility-scale photovoltaics in the United States

Table 2. Total Estimated Technical Potential for Urban Utility-Scale Photovoltaics by State[a]

State	KM^2	GW	GWh		State	KM^2	GW	GWh
Alabama	426	20	35,851		Montana	127	6	11,371
Alaska	2	<1	166		Nebraska	142	7	12,954
Arizona	1,096	53	121,306		Nevada	225	11	24,894
Arkansas	332	16	28,961		New Hampshire	49	2	3,790
California	2,321	111	246,008		New Jersey	527	25	44,307
Colorado	399	19	43,471		New Mexico	646	31	71,356
Connecticut	101	5	7,717		New York	683	33	52,803
Delaware	190	9	14,856		North Carolina	789	38	68,346
District of Columbia	<1	<1	8		North Dakota	57	3	4,871
Florida	830	40	72,787		Ohio	1,190	57	86,496
Georgia	506	24	43,167		Oklahoma	534	26	50,041
Hawaii	35	2	3,725		Oregon	271	13	25,783
Idaho	251	12	23,195		Pennsylvania	754	36	56,162
Illinois	1,325	64	103,552		Rhode Island	24	1	1,788
Indiana	1,274	61	98,815		South Carolina	398	19	33,835
Iowa	324	16	27,092		South Dakota	51	2	4,574
Kansas	317	15	31,706		Tennessee	596	29	50,243
Kentucky	339	16	26,515		Texas	3,214	154	294,684
Louisiana	675	32	55,669		Utah	293	14	30,492
Maine	40	2	3,216		Vermont	22	1	1,632
Maryland	379	18	28,551		Virginia	326	16	27,451
Massachusetts	228	11	17,470		Washington	402	19	33,690
Michigan	699	34	50,845		West Virginia	42	2	3,024
Minnesota	419	20	33,370		Wisconsin	728	35	54,939
Mississippi	318	15	26,366		Wyoming	75	4	7,232
Missouri	377	18	30,549		**U.S. Total**	**25,369**	**1,218**	**2,231,694**

[a] Non-excluded land was assumed to be available to support development of more than one technology.

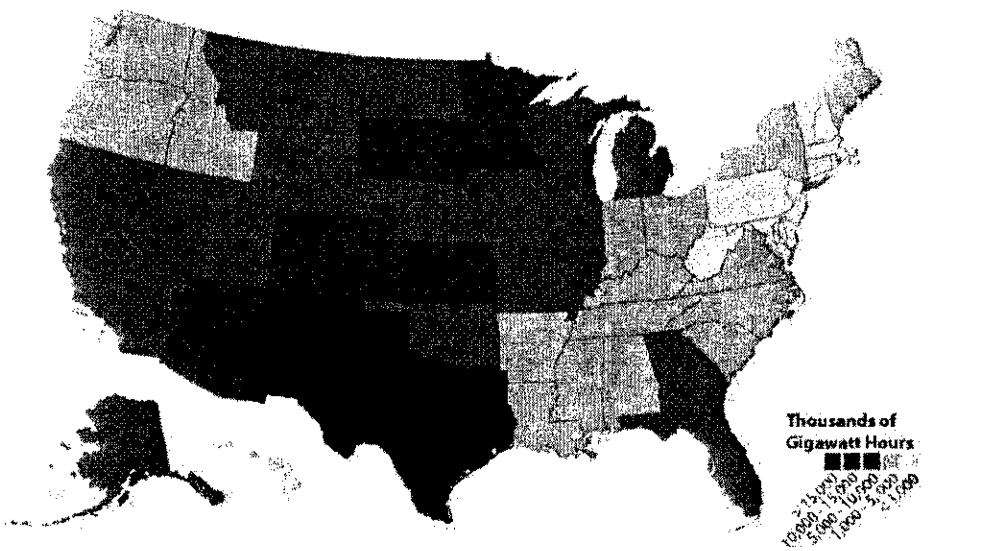

Figure 3. Total estimated technical potential for rural utility-scale photovoltaics in the United States

Table 3. Total Estimated Technical Potential for Rural Utility-Scale Photovoltaics by State[a]

State	KM^2	GW	GWh	State	KM^2	GW	GWh
Alabama	44,058	2,115	3,706,839	Montana	91,724	4,403	8,187,341
Alaska	187,608	9,005	8,282,976	Nebraska	101,457	4,870	9,266,757
Arizona	107,231	5,147	11,867,694	Nevada	77,751	3,732	8,614,454
Arkansas	57,239	2,747	4,986,389	New Hampshire	741	36	57,364
California	83,549	4,010	8,855,917	New Jersey	5,232	251	439,774
Colorado	94,046	4,514	10,238,084	New Mexico	147,652	7,087	16,318,543
Connecticut	256	12	19,628	New York	19,294	926	1,492,566
Delaware	3,483	167	272,333	North Carolina	48,892	2,347	4,232,790
District of Columbia	0	0	0	North Dakota	114,228	5,483	9,734,448
Florida	58,597	2,813	5,137,347	Ohio	49,908	2,396	3,626,182
Georgia	64,343	3,088	5,492,183	Oklahoma	99,641	4,783	9,341,920
Hawaii	431	21	38,033	Oregon	39,267	1,885	3,740,479
Idaho	42,613	2,045	3,936,848	Pennsylvania	7,430	357	553,356
Illinois	103,524	4,969	8,090,985	Rhode Island	184	9	13,636
Indiana	62,891	3,019	4,876,186	South Carolina	32,399	1,555	2,754,973
Iowa	83,763	4,021	6,994,159	South Dakota	111,350	5,345	10,008,873
Kansas	144,996	6,960	14,500,149	Tennessee	26,396	1,267	2,225,990
Kentucky	23,319	1,119	1,823,977	Texas	425,230	20,411	38,993,582
Louisiana	49,876	2,394	4,114,605	Utah	49,797	2,390	5,184,878
Maine	13,723	659	1,100,327	Vermont	739	35	54,728
Maryland	7,773	373	585,949	Virginia	22,378	1,074	1,882,467
Massachusetts	1,074	52	82,205	Washington	20,759	996	1,738,151
Michigan	71,741	3,444	5,215,640	West Virginia	729	35	52,694
Minnesota	135,627	6,510	10,792,814	Wisconsin	66,788	3,206	5,042,259
Mississippi	59,997	2,880	4,981,252	Wyoming	59,464	2,854	5,727,224
Missouri	65,767	3,157	5,335,269	U.S. Total	3,186,955	152,974	280,613,217

[a] *Non-excluded land was assumed to be available to support development of more than one technology.*

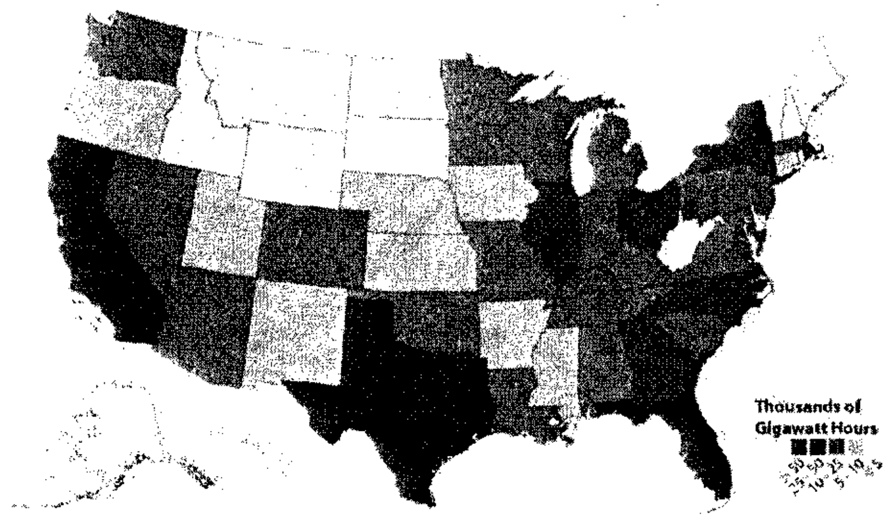

Figure 4. Total estimated technical potential for rooftop photovoltaics in the United States

Table 4. Total Estimated Technical Potential for Rooftop Photovoltaics by State[a]

State	GW	GWh	State	GW	GWh
Alabama	13	15,476	Montana	2	2,194
Alaska	1	NA	Nebraska	4	5,337
Arizona	15	22,736	Nevada	7	10,767
Arkansas	7	8,485	New Hampshire	2	2,299
California	76	106,411	New Jersey	14	15,768
Colorado	12	16,162	New Mexico	4	6,513
Connecticut	6	6,616	New York	25	28,780
Delaware	2	2,185	North Carolina	23	28,420
District of Columbia	2	2,490	North Dakota	2	1,917
Florida	49	63,987	Ohio	27	30,064
Georgia	25	31,116	Oklahoma	9	12,443
Hawaii	3	NA	Oregon	8	8,323
Idaho	3	4,051	Pennsylvania	20	22,215
Illinois	26	30,086	Rhode Island	2	1,711
Indiana	15	17,151	South Carolina	12	14,413
Iowa	7	8,646	South Dakota	2	2,083
Kansas	7	8,962	Tennessee	16	19,685
Kentucky	11	12,312	Texas	60	78,717
Louisiana	12	14,368	Utah	6	7,514
Maine	2	2,443	Vermont	1	1,115
Maryland	13	14,850	Virginia	19	22,267
Massachusetts	10	11,723	Washington	13	13,599
Michigan	22	23,528	West Virginia	4	4,220
Minnesota	12	14,322	Wisconsin	12	13,939
Mississippi	7	8,614	Wyoming	1	1,551
Missouri	13	16,160	**U.S. Total**	**664**	**818,733**

[a] Non-excluded land was assumed to be available to support development of more than one technology.

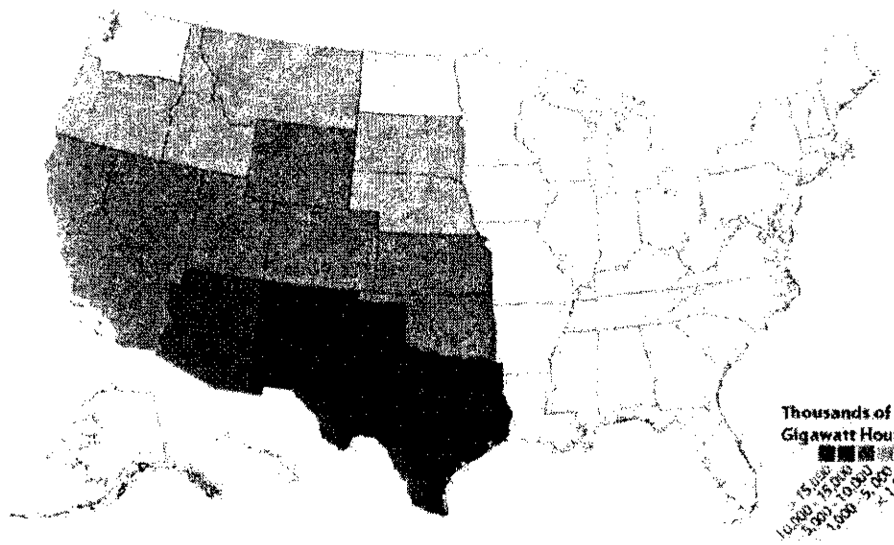

Figure 5. Total estimated technical potential for concentrating solar power in the United States

Table 5. Total Estimated Technical Potential for Concentrating Solar Power by State[a]

State	KM²	GW	GWh			KM²	GW	GWh
Alabama	0	0	0		Montana	16,939	557	1,540,288
Alaska	0	0	0		Nebraska	53,305	1,753	4,846,929
Arizona	107,239	3,528	12,544,334		Nevada	77,760	2,558	8,295,753
Arkansas	0	0	0		New Hampshire	0	0	0
California	82,860	2,726	8,490,916		New Jersey	0	0	0
Colorado	94,173	3,098	9,154,524		New Mexico	147,748	4,860	16,812,349
Connecticut	0	0	0		New York	0	0	0
Delaware	0	0	0		North Carolina	0	0	0
District of Columbia	0	0	0		North Dakota	396	13	36,050
Florida	4	0	359		Ohio	0	0	0
Georgia	0	0	0		Oklahoma	55,113	1,813	5,068,036
Hawaii	168	6	15,370		Oregon	30,927	1,017	2,812,126
Idaho	38,523	1,267	3,502,877		Pennsylvania	0	0	0
Illinois	0	0	0		Rhode Island	0	0	0
Indiana	0	0	0		South Carolina	0	0	0
Iowa	0	0	0		South Dakota	17,922	590	1,629,660
Kansas	87,698	2,885	7,974,256		Tennessee	0	0	0
Kentucky	0	0	0		Texas	235,398	7,743	22,786,750
Louisiana	0	0	0		Utah	49,799	1,638	5,067,547
Maine	0	0	0		Vermont	0	0	0
Maryland	0	0	0		Virginia	0	0	0
Massachusetts	0	0	0		Washington	1,778	59	161,713
Michigan	0	0	0		West Virginia	0	0	0
Minnesota	0	0	0		Wisconsin	0	0	0
Mississippi	0	0	0		Wyoming	59,457	1,956	5,406,407
Missouri	0	0	0		U.S. Total	1,157,209	38,066	116,146,245

[a] Non-excluded land was assumed to be available to support development of more than one technology.

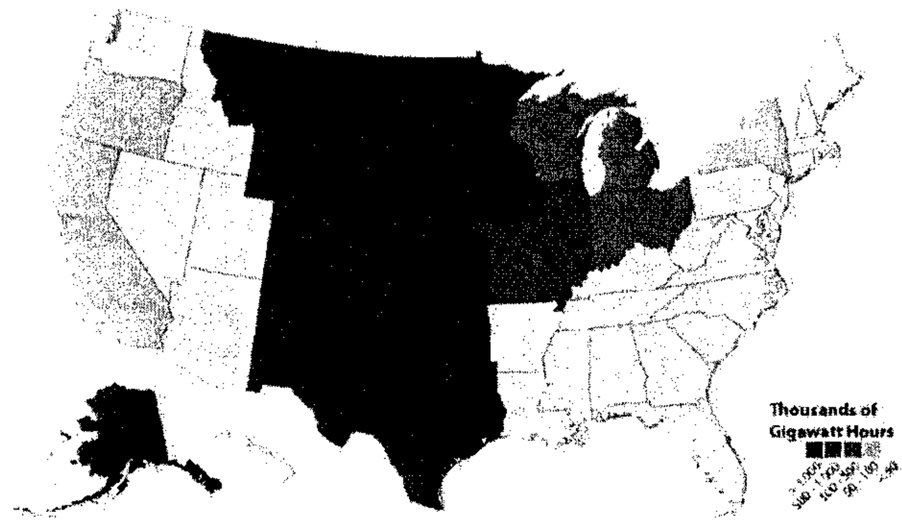

Figure 6. Total estimated technical potential for onshore wind power in the United States

Table 6. Total Estimated Technical Potential for Onshore Wind Power by State[a]

State	KM²	GW	GWh		State	KM²	GW	GWh
Alabama	24	<1	283		Montana	188,801	944	2,746,272
Alaska	98,669	493	1,373,433		Nebraska	183,600	918	3,011,253
Arizona	2,181	11	26,036		Nevada	1,449	7	17,709
Arkansas	1,840	9	22,892		New Hampshire	427	2	5,706
California	6,822	34	89,862		New Jersey	26	<1	317
Colorado	77,444	387	1,096,036		New Mexico	98,417	492	1,399,157
Connecticut	5	<1	62		New York	5,156	26	63,566
Delaware	2	<1	22		North Carolina	162	<1	2,037
District of Columbia	0	0	0		North Dakota	154,039	770	2,537,825
Florida	<1	<1	<1		Ohio	10,984	55	129,143
Georgia	26	<1	323		Oklahoma	103,364	517	1,521,652
Hawaii	494	2	7,787		Oregon	5,420	27	68,767
Idaho	3,615	18	44,320		Pennsylvania	661	3	8,231
Illinois	49,976	250	649,468		Rhode Island	9	<1	130
Indiana	29,646	148	377,604		South Carolina	37	<1	428
Iowa	114,143	571	1,723,588		South Dakota	176,483	882	2,901,858
Kansas	190,474	952	3,101,576		Tennessee	62	<1	766
Kentucky	12	<1	147		Texas	380,306	1,902	5,552,400
Louisiana	82	<1	935		Utah	2,621	13	31,552
Maine	2,250	11	28,743		Vermont	590	3	7,796
Maryland	297	1	3,632		Virginia	359	2	4,589
Massachusetts	206	1	2,827		Washington	3,696	18	47,250
Michigan	11,808	59	143,908		West Virginia	377	2	4,952
Minnesota	97,854	489	1,428,525		Wisconsin	20,751	104	255,266
Mississippi	0	0	0		Wyoming	110,415	552	1,653,857
Missouri	54,871	274	689,519		**U.S. Total**	**2,190,952**	**10,955**	**32,784,004**

[a] Non-excluded land was assumed to be available to support development of more than one technology.

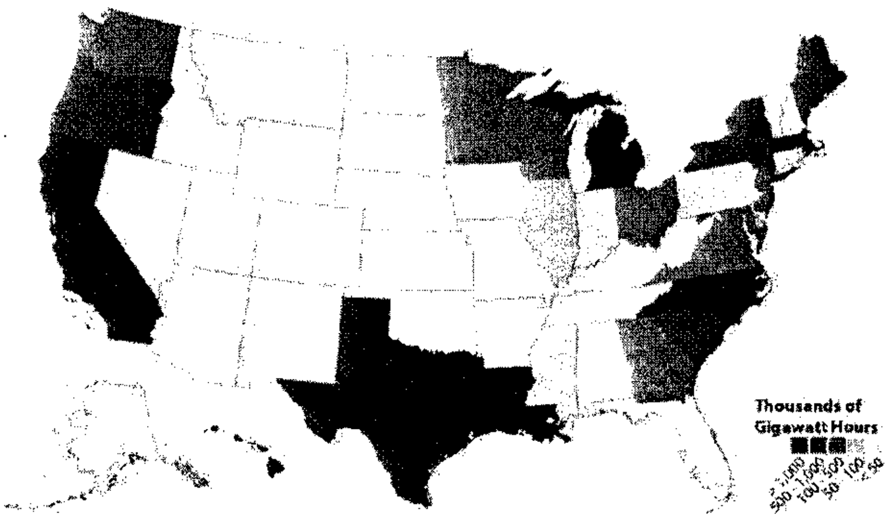

Figure 7. Total estimated technical potential for offshore wind power in the United States

Table 7. Total Estimated Technical Potential for Offshore Wind Power by State[a]

State	KM²	GW	GWh		State	KM²	GW	GWh
Alabama	0	0	0		Montana	NA	NA	NA
Alaska	NA	NA	NA		Nebraska	NA	NA	NA
Arizona	NA	NA	NA		Nevada	NA	NA	NA
Arkansas	NA	NA	NA		New Hampshire	691	3	14,478
California	130,967	655	2,662,580		New Jersey	20,387	102	429,808
Colorado	NA	NA	NA		New Mexico	NA	NA	NA
Connecticut	1,434	7	26,545		New York	29,215	146	614,280
Delaware	3,008	15	60,654		North Carolina	61,204	306	1,269,627
District of Columbia	NA	NA	NA		North Dakota	NA	NA	NA
Florida	1,930	10	34,684		Ohio	8,361	42	170,561
Georgia	11,726	59	220,807		Oklahoma	NA	NA	NA
Hawaii	147,389	737	2,836,735		Oregon	45,002	225	962,723
Idaho	NA	NA	NA		Pennsylvania	1,135	6	23,571
Illinois	3,174	16	66,070		Rhode Island	4,193	21	89,115
Indiana	9	<1	166		South Carolina	26,643	133	542,218
Iowa	NA	NA	NA		South Dakota	NA	NA	NA
Kansas	NA	NA	NA		Tennessee	NA	NA	NA
Kentucky	NA	NA	NA		Texas	54,289	271	1,101,063
Louisiana	68,123	341	1,200,699		Utah	NA	NA	NA
Maine	29,484	147	631,960		Vermont	NA	NA	NA
Maryland	10,382	52	200,852		Virginia	17,815	89	361,054
Massachusetts	36,815	184	799,344		Washington	24,193	121	488,025
Michigan	84,515	423	1,739,801		West Virginia	NA	NA	NA
Minnesota	5,843	29	100,455		Wisconsin	16,134	81	317,755
Mississippi	643	3	10,172		Wyoming	NA	NA	NA
Missouri	NA	NA	NA		U.S. Total	844,703	4,223	16,975,802

[a] Non-excluded land was assumed to be available to support development of more than one technology.

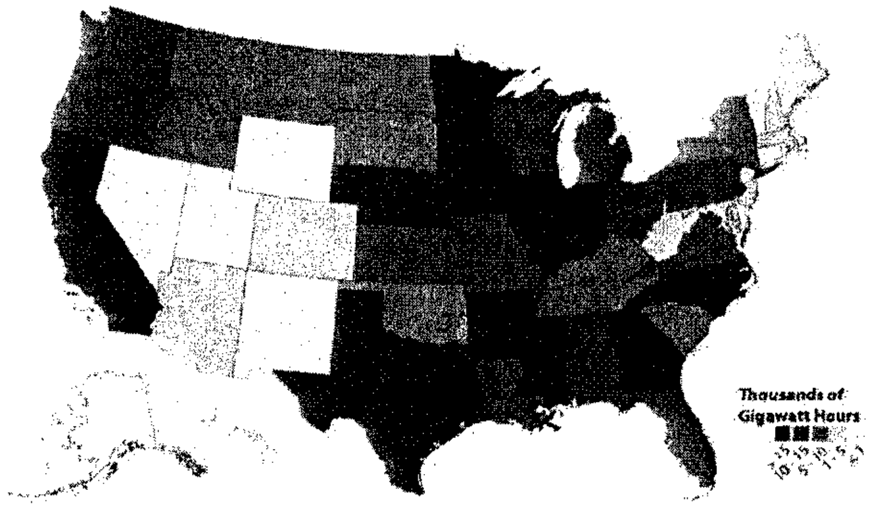

Figure 8. Total estimated technical potential for biopower in the United States

Table 8. Total Estimated Technical Potential for Biopower by State[a]

State	GW	GWh	State	GW	GWh
Alabama	2	12,727	Montana	<1	5,072
Alaska	<1	575	Nebraska	2	17,023
Arizona	<1	1,925	Nevada	<1	614
Arkansas	2	15,444	New Hampshire	<1	1,343
California	4	27,919	New Jersey	<1	3,523
Colorado	<1	4,138	New Mexico	<1	949
Connecticut	<1	909	New York	1	8,509
Delaware	<1	898	North Carolina	2	16,650
District of Columbia	<1	66	North Dakota	1	8,216
Florida	2	13,358	Ohio	2	14,372
Georgia	2	16,903	Oklahoma	<1	5,094
Hawaii	<1	724	Oregon	2	14,684
Idaho	<1	5,958	Pennsylvania	2	13,446
Illinois	4	31,960	Rhode Island	<1	618
Indiana	2	17,920	South Carolina	1	8,415
Iowa	4	28,928	South Dakota	1	8,615
Kansas	2	12,857	Tennessee	1	8,080
Kentucky	1	8,322	Texas	3	21,976
Louisiana	2	14,873	Utah	<1	862
Maine	<1	4,398	Vermont	<1	695
Maryland	<1	3,329	Virginia	1	10,365
Massachusetts	<1	2,149	Washington	2	13,826
Michigan	2	11,897	West Virginia	<1	2,688
Minnesota	3	21,391	Wisconsin	2	13,295
Mississippi	2	15,287	Wyoming	<1	553
Missouri	2	13,986	**U.S. Total**	**62**	**488,326**

[a] Non-excluded land was assumed to be available to support development of more than one technology. All biomass feedstock resources considered were assumed to be available for biopower use; competing uses, such as biofuels production, were not considered.

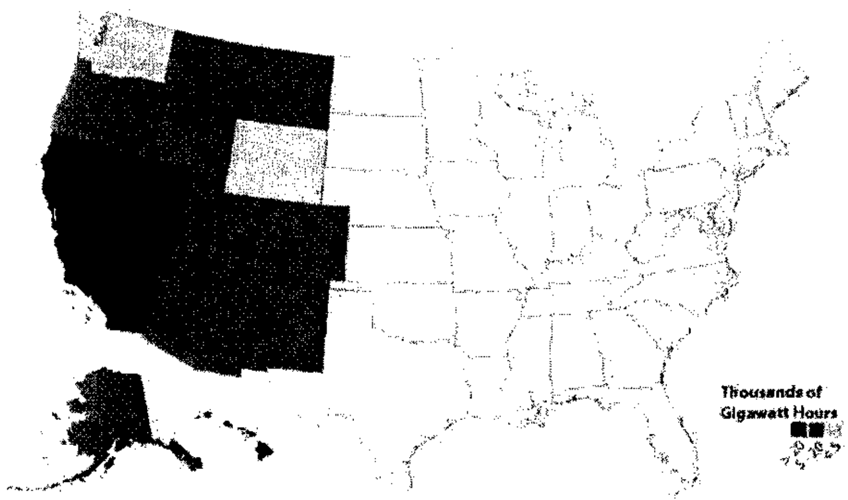

Figure 9. Total estimated technical potential for hydrothermal power in the United States

Table 9. Total Estimated Technical Potential for Hydrothermal Power by State[a]

State	GW	GWh		State	GW	GWh
Alabama	<1	<1		Montana	<1	6,548
Alaska	2	15,437		Nebraska	<1	<1
Arizona	1	8,330		Nevada	6	45,321
Arkansas	<1	<1		New Hampshire	<1	<1
California	17	130,921		New Jersey	<1	<1
Colorado	1	8,954		New Mexico	2	12,933
Connecticut	<1	<1		New York	<1	<1
Delaware	<1	<1		North Carolina	<1	<1
District of Columbia	<1	<1		North Dakota	<1	<1
Florida	<1	<1		Ohio	<1	<1
Georgia	<1	<1		Oklahoma	<1	<1
Hawaii	3	20,632		Oregon	2	18,200
Idaho	2	17,205		Pennsylvania	<1	<1
Illinois	<1	<1		Rhode Island	<1	<1
Indiana	<1	<1		South Carolina	<1	<1
Iowa	<1	<1		South Dakota	<1	<1
Kansas	<1	<1		Tennessee	<1	<1
Kentucky	<1	<1		Texas	<1	<1
Louisiana	<1	<1		Utah	2	12,982
Maine	<1	<1		Vermont	<1	<1
Maryland	<1	<1		Virginia	<1	<1
Massachusetts	<1	<1		Washington	<1	2,547
Michigan	<1	<1		West Virginia	<1	<1
Minnesota	<1	<1		Wisconsin	<1	<1
Mississippi	<1	<1		Wyoming	<1	1,373
Missouri	<1	<1		**U.S. Total**	**38**	**308,156**

[a] Non-excluded land was assumed to be available to support development of more than one technology.

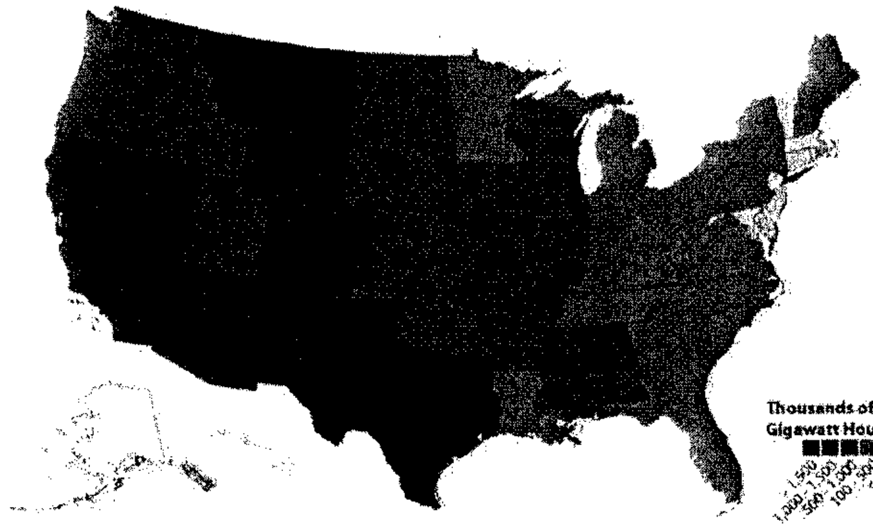

Figure 10. Total estimated technical potential for enhanced geothermal systems in the United States

Table 10. Total Estimated Technical Potential for Enhanced Geothermal Systems by State[a]

State	GW	GWh	State	GW	GWh
Alabama	68	535,490	Montana	209	1,647,304
Alaska	NA	NA	Nebraska	118	927,996
Arizona	157	1,239,148	Nevada	160	1,262,175
Arkansas	80	628,622	New Hampshire	13	104,314
California	170	1,344,179	New Jersey	4	35,230
Colorado	159	1,251,658	New Mexico	180	1,417,978
Connecticut	7	56,078	New York	48	375,401
Delaware	3	22,813	North Carolina	53	420,741
District of Columbia	<1	698	North Dakota	104	820,226
Florida	47	374,161	Ohio	63	495,922
Georgia	45	353,206	Oklahoma	99	779,667
Hawaii	NA	NA	Oregon	116	914,105
Idaho	126	993,257	Pennsylvania	42	327,341
Illinois	86	676,056	Rhode Island	1	11,492
Indiana	55	434,258	South Carolina	46	364,105
Iowa	77	606,390	South Dakota	117	921,973
Kansas	126	989,676	Tennessee	54	428,380
Kentucky	61	484,659	Texas	384	3,030,251
Louisiana	61	484,271	Utah	119	939,381
Maine	48	377,075	Vermont	5	35,617
Maryland	11	86,649	Virginia	37	290,737
Massachusetts	12	92,227	Washington	71	563,024
Michigan	58	457,850	West Virginia	33	261,376
Minnesota	47	369,785	Wisconsin	82	647,173
Mississippi	71	559,056	Wyoming	136	1,070,079
Missouri	106	835,445	**U.S. Total**	**3,976**	**31,344,696**

[a] Non-excluded land was assumed to be available to support development of more than one technology.

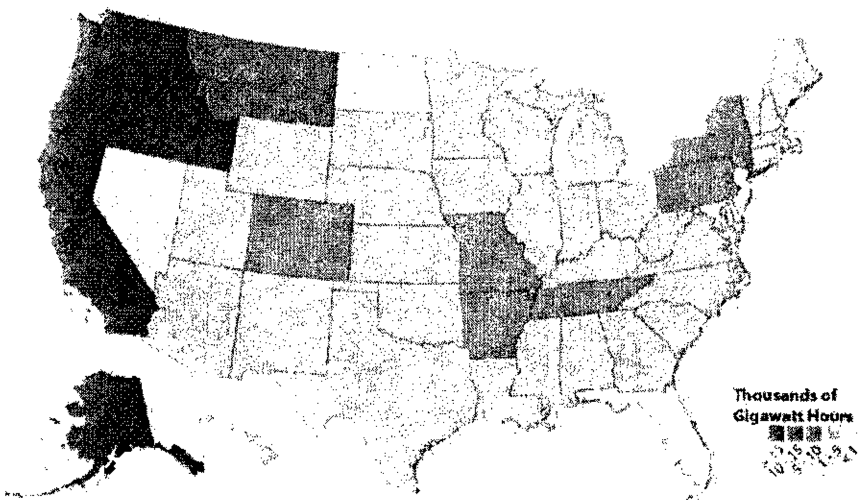

Figure 11. Total estimated technical potential for hydropower in the United States

Table 11. Total Estimated Technical Potential for Hydropower by State[a]

State	Count	GW	GWh		State	Count	GW	GWh
Alabama	2,435	<1	4,103		Montana	6,859	3	14,547
Alaska	3,053	5	23,676		Nebraska	2,880	<1	3,142
Arizona	1,958	<1	1,303		Nevada	1,489	<1	846
Arkansas	3,268	1	6,093		New Hampshire	810	<1	1,741
California	9,692	7	30,024		New Jersey	402	<1	549
Colorado	5,060	2	7,789		New Mexico	1,810	<1	1,363
Connecticut	659	<1	922		New York	4,839	2	6,711
Delaware	25	<1	31		North Carolina	2,131	<1	3,037
District of Columbia	2	<1	<1		North Dakota	572	<1	347
Florida	493	<1	682		Ohio	1,791	<1	3,046
Georgia	2,100	<1	1,988		Oklahoma	2,824	<1	3,016
Hawaii	437	<1	2,602		Oregon	7,993	4	18,184
Idaho	6,706	4	18,758		Pennsylvania	4,466	2	8,368
Illinois	1,330	1	4,883		Rhode Island	86	<1	59
Indiana	1,142	<1	2,394		South Carolina	889	<1	1,889
Iowa	2,398	<1	2,818		South Dakota	1,712	<1	1,047
Kansas	3,201	<1	2,508		Tennessee	2,610	1	5,745
Kentucky	1,394	<1	4,255		Texas	4,366	<1	3,006
Louisiana	934	<1	2,423		Utah	3,394	<1	3,528
Maine	1,373	<1	3,916		Vermont	1,207	<1	1,710
Maryland	491	<1	814		Virginia	2,601	<1	3,657
Massachusetts	560	<1	1,197		Washington	7,310	6	27,249
Michigan	1,942	<1	1,181		West Virginia	1,711	1	4,408
Minnesota	1,391	<1	1,255		Wisconsin	1,863	1	2,287
Mississippi	1,536	<1	2,211		Wyoming	2,842	1	4,445
Missouri	5,089	2	7,198		**U.S. Total**	**128,126**	**60**	**258,953**

[a] Non-excluded land was assumed to be available to support development of more than one technology.

Discussion

Table 12 summarizes the estimated technical generation and capacity potential in the Unites States for each renewable electricity technology examined in this report. As estimates of technical, rather than economic or market, potential, these values do not consider:

- Allocation of available land among technologies (available land is generally assumed to be available to support development of more than one technology and each set of exclusions was applied independently)
- Availability of existing or planned transmission infrastructure that is necessary to tie generation into the electricity grid
- The relative reliability or time-of-productions of power
- The cost associated with developing power at any location
- Presence of local, state, regional or national policies, either existing or potential, that could encourage renewable development
- The location or magnitude of current and potential electricity loads.

While not a direct comparison, given the above considerations, one useful point of reference for the generation potential estimate is annual electricity retail sales in the United States. In 2010, aggregate sales for all 50 states were roughly 3,754 TWh (see Appendix B).

Table 12. Total Estimated Technical Potential Generation and Capacity by Technology

Technology	Generation Potential (TWh)[a]	Capacity Potential (GW)[a]
Urban utility-scale PV	2,200	1,200
Rural utility-scale PV	280,600	153,000
Rooftop PV	800	664
Concentrating solar power	116,100	38,000
Onshore wind power	32,700	11,000
Offshore wind power	17,000	4,200
Biopower[b]	500	62
Hydrothermal power systems	300	38
Enhanced geothermal systems	31,300	4,000
Hydropower	300	60

[a] Non-excluded land was assumed to be available to support development of more than one technology.
[b] All biomass feedstock resources considered were assumed to be available for biopower use; competing uses, such as biofuels production, were not considered.

Updates to these technical potentials are possible on an ongoing basis as resource, system, exclusions and domain knowledge change and data sets improve in quality and resolution. In this study, we identified areas of potential improvements that include the acquisition of localized PV capacity factors, updated exclusion layers, and the use of updated land-cover data sets.

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Appendix A. Exclusions and Constraints, Capacity Factors, and Power Densities

Table A-1. Exclusions and Constraints for Urban Utility-Scale Photovoltaics

Slope Exclusion	> 3%	
Contiguous Area Exclusion	< 0.018 km^2	
Land Type(s) Exclusion	Within Urban Boundaries	ESRI (2004)
	Landmarks	ESRI (2007a)
	Parks	ESRI (2007b)
	MRLC - Water	MRLC (n.d.)
	MRLC - Wetlands	MRLC (n.d.)
	MRLC - Forests	MRLC (n.d.)
	MRLC -Impervious Surface >= 1%	MRLC (n.d.)

Table A-2. Capacity Factors for Utility-Scale Photovoltaics[a]

State	Capacity Factor	State	Capacity Factor	State	Capacity Factor
Alabama	0.200	Maine	0.191	Oklahoma	0.223
Alaska	0.105	Maryland	0.179	Oregon	0.227
Arizona	0.263	Massachusetts	0.182	Pennsylvania	0.177
Arkansas	0.207	Michigan	0.173	Rhode Island	0.176
California	0.252	Minnesota	0.189	South Carolina	0.202
Colorado	0.259	Mississippi	0.197	South Dakota	0.214
Connecticut	0.182	Missouri	0.193	Tennessee	0.201
Delaware	0.186	Montana	0.212	Texas	0.218
Florida	0.209	Nebraska	0.217	Utah	0.248
Georgia	0.203	Nevada	0.263	Vermont	0.176
Hawaii	0.210	New Hampshire	0.184	Virginia	0.200
Idaho	0.220	New Jersey	0.200	Washington	0.199
Illinois	0.186	New Mexico	0.263	West Virginia	0.172
Indiana	0.184	New York	0.184	Wisconsin	0.180
Iowa	0.199	North Carolina	0.206	Wyoming	0.229
Kansas	0.238	North Dakota	0.203		
Kentucky	0.186	Ohio	0.173		
Louisiana	0.196				

[a] (SAM)

Table A-3. Exclusions and Constraints for Rural Utility-Scale Photovoltaics and Concentrating Solar Power

Slope Exclusion	> 3%	
Contiguous Area Exclusion	< 1 km^2	
Land Type(s) Exclusion	Urban Areas	ESRI (2004)
	MRLC - Water	MRLC (n.d.)
	MRLC - Wetlands	MRLC (n.d.)
	BLM ACEC Lands (Areas of Critical Environmental Concern) (BLM 2009)	BLM (2009)
	Forest Service IRA (Inventoried Roadless Area) (USFS 2003)	USFS (2003)
	National Park Service Lands	USGS (2005)
	Fish & Wildlife Lands	USGS (2005)
	Federal Parks	USGS (2005)
	Federal Wilderness	USGS (2005)
	Federal Wilderness Study Area	USGS (2005)
	Federal National Monument	USGS (2005)
	Federal National Battlefield	USGS (2005)
	Federal Recreation Area	USGS (2005)
	Federal National Conservation Area	USGS (2005)
	Federal Wildlife Refuge	USGS (2005)
	Federal Wildlife Area	USGS (2005)
	Federal Wild and Scenic Area	USGS (2005)

Table A-4. Capacity Factors for Concentrating Solar Power[a]

Class	Kwh/m2/day	Capacity Factor
1	5–6.25	0.315
2	6.25–7.25	0.393
3	7.25–7.5	0.428
4	7.5–7.75	0.434
5	> 7.75	0.448

[a] (SAM)

Table A-5. Exclusions and Constraints for Onshore Wind Power

Slope Exclusion	> 20%	
Distance Exclusion	< 3 km Distance to Excluded Area (does not apply to water)	
Land Type(s) Exclusion	50% Forest Service Lands (includes National Grasslands, excludes ridge crests)	USGS (2005)
	50% Department of Defense Lands (excludes ridge crest)	USGS (2005)
	50% GAP Land Stewardship Class 2 - Forest	CBI (2004)
	50% Exclusion of non-ridge crest forest (non-cumulative over Forest Service Land)	USGS (2005)
	Airports	ESRI (2003)
	Urban Areas	ESRI (2004)
	LULC - Wetlands	USGS (1993)
	LULC - Water	USGS (1993)
	Forest Service IRA (Inventoried Roadless Areas)	USFS (2003)
	National Park Service Lands	USGS (2005)
	Fish & Wildlife Lands	USGS (2005)
	Federal Parks	USGS (2005)
	Federal Wilderness	USGS (2005)
	Federal Wilderness Study Area	USGS (2005)
	Federal National Monument	USGS (2005)
	Federal National Battlefield	USGS (2005)
	Federal Recreation Area	USGS (2005)
	Federal National Conservation Area	USGS (2005)
	Federal Wildlife Refuge	USGS (2005)
	Federal Wildlife Area	USGS (2005)
	Federal Wild and Scenic Area	USGS (2005)
	GAP Land Stewardship Class 2 - State & Private Lands Equivalent to Federal Exclusions	CBI (2004)

Table A-6. Capacity Factor for Offshore Wind Power[a]

Depth	Class	Watts/m^2	Capacity Factor
Shallow			
0–30 meters	3	300–400	0.36
0–30 meters	4	400–500	0.39
0–30 meters	5	500–600	0.45
0–30 meters	6	600–800	0.479
0–30 meters	7	> 800	0.5
Deep			
> 30 meters	3	300–400	0.367
> 30 meters	4	400–500	0.394
> 30 meters	5	500–600	0.45
> 30 meters	6	600–800	0.479
> 30 meters	7	> 800	0.5

[a] (ReEDS)

Table A-7. Conversion of Offshore Wind Speeds at 90 Meters to Power Classes[a]

Wind Speed (meters / second)	Power Class
6.4–7.0	3
7 .0–7.5	4
7.5–8.0	5
8.0–8.8	6
> 8.8	7

[a] Marc Schwartz, NREL Wind Analyst, personal communication

Table A-8. Exclusions and Constraints for Offshore Wind Power[a]

Distance Exclusion	< 50 nautical miles from shoreline
Land Type(s) Exclusion	
Federal Exclusions	National Marine Sanctuaries
	Marine Protected Areas Inventory – 'NAL', 'NIL', 'NTL'
	Office of Habitat Conservation Habitat Protection Div. EFH – Shipping Routes, Sanctuary Protected Areas
	NOAA Jurisdictional Boundaries and Limits – Coastal National Wildlife Refuges – Pacific
	Navigational & Marine Infrastructure – Shipping Lanes, Drilling Platforms (Gulf), Pipelines (Gulf), Fairways (Gulf)
	NWIOOS – Towlane Agreement WSG 2007
	World Database on Protected Areas Annual Release 2009 Global Data set – Offshore Oil & Gas Pipelines/Drilling Platforms
Texas	Pipelines & Easements
	Audubon Sanctuaries
	Gulf Inter-coastal Waterway/Ship Channels
	National Wildlife Refuges
	Shipping Safety Fairways
	State Coastal Preserves
	Dredged Material Placement Sites
	State Tracts with Resource Management Codes
North Carolina	Significant Natural Heritage Areas
	Sea Turtle Sanctuary
	Crane Spawning Sanctuary
Great Lakes	IM ACC EPA
	IM Ship Routes
Virginia	Near-shore Coastal Parks
	Threatened & Endangered Species Waters
	Crab Sanctuary
	Security Areas
	Striped Bass Sanctuary
	State Park & State Dedicated Natural Area Preserve (w/in 1 mile of shoreline)
Rhode Island	Habitat Restoration Area

	Hazardous Material Sites Designated by the U.S. EPA and RIDEM (w/in 0.5 miles of shoreline)
	CRMCWT08 (Type = 1 or 2)
South Carolina:	Refuges
	OCRM Critical Area
New Hampshire	Conservation Focus Area
Florida	Ocean Dredged Material Disposal Sites
	Aquatic Preserve Boundaries
California	Cordell Banks Closed Areas
Massachusetts	Ferry Routes
Oregon	Oregon Islands National Wildlife Refuges USFWS 2004
	Oregon Marine Managed Areas
	Oregon Cables OFCC 2005
	Dredged Material Disposal Sites ACDE 2008
New Jersey	New Jersey Coastal Wind Turbine Siting Map – Exclusion Areas

[a] Exclusions were developed by Black & Veatch (2009).

Table A-9. Exclusions and Constraints for Enhanced Geothermal Systems[a]

Land Type(s) Exclusion	National Park Service Lands
	Fish and Wildlife Service Lands
	Federal Parks
	Federal Wilderness
	Federal National Monuments
	Federal National Battlefields
	Federal Restoration Areas
	Federal National Conservation Areas
	Federal Wildlife Refuge Areas
	Federal Wild and Scenic Areas

a USGS (2005)

Table A-10. Power Densities for Enhanced Geothermal Systems[a]

Temperature C	MW / km^2
150–200	0.59
200–250	0.76
250–300	0.86
300–350	0.97
> 350	1.19

[a] Augustine (2011)

Table A-11. Exclusions and Constraints for Enhanced Geothermal Systems[a]

Depth Constraints	Depth > 3 and < 10 km
Land Type(s) Exclusion	National Park Service Lands
	Fish and Wildlife Service Lands
	Federal Parks
	Federal Wilderness
	Federal National Monuments
	Federal National Battlefields
	Federal Restoration Areas
	Federal Conservation Areas
	Federal Wildlife Refuge Areas
	Federal Wild and Scenic Areas

[a] USGS (2005)

Appendix B. Energy Consumption by State

Electric retail sales in the United States were roughly 3,754 TWh in 2010 (EIA).

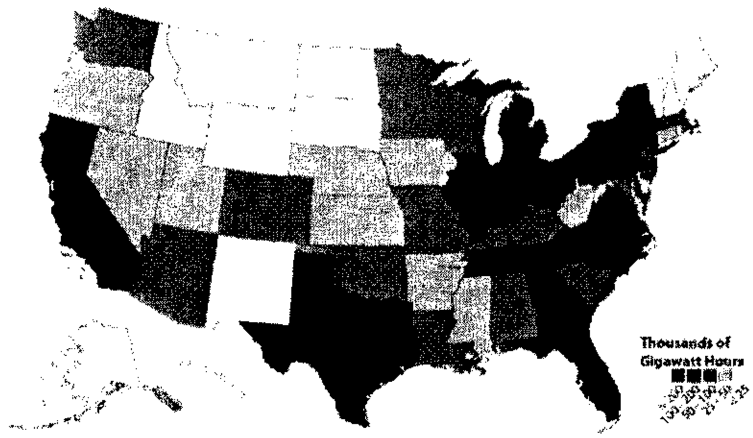

Figure B-1. Electric retail sales in the United States in 2010 (EIA).

Table B-1. Electric Retail Sales by State, 2010[a]

State	GWh		State	GWh
Alabama	90,863		Montana	13,423
Alaska	6,247		Nebraska	29,849
Arizona	72,832		Nevada	33,773
Arkansas	48,194		New Hampshire	10,890
California	258,525		New Jersey	79,179
Colorado	52,918		New Mexico	22,428
Connecticut	30,392		New York	144,624
Delaware	11,606		North Carolina	136,415
District of Columbia	11,877		North Dakota	12,956
Florida	231,210		Ohio	154,145
Georgia	140,672		Oklahoma	57,846
Hawaii	10,017		Oregon	46,026
Idaho	22,798		Pennsylvania	148,964
Illinois	144,761		Rhode Island	7,799
Indiana	105,994		South Carolina	82,479
Iowa	45,445		South Dakota	11,356
Kansas	40,421		Tennessee	103,522
Kentucky	93,569		Texas	358,458
Louisiana	85,080		Utah	28,044
Maine	11,532		Vermont	5,595
Maryland	65,335		Virginia	113,806
Massachusetts	57,123		Washington	90,380
Michigan	103,649		West Virginia	32,032
Minnesota	67,800		Wisconsin	68,752
Mississippi	49,687		Wyoming	17,113
Missouri	86,085		**U.S. Total**	**3,754,486**

[a] EIA